

An hourglass-shaped graphic with a globe in the top bulb and a smaller globe in the bottom bulb. The hourglass is light blue and has a dark blue top and bottom. The globe in the top bulb is dark blue, and the globe in the bottom bulb is light blue. The text is centered within the hourglass.

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February 2, 2009

Congressional Research Service

Report RL31218

Commercial Remote Sensing by Satellite: Status and Issues

Richard Rowberg, Resources, Science, and Industry Division

Updated January 7, 2002

Abstract. This report presents a review of the current commercial remote sensing industry including the current status of the industry and an analysis of key issues that are likely to affect its future. It provides a description of the technology of satellite remote sensing followed by a review of the history of its development. It examines three areas that encompass most of the important issues relating to the industry's development: the commercial market potential and the role of the federal government as a purchaser and provider of remote sensing images; national security concerns about commercial remote sensing satellites; and federal regulation of the industry. Finally, the report presents a discussion of policy considerations.

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CRS Report for Congress

Received through the CRS Web

Commercial Remote Sensing by Satellite: Status and Issues

Updated January 8, 2002

Richard E. Rowberg
Senior Specialist in Science and Technology
Resources, Science, and Industry Division

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Commercial Remote Sensing by Satellite: Status and Issues

Summary

Since the late 1970s, spurred by the launch of the NASA Landsat satellites and later by the success of the French SPOT satellite, Congress has been taking steps to promote a commercial remote sensing industry in the United States. The Land Remote Sensing Act of 1992 coupled with Presidential Decision Directive 23 in 1994 gave new impetus to the industry by permitting commercial companies to launch high resolution (1 meter or less) remote sensing satellites. While a commercial satellite remote sensing industry has emerged, however, so far it has not been the success envisaged by its early proponents. Nevertheless, the industry is growing and the images of the terrorist attack on the World Trade Center obtained by the Ikonos 2 satellite operated by a U.S. company, Space Imaging, has recently given particular prominence to the industry. The domestic industry's future, however, appears uncertain. It has not turned a profit and still depends largely on purchases of images by the federal government to remain in operation. Nevertheless, congressional interest remains strong. One relevant bill, H.R. 2426, dealing with remote sensing applications, has been introduced in the 107th Congress to date.

Competition from aerial remote sensing; the slow development of a market for remote sensing products outside local, state, and federal governments; competition from government-subsidized, foreign remote sensing satellites; and regulations resulting from national security concerns are among other factors that have slowed the development of the U. S. commercial satellite remote sensing industry. Federal support for the industry is concentrated in the Department of Defense's (DOD's) National Imagery and Mapping Agency (NIMA) and the National Aeronautics and Space Administration (NASA). NIMA support, however, has been spotty because of funding limitations and DOD actions that are limiting the need for imagery by NIMA from commercial satellites.

The industry is also creating national security benefits and challenges. The U.S. intelligence community is finding that commercial remote sensing images can supplement those of its own satellites. At the same time, the possibility that potential adversaries and terrorist groups may obtain access to sensitive images has resulted in federal regulations that restrict acquisition and publication of such images for national security and foreign policy reasons. This shutter control provision is controversial and is likely to result in a court challenge if and when it is invoked. In the current situation in Afghanistan, the U.S. government has avoided this possibility by contracting with Space Imaging, a private firm, for exclusive rights to all images covering the Operation Enduring Freedom area of operations.

Future growth of the U.S. industry will likely depend on steady and broad-based federal support, development of new applications that result in an expanding market, and resolution of regulatory uncertainties, primarily the shutter control provisions.

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Commercial Remote Sensing by Satellite: Status and Issues

Introduction

Background

Since the beginning of the space age, observation of the Earth (remote sensing) by satellite and human-occupied space vehicles has played an important role in U.S. and international space programs. The earliest remote sensing satellites were used for national security purposes.¹ Early on, however, space policy makers and others recognized the potential importance of remote sensing for civilian purposes such as environmental and climate monitoring. Such satellites began appearing in the early 1960s. Furthermore, once these satellites were in operation, many in the space community began advocating transferring responsibility for developing and operating civilian remote sensing satellites to the private sector. This effort became the policy of the United States in 1979, and, since then, congressional and administrative action has attempted to implement that policy. The Land Remote-Sensing Commercialization Act of 1984 (P.L.98-965) set out terms for transferring the government-owned Landsat satellite program to the private sector. The Land Remote Sensing Policy Act of 1992 (P.L.102-555) repealed the previous Act, declared commercialization of land remote sensing to be a long-term policy goal of the United States, and established procedures for licensing private remote sensing operators.²

While a commercial satellite remote sensing industry has emerged in the United States in recent years, it has not been the success envisaged by its early proponents. Competition from aerial remote sensing (aircraft and balloons); the slow development of a market for remote sensing products outside local, state, and federal governments; competition from government-subsidized, foreign remote sensing satellites; and regulations resulting from national security concerns, among other factors, have slowed the development of a healthy commercial satellite remote sensing industry. A commercial remote sensing industry has been established, however, and by all accounts is growing.³ The images of the aftermath of the terrorist attack on the World Trade Center obtained by the Ikonos 2 satellite operated by Space Imaging gave particular prominence to the existence of the commercial remote sensing industry in this country.

¹Remote sensing satellites for national security purposes are called reconnaissance satellites.

²P.L. 102-555, sec. 2 and sec. 201.

³Barnaby J. Feder, "Bird's-Eye Views, Made to Order," *New York Times*, October 11, 2001, sec. F1, 1.

While the industry is growing, however, its future appears uncertain. The industry has not turned a profit and still depends largely on purchases of images by the federal government to remain in operation.⁴ While action has been modest in the 107th Congress to date, congressional interest remains strong in the development of a healthy commercial remote sensing industry.⁵ This report presents a review of the current status of the industry and an analysis of key issues that are likely to affect its future. It begins with a brief description of the technology of satellite remote sensing followed by a brief review of the history of its development. Next, the report examines three areas that encompass most of the important issues relating to the industry's development. They are: the commercial market potential and the role of the federal government as a purchaser and provider of remote sensing images; national security concerns about commercial remote sensing satellites; and federal regulation of the industry. Finally, the report presents a discussion of policy considerations.

