International Cooperation and Competition 4

A U.S. national strategy for satellite remote sensing must take into account the increasing importance of international remote sensing activities. The growing number of countries that are active in remote sensing and the increasing number and depth of international interactions among remote sensing programs have created expanding opportunities for the United States to benefit from international cooperation in remote sensing. The changing international scene also poses new challenges to U.S. competitiveness in commercial remote sensing and force a reconsideration of national security interests in remote sensing technologies.

Several factors have led to the increasing international interactions in remote sensing, which include both cooperation among governmental programs and competition in commercial activities. First, the market for satellite data is naturally a global one, in terms of both supply and demand. The supply is global because satellites are capable of viewing the entire globe as they orbit Earth.[1] The demand is global because users around the world are making increasing use of satellite data and because many of the

[1] Not all satellites have global scope, but all are capable of viewing very large regions of Earth. Satellites in polar orbit can observe the entire globe as Earth rotates under their orbits; those in lower-inclination orbits miss regions that are too far north or south; those in geosynchronous orbit view continuously the same region—roughly a third—of Earth's surface. Article 11 of the Outer Space Treaty (United Nations, *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*, Jan. 27, 1967) recognizes the right of satellites to pass over international boundaries with impunity, and *The United Nations Principles Relating to Remote Sensing of the Earth from Space* reaffirm the legitimate role of remote sensing satellites. See U, S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, OTA-ISS-604 (Washington, DC: U.S. Government Printing Office, August 1994), box 5-3.

applications of satellite data, such as weather forecasting and global change research, depend on the availability of global data sets.

The national pursuit of technological self-sufficiency has helped produce a second factor behind the internationalization of remote sensing: the increasing international diffusion of technical capabilities. Although commercial firms are playing an increasingly large role in satellite remote sensing, national governments continue to predominate. Canada, Europe, India, Japan, and Russia all have substantial and overlapping capabilities in remote sensing. This creates new opportunities for international cooperation in remote sensing, but it poses challenges to U.S. leadership. U.S. policies and practices no longer determine international standards by default. Instead, the United States faces the more difficult task of providing leadership through consensus building and accommodating the interests of other countries.

The third critical factor affecting international remote sensing activities is the worldwide interest in reducing costs. This leads to two competing impulses:

- the growing interest in international cooperation in order to increase the cost-effectiveness of remote sensing programs, particularly to eliminate unnecessary duplication among various national programs; and
- the tendency toward commercialization, provided by government agencies to recover some of the costs of developing and operating remote sensing systems.

These two impulses are in conflict because international cooperation relies on the relatively open exchange of data, while commercialization depends on the ability to limit data access only to paying customers. Because of this conflict, efforts to promote international cooperation in an era of multiple suppliers have focused first on the coordination of data policies.[2] **The development of successful data-exchange policies will be critical to future international cooperation in remote sensing.**

These three factors have led to programs of international cooperation and plans for continuing the expansion of international cooperation in remote sensing. The ultimate scope and direction of this cooperation will depend on several factors:

- the ability to preserve effective data-exchange mechanisms;
- the ability to share equitably both the costs of developing and operating remote sensing systems and control over those systems, without creating cumbersome financial and administrative arrangements;
- the confidence of all international partners in their ability to rely on one another (thus, the United States needs to judge the reliability of its partners and to strive to be a reliable partner itself); and
- the uncertain political and economic stability of Russia.

International cooperation will evolve slowly through successive generations of satellite systems as experience determines whether the United States can work effectively with other countries on remote sensing programs.

This chapter begins with a brief discussion of international interests and activities in satellite remote sensing. The following sections discuss the risks and benefits of expanded international cooperation in remote sensing, with particular attention to the implications for commercial markets and for national security interests. The concluding sections apply these considerations to an analysis of a range of options for future organizational structures to support enhanced international cooperation in remote sensing.

[2] U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, op. cit., ch. 5.

INTERNATIONAL REMOTE SENSING NEEDS

For the most part, international uses of remote sensing are similar to those in the United States (see chapter 2). Some of these applications have data requirements that are truly international in character. In other cases, the data requirements are essentially local, although the needs of some foreign users, particularly in developing countries, are qualitatively different from those of U.S. data users.

