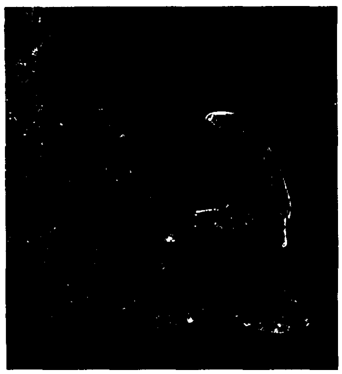
Government and Private Sector Roles in a Developing Market for Geospatial Data

4

As noted in chapter 2, all of the civilian remote sensing satellite systems the United States now operates were developed with public funds to provide data in support of the public good for weather predictions, climate and global change studies, and to manage U.S. renewable and nonrenewable resources. Some of these data, especially multispectral data that provide information about Earth's surface, have proved to have commercial value as well.[1] Such data are provided by the Landsat system and the AVHRR instrument on the National Oceanic and Atmospheric Administration (NOAA)'S POES system.[3] In the future, data from synthetic aperture radar systems will likely develop significant commercial value as well.[4]

Today, space technology, coupled with advanced computer software and hardware techniques, provides expanding opportunities for viewing and analyzing the Earth, its environment, and its resources. As entrepreneurs continue to work with remotely sensed data, they are likely to discover new profit-making uses



[1] See app. B and U.S. Congress, Office of Technology Assessment, *Remote Sensing and the Private Sector: Issues for Discussion* (Washington, DC: U.S. Government Printing Office, 1984), appendices A-1, for a discussion of some of these uses.

[2] Advanced Very High Resolution Radiometer

[3] Polar-orbiting Operational Environmental Satellite

[4] For example, researchers using data collected by the synthetic aperature radar aboard the European Space Agency's ERS-1 satellite have shown their utility in monitoring agricultural activities and in urban planning. See Commission of the European Communities, Institute for Remote Sensing Applications, *Annual Report, 1992,* for discussions of applications in agriculture, mapping, and monitoring that would have commercial value,

for data from remote sensing satellite systems.[5] Although most applications of remotely sensed data are now oriented toward supporting government programs, private firms have expressed increasing interest in 1) expanding value-added[6] activities using remotely sensed data, and 2) building and operating satellite systems.

This chapter discusses how remotely sensed data of Earth's surface, increasingly termed geospatial data, serve public and private interests and examines industry efforts to operate and market data from privately developed remote sensing systems. The chapter also summarizes the characteristics of the current and potential future market for remotely sensed land data. Finally, it discusses the competitive position of the United State vis-a-vis other spacefaring nations in data delivery and applications.

REMOTE SENSING AS A PUBLIC GOOD

Photography and other remote sensing technologies that use aircraft and balloons as platforms have been an important source of data about the Earth for over a century. In 1960, with the launch of its experimental weather satellite, TIROS, NASA was able to show the utility of gathering data from space. Remote sensing satellites are particularly well suited to providing information about weather and the environment.[7] They offer synoptic, worldwide coverage, can operate over hostile territory, and can cover the entire Earth in a period ranging from a day to several weeks.[8]

Experiments with data from TIROS and other research satellites led to the development of the POES and GOES[9] systems, operated by NOAA, and the DMSP[10] satellite system operated by the Department of Defense. These systems provide important data about weather and climate, as well as low-resolution data about the land and oceans. The contributions of remotely sensed data to the public good became especially apparent after the launch of the first operational weather satellites in the 1960s and 1970s: the GOES system (first launched in 1975) tracks both slow moving weather fronts and rapidly developing violent storms. GOES images have contributed to improved early warning of violent storms, resulting in an estimated 50-percent decrease in storm-related deaths[11] (table 4-1), GOES-8, the most advanced GOES satellite,[12] is expected to provide increased ability to track damaging storms (figure 4-l).

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[5] For example, NASA IS designing the sensors for its Earth Observing System (EOS) to serve the interests of global change scientists. However, if previous experience with data from the Landsat multispectral scanner and the AVHRR sensor aboard NOAA's polar-orbiting satellites provide a guide, we may expect that entrepreneurs will find profit-making uses for data from EOS as well.

6 Value-added firms provide information" services to both private and government customers by processing and "adding value to" remotely sensed data.

7 A public good is a good or service for which it is impossible or undesirable for reasons of efficiency to charge customers a Price or user fee for services rendered. Public goods are therefore frequently provided by government and paid for out of tax revenues. See U.S. Congress, Office of Technology Assessment, *Remote Sensing and the Private Sector, Issues for Discussion,* op. cit., pp. 45-47.

8 See U.S. Congress, Office of Technology Assessment, *The Future of Remote Sensing from Space: Civilian Satellites and Applications,* OTA-ISC-558 (Washington, DC: U.S. Government Printing Office, July 1993).

[9] Geostationary Operational Environmental Satellite

10 Defense Meteorological Satellite Program

11 For a history of weather satellites, see *Weather sate//i/es: Systems, Data, and Environmental Applications,* edited by P. Krishna Rao, Susan J. Holmes, Ralph K Anderson, Jay S. Winston, and Paul E. Lehr, Boston, American Meteorological Society, 1990. Also see William James Burroughs, *Watching the World's Weather* (Cambridge, MA: Cambridge University Press, 1991).

12 This is the first satellite in the GOES-Next series, which was successfully launched on Apr. 12, 1994 aboard an Atlas launcher. NOAA expects to make it operational by October.

TABLE 4-1: Billion-Dollar U.S. Weather Disasters, 1980-1993

1	**California Wildfires,** fall 1993 Southern California, estimated at least $10 billlon damage/costs, 4 deaths
2	**Severe Flood,** summer 1993, Central U.S , estimated $120 billion damage/costs, estimated 48 deaths
3	**Drought./Heat Wave,** summer 1993, Southeastern U S , estimated $1,0 billion damage/costs, death toll unknown
4	**Storm/Blizzard,** March 1993 Eastern US , over $20 billion damage/costs, estimated 270 deaths
5	**Hurricane Iniki,** September 1992 Hawaiian island of Kauai, about $1,8 billion damage/costs, 6 deaths
6	**Hurricane Andrew,** August 1992 Florida and Louisiana, about $25.0 billion damage/costs, 58 deaths
7	**Hurricane Bob,** August 1991 Mainly coastal North Carolina, Long Island, and New England, $1 5 billion damage/costs, 18 deaths
8	**Hurricane Hugo,** September 1989 North and South Carolina, $71 billion damage/costs, 57 deaths
9	**Drought/Heat Wave,** summer 1988. Central and Eastern U S , estimated $400 billion damage/costs, estimated 5,000 to 10,000 deaths
10	**Hurricane Juan,** October-November 1985 Louisiana and Southeastern U S , $15 billion damage/costs, 63 deaths
11	**Hurricane Elena,** August-September 1985 Florida and Louisiana, $1 3 billion damage/costs, 4 deaths
12	**Hurricane Alicia,** August 1983 Texas, $20 billion damage/costs, 21 deaths
13	**Drought/Heat Wave,** June-September 1980 Central and Eastern U S , estimated $200 billion damage/costs, estimated 1300 deaths

The U S has sustained some very expensive weather-related disasters over the past 14 years. These disasters have placed a great strain on federal, state and local governments as well as the insurance industry In fact, the past SIX years (1 988-1 993) have produced nine weather related disasters exceeding $1.0 billion with estimated costs exceeding $91 4 billion All figures reflect direct and indrect damages or deaths