Satellite Remote Sensing Technology, Applications, and History

Technology

Remote sensing is defined as any observation made at a point removed from the object under investigation. More commonly it refers to observations of areas of land and water covering the earth by airplane or satellite. Aerial remote sensing currently operates from altitudes of about 500 meters to 20 kilometers (km) with the latter being the domain of aircraft such as the U2 for national security purposes. The range of operation for most spacecraft and satellite remote sensing is about 250 km to 1000 km with satellites close to the 1000 km level.⁶ Some remote sensing satellites also operate in geostationary orbit at 36,000 km. By the nature of that orbit, these satellites remain over the same place on Earth at all times.

Remote sensing involves collecting an image of a region on the Earth by one of two means: passive or active.⁷ Passive sensing, which is the mode of operation of most remote sensing satellites today, monitors the objects under investigation by using electro-optic sensors to collect solar radiation reflected off the object. Active sensing uses a source of electromagnetic radiation — usually radar — carried on board the satellite. These types of systems are discussed below.

⁴John C. Baker, Kevin M. O'Connell, and Ray A. Williamson, "Conclusions" in *Commercial Observation Satellites*, ed. by John c. Baker, et. al. (Arlington, VA and Bethesda, MD: RAND and ASPRS, 2000) 559.

⁵To date, one bill affecting the commercial remote sensing industry has been introduced. That is H.R. 2426, the Remote Sensing Applications Act of 2001.

⁶Paul J. Gibson, *Introductory Remote Sensing: Principles and Concepts* (London: Routledge, 2000), 2.

⁷Most of the information in this section is based on material found in Gibson, *Introductory Remote Sensing*, 12-126.

The span of electromagnetic radiation (spectrum) from the sun used by passive remote sensing ranges from the familiar visible radiation to the near and thermal infrared. Not all of this spectrum will pass through the earth's atmosphere, however, so sensors on a remote sensing system have to be designed to receive those portions that can penetrate the atmosphere. Also, not all of the radiation monitored by a remote sensing satellite comes from reflections off the Earth's surface. Radiation is reflected off clouds and other particles in the atmosphere thereby giving these satellites the ability to monitor phenomena such as temperature and water vapor content at different atmospheric layers. As for reflection off the surface, the nature of the object from which the radiation reflects determines where in the spectrum it lies. As a result, different surface features such as vegetation, water, rocks, and populated areas have different spectral signatures. In addition, other factors such as the relative position of the sun and surface coverings such as snow affect that signature. Because of this behavior, remote sensing systems can be designed for detailed study of many aspects and characteristics of the planet and its atmosphere.

Remote sensing sensors are generally classified as panchromatic (PAN) or multispectral (MS). The former produce data in black and white, while the latter produce data in color. MS sensors record images that provide the means to identify and study characteristics of different surface features. These sensors usually include portions of the spectrum in both the visible and infrared regimes. Recently, hyperspectral sensors have been developed that divide up the spectrum into many more, smaller bands than MS sensors for even more detailed characterization of surface features.

The first remote sensing satellites recorded images on film. All current satellites use digital systems to record the images, and have many advantages over film systems. In particular, digital image data can be transmitted to ground-based stations and digital data are able to be processed on computers.

An important feature of remote sensing systems is resolution. There are four measures of resolution: spectral resolution which is measure of the narrowness of the spectral band that can be determined; temporal resolution which measures the frequency at which data of the same region can be obtained; radiometric resolution which measures how many levels of gray can be determined on a black and white image; and spatial resolution. The latter gives the smallest dimension an object can have and still be distinguished from other objects. It is the measure usually cited when characterizing a remote sensing satellite. The Ikonos 2 satellite has a spatial resolution of 0.82 meters for PAN images and four meters for MS images.⁸ Spatial resolution is primarily dependent on the optical system used to collect the reflected radiation.

Temporal resolution, or revisit time, is an important feature of remote sensing satellites along with the area of ground that can be observed at any given instant. The lower the orbit, the shorter the revisit period. Lower orbits, however, also reduce the area of ground that can be covered. By using sensors that can look both forward and

⁸Frank Sietzen, Jr., "Advanced imagery raises the ante," *Aerospace America*, Sept. 2001, 39.

back from the satellite, a particular point on the surface can be observed much more frequently than by the revisit rate.

The other type of remote sensing, active systems, primarily use radar as the source of electromagnetic radiation. Radar has two major advantages over reflected solar radiation: it can penetrate cloud cover and it can be used at night because it does not depend on the sun. Active systems, therefore, can make observations that cannot be made by passive systems. Radar observations, however, are more complex and costly than passive systems and have been slower to develop. Advances in radar imaging technology, however, have increased interest in these systems in recent years. In particular, synthetic aperture radar (SAR) greatly increases resolution along the path of the satellite (azimuthal resolution) by increasing the effective size of the radar antenna. The effective increase is well beyond the practical limit of a conventional antenna. The improvement is so great that all recent and proposed radar remote sensing satellites are using or will use SAR. One application of SAR is the use of radar to determine variations in surface elevation.

In addition to technologies for obtaining images, a very important aspect of remote sensing is the processing of the raw images to facilitate the analysis and application of the data. This so-called value-added step consists primarily of the development and application of software to analyze the content of the images. Because the latter are in a digital format, much of this processing is done with the use of computers. One example is the combination of raw images with geographic information systems (GIS) to enable the updating of GIS databases with remote sensing data.⁹ In addition to computer software, human expertise in interpreting remote sensing images is an important component of this value-added step.

Applications

Applications of satellite remote sensing are varied and growing.¹⁰ The type of application varies primarily with the portion of the spectrum that can be observed by a sensor, by the spatial resolution of that sensor, and by whether the sensors are passive or use radar. Most current satellites carry a range of sensors so that they can perform a variety of applications. A small but growing number of remote sensing satellites, however, are single purpose systems.

Satellites with low spatial resolution — over one kilometer (km) — are generally used for collecting meteorological and environmental data. An example is the NOAA meteorological satellite series operating in an orbit of 855 km using a multispectral sensor with a resolution of 1.1 km. Meteorological data include monitoring cloud cover, climate change and the atmosphere, rainfall, storm events, and the oceans. The hole in the ozone layer over Antarctica was first observed by the Nimbus 7 satellite in the early 1970s. Environmental observations include vegetation assessment, monitoring of natural hazards (primarily major weather events), and geology. The last

⁹Kevin O'Connell and Beth E. Lachman, "From Space Imagery to Information: Commercial Remote Sensing Market Factors and Trends," *Commercial Observation Satellites*, 64.