Weather forecasting is the most established international application of satellite remote sensing.[3] The related endeavors of scientific studies and operational monitoring of oceans and climate, as proposed under the planned Global Climate Observing System (GCOS) and Global Ocean Observing System (GOOS),[4] also require data that are international in scope, as would a proposed Environmental Disaster Observation System (EDOS).[5] These global applications require operational mechanisms for the international exchange of raw and processed data, including the in situ data[6] that remain critical to the quantitative interpretation of satellite data.

Many applications of remote sensing—particularly land remote sensing—require only local or regional data. Yet these uses of remote sensing, applied in widely dispersed locations, often require nearly identical types of data. With their global coverage, satellites offer an economy of scope in meeting data needs in different parts of the world. Despite this, the desire for technological development and autonomy has led many countries to develop independent capabilities in land remote sensing. These countries have taken a range of approaches to the public and private-sector roles.

Other international differences arise from contrasting data needs in different parts of the world, particularly in the developing world. Poorer, developing countries often lack fundamental information about land cover, land use, and natural resources and have limited administrative and financial resources for collecting that information on their own.[7] Providing this basic information through remote sensing could improve substantially the ability of developing countries to manage their natural resources and develop their economies in ways that respect the natural environment,[8] although it could also be used to strengthen the control of authoritarian regimes. Accomplishing development and resource management goals involves much more than simply providing satellite data; it often requires foreign assistance in developing national capabilities to

3 For more information on the data-exchange requirements and mechanisms used in weather forecasting, see U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, op. cit., ch. 5.

4 Plans for GCOS and GOOS, which are currently under development, will probably rely on a mixture of new satellite and in situ instruments and instruments planned for other purposes. For information on GCOS, see Joint Scientific and Technical Committee for GCOS, *GCOS: Responding to the Need for Cl/inure Observations*, WMO No. 777 (Geneva: World Meteorological Organization, 1992); for information on GCOS, see D.J. Baker, "Toward a Global Ocean Observing System," *Oceans* 34(1):76-83, spring 1991; and National Oceanic and Atmospheric Administration, *First Steps Toward a U.S. COOS: Report of a Workshop on U.S. Contributions to a Global Ocean Observing System*, October 1992 (available from Joint Oceanographic Institutions Inc., Washington, DC).

5 For a history of this idea, see J. Johnson-Freese, "Development of a Global EDOS: Political Support and Constraints," *Space Policy IO(1)*1:45-55, 1994. EDOS would not necessarily require a new, dedicated system of satellites, but could rely on timely access to data from satellites designed primarily for other purposes.

6 In contrast to remotely sensed data, in situ data are measured at the location of the phenomenon that is being observed.

7 India is the main exception to this rule, with a substantial commitment to developing its own remote sensing capabilities. China and Brazil also have significant remote sensing programs.

8 Committee on Earth Observations Satellites, "The Relevance of Satellite Missions to the Study of the Global Environment," paper presented at the United Nations Conference on En\ ironment and Development, Rio de Janeiro, June 1992.

BOX 4-1: International Remote Sensing Activities

The past decade has seen a large number of countries join the United States and the former Soviet Union in civilian space-based remote sensing activities. Europe (particularly France), Japan, India, and China have deployed satellite systems, several others plan to do so, and many more countries and organizations use the data obtained from these satellites. These countries have undertaken remote sensing programs for a variety of reasons, including national security and national autonomy in space technology, but also in large part to benefit from the practical applications of environmental data from satellites.

The countries now involved in satellite remote sensing share many common interests. This has led to competition both for prestige and for a share of international markets and increasing intergovernmental cooperation of various types (see appendix B for more details):

- **Data exchanges.** Agreements for the cooperative reception and exchange of data from satellites, along with complementary in situ data, were the earliest form of cooperation in remote sensing. From the earliest days of its civilian remote sensing programs, the United States developed partnerships with other countries for the scientific and operational use of remotely sensed satellite data.
- **Joint projects.** Joint satellite projects are one common form of cooperation. Typically, these involve one country providing instruments to fly on another country's satellite. NOAA and NASA have both flown instruments from other countries and have provided instruments to fly on foreign platforms. As examples, Canada, France, and Britain have contributed instruments to NOAA's Polar-orbiting Operational Environmental Satellite System (POES) platforms, and NASA placed the Total Ozone Mapping Spectrometer (TOMS) on a Soviet Meteor satellite in 1991.[1] More such joint projects are under way.
- **International coordinating bodies.** Several formal and informal intergovernmental bodies also exist to promote broader international coordination of remote sensing programs and policies. The Committee on Earth Observation Satellites (CEOS) has broad membership (table B-4) and works to develop agreements by consensus on data policies and standards. CEOS adopted a revised Resolution on Satellite