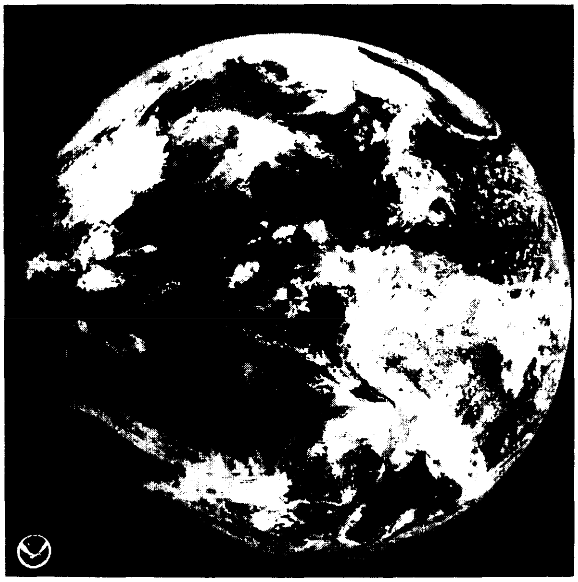
SOURCE NOAA National Climactic Data Center, Research Customer Service Group, 1994

Realizing that moderate-resolution, multispectral data about the land would benefit the scientific analysis of land processes, as well as provide data for a wide variety of applications, NASA designed and launched (in 1972) the world's first land remote sensing satellite—Landsat 1. Follow-on Landsat satellites'[13] have expanded the capabilities of land remote sensing from space and have led to a small, but growing user community.

Remotely sensed data are used by state and local governments for civil engineering, urban planning, resource management, and a host of other applications (apps. B and C). Satellite data are also critical to many legislatively mandated functions of federal government agencies. The Departments of Agriculture and Interior routinely employ remotely sensed data to monitor and inventory crops and habitat. The Forest Service uses these data to monitor the forests and to make resource decisions (app. C). One program, the National Wetlands Inventory, conducted by the Department of Interior's Fish and Wildlife Service,

[13] Landsats 4 and 5, launched in 1982 and 1984, respectively, are still operating, though at much reduced capacity. The replacement Landsat 6 was launched in September 1993, but failed to reach orbit.

FIGURE 4-1: First Image Captured by GOES-8, May 9, 1994



SOURCE National Oceanic and Atmospheric Adminstration, 1994

has particular impact on land use and wildlife management. The inventory[14] requires extensive use of both aircraft and satell ite data to track available habitat for wildlife and extent of wetlands. Remotely sensed data may also allow resource managers to be more efficient in managing renewable and non-renewable resources, providing information on pollution and pollution abatement, and ensuring the safe disposal of hazardous materials. Appendix B offers an example of the use of Landsat and other data by the Bureau of Land Management in categorizing and monitoring land characteristics of the El Malpais National Conservation Area in New Mexico.

Remote sensing technologies have also contributed to military and intelligence successes. The military services and the intelligence community use satellites to monitor international military activities, monitor compliance with arms control treaties, and prepare for deploying troops. U.S. and allied troops made extensive use of Landsat and SPOT imagery in the Persian Gulf Conflict to make maps, determine potential transportation routes, assess enemy fortifications, and analyze damage to the landscape from oil well fires. Afterward, Landsat and SPOT images were used to evaluate the environmental consequences of the war.[15] In addition to using dedicated surveillance satellites, the military services also rely on Landsat imagery for cartography, terrain analysis, and change detection.[16]

COMMERCIAL PROVISION AND USE OF REMOTELY SENSED DATA

Successful government projects involving remote sensing from space sparked commercial interest almost from the very beginning of the programs. Until recently, virtually all private efforts have been centered in the value-added industry, composed of a growing number of relatively small firms who provide information services for local, state, and federal agencies and private customers. Value-added firms use geographic information systems (GIS)[17] and other analytical tools to combine data from the Landsat and SPOT satellites, and from NOAA's POES satellites, with other data to provide a wide variety of useful information for customers. During the past 15 years, oil and mineral extraction companies, urban planners, retail chains, resource managers, futures traders, and cartographers (table 4-2) have recog-

14 Mandated by the *Wild Bird Conservation Act*, 1992 (PL 102-440); the *Coastal Wetlands Planning protection and Restoration Act, 1990 (Sec.* 305); *Emergency Wetlands Resource Act, 1986 (See* 401A, PL 99-1288); and the *Clean Water Act, 1977,* as Codified in U.S. Code 33, Section 1288.

15 National Geographic Society, Committee for Research and Exploration, "Environmental Consequences of the Gulf War: 1990-1991 ," *Research and Exploration, vol. 7* (special issue), 1991.

16 U.S. Congress, Office Of Technology" Assessment, *The Future of Remote Sensing from Space: Civilian Satellites and Applications,* app. C.

17 *See* ch. 2.

TABLE 4-2: Potential Remote Sensing Markets

Industry	Government
Agricultural/agribusiness	State and local government
Engineering and construction	Department of Agriculture
Extraction	NOAWDept of Commerce
Fisheries	Department of Defense
Forestry	Department of Energy
Insurance	Department of Interior
Investment	Department of Transportation
Legal	Environmental ProtectIon Agency
Mapping (Including land-use, urban planning)	NASA
Marketing	Agency for International Development
News Media	
Real Estate	**Other**
Simulation trainlng	Foreign governments
Transportation (land and ocean)	Archaeology research
Utilities	Biology/botany
Waste management	Global change research
	Disease tracking and health management

SOURCE KPMG Peat Marwck, NASA, and the Ohio State Unwersity Center for 'Mappingat *Market Review*, 1992

nized the commercial potential of remote] y sensed data. Appendix B provides several specific examples demonstrating how firms and government agencies turn remotely sensed land data into useful information.

Starting in the late 1970s, the government attempted to commercialize the Landsat series of satellites, an experiment that proved only partially successful. [18] During the Carter Administration, officials had reached the conclusion that remote sensing technology was sufficiently mature to move Landsat from an R&D project to an operational system. Eventually, they believed, sufficient market for data would develop to allow a transition to commercial development and operation. Because NASA's charter stresses the research and development character of the agency and does not specifically give the agency the mandate to operate on-going systems, the operational elements of Landsat were transferred to NOAA in the Department of Commerce, which has extensive experience in operational satellite systems. However, NASA retained the R&D program for remote sensing hardware. Effectively, this separated the research from the operational users who constituted the data market and lessened the ties between these two areas.

In 1992, after it became clear that the attempt to commercialize Landsat was not fully successful, Congress, the National Space Council, NASA, NOAA, and Department of Defense (DOD) reached the conclusion that maintaining continu-

18 See U.S. Congress, Office Of Technology Assessment, *The Future of Remote Sensing from Space*, op. cit., p. 49 for a summary of those attempts. David P. Radzanowski, *The Future of the Land Remote Sensing System (Landsat)*, Congressional Research Service, 91-685 SPR, 1991, for a more detailed account.

ity of the Landsat program was important to the national interest. 19 They also wished to provide in some form for the continued commercial ization of land remote sensing from space. Congress passed the Land Remote Sensing Policy Act of 1992 (box 4-1), which established a joint DOD-NASA effort to build and operate Landsat 7.