¹⁰Much of this section is largely based on material found in Gibson, *Introductory Remote Sensing*, 127-150.

item includes large area mapping including entire continents, and the use of thermal infrared data for monitoring volcanos.

Medium resolution satellites (less than 100 m) are used primarily for environmental monitoring and a range of other applications including military observations and mapping of urban areas. An example of these satellites is the Landsat series. The first five in the series were launched and operated by the National Aeronautics and Space Administration (NASA). The sixth was destroyed in a launch failure. Landsat 7 was built and launched by NASA, and is now operated by the United States Geological Survey (USGS) of the Department of Interior, which maintains a Web site with information about the satellite and products available from it [<http://landsat7.usgs.gov/about.html>]. Landsat 7 operates in a 705 km orbit and is equipped with an 8-band ETM+ (Enhanced Thematic Mapper Plus) sensor. One band of the ETM+ provides 15 m PAN data; six bands provide 30 m data in the visible, near- and short wave-infrared bands; and one band provides 60 m data in the thermal infrared band. Landsat 5, which was launched in 1984 and is still operating, has two sensors. One is a 7-band multispectral Thematic Mapper providing 30 m data in the visible, near infrared, middle infrared, and far infrared bands. The other is a 4-band multispectral scanner (MSS) providing 80 m data in the visible and near infrared bands.¹¹ It also is now operated by USGS. Environmental applications of Landsat data include monitoring ocean and other marine conditions such as thermal pollution, mapping of vegetation properties such as crop health, and the mapping of geological features such as faults. It was a Landsat satellite that detected a thermal plume in Chernobyl Lake, giving the world the first notice of the 1986 accident at the Soviet nuclear reactor. Because the revisit time of these satellites is relatively long — several days — their ability to study the effects of pollution is limited. In another category, Landsat and the French satellite SPOT were used during the Gulf War to monitor oil field fires in Kuwait and other events of military interest.

High resolution remote sensing satellites (10 m and less) are relatively recent. The Ikonos 2 satellite, owned and operated by the U.S. company Space Imaging, was launched in 1999 and has a 0.82 m PAN sensor and a 4 m MS sensor. Recently, India launched a 1 m PAN satellite and several other countries are operating or planning launches of high resolution remote sensing satellites.¹² A range of mapping applications are possible with these satellites including city planning, transportation and development planning, property marketing, and pollution monitoring. These satellites also offer increased potential for national security applications. Ikonos 2 is being used by the U.S. military in the current war in Afghanistan. In addition, images from that satellite were used extensively by the media following the September 11 attacks on the World Trade Center and the Pentagon. A range of other national security applications, including force monitoring and treaty verification, are envisaged for these high resolution satellites.

The final category is radar imaging. This category is currently represented by a few satellites using synthetic aperture radar (SAR) sensors, including Canada's

¹¹NASA. Landsat-D Prime Prelaunch Mission Operation Report. Report No. E-668-84-02. February 21, 1984. p. 11-15. (Prior to launch, Landsat 5 was named Landsat-D Prime.)

¹²See Frank Sietzen, Jr., *Aerospace America*, 39, for a list.

RADARSAT-1 with an 8 m SAR system. The special characteristics of radar sensing make it useful for meteorological, environmental, and mapping applications. In the case of weather, wind speed and ocean wave height can be measured. Images of surface texture that can be obtained using radar make possible observations of oil slicks, land and sea ice, and ocean currents, among other things. Topological measurements are also possible because of the ability of radar sensing to determine changes in surface height. Information on deforestation, crop growth, and hydrological processes, particularly in regions with extensive cloud cover, can be obtained with radar systems.

Applications of remote sensing are many and varied. With the growth of high-resolution sensors, they should expand into areas currently within the purview of aerial remote sensing. How competitive satellite remote sensing will be and whether it can capture a significant portion of the commercial market, such as mineral and petroleum exploration and real estate development, remains to be seen. This issue will be discussed more fully below.

History

Remote sensing by satellite began in 1960 with the CORONA project, a series of high-resolution satellites used for surveillance of the Soviet Union. These satellites operated at low orbits (150-450 km) and used cameras to obtain photographic images.¹³ Also in 1960, the United States launched the first weather satellite, TIROS-1. Its purpose was to provide early warning of major storms. In 1972, the first Earth monitoring satellite — Earth Resources Technology Satellite (ERTS-1) — was launched. The purpose of ERTS-1 was to gather information about agricultural and environmental conditions. This satellite was renamed Landsat 1 and was the first of three satellites that made up the first Landsat generation (Landsat 1-3).

Landsat 1, 2 and 3 carried two scientific instruments: a return beam vidicon (RBV) camera and a multispectral scanner (MSS). On Landsat 1 and 2, the RBV camera had a resolution of 70-80 m; on Landsat 3 it was 26-40 m. The MSS on Landsat 1 and 2 scanned in four visible wavelengths; a fifth band for measuring thermal (infrared) radiation was added to Landsat 3. MSS resolution was 80 meters for the first four bands, and 240 m for the fifth band.¹⁴ In 1982, the first of a second generation Landsat series was launched—Landsat 4. An identical spacecraft, Landsat 5, was launched in 1984. These satellites each had 30 m Thematic Mappers and 80 m MSS's (described earlier). Landsat 6 was launched in 1993, but was lost when its launch vehicle failed. The most recent member of the series, Landsat 7, was launched in 1999. Landsat 5 and Landsat 7 are both currently operating.

¹³The CORONA project ended in 1972. The images were declassified in 1995 and made available to the public. Gibson, *Introductory Remote Sensing*, 6-7. For a detailed history of Corona, see Dwayne A Day, et.al., *Eye in the Sky: The Story of the Corona spy Satellites*, Smithsonian Press (Washington) 1998.

¹⁴U.S. Congress. House. Committee on Science and Technology. United States Civilian Space Programs. Volume II: Applications Satellites. Chapter 5: Earth Resources and Environmental Monitoring Satellites. Prepared by the Congressional Research Services. 98th Congress, 1st session. Washington, U.S. Govt. Print. Off., May 1983. p.222-223.