(continued)

[1] At the time, this involved difficult export-control negotiations because the TOMS instrument carries electronic circuits hardened to withstand radiation.

make effective use of data from satellites and of in situ data.[9]

THE BENEFITS AND RISKS OF INTERNATIONAL COOPERATION

These common interests in remote sensing, combined with the equally common desire for technological independence, have led an increasing number of countries to undertake civilian space-based remote sensing programs (appendix B). The programs have often begun as independent efforts, but many countries have pursued international cooperation as a way to increase the cost-effectiveness of their national programs. This cooperation has taken a variety of forms (box 4-1).

Each cooperative arrangement has dealt with the problem of facilitating data exchanges and harmonizing data-access policies among the participating agencies (box 4-2). These efforts to coordinate satellite remote sensing programs and their associated data policies form the foundation for a steady expansion of international cooperation.

International cooperation in remote sensing presents the United States with an array of benefits and risks. Many of these benefits and risks apply

[9] See the section on international development in U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, op. cit., ch. 5.

BOX 4-1: International Remote Sensing Activities (Cont'd.)

Data Exchange Principles in Support of Global Change Research in 1992[2] and has begun to develop similar principles for operational environmental uses of satellite data for the public benefit. The Earth Observation International Coordination Working Group (EO-ICWG) represents a different type of cooperation, a working partnership among a smaller set of agencies (table 4-2) to provide more detailed coordination of selected satellite programs into an International Earth Observing System (IEOS, box 4-5).

- **Regional organizations.** The closest international cooperation occurs among the countries of Europe, which have established two regional organizations that deal extensively with remote sensing. The European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) (box 4-6) exist primarily to aggregate the technical and financial resources of European countries to support space research and development and meteorological satellites, respectively; they play roles similar to those of NASA and NOAA in the United States.
- **United Nations organizations.** Several international organizations affiliated with the United Nations also have substantial roles in remote sensing, most notably, the World Meteorological Organization (WMO) and its World Weather Watch (WWW) program (box 4-3). WWW is a cooperative program for carrying out the international exchange of basic meteorological data for operational weather forecasting. This includes shared responsibility for data collection, processing, and transmission.
- **Research programs.** The modern tradition of large-scale international cooperation in earth and environmental sciences dates back to the International Geophysical Year in 1957. It has expanded in recent years because of growing international concerns over changes in the global environment. International programs[3] have helped establish an international global change research agenda that guides national research efforts, including the U.S. Global Change Research Program.

[2] See the minutes of the Sixth CEOS Plenary Meeting, London, December 1992, available from the CEOS Secretariat through the European Space Agency, NASA, and Japan's National Space Development Agency.

[3] The World Climate Research Programme (WCRP), the International Geosphere-Biosphere Programme (IGBP), and the Human Dimensions of Global Environmental Change Programme (HDP) are international research programs aimed at understanding the physical, chemical, biological, and social processes that contribute to global change. The Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS), all in various stages of planning, aim to provide continuous comprehensive measurements of key indicators of global change. U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, OTA-ISS-604 (Washington, DC: U.S. Government Printing Office, September 1994), ch. 5.

SOURCE: Office of Technology Assessment, 1994

equally (o interagency coordination within the U.S. government. but some issues are unique or more pronounced in an international context. An expansion of international cooperation should aim to enhance the benefits of cooperation without adding unnecessary risks.

Benefits of Cooperation

- ***Reducing cost.*** Many of the agencies involved in remote sensing share common goals and have developed overlapping satellite programs. Facing budget constraints, these agencies are looking for ways to coordinate their programs to eliminate unnecessary duplication and, thereby, to reduce their overall cost.
- ***Reducing technological and program risk.*** Some degree of redundancy is necessary, particularly for meteorological and other operational satellite programs. The exchange of backup satellites between the National Oceanic and Atmospheric Administration (NOAA) and its European counterparts is a case in point: NOAA provided a backup geostationary satellite, the Geostationary Operational Environmental Satellite (GOES), when Europe had problems with its Meteosat program, and Eu-

BOX 4-2: The Importance of Data Access and Exchange

International data access and exchange is critical to any future cooperative arrangements in remote sensing. The principal purpose of cooperation is to satisfy the data and information requirements of all parties as effectively and economically as possible. Any cooperative effort, therefore, requires a workable mechanism for providing the participants with the data they need. The same considerations apply to commercial remote sensing ventures.[1]

Data exchange involves a combination of formal agreements on data-access policy and the development of data-management systems to carry out those agreements. Data-access policy involves questions of who should have access to data and under what conditions. These conditions include considerations of price, timeliness, and restrictions on redistribution to third parties. Data management includes the acquisition, transmission, processing, storage, and dissemination of data and information, as well as the information systems necessary to carry out these functions. Both data policy and data management pose potential problems for international cooperation.