The argument for continuing to acquire Landsat-type data for use by government agencies was strengthened by the realization that these data

BOX 4-1: A Synopsis of the Land Remote Sensing Policy Act of 1992

On October 28 1992, Congress passed the Land Remote Sensing Policy Act of 1992 (Policy Act), [1] repealing the Land-Remote Sensing Commercialization Act of 1984 (i-andsat Act) [2] The new law's focus is long-term remote sensing policy and its numerous facets. Specific matters addressed by the Policy Act include program management; Landsat 7 procurement; Landsat 4 through 7 data policy; transfer of Landsat 6 program responsibilities; regulatory authority and admimstration of public and private remote sensing systems; federal research and development, advanced technology demonstratin; Landsat 7 successor systems, data availability and archiving; and the continued prohibition of weather satellite commercialization As a whole the new legislation has three primary features a focus on the value of remote sensing in conducting global change research and other public sector applications, a recashng of the remote sensing activities, and provisions for the future evolution of remote sensing policy

The new law recognizes that Landsat data has research value to educational institutions, nonprofit public interest entitieshtles, and federal governmental researchers and that the previously high cost of Landsat data impeded its use for scietific purposes. Availability of unenhanced Landsat data to U.S government supported researchers and agencies IS the minimum standard set by the act with full availability of Landsat 7 data to all users at the cost of fulfilling user requests its long-term objective Global change research and the United States Global Change Research Program are both specifically cited as activities to be supported by the acquisition of unenhanced Landsat data. Research needs contained in the Global Change Research Act of 1990 are adopted as Policy Act mandates

The Policy Act also recognizes the commercial value of land remote sensing but acknowledges that full commercialization of the Landsat program cannot be achieved within the foreseeable future and is, therefore, an inappropriate near-term national goal It identifies successful commercialization of the Landsat program as a long-term goal with a viable role for the private sector in the promotion and development of the value-added market Preference is also expressed for the private sector in operating U S ground stations and other means for direct access to unenhanced data from government satellites, and utilizing governmental satellites on a space available basis. Long-term private sector preference is expressed for funding and managing a Landsat 7 follow-on system. Commercial remote sensing licenses have already been granted to three private sector corporations under the Act

[1] Public Law 102-555 (106 STAT 4163)

[2] Public Law 98-365 (98 STAT 451)

(continued)

19 As the House Committee on Science, Space, and Technology Report to accompany H.R. 3614 points out (pp. 32-3), the term "continuity" can be used in at least three different ways: 1) continuity of the Landsat program, 2) continuity of the data stream from the Landsat satellites, and 3) continuity of data format, scale, and spectral response. The latter is especially important to Earth scientists attempting to study global change. The Committee report then noted, "The Committee has decided that one of the bill's principal goals should be to enhance the use of Landsat data for public service applications." p. 43.

could be a major contributor to understanding and monitoring the effects of global change.[20] For this application, continuity of the data stream is extremely important.

The rapid growth of the GIS industry provides a third important incentive to continue the Landsat program, because these systems have aided the value-added industry (firms that process and add

BOX 4-1: A Synopsis of the Land Remote Sensing Policy Act of 1992 (cont'd.)

A major change from the Landsat Act is that the new law modifies the nondiscriminatory access data policy as applled to private system operators. They are now required to make unenhanced data available only to the governments of sensed states, thus freeing them 10 make data available to all other customers according to market forces, Originally a foreign policy Intended to assuage nonspacefarlng nations' fears of economic and military espionage, nondiscriminatory access required that data from the government funded and operated Landsat system be made available to all users at the cost of reproduction and distribution Under the Landsat Act the policy was Interpreted to mean that private operators had to charge the same price to all users which, at thousands of dollars per frame, put the data beyond the reach of many researchers and developing nations.

The converse effect of requiring private operators to make data available only to sensed states is that the Policy Act recommits the United States to the foreign policy aspects of nondiscriminatory access and acknowledges the Interests of foreign nations in preserving nondiscriminatory distributiondlstnbutlon The Act still places government systems under the nondiscriminatory access policy,

The Secretary of Defense and the NASA Administrators are jointly responsible for the Landsat Management Program and maintaing unclassified data continuity The management program is to be equally funded by NASA and DOD and had to report to Congress in October 1993, and biennially thereafter, regarding public comments about system use, volume of use, and, recommendations for policyy and programmatic changes. Management responsibilities include contract oversight, bringing Landsat 7 online, operating the Landsat system, meeting the requirements of the Global Change Research Act of 1990, and coordinating an advanced remote sensing technology demonstration program DOD was responsible for satellite and sensor design and development NASA was responsible for ground operations and data distribution The President is authorized to declassify intelligence satellite technology for the Landsat advanced technology demonstration program, The Landsat Management Program WilI seek Impartial advice through the Landsat Advisory Process, which will draw perspectives from state and local government agencies, academia, and business, as well as from a broad diversity of people of age, gender, and race

3 Now that the Department of Defense has decided not to participate in procuring and operating Landsat 7 the Clinton Administration and Congress have worked out new arrangements for managing Landsat NASA, NOAA, and the U S Geological Survey will jointly develop operate and distribute data from Landsat 7

SOURCE Joanne Gabrynowicz, 1994.

[20] J. Roughgarden et al., "What Does Remote Sensing Do for Ecology'?" *Ecology, vol.* 72, No. 6, 1991, pp. 1918-192 l; U.S. Executive office of [he president, Office of Science and Technology Policy, Committee on Earth Sciences, *Our Changing Planet: A U.S. Strategy for Global Change Research: A Report by the Committee on Earth Sciences to Accompany the U.S. President's Fiscal Year 1990 Budget* (Washington, DC Office of Science and Technology Policy, 1989).

interpretive information to Landsat data). The ease of incorporating remotely sensed data with other geospatial informational has led to a broadly diversified market for these data and has markedly increased their market potential.

Under the joint management agreement between DOD and NASA, DOD was to procure the satellite and NASA would operate it. As conceived by DOD and NASA, Landsat 7 would have carried two primary sensors—an Enhanced Thematic Mapper (ETM) and the High Resolution Multispectral Stereo Imager (HRMSI).[22] NASA decided in late 1993 that it could not afford to pay for the installation and operation of the ground station capable of receiving and processing data from the HRMSI sensor. In response, DOD decided to drop out of the agreement and turn the development and operation of Landsat 7 over to NASA.[23]

Given the importance of Landsat data to global change research, NASA officials have reluctantly decided to build a Landsat 7 including only the ETM. The spacecraft will have the capacity to carry an additional sensor. NASA is making space available for a "flight of opportunity" for a small sensor developed and funded by a government or private entity outside NASA.

The Landsat system may eventually build a large enough market to sustain full commercial operations. However, the recent entry of privately financed systems will likely push commercialization of land remote sensing in another direction.

Major technological improvements, which enable industry to build smaller, less costly satellite systems, has led to proposals from several firms or consortia to build and operate commercial remote sensing satellites focused on serving the market for images of the land and coasts. Data from these satellite systems, if deployed, would not be comparable to data from the Landsat and SPOT systems but would complement them. The following paragraphs summarize the systems and the kinds of data they expect to market:

- ***Orbital Sciences Corp. (OSC)*** plans to launch the company's SeaStar satellite, which will carry the Sea Viewing Wide Field-of-View Sensor (SeaWiFS). SeaWiFS will collect low-resolution (1 to 4 km) multispectral digital data (eight color bands in the visible and near infrared) about the surface of the ocean.[24] OSC expects to market these so-called ocean color data to companies engaged in marine transportation, fishing, offshore oil exploration and productions, and environmental management. The SeaWiFS sensor is based on the Coastal Zone Color Scanner originally developed and flown by NASA. In an experimental arrangement, NASA agreed to purchase five years of SeaWiFS data from OSC in return for an up-front payment of $43.5 million. With NASA as an anchor tenant, the arrangement allowed OSC to approach the financial market for the balance of funding OSC needed to build and operate the satellite. This arrangement will provide a useful test of the principle of purchasing data rather than satellite systems from the private sector.[25]
- ***WorldView Imaging Corp.*** is developing a multispectral land remote sensing satellite system capable of ***3*** meter resolution in stereo (3 meter panchromatic; 15 meter in three color

[21] Such as maps delineating ownership boundaries and data on soils, hydrology, and ecology.