The first three Landsat satellites were built and launched by NASA, and they were operated by NASA until 1979. At that point, management was transferred to the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce with the hope that a commercial remote sensing industry would develop.¹⁵ NOAA also assumed responsibility for developing Landsat 4 and 5. The early Landsat program did much to show the value of remote sensing and fostered the development of private sector firms dedicated to extracting useful information from the Landsat images for commercial purposes.¹⁶ In 1984, Congress passed the Land Remote-Sensing Commercialization Act of 1984 (P.L.98-965). The Act enabled the establishment of the Earth Observing Satellite Corporation (EOSAT) which assumed operational responsibility for the existing Landsat satellites and, with federal assistance through NOAA, was to develop and operate Landsat 6 and 7. A dispute ensued about the funding of the new Landsat systems, and only Landsat 6 was built under the NOAA/EOSAT arrangement. Much of the dispute revolved around whether public or private use of the Landsat data should have primacy.¹⁷ There were also concerns about whether federal contributions to the Landsat program would be adequate to ensure its continuity and whether there was adequate demand to support the satellites in the private market.

Pressure built up in the early 1990s to return Landsat operation to the federal government. In 1992, the Land Remote Sensing Policy Act of 1992 was passed which repealed the 1984 Act and transferred responsibility for the Landsat system to NASA and the Department of Defense (DOD) from NOAA and EOSAT.¹⁸ One of the important goals of this legislation was to ensure continuity of Landsat data. Soon after this legislation was passed, DOD withdrew from the arrangement.¹⁹ Landsat 7, which was developed and launched by NASA as part of its Earth Observing System (EOS) program, is now operated by USGS. USGS also operates Landsat 5, the only other operating Landsat satellite.

In addition to the Landsat series, other civilian remote sensing satellites have been launched since the early 1980s. The most well known of these are the three SPOT satellites — SPOT 1, SPOT 2, and SPOT 4 — launched in 1986, 1990, and 1998 respectively.²⁰ These satellites were developed and are operated by Spot Image, a French company. Each of these satellites have 10m PAN and 20 m MS sensors. A

¹⁵For further discussion of the early history of Landsat privatization, see Congressional Research Service, *The future of land remote sensing satellite system (Landsat)*, by David Radzanowski, 91-685, September 16, 1991.

¹⁶Ray A. Williamson, "Remote Sensing Policy and the Development of Commercial Remote Sensing," *Commercial Observation Satellites*, 40.

¹⁷*ibid.*, 43.

¹⁸As noted above, this action did not change federal policy in support of a commercial remote sensing industry; rather it recognized the possibility that such an industry would take longer to develop than was believed in the early 1980s.

¹⁹For further discussion of this period in remote sensing policy, see Congressional Research Service, *Public and Commercial Land Remote Sensing From Space: Landsat 7, Lewis and Clark, and Private Systems*, by David Radzanowski, 95-346 SPR, February 23, 1995.

²⁰A third satellite, SPOT 3, was launched in 1993 but ceased operation in 1996.

fifth satellite, SPOT 5 with 2.5 m PAN and 10 m MS sensors, is planned for launch in 2002. SPOT was the first commercial remote sensing satellite and helped fuel optimism about the development of a strong commercial remote sensing market in the early 1990s.²¹

Most recently, Ikonos 2, developed by Space Imaging, was launched. As noted, it supplied images of the September 11 attack on the World Trade Center and currently supplies images of the war in Afghanistan.²² After two failures, DigitalGlobe (formerly Earth Watch) successfully launched QuickBird in October 2001, which has both PAN and MS sensors.²³ Another company, Orbimage, suffered a launch failure with its OrbView 4 satellite in 2001.

In addition to these satellites, other countries have or are planning to launch high resolution remote sensing satellites. In addition to India, a joint U.S./Israeli venture successfully launched a 1.8 meter (PAN) satellite, EROS 1A, in December 2000 and several other countries have recently launched or are planning to launch over the next few years high resolution remote sensing satellites.²⁴

Issues

Commercial Market Potential and Government Role

As noted above, development of a healthy commercial satellite remote sensing industry has been a long-term goal of the federal government. While attempts to create such a market by the commercialization of Landsat in the 1980s were not successful, several factors led to a new attempt in the 1990s. These factors included the emergence of lower-cost access to space, the use of commercial remote sensing data during the Gulf War, expansion of satellite remote sensing by foreign governments, growth in sales from SPOT, and concern about the health of the U.S. aerospace industry following the end of the Cold War.²⁵ This interest culminated in Presidential Decision Directive 23 (PDD-23), issued on March 24, 1994, which set forth guidelines for anyone applying for a remote sensing satellite operating license under the 1992 remote sensing act. These guidelines cover any activity that involves foreign access to images, technology, and systems.²⁶ The intent of the directive was to clear up uncertainties about license conditions that had existed since the 1992 Act. One feature of the directive was that the federal government would have the right to limit, for national security reasons, a licensee's satellite observations. This "shutter control" provision has been controversial and will be discussed more fully below.

²¹Kevin O'Connell and Beth E. Lachman, *Commercial Observation Satellites*, 69.

²²Ikonos images can be seen on <http://www.spaceimaging.com/level1/index33.htm>

²³Frank Sietzen, "Advanced imagery," 39.

²⁴See Frank Sietzen, Jr., *Aerospace America*, 39, for a list.

²⁵Kevin O'Connell and Beth E. Lachman, *Commercial Observation Satellites*, 56.

²⁶See <http://www.fas.org/irp/offdocs/pdd23-2.htm>.

With the issuance of PDD-23, the number of license applications grew significantly. At least 11 licenses have been granted by the U.S. Department of Commerce since 1994, including those for three satellites that are now operating — Ikonos 2, Microlab 1 (Orbview-1), and SeaStar (Orbview-2)²⁷. The latter two satellites were developed by Orbimage, a division of Orbital Sciences Corporation (OSC). Three other satellites granted licenses were launched, but failed to achieve operational status. They were EarlyBird, launched in 1997, and QuickBird 1, launched in 2000. Both were developed by Earth Watch (now DigitalGlobe). In the first case, the satellite achieved orbit, but lost power five days after launch. In the second case, the satellite failed to reach orbit. (As noted, a new satellite, QuickBird, was successfully launched in 2001.) In September 2001, Orbview-4, developed by Orbimage, was launched but failed to reach orbit. This satellite had a 1 meter (PAN), a 4 meter (MS), and an 8 meter hyperspectral (HS) sensor suite.²⁸

In addition to regulating domestic commercial remote sensing satellites, the U.S. government is the largest customer of images from those satellites. Acting at the direction of Congress, the major users of these images, NASA and the National Imagery and Mapping Agency (NIMA) of the Department of Defense (DOD), established programs to support the development of a commercial remote sensing industry.²⁹ NASA purchases commercial imagery to supplement data obtained from its own satellites. For many years, the Commercial Remote Sensing Project (now the Earth Science Applications Directorate) at Stennis Space Center had responsibility for these purchases as part of NASA's applications program. While Stennis remains the primary purchaser of remote sensing data for applications, other NASA offices and centers now are involved in such purchases to support their scientific activities. NIMA has created a Commercial Imagery Program to help industry develop capabilities to provide it with products to assist its mapping mission. In addition, NIMA has established contracts with several remote sensing firms for the purchase of image products and services. In both cases, actions are being taken by the agencies to support the development of a commercial industry that can be relied upon as a steady supplier of imagery.

Despite the optimism and federal activities described above, the outlook for commercial remote sensing is uncertain. Currently annual worldwide revenues are estimated to be from \$300 million to \$2 billion depending on what is included. The higher figure includes all analytical and consultant services provided in addition to the raw images. At present, no commercial remote sensing satellite owner is profitable.³⁰

²⁷Microlab 1 is operated by Orbital Sciences Corporation (OSC), but carries instruments for experiments funded by NASA and NSF. SeaStar is also operated by OSC and carries a NASA instrument, SEAWIFS, designed to monitor ocean conditions. OSC retains the rights to the data, however, and is marketing information on ocean fishing locations.

²⁸As a result of the failure, Orbimage filed for Chapter 11 bankruptcy. "Orbimage announces financial restructuring following launch failure," *Aerospace Daily*, Sept. 26, 2001, 3.

²⁹P.L. 105-303; Sec. 107 for provisions about NASA.

³⁰Barnaby J. Feder, *New York Times*, F1.

There appear to be several reasons for the current uncertain state of the industry. Image prices are relatively high, which has restrained demand, particularly from smaller users such as academic researchers, local governments, and small businesses that might have a need for high resolution images. Evidence to date suggests a strong price sensitivity in the market.³¹ Second, aerial remote sensing continues to present stiff competition, particularly as it adopts new technologies that enable lower cost, higher resolution digital images. Currently, aerial remote sensing makes up about 90% of the commercial remote sensing market.³² A third factor is the level of value-added services that facilitate the application of remote sensing images. Given the limited expertise in interpreting and assessing remote sensing images by many potential users, such value-added services will be crucial to the future of the remote sensing industry. A similar situation existed with the development of geographic information systems (GIS). As GIS technologies matured, processes were developed that made them easier to use and, consequently, resulted in an expanded market.³³ The natural connection between remote sensing imagery and GIS may be an important stimulus in developing remote sensing markets.

A fourth factor is the role of the federal government as a purchaser of images. In particular, for various reasons, the NIMA strategy described above does not appear to be providing the stimulus hoped for. In a recent review of that strategy, NIMA officials reaffirmed the agency's desire for a "robust space-based [remote sensing] capability", but also stated that it does not have the funds to buy as much commercial imagery as it desires.³⁴ This lack of funds has hurt the industry, which was counting on strong support from the federal government in the form of purchases of products and services. Without such support, industry officials claim it will be hard to raise the capital needed to build and launch the next generation of commercial remote sensing satellites which includes a 0.5 m resolution (PAN) system planned for 2004.³⁵

Others argue that NIMA does not have adequate resources to process and disseminate the images it already receives and will receive from the National Reconnaissance Office (NRO) and other sources in the next several years.³⁶ As a consequence, these analysts suggest that it is not reasonable to expect that more funds should be added to the NIMA budget to buy more images.³⁷ At the same time, these observers note that the commercial remote sensing industry has not expanded its

³¹ibid., F7.

³²Nick Jonson, "Make or break year for satellite imagery providers, analyst says," *Aerospace Daily*, June 7, 2001, 4.

³³Kevin O'Connell and Beth E. Lachman, *Commercial Observation Satellites*, 66.

³⁴Catherine MacRae, "Updated commercial imagery strategy cites need to back industry," *Inside the Pentagon*, July 26, 2001, 1. See also, Congressional Research Service, *U.S. Space Programs: Civilian, Military, and Commercial*, by Marcia Smith, IB92011, 8.

³⁵ibid., 2.

³⁶The NRO is a DOD department that builds and operates U.S. reconnaissance satellites. It is the source of most of the data NIMA disseminates.

³⁷Beth Larson and Kirk McConnell, "The Problem with Commercial Imagery," *Space News*, July 23, 2001, 13.

commercial market enough to be able to survive without substantial purchases from NIMA. Others, while acknowledging NIMA's situation, suggest that NIMA should look to the commercial remote sensing industry for the technologies, products, and services that can assist with processing and dissemination rather than more images.³⁸ They note that rapid advances are being made in spatial image-related technologies primarily in commercial market, and that NIMA should take advantage of these changes. Furthermore, they argue that it is not certain that the commercial remote sensing industry needs substantial federal investment to survive, but rather the U.S. government should "offer a clear commitment and stick with it ..."³⁹

While NASA, acting at the direction of Congress (P.L.105-303), also has adopted a strategy of supporting commercial remote sensing, its support of the industry is likely to be significantly smaller than NIMA's. The requirements of NASA's Earth Science Enterprise (ESE), which is responsible for the agency's remote sensing activities, are typically very specialized and require sensors that are not usually found on commercial satellites. For example, NASA is interested in measuring climate parameters, such as atmospheric water vapor, temperatures, and wind speeds, for its study of global climate change. In the cases where NASA is using commercial remote sensing data, the satellites are carrying specially designed NASA instruments.

Other federal agencies also use remote sensing data. In a report recently released by the Senate Governmental Affairs Committee, Subcommittee on International Security, Proliferation, and Federal Services, it was reported that of 19 civilian agencies polled, 15 used remote sensing data in some form.⁴⁰ The agencies also expressed concern about their ability to use such data as effectively as they would like. In particular, they cited high costs of commercial data, processing, and analysis; and lack of technology and trained personnel to fully exploit imagery.