[22] The ETM would collect data of 30 m resolution in 6 visible and infrared bands and of 60 m resolution in a thermal infrared band. It would also carry a panchromatic "sharpening" band of 15 m resolution. The HRMSI would collect stereo data of 10 m resolution in four visible and infrared bands and 5 m resolution in a panchromatic band,

[23] Letter of John Deutch, Under Secretary of Defense, to Congressman George E. Brown, Chairman of the House Committee on Science, Space, and Technology, Dec. 9, 1993.

[24] Matthew R. Willard, "SeaStar to Offer Ocean Monitoring Data," *Earth Observation Magazine,* January 1994, pp. 30-32.

[25] See Office of Technology Assessment, *The Future of Remote Sensing From Space*, op. cit., p. 87, for a discussion of the OSC/NASA agreement and the role of data purchases in promoting the remote sensing industry.

bands). It received an operating license from the Department of Commerce in January 1993 and has begun to construct two satellites and an online data distribution system. World View expects to launch its first satellite in late 1995.

- ***Space Imaging Inc.*** (Lockheed) is designing a multispectral stereo land remote sensing satellite system capable of 1 meter resolution (1 meter panchromatic; 4 meter in four color bands). Lockheed received an operating license on April 22, 1994,[26] and expects to launch its system by late 1997.
- Eyeglass *International. Orbital Sciences Corp., Itek, Inc. and GDE Systems, Inc.* have formed a consortium to develop the Eyeglass Earth Imaging System, which would collect 1 meter stereo panchromatic data and received an operating license on May 9, 1994. The Eyeglass consortium plans to begin operations in early 1997.

These developments provide convincing signs that the remote sensing industry is changing. Eventually, a stronger commercial presence is likely to make additional types of data available to consumers at a range of prices. However, for the next decade the provision of remotely sensed data is likely to continue to be dominated by governments, which will function both as providers and as consumers of data.

ELEMENTS OF RISK AND THE ROLE OF GOVERNMENT

The advent of commercial remote sensing raises important questions for Congress regarding the appropriate roles of government and the private sector in this market. For instance, is it in the public interest to provide funding or tax breaks for commercial remote sensing startups? Will government users purchase data from commercial providers? Will government investigate new ways of obtaining data sets in partnership with commercial firms? Answers to these and other related questions will have a significant impact on companies about to enter the commercial remote sensing industry. **The United States is at a critical point in the development of the market for remotely sensed data and for private operation of remote sensing systems. By its actions, the federal government could help or hinder the development of the data market.**

All space exploration and most satellite development have been made possible by massive government investment. Satellites and space payloads are generally complex, expensive to build,[27] and require years of development. Satellite communications remains the only well-developed commercial space effort. Transportation to orbit remains very expensive and relatively risky. In other words, the technological and market risks of space-based business endeavors are considerable. Therefore, private financial sources have been unwilling to fund most ventures. Within the U.S. political system, which maintains as much distance as possible between government agencies and private enterprise, government programs designed to encourage new private commercial ventures must be structured to reward a certain level of risk taking on the part of private industry, while staying out of its way as much as possible.

Firms must consider several types of risks when beginning new technologies to market. The following briefly summarizes these risks and outlines the possible role of government in reducing them:

1. *Technoligical risk.* Will the invention or innovation work as intended?
2. *Market risk.* Is there a market and can the company capture sufficient market share to be successful? Will the U.S. government or other governments compete?
3. *Financial risk.* Will investors be rewarded with the prospect of sufficient return to encourage

[26] Lockheed applied for an operating license from the Department of Commerce on June 10, 1993.

[27] See U.S. Congress, Office of Technology Assessment, *Affordable Spacecraft: Design and Launch Alternatives*, OTA- BP-I SC-60 (Washington, DC U.S. Government Printing office, January 1990).

them to finance a project in comparison to other investment opportunities?

4. *Policy risk.* Will federal government policy encourage investors to place their money at risk? Will government policy remain stable?

Technological Risk

Government research and development (R&D) in a vast array of technologies related to remote sensing has already helped in overcoming technological risks in the development of commercial instruments and satellites. For example, technology developed at the national laboratories has led to the availability of lightweight, low cost sensors and cameras.[28]

The government can also assist firms to overcome technological barriers by pursuing an aggressive R&D program oriented toward the problems facing commercial firms in providing remote sensing information products. NASA, for example, has pursued several programs since 1972 to encourage the development of new applications for data from Landsat and other systems.

Market Risk

Through policy and legislation, government provides for the protection of intellectual property rights. Government can contribute to new market development in various ways, ranging from in-house government research to cooperative research ventures. In addition, government agencies can monitor their own operations to ensure that projects with commercial appeal do not compete with private alternatives.

NASA has provided training and other help to state and local governments in applying remotely sensed data to problems such as transportation routing, urban planning, environmental inventory, and coastal ecosystem studies. It has also supported universities in the development of educational materials and courses to train students in the use of remotely sensed data. In the early years of Landsat, NASA distributed data to researchers, universities, and other interested parties at no cost. In the 1980s, it established two programs designed to target commercial uses of the data, the Earth Observations Commercial Applications Program (EOCAP), and a program to support commercial demonstrations of space technologies, including remote sensing.

NASA's EOCAP, which is administered by NASA's Stennis Space Center in Mississippi, awarded approximately $10 million between 1988 and 1991 for 31 projects.[29] The funding was matched by private sector financing. In late 1993, NASA made an additional $3,000,000 in matching grants.[30] The program is oriented toward Commercial remote sensing and covers a wide variety of applications and markets. EOCAP'S contributions to commercial interests are designed to encourage transfer of knowledge and know-how from R&D efforts to business.[31] Revenues realized from the first round of projects is far below that anticipated.[32] Yet the program has resulted in many process innovations that may eventually be commercially significant.[33]

[28] Walter S. Scott, testimony before a joint hearing of the Committee on Science, Space, and Technology and the Permanent Select Committee on Intelligence, U.S. House of Representatives, Feb. 9, 1994.

[29] See Molly K. Maculey, "NASA'S Earth Observations Commercialization Program: A Model Government Approach," May 1993, for additional details.

[30] William Boyer, "NASA Center Ready To Award More Remote-Sensing Grants," *Space News*, Aug. 23-29, 1993, p. 18.

[31] See app. B, "Managing Pipeline Rights-of- Way," for one example of an EOCAP partnership project.

[32] Ibid., p. I I.

33 Tom Koger, "NASA's EOCAP Program: The Partnership Advantage from Vision to Real ity," *Earth Observation Magazine*, July/August 1993, pp. 36-40.