In addition to purchasing commercial remote sensing images, the federal government also markets images and may act as a competitor to the commercial industry. Landsat 7, operated by USGS, makes available its images to the public at cost. Some claim that the availability of Landsat 7 images at cost has helped expand the potential market for remote sensing data.⁴¹ The availability of raw images from Landsat also appears to help the commercial remote sensing industry by forcing users of Landsat images to go to commercial value-added firms for processing and analysis. Recently, however, USGS has proposed offering levels of enhancement as well as the raw data.⁴² Many value-added firms argue that such actions would be harmful to their

³⁸Kevin M. O'Connell, "The Problem Without Commercial Imagery," *Space News*, September 3, 2001, 15.

³⁹ibid.

⁴⁰Report by the Senate Committee on Governmental Affairs, Subcommittee on International Security, Proliferation, and Federal Services, *Assessment of Remote Sensing Data Use by Civilian Federal Agencies*, December 12, 2001.

⁴¹Ray A. Williamson, *Commercial Observation Satellites*, 49.

⁴²Jason Bates, "Satellite Imagery Firms Rally Against Landsat 7 Proposal," *Space News*, (continued...)

segment of the industry,⁴³ and that the 1992 Land Remote Sensing Act restricts the sale of Landsat images to “unenhanced” data.

A debate is developing over who should build and operate the next Landsat mission. In order to ensure continuity of Landsat data, NASA has stated that a new satellite — the Landsat Data Continuity Mission — will likely be needed by the end of the decade when the design life of Landsat 7 is complete. Currently, NASA has stated that it wants that follow-on mission to be financed, built, and operated by a private company.⁴⁴ In addition, the 1992 Land Remote Sensing Act, the 1998 Commercial Space Act, and the 2000 NASA Authorization Act express preference for a commercial Landsat Data Continuity Mission. Several remote sensing advocates in the private sector also support a private Landsat 7 follow-on.⁴⁵ These preferences are based on the belief that a privately owned Landsat will best promote the policy of developing a commercial remote sensing industry, and that imagery from such a system will cost less to the federal government. Others, however, argue that this Landsat follow-on mission should be built by NASA. They point out that at a workshop held by NASA on the Continuity Mission, it was the consensus of commercial remote sensing image providers at the meeting that there was insufficient promise of an adequate financial return from a Landsat 7 follow-on to justify private investment.⁴⁶ In addition, members of the value-added segment of the industry in attendance argued that a privately owned Landsat that could set prices for images as it chose could prove detrimental.⁴⁷ They noted that the availability of Landsat 7 data at cost has been very helpful in stimulating growth of the value-added segment.

The U.S. government is also influencing the development of the commercial remote sensing industry through its regulation. In particular, the possibility that the federal government may impose restrictions on what a licensee can observe and transmit, has added a measure of uncertainty to the market. While shutter control has not been invoked to date, the possibility may create concern on the part of potential commercial purchasers of remote sensing imagery that they may lose access to those images during times of national emergency.

A fifth factor is the effect of foreign competition. In addition to the French, Indian, and Israeli launches mentioned above, several other foreign remote sensing satellites are either operating or are planned to be launched within the next several

⁴²(...continued)

September 10, 2001, 4.

⁴³ibid.

⁴⁴Warren Ferster, “Following Landsat 7, NASA Wants Commercial Imager,” *Space News*, April 12, 1999.

⁴⁵Dr. Murray Felsher, “Space Imaging’s Good Work,” *Space News*, July 23, 2001, 13.

⁴⁶Joanne Irene Gabrynowicz, “Law, Practicality and Landsat Data Continuity,” *Space News*, February 19, 2001, 13.

⁴⁷ibid.

years.⁴⁸ These satellites, which are government owned or are highly subsidized by the government, are or will be offering imagery and services similar to those of U.S. commercial remote sensing satellites. Competition from these entities is likely to be substantial and could seriously hinder the growth of a domestic commercial industry.

It is clear that while the market for commercial remote sensing is growing, there is little expectation that the industry will be profitable anytime soon. Non-governmental applications have been slower to develop than anticipated, and competition from aerial remote sensing and foreign competitors is substantial. It is possible that the new generation of 1 meter (PAN) or better satellites may provide the stimulus needed to develop new, profitable applications. Until that happens, however, the economic future of the industry is uncertain.

National Security and Commercial Satellites

Commercial remote sensing satellites offer both benefits and concerns for national security. The U.S. government has made and is making extensive use of these satellites in a variety of national security-related activities. In addition to those noted above, U.S. intelligence officials are purchasing commercial images to supplement those obtained from their own satellites. Although the latter have much higher resolution, they are spread thin and the highest resolution is not always necessary.⁴⁹ Furthermore, costs of processing commercial images are generally less than obtaining images from intelligence satellites, and the commercial satellites are often in a better position because of greater coverage. In another action, immediately after the start of bombing in Afghanistan, NIMA contracted with Space Imaging for exclusive rights to all images taken by Ikonos 2 of the Operation Enduring Freedom area of operations.⁵⁰ NIMA signed a 30-day contract in October, 2001, which was extended for another 30 days in November.⁵¹ Under the contract, NIMA approved what, if any, images could be released for public use. In a related move, DOD requested \$1 billion to purchase commercial satellite imagery from the \$40 billion emergency funding package approved by Congress following the September 11 terrorist attacks.⁵²

Nevertheless, risks remain about the growing presence of high resolution, commercial remote sensing satellites. Indeed, the existence of these risks appears to be a major reason for NIMA's action in contracting for exclusive rights to the Ikonos 2 images from Afghanistan. Potential adversaries could use remote sensing imagery to determine U.S. military preparations and operations.⁵³ They could also use such

⁴⁸See Frank Sietzen, Jr., *Aerospace America*, 39, for a list.

⁴⁹Barnaby J. Feder, *New York Times*, F7.

⁵⁰“Shutter Control.” *Aviation Week & Space Technology*, October 22, 2001, 25.

⁵¹*Communications Daily*, November 7, 2001, 10.

⁵²Tony Capaccio, “U.S. Pentagon Asks \$19 Bln For Weapons, Intelligence,” *Bloomberg.com*, September 19, 2001.

⁵³John C. Baker and Dana J. Johnson, “Security Implications of Commercial Satellite
(continued...) ”

imagery to facilitate military actions against another state or against insurgent groups within their borders. While terrorist organizations could in principle use remote sensing imagery, it may not provide much added value to information it can obtain in other ways. A more critical concern is the possibility that commercial remote sensing could be used by terrorists to compromise U.S. counter terrorism moves.⁵⁴ There is also the risk that access to commercial remote sensing imagery may permit adversaries or related groups to devise ways to limit the effectiveness of U.S. efforts to use remote sensing to monitor their activities.