A 1984 amendment to the National Aeronautics and Space Act of 1958 directed NASA to assist the private sector in commercializing space activities.[34] Since 1985 NASA has funded the Centers for the Commercial Development of Space (CCDS) Program, a three-way partnership with universities and industry in which NASA provides start-up funds, and industry and the universities contribute funding and expertise. In time, NASA expects the centers to operate without government aid. NASA's objective is to locate centers at universities and to induce companies outside the aerospace industry to cooperate in developing future commercial uses of space through R&D. Remote sensing is one of several commercial opportunities that qualify for CCDS funds.[35]

The Center for Mapping of Ohio State University focuses on integrating GPS, GIS, and remote sensing technologies for a variety of mapping projects. The Space Remote Sensing Center in Mississippi has developed methods of using remotely sensed data for agricultural and other purposes.

The government can also reduce market risk by agreeing to purchase data rather than satellite systems from private firms,[36] much as the U.S. Geological Survey or the U.S. Department of Agriculture purchase aerial photographs from engineering and survey firms.[37] Agencies can also work directly with private firms in developing products that have broad market potential as well as being of use to the government.[38]

Financial Risk

Under present conditions, the single most important risk faced by private firms is financial. Can they convince the venture capital markets that they have reduced risks to an acceptable level? The government could assist in overcoming these financial risks by working with firms to provide creative financing arrangements, especially for data that the government needs anyway.

Various creative commercially driven incentive programs in space activities have been or are being implemented. If Congress wishes to stimulate greater creativity in government's assistance to civilian remote sensing, it could consider encouraging innovative management techniques, coupled with adequate incentives for government managers to explore new business arrangements with industry. Congress might also consider options to modify existing restrictions on multiyear funding for long-term R&D programs, and upfront payment for goods/services to be delivered at a later date.

Several examples of cooperative mechanisms exist. For instance, NASA joint endeavors are a mechanism for industry and government to work on a project together without exchanging funds

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[34] However, as noted in the 1992 report, U.S. Congress, Congressional Budget Office, *Encouraging Private Investment in Space Activities* (Washington, DC: Congressional Budget Office, February 1991), few of these ventures have sufficient market to prove commercially successful.

[35] In December 1993, NASA decided to close down six of the 17 CCDS it had funded, on grounds that they had failed to draw matching funds from industry or to establish clearly defined commercial goals, None of the closed CCDSs were pursuing the development of remote sensing technologies. Liz Tucci, "Six CCDs To Close: Industry Divided," *Space News*, Jan. 3-10, 1994, pp. 1,20.

[36] See below for details about NASA cooperation with Orbital Sciences Corp. in its SeaStar commercial satellite program.

[37] The USGS manages a highly successful program in partnership *with* the states to provide complete aerial coverage of the United States. The National Aerial Photographic Program now reimages the entire United States once every five years.

[38] While not yet an accepted process in government, large companies regularly team with small companies, providing them with expertise collected by large organization (lawyers, accountants, facilities, etc.), receiving in return access to new technology and a partner that is more flexible and can respond rapidly to new developments.

BOX 4-2: The SeaStar Program as an Example of Innovative Government Role

The SeaStar system is a commercial/government partnership between NASA and Orbital Sciences Corp (OSC). The following discusses the mechanics of the SeaStar program and its characteristics. Some of these might be applied to other proposals for commercial remote sensing systems.

Orbital Sciences Corp. and the U.S. government entered into a unique agreement in which NASA contributed $43.5 million over the 18 months of satellite construction in return for a stream of data over a five-year period beginning after the satellite is launched and transmitting data. Then, the "price" of the data sales to the government was calculated to equal the sum of monthly data "purchases" over the five year period that would reimburse the government for the upfront commitment, The government was willing to finance a major part of the construction costs, forgo the interest on the investment, and recover its investment by acquiring data at no additional cost over five years, Regardless of whether this was a good financial investment for the government (a difficult and unreliable metric since the value of the SeaStar data is not established and the comparative costs of obtaining the data through other mechanisms or programs is not known), this type of government/industry arrangement can stimulate the private sector into attempting commercial ventures that it otherwise would not be able to afford,

Other factors that influenced the creation of this public-private partnership include:

- Relatively inexpensive satellite with focused commercial use and market (fishing industry primarily),
- Data that the government is willing to purchase for its own needs and for research needs,
- Sensor that is an improvement on the earlier Ocean Color Sensor, which NASA had already tested extensively.
- Data from the Ocean Color Sensor had been used extensively by ocean scientists.
- Encryption techniques that permit data to be withheld, if necessary, for security reasons.
- Identified commercial market,
- Minimal government oversight in satellite construction and launch.
- Government liens on satellite until completion of contractual requirements.

SOURCE: Office of Technology Assessment, 1994

(therefore taking the agreements out of the acquisition regulations). Many research joint endeavors have worked smoothly and well.[39] However, when companies proposed hardware sharing through joint endeavors, many questions were raised about the use of this mechanism and the legality of it compared to normal procurements.[40] The anchor tenant concept provides a way around the U.S. government ban on multiyear contracts and guaranteed future purchases (box 4-2).[41]

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39 The first, and best documented, joint endeavor was for electrophoresis research in space. NASA agreed to provide flight opportunities and McDonnell-Douglas/Johnson & Johnson provided the research equipment, supplies, and personnel. The research efforts were successful, but the project ended and companies developed alternative terrestrial methods of producing similar drugs. Other joint endeavors between NASA and private companies (e.g., DuPont, John Deere, 3M) have been primarily for research on materials processing in space.

40 The Industrial Space Facility (Space Industries, Inc.) is an example where NASA negotiated a memorandum of agreement to proceed, but the project was not approved. The reasons for the failure of this agreement were complicated, but one of the primary concerns was the overlap in uses of the Industrial Space Facility and NASA's proposed Space Station.

41 Spacehab, which is a private company formed to construct a module for the Space Shuttle that would include space to be sold to Private customers for performing research, could not get a future guarantee of purchases from the government, only a nonbinding commitment. To obtain private financing, Spacehab had to purchase an expensive private insurance policy that covered the loan if the government reneged on the purchases. Spacehab has flow one Shuttle mission. However, relatively few commercial customers have bought space and most experiments on Spacehab have been government sponsored. Its future as a commercially profitable venture has not yet been proven.

Other examples include long-term lease arrangements (often used in real estate transactions involving government use of facilities, but also applied to other situations), lease-purchase agreements, government-owned, company operated laboratories (government cooperatives such as Oak Ridge, Jet Propulsion Laboratory, etc.), and newer joint research consortia such as Sematech.

Policy Risk

New ventures that require a government license must meet the licensing requirements. However, in areas where government policy has not been formulated, or where it is in flux, private firms face substantial risk that they will be caught up in the process of developing new policy. Such was the case with Lockheed Corp. and the Eyeglass consortium. Lockheed applied for a license to launch and operate a private remote sensing system on June 10, 1993. Because Lockheed was seeking permission to operate a system capable of sensing objects as small as 1 meter, and sell the data worldwide, officials in the Clinton Administration became concerned that the sale of data from such a system would jeopardize national security. They delayed issuing a license until all the agencies concerned could agree on the license terms. Because no policy was in place for developing operational guidelines, the process took until April 22, 1994, far longer than the 120 days specified in the *Land Remote Sensing Policy Act of 1992.*[42] First the policy had to be developed[43] and then each individual license had to be considered on its merits. While such policy deliberations are extremely important in ensuring the maintenance of U.S. national security, extensive policy debate among several government agencies, or changes of policy, can inhibit the development of new industries.