In the near term, these risks do not appear to be as serious as they are likely to be in the longer term.⁵⁵ At present, most countries in currently sensitive areas do not have the capabilities for processing and analyzing remote sensing images required to make full use of their potential. Other near-term factors that may limit national security risks are that short turn around access — less than 24 hours — is not likely to be available to non-satellite nations for several years; extensive cloud cover limits the value of conventional remote sensing in many areas; and processing technology for making full use of remote sensing imagery may be many years off.

A recent announcement by the Gulf Cooperation Council, a group of Arab states in the Persian Gulf region, that they are exploring the possibility of purchasing their own remote sensing satellite suggests, however, that some of these mitigating factors may be eliminated or greatly reduced relatively soon.⁵⁶ In addition, technological advances such as the penetration of high resolution radar satellites and more automated image processing will help overcome some of the other factors.

The expansion of foreign remote sensing systems could present the United States with significant national security risks. Should that happen, it may be necessary to consider options to neutralize as much of the risk as possible. Such actions, however, would have to be weighed against harm that could come about by reducing the potential national security benefits of increased accessibility to high resolution remote sensing satellites. In particular, as many analysts have suggested, such systems could make the planet more transparent, leading to a world where malevolent intentions are more easily observed and thwarted, and, thus they could possibly act as a significant deterrent to conflict.⁵⁷

An indirect national security concern could arise as a result of misuse of remote sensing imagery by individuals and organizations that are not adequately trained to interpret those images. Interpreting remote sensing images is difficult and involves detection, identification, measurement, and analysis. Without proper equipment or

⁵³(...continued)

Imagery,” *Commercial Observation Satellites*, 116.

⁵⁴ibid., 117.

⁵⁵ibid., 120-125.

⁵⁶Warren Ferster and Gopal Ratnam, “Gulf States Consider Buying Spy Satellite,” *Space News*, December 10, 2001, 1.

⁵⁷John C. Baker, Kevin M. O’Connell, and Ray A. Williamson, *Commercial Observation Satellites*, 563.

training, incorrect interpretation of images can result, particularly if they are somewhat ambiguous in the first place.⁵⁸ Differences of opinion, even contentious debate, could develop over competing interpretations of their meaning.

Such debates can have implications for national security because many times they are about images of objects of military significance that are the basis of proposed foreign policy or other actions. Examples include satellite images of long-range missile development in North Korea and nuclear weapons testing in Pakistan and India.⁵⁹ If the debates are the result of misinterpretation by untrained analysts, they could create credibility problems with the imaging process and undermine U.S. foreign policy. These concerns could be mitigated by cooperative arrangements between experienced and newer, untrained users of remote sensing images. This cooperation could be particularly beneficial for the news media and non-governmental organizations.

Regulation and Commercial Remote Sensing: Shutter Control

The Land Remote Sensing Act of 1992 is the basis for regulation by the federal government of the commercial remote sensing industry.⁶⁰ According to the 1992 Act, a license must be granted before an entity can begin operating a remote sensing satellite. The licensee must protect U.S. national security, observe international obligations of the United States, make raw images available at a reasonable cost to the governments of the lands observed, and notify the Secretary of Commerce of any significant international agreements entered into by the licensee. The Act also prohibits use of remote sensing to gather, transmit, or deliver defense related information for the benefit of any foreign government or to publish photographs of defense facilities. As noted above, Presidential Decision Directive 23 (PDD-23) was issued in 1994 to specify the policy of the Clinton Administration towards commercial remote sensing. The directive allows the Secretary of Commerce to limit image collection and distribution by licensed remote sensing satellites for national security reasons, the so-called shutter control provision. The policy outlined in PDD-23 also promotes the remote sensing industry and provides for low cost access to the images for the United States.

There remains ambiguity and uncertainty in the remote sensing industry about the current regulatory framework governing commercial remote sensing in this country. Rules implementing the Act have taken over eight years from its enactment to develop, with an interim final rule published in July 2000. An attempt was made to clarify the regulations during the 105th Congress, but no amendments to the 1992 Act were included in the Commercial Space Act of 1998 (P.L.105-303). The 1998 Act did, however, reiterate Congress's intent that the federal government pursue opportunities to purchase commercial remote sensing imagery when possible.

⁵⁸John C. Baker, "New Users and Established Experts: Bridging the Knowledge Gap in Interpreting Commercial Satellite Imagery," *Commercial Observation Satellites*, 542.

⁵⁹*ibid.*, 534, 543.

⁶⁰The discussion in this section is based primarily on Bob Preston, "Space Remote Sensing Regulatory Landscape," *Commercial Observation Satellites*, 501.

At issue in the regulations is whether the doctrine of prior restraint — shutter control — can be used to limit actions by remote sensing entities and whether restrictions can be imposed based on foreign policy considerations. In the first case, the debate centers on whether there is adequate justification for regulations that prevent the publication of images prior to any event that may justify that action. Some argue that concerns that national security could be endangered by publication of such images may not be sufficient to justify the use of prior restraint. They argue that it is necessary to prove that application of shutter control would prevent the loss of life before a prior restraint regulation could be established. Others argue that national security considerations are sufficient, and that the use of prior restraint is justified even if the level of danger cannot be specified in advance.

There is also debate about whether the Act authorizes the use of foreign policy concerns as a justification for shutter control prohibiting the acquisition and publishing of remote sensing images of sensitive areas. PDD-23 does include foreign policy along with national security as a justification for shutter control. Some have argued that the term foreign policy in this context is too vague and a more precise expression is needed. These observers suggest the basis for shutter control should be protection of international obligations when harm is possible if images are obtained and published.

The crux of this issue is how to balance the seemingly conflicting goals of promoting a commercial remote sensing industry while also protecting national security. The difficult regulatory challenge is to prevent inappropriate use of remote sensing in gathering information on national security sites for a possible adversary without excessively hindering legitimate commercial operation. While prior restraint through the application of shutter control would likely achieve the first goal, its application could cause severe financial harm for the entity targeted. As noted above, however, the U.S. government has taken another path in the current situation in Afghanistan by contracting with Space Imaging for exclusive rights to the Ikonos 2 images. This has the advantage of preserving the commercial livelihood of the firm while denying access to potentially critical images by adversaries of the United States. It also has the advantage of avoiding a likely court challenge over the legality of using prior restraint in establishing shutter control. The action has not been spared criticism, however, as some have claimed the move is more to control information flow to the public than to assure access to strategic images.⁶¹

Whether such “commercial” actions can be taken in all cases where shutter control might be invoked seems problematic. If not, there does not appear to be any other option than prior restraint. Even then, a court challenge is likely. Furthermore, as the number of high-resolution remote sensing satellites outside the control of the United States grows, the application of shutter control or exclusive purchase contracts will become less and less effective in preventing unwanted access to sensitive images.