In summary, **Congress could assist most effectively in the development of the remote sensing industry by providing upfront funding in return for future data deliveries and modest R&D support for the development of new technologies. The** federal government has invested heavily in research satellites, data receiving equipment, data processing facilities, and other technologies. Instruments and expertise are readily available for satellite construction and launch, and private companies are contributing to the development of the data and information market by adding value to the unenhanced data and selling data to consumers. Finally, researchers have demonstrated the utility of remotely sensed data.

GROWTH OF DATA MARKETS

Over the lifetime of the Landsat program, the market for remotely sensed data has increased,[44] with new market segments added as customers have found new applications for the data.[45] If the brief history of this industry is any indication, future systems that offer improved resolution, stereo capability, or other features will result in still greater expansion of the market. When Landsat was the only operating civilian land remote sensing satellite, it generated considerable interest, but market growth was slow. When SPOT Image. S. A., entered the market in 1987 (box 4-3), many in the U.S. space community feared that SPOT data, because of their higher resolution, would draw customers from EOSAT. Yet sales of SPOT data has helped to stimulate overall market growth.

42 15 USC 5621.

43 "U.S. Policy on Foreign Access to Remote Sensing Space Capabilities," White House Fact Sheet, Mar. 10, 1994.

44 However, revenue from data sales alone is not sufficient to support development of sensors, satellite platforms, and the launch and operation of the Landsat system.

45 David L. Evans and Zhilian Zhu, "AVHRR for Forest Mapping: National Applications and Global Implications", David G. Wagner. et. al., "Determination of Irrigated Crop Consumptive Water Use by Remote Sensing and GIS Monitoring", and Young -Kyun Lee and Mark McCord, "Vessel Routing Impacts of Temporal Altimeter Coverage in the Gulf Stream Region" in *Proceedings of 1993 Convention of the American Congress of Surveyors and American Society of Photogrammetry and Remote Sensing*, Feb. 15-18, 1993.

BOX 4-3: Non-U.S. Surface Remote Sensing

The utility of remotely sensed data in serving public needs, plus the prestige that the operation of sophistcated remote sensing systems confers on a space organization, have led other countries and organizations to develop remote sensing systems.

France In 1987, the French space agency, Centre National ‘Etudes Spatial (CNES) launched the first SPOT satellite to gather remotely sensed land data in the visible and near infrared wavelengths France planned from the start to sell data from the SPOT system on a commercial basis and started a French Incorporated firm, SPOT Image, S A , to market the data around the world SPOT Image has created subsidiary corporations in several other countries to sell data in regional markets and to assist in developing new data products The SPOT satellites provide strong competition to sales of data from the Landsat system

Japan In 1992, the Japanese government launched its Japanese Earth Resources Satelite (JERS-1) to gather Earth resources data from both a visual and infrared instrument and a synthetic aperature radar Japan is marketing data from JERS-1 through the Remote Sensing Technology Center (RESTEC), a foundation established in 1975 under the guidance of the Science and Technology Agency and NASDA, the Japanese Space Agency

India The Indian government operates the Indian Remote Sensing (IRS) satellite, which collects multispectral data of 36 and 72 meters resolution Recently, the U S firm EOSAT signed an agreement with the National Remote Sensing Agency of India for exclusive global marketing rights to data from the IRS satellites

Russia Russia operates the Resurs remote sensing satellite, which collects multispectral photographic data of relatively high resolution (2-10 m) Soyuzkarta, a Russian company, IS marketing data of 2 m resolution Earlier, Russia operated the Almaz synthetic aperature radar satellite and attempted to market data from it, with only partial success

Canada Canada is developing Radarsat, a synthetic aperature radar satellite devoted to collecting data for a variety of tasks, Including ice mapping, ship navigation, and resource exploration and management. Canada expects to launch Radarsat in 1995

The proliferation of non-U S systems poses a long-term competitive challenge to the United States, particularly as users gain more experience using the data On the other hand, users’ experience can be expected to contribute to overall global growth of the data market

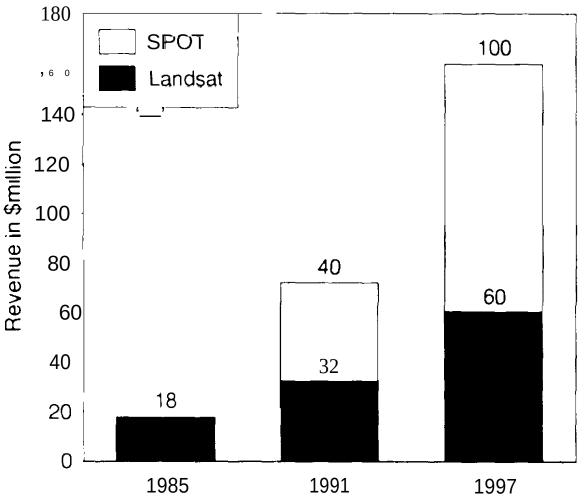
SOURCE : Office of Technology Assessment, 1994

Except for 1993, the market for remotely sensed data from both Landsat and SPOT has increased over the lifetime of the satellites (figure 4-2).

Market studies of land remote sensing range from studies of demand for geospatial data to evaluations of the growth of data processing, especially for GIS. Many past market surveys were overly optimistic. For example, some studies conducted in the mid 1980s forecast a demand for remotely sensed data approaching $1 billion per year by 1994, and between $6 and $10 billion by the end of the decade.[46] Current studies often lump the

[46] The Department of Commerce predicted in 1988 that data, value-added services, and associated products would be worth $6 billion by 1998. Former EOSAT executive vice-president Peter Norris predicted unprocessed data sales of $1 billion by 1994. See "The Selling of Remote Sensing," *Satellite Communications*, December 1988, p. 14; "Growth Stability Predicted for Commercial Space Ventures," *Aviation Week and Space Technology*, Mar. 14, 1988.

FIGURE 4-2: Remotely Sensed Data Sales Trends



Revenue generated by SPOT and Landsat Increased after the introduction of SPOT 10 meter data The trend will likely continue into the future especially If systems with higher resolution are developed

SOURCE National Aeronautics and Space Administratlon, Advanced Research Projects Agency 1993

TABLE 4-3: Revenue Generated by Remote Sensing Activity, 1992 ($ millions)

Activity	Annual Revenue
Data acquisition (Includes satellite and aircraft)	$150
Data distribution/conversion (Includes GIS)	$100
Information products/services (value-added processing)	$300
Hardware/software	$300
Total	$850

SOURCE National Aeronautic and Space Administration EOSAT, Matra.Peat-Marwick

amount spent on data together with the amount of data processing equipment purchased. Although sales of remote] y sensed data may spur some commerce in data processing hardware and software, most sales of general purpose computers and other equipment will serve other purposes as well and cannot be counted for remote sensing industry totals.

Table 4-3 summarizes the market for land remote sensing data, services, and associated hardware and software. Table 4-4, which provides a breakdown of raw data sales, estimates a market for raw (unprocessed) data in 1992 of about $150 million. The value-added industry ($300 million) provides finished data products to users internationa] y. The revenues of the value-added industry will likely increase, as additional data customers discover the value of remotely sensed data.

Data from aircraft and from satellites are characterized by geographic coverage and by price: satellite images tend to cover larger areas at a low'-er price per area than images acquired by aircraft.[47] Satellite systems have high capital costs, but produce data of low marginal cost. Aircraft systems are the reverse. Satellites do not require a dedicated flight each time new data tire needed. and are more likely to provide digital multispec - tral data than aircraft systems. On the other hand, aircraft remote sensing systems can provide higher resolution than existing civilian satellite systems over well-defined geographic areas. In addition, aircraft can fly below high-level clouds that would make satellite data unusable. Increasingly. aircraft and satellite data are combined and merged with other data to create valuable information products.