⁶¹Pamela Hess, *United Press International*, October 12, 2001.

Policy and Conclusions

To date, federal policy directed at facilitating the development of a strong commercial remote sensing industry appears to have had mixed success. While an industry exists, its future appears uncertain. There are at least three options that might improve the outlook should that remain a national policy goal. They are federal investment, applications development, and regulatory stability.

It seems clear that federal investment in the industry at some level is likely to be required for an indefinite period. While the primary source of this support is now NASA, NIMA, and the intelligence community, Congress may wish to encourage expansion of that base to other agencies such as the Departments of Agriculture, Interior, and Transportation. As noted in the discussion about NIMA's role, such support may be most beneficial if it includes processing and interpretive services as well as the collection of imagery. In that way, the important value-added sector of the industry would also receive assistance. Some observers have argued that an important condition for such investment is that it focus on the missions of the funding agencies and not be set up primarily to develop the industry.⁶²

In a related matter, Congress may wish to reexamine the Landsat Data Continuity Mission. While there appear to be strong arguments supporting private sector development, depending on the state of the industry when the satellite is needed, private development may not be practical. It may be necessary for NASA to provide some or all of the funding for the project if it is to be built in a timely manner. Arguments by segments of the remote sensing industry suggest such a situation would still be beneficial. Whatever decision is made, it appears important that the system maximize support for the industry while maintaining broad public access to images.

Congress may also wish to expand its consideration of applications development. Perhaps even more important than federal investment is the development of remote sensing applications that would drive an expanded market. The value-added and applications research component of the U.S. commercial remote sensing industry is an important reason for the U.S. lead in this industry. To maintain that lead, it will be important that industry is encouraged to continue to seek innovative applications. Applications that would permit small users that do not possess the technology or resources of large users such as NIMA to make full use of the potential offered by these images may be of particular importance. Congress may wish to provide funds to relevant agencies to support research and development for new remote sensing applications that could be of value to state and local governments and to non-governmental organizations.⁶³ The Remote Sensing Applications Act of 2001, H.R.2426, sponsored by Rep. Udall and introduced on June 28, 2001, would direct NASA to: "establish a program of grants for pilot projects to explore the integrated use of sources of remote sensing and other geospatial information to address State, local, regional, and tribal agency needs,"

⁶²Kevin M. O'Connell, *Space News*.

⁶³Space Enterprise Council, "Promote a Competitive U.S. Commercial Remote Sensing Industry," *U.S. Chamber of Commerce*, (Washington, DC) July 2001.

In a recent report, the National Research Council (NRC) of the National Academies found that there were several “gaps that must be bridged” if effective civilian applications of remote sensing were to be developed.⁶⁴ Included were the gaps between raw remote sensing data and useful information, between the expertise of experienced suppliers and users of remote sensing data and potential new users, and between the acquisition cost of raw remote sensing data and the cost of products that permit full utilization of that data. To address these gaps and enhance applications development, the NRC made several recommendations. Among them are that NASA’s Earth Science Enterprise develop cost-benefit analyses of a range of remote sensing applications and the costs of implementing those applications; that NASA, NOAA, the Department of Agriculture, and USGS provide funds to develop training materials and courses for new users of remote sensing data; that NASA, NOAA, USGS, and other relevant civilian agencies support remote sensing applications research; that data producers establish mechanisms to obtain feedback and advice from the user community; and that data standards and protocols be established.

Much of the responsibility for developing such applications for the commercial sector, however, will likely fall on the industry itself. One observer has suggested that partnerships between companies that operate satellites and those that provide the value-added services may be helpful in this connection.⁶⁵ Development of applications and processing that reduce the cost of using imagery and take advantage of the unique contribution of satellite remote sensing will be particularly important.

Congress may also wish to consider ways to improve the regulatory environment. A stable regulatory environment appears to be important for future growth of the commercial remote sensing industry. While concern has been expressed about the current ambiguity in regulatory procedures, that uncertainty has not prevented the issuing of several licenses since 1994. Nevertheless, uncertainty is not conducive to long term growth of the industry. The key factor is the application of shutter control. If shutter control is invoked, it seems important that it be done in a way that minimizes disruption by offering alternatives, if possible, and that clearly spells out the reasons for the constraints. Some have also suggested that foreign policy not be used as a reason for invoking shutter control, but rather specific reference should be made to protection of “U.S. diplomatic forces, installations, and operations.”⁶⁶ While this change would provide a more specific basis for applying shutter control, it may leave out important national considerations that involve a broader definition of foreign policy such as meeting international obligations.

Regulatory stability is also likely to be important when considering emerging technologies. In particular, as hyperspectral and synthetic aperture radar (SAR) sensors gain in resolution, they may pose new regulatory challenges because of their capabilities with respect to national security considerations. Currently, the United States limits commercial SAR resolution to 5 meters. Foreign SAR systems such as Canada’s proposed RADARSAT 2, however, are planned with higher resolution and

⁶⁴The National Research Council, The National Academies, *Transforming Remote Sensing Data into Information and Applications*, (Washington, DC) December 2001.

⁶⁵Nick Jonson, *Aerospace Daily*,

⁶⁶Bob Preston, *Commercial Observation Satellites*, 521.

maintaining the 5 meter limit may hinder U.S. competitiveness in this area. A regulatory scheme that recognizes the realities of the international market may be necessary.

The commercial remote sensing industry has not developed as rapidly as proponents hoped. Furthermore, the U.S. lead in commercial remote sensing may be threatened by growing foreign competition. Nevertheless, an international commercial remote sensing industry is a reality and is changing the way many government and non-government entities approach geospatial and intelligence matters. As pointed out by the authors of *Commercial Observation Satellites*, this presence appears to be ushering in an age of “global transparency.” As sensor resolution and the technology for processing and interpreting data improves, this transparency will grow. Any congressional actions to address the future of U.S. commercial remote sensing likely will have to address the ramifications of these international transparency and competition realities.