The revenues of individual data providers continue to increase. EOSAT'S total revenues have grown consistently since 1979 (figure 4-3).[48] EOSAT'S international sales revenue has increased by 12 to 16 percent annually between 1989 and 1991; over the same period, U.S. sales increased by 10 to 24 percent per year. Spot Image's revenue has increased at similar rates. Data sales from the European Space Agency's first Environmental Research Satellite (ERS - 1) are increasing as well, By

[47] The costs of producing satellite data are generally higher than aerial photography. The development and launch costs of even a small remote sensing satel I ite are substantial. A commercial venture must recoup up front Investment from data sales over a period of 2-5 years.

[48] EOSAT's Landsat data sales experienced a modest downturn in 1993 as a result, in part, of the loss of Landsat 6. SPOT Image also experienced a downturn in its 1993 revenue.

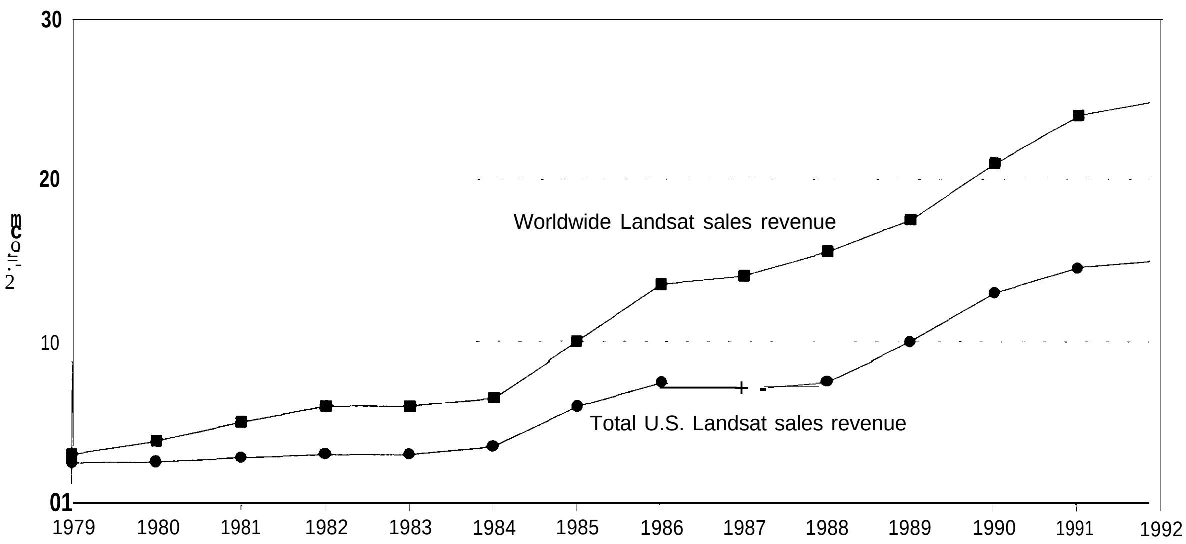
TABLE 4-4: Market for Surface Remote Sensing Data (1992)

Provider	Product	Annual Revenue
SPOT Image	Multispectral	**$40,000,000**
EOSAT	Multispectral	**$25,000,000**
ESA	ERS-1 Radar	$1,000,000
USGS	Orthophotoquads; 1 meter aerial photos; Landsat, AVHRR data	$7,300,000
USDA	USGS orthophotoquads, 1 meter aerial photos	$3,500,000
U S Commercial aerial photography firms	Aerial photography	$40,000,000’
Non-U S commercial aerial photography		$25,000,000’
Indian, Chinese, Russian satellite data	Multispectral digital and film	$10,000,000’
Estimated total		$151,000,000

* Estimate

SOURCE Offlce of Technology Assessment, 1993

FIGURE 4-3: Landsat Data Sales, U.S. and Worldwide, 1979-1992



SOURCE EOSAT, *Worldwide Landsat Data Sales*, 1991 See also Arturo Silvestrini testimony before the House Committee on Science, Space, and Technology spring 1992 the end of May, 1993, the total 1993 sales of Europe's ERS- 1 satellite ($480.000) had already surpassed the total sales amount for 1992.[49]

As noted in chapter 2, the primary repository for Earth resources data is the U.S. Geological Survey's Earth Resources Observation Systems (EROS) Data Center, located in Sioux Falls, SD. EROS Data Center annually sells about $6 to 8 million worth of remotely sensed products, derived from both aircraft and satellite based sensors. Tables 4-5, 4-6 and 4-7 detail the 1992 sales activity of the EROS Data Center

The U.S. Department of Agriculture (USDA) also sells remotely sensed data, most of it acquired by aircraft. In 1992, the USDA sold $3.5 million worth of data, or nearly 1.3 million photographic units. Seventy-five percent of the sales were government purchases.

Appendix B provides examples of several applications of remote sensing. As the resolution and other aspects[50] of commercially available remotely sensed data improve, and as customer access to data expands, it is likely that these applications will create a greater market for data, and other new applications will be added. The data market will also likely increase as software developers improve the user-friendliness of their software for processing and analyzing data.

Current market demand for remotely sensed data is concentrated in five segments (figure 4-4). As the remote sensing industry matures, it will likely experience increased diversification in the application of data, and the development of niche markets. For example, the data needs of a timber company are quite different from the needs of a vineyard, both of which are included in the agriculture/forestry segment. In particular, the vineyard will have far more stringent time requirements for delivery of data than the timber company; the two products have varying value per acre, and grapes require annual harvesting and more careful monitoring during certain seasons.

TABLE 4-5: Fiscal Year 1992 Numbers of Products and Services Provided by USGS

	USGS	EOSAT*
Photographic products	2,916,346	73,658
Dlgltal products/processing	1,497,596	1,738,810
Reference aids	9,020	8,641
Miscellaneous	79,685	1,026,233
Total	**4,502,647**	**2,847,042**

• Products produced at EOSAT but sold through EROS Data Center

SOURCE U.S Geological Survey, EROS Data Center FY 1992 *Annual Report,* p 16

TABLE 4-6: Photographic Data Sold by the EROS Data Center

Aerial photography products	Market
National aerial photography program	$1,777,533
Side lookIng airborne radar	17,123
Other	13,566
Satellite	
AVHRR	50,309
Other	449,781
Digital film recorder products	174,705
USGS Landsat MSS data	122>700
Other photographic	310,630
Total	**S2,916,347**

SOURCE EROS Data Center 1992

TABLE 4-7: Digital Data Sold by EROS Data Center

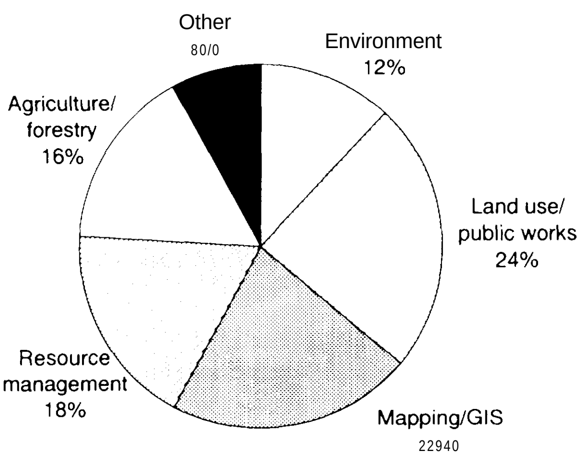
Digital data products	Market
Data processing	$815,014
Side Looking Airborne Radar	4,384
AVHRR	404936
National Digital Cartographic Data Base	62,092
USGS Landsat MSS Data	164,200
National Uranium Data	1,840
Other digital products	55,669
Total	$1,508,135

SOURCE EROS Data Center Annual Report of Dala Services, Fiscal Year 1992

[49] *Space News*, May 24-30,1993, p. 12.

[50] For example, the availability of stereo data.

FIGURE 4-4: Estimated Remote Sensing Market Demand (as a percent of 1992 revenues)



NOTE Demand for remotely sensed data in these markets IS likely to grow GIS/Mapptng IS perhaps the fastest growth area for remotely sensed data but in some ways IS an artificial distinction since the data used in GIS often support applications classed in one of the other categories above

SOURCE National Aeronautics and Space Administration Advanced Research Projects Agency 1993

Remotely sensed data provide tools for improving productivity in many industries. Data providers consider a combination of factors (including price, required resolution, swath width, and the availability of data in a timely fashion) characterizing groups of consumers that cross-cut traditional "applications."5 For example, cartographers generally have different resolution, scene size requirements and price thresholds than do agricultural users. Yet in many instances, customers in both markets would purchase similar data. Data providers are also challenged to find ways to sell data multiple times, lower the cost of data to users, and meet other requirements of customers. Table 4-8 offers a general depiction of some factors that influence the consumers of remotely sensed data products,

Growth of the market for geospatial data will depend primarily on:

1. the ability of the marketplace to find additional applications for data from existing systems;

TABLE 4-8: General Market Requirements for Remotely Sensed Data

Bands	Resolution	Minimum scene size*	Revisit	Price tolerance	Application
Visble near-IR, radar	5-15 m	40km x 40km	Weekly-monthly	$150-1,500	Land-use planning
Visble, near-IR, radar	1-5 m	40km x 40km	Monthly	$500-1,500	Mapping
Visible, near-IR, (hyperspectral)	4-3cl m	40km x 40km	Weekly	$1,000-4,000	Resource management
Visible, IR	2-10 m	40km x 40km	Weekly	$1,000-4,000	Environmental assessment
IR, radar	20-1000 m	80km x 80km	2 days	$500-1,000	Marine
Visble, IR	4-30 m	40km x 40km	2 days	$500-2,000	Agricultural/ forestry

* Varies by specific application

SOURCE National Aeronauticshcs and Space Administration Advanced Research Projects Agency, Off Ice of Technology Assessment

5 Some potential markets have specific timeliness demands--the data will only be useful (and, therefore, will only be purchased) if they can be reliably delivered within certain time constraints. If these constraints cannot be met, the market will not materialize. Likewise, historical data will have appeal to t~ther markm. Reliable access tc) well-archived data sets will be required for many research applicati(ms.

2. the distribution of data with higher spectral, spatial, and temporal resolution than now collected;
3. the development of user friendly software that will enable a wider set of users to apply raw data to new problems;
4. the ability of data providers to reach the customer quickly and efficiently; and
5. reductions in the costs of providing raw data. The availability of data having better features (e.g., stereo) than currently offered by either EOSAT (the Landsat system) or by SPOT Image, could also stimulate the market, especially if these data can reach the customer in a timely and cost-efficient manner.

An $850 million remote sensing market itself is not enough to support a commercial venture with high costs. The costs to develop, launch, and operate a remote sensing satell ite have ranged between $100 and $800 million, depending on the satellite's capability and weight. Since the sales of raw satellite data will capture only a small part of that $850 million market, commercial viability of the market will depend on reducing system costs significantly, and/or tapping a new market niche. Regardless, the financial risks involved in this market are substantial.

INTERNATIONAL COMPETITION IN DATA SERVICES

As noted earlier, the United States faces increasing competition from sales of data generated by foreign satellite systems (box 4-3). During the 1970s and the 1980s, the United States had a monopoly on satellite systems, and gained considerable experience in working with the data for scientific and operational purposes. U.S. agencies and companies developed powerful software to process and analyze large quantities of data efficient] y. Over the last decade, however, data users around the world have acquired similar experience. Recently, software developers, especially in Europe, have begun to develop powerful GIS and other software for processing remotely sensed data and turning them into useful information .52

FIGURE 4-5: Synthetic Aperature Image of Zermatt, Rhone Valley, Taken by ERS-1

SOURCE European Space Agency, 1993

The Europeans and the Japanese are gaining valuable experience in working with multispectral and SAR data. **The lack of a U.S. operational synthetic aperture radar system (box 4-4) may, in time, present a considerable competitive challenge to the United States, both in terms of experience with building and operating a SAR satellite system and in terms of using the data for operational purposes. Although** U.S. scientists have access to ERS-1 data for research purposes, relatively few U.S. resources have been devoted to experimenting with the data for operational purposes. Data from the SAR instrument on ERS-1 (figure 4-5) have potential for use in a wide variety of applications. European scientists have devoted considerable time and effort into learning

52 The countries of Eastern Europe have demonstrated their interest and capabilities in software development, particularly in analyzing data for operational purposes. See Robin Armani, testimony before the Senate Select Committee on Intelligence, Nov. 17, 1993.

BOX 4-4: U.S. Synthetic Aperature Radar Experiments

Instead of developing a free-flying synthetic aperature radar instrument to continue the experiments begun with NASA's Seasat in the late 1970s, NASA decided to build SAR instruments capable of being operated from the Space Shuttle. It has flown Shuttle Imaging Radar-A (SIR-A) and SIR-B on several Shuttle flights, gathering data that would allow NASA scientists to experiment with SAR data.

NASA'S-C (SIR-C), has recently flown on the Shuttle. Although the flight was highly successful, it returned several days worth of data along the orbital path of the Space Shuttle. Although these data will contribute to greater scientific understanding of spaceborne radar systems and their capabilities, the system will not return data that can be used for operational purposes. If SIR-C proves successful in operations from the Shuttle, NASA could convert the instrument to a free-flying, polar-orbitingl spacecraft for $150 to $250 million,[2] giving U.S. scientists and remote sensing specialists important experience in using SAR data for both scientific and operational uses.

1 The use of the polar orbit would make it possible for the satellite to gather data about the land, ocean, and ice Over the entire Earth. The shuttle is limited to covering only mid latitudes

[2] Jet Propulsion Laboratory internal study, 1993.

SOURCE Office of Technology Assessment, 1994

how to make the data useful for ocean shipping, agriculture, and other applications.

The U.S. private sector has been a world leader in the development of GIS and other data processing software. It is likely to continue to lead the world for some time. However, the development and operation by other nations of multispectral and SAR satellite systems will give the private sectors of those countries considerable incentive to improve their own software and market it world wide. The operation of satellite systems and the market for data systems is closely linked. **If Congress wants to maintain U.S. competitiveness in remote sensing data handling and processing, it may wish to ensure that the United States continues to operate one or more multispectral satellite systems that would provide moderate resolution data about the land and oceans on an operational basis.** Congress has several options to assist U.S. competitiveness. It could continue to fund the development and operation of Landsat 7, funded by the federal government. Alternatively, it could assist the development of privately operated land remote sensing satellites by directing agencies to purchase data rather than systems from industry. Because the data from Landsat 7, and the data from proposed privately operated satellites would complement each other, rather than compete, Congress may want to pursue both courses of action.