NOAA, NASA, and the Department of State have traditionally pushed for the full and open exchange of environmental satellite data in international agreements, particularly cooperative agreements on global change research. However, other national agencies have adopted a variety of more restrictive policies on data access.[2] For example, Eumetsat is planning to encrypt Meteosat data and charge nonmember countries in Europe for access to the raw data. NOAA and other national agencies will probably continue to have free access but may not make the data freely available to third parties as they have in the past. As another example, Canada plans to recover the costs of operating Radarsat by commercial sales, including sales to government agencies.[3]

These more restrictive policies reflect differences in policy and circumstance between U.S. and foreign agencies. For years, the United States has debated the proper role of the public and private sectors in remote sensing, particularly land remote sensing. The Land Remote Sensing Policy Act of 1992 (P.L. 102-555) codifies the current working consensus on these roles.[4] Many countries, especially in Europe, see remotely sensed data as valuable commodities, obtained at substantial cost and not to be given away freely. Many national agencies in Europe face considerable pressure to recover some of their costs through the sale of data. Their limited data needs might not justify the cost of a satellite system unless they can spread the costs over a broader range of users by charging them for data access.

Many countries also argue that those who use remotely sensed data should pay a larger share of the costs of collecting the data. This applies whether the user is a private company or a government agency. These payments would give the users a greater interest in and greater influence over the operation of the remote sensing system.

Some countries also advocate making government agencies pay a greater share of data costs as a more honest form of accounting. To maintain current activities or undertake new ones, user agencies

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[1] See R. Mansell and S. Paltridge, "The Earth Observation Market: Industrial Dynamics and Their Impact on Data Policy," *Space Policy* 9(4):286-298, November 1993; and R. Harris and R. Krawec, "Earth Observation Data Pricing Policy," *Space Policy* 9(4):299-318, November 1993.

[2] R. Harris and R. Krawec, "Some Current International and National Earth Observation Data Policies," *Space Policy* 9(4): 273-285, November 1993.

[3] In exchange for providing launch services, the U.S. government will receive free access to Radarsat data for some purposes.

[4] See chapter 3 and appendix D on Landsat policy history.

BOX 4-2: The Importance of Data Access and Exchange (Cont'd.)

would then need additional budget authority, presumably budget authority that currently belongs to the agency that supplies the data. This transfer of budget authority can be difficult.[5]

Furthermore, many countries allow a much greater commercial role for the government than does the United States. For example, the British Meteorological Office charges oil companies operating in the North Sea commercial rates for specialized weather forecasts, and the French space agency Centre National d'Études Spatiales (CNES) owns a 34-percent share of SPOT Image. Open data access would interfere with these state commercial ventures. Not only are government data not generally considered to belong to the public, but national governments often hold copyrights on the data they collect.

Disagreements over pricing policy also reflect different views of how best to stimulate the market—both governmental and commercial—for remotely sensed data. Does charging commercial prices encourage the market to be more responsive or discourage the development of new applications? Do payment mechanisms and restrictive license agreements create unnecessary impediments to the efficient and effective use of satellite data? Should governments continue to build their own data-collection systems or rely more on commercial data suppliers?

Beyond the coordination of policies on data access and pricing, international data exchange requires systems for collecting, processing, archiving, and disseminating remotely sensed data. The development and implementation of these data-management systems pose substantial challenges for international coordination.

First, the data-management systems need to have adequate capacity to meet the needs of users both inside and outside a given agency. Especially in their initial implementation, data systems often do not satisfy these requirements, as evidenced by early problems in distributing data from both Europe's ERS-1 and Japan's JERS-1 satellites. Most foreign agencies recognize the need for adequate data-management systems, but none has yet made a commitment of resources comparable to NASA's planned investment in the EOS Data and Information System (EOSDIS).[6]

Second, data-management systems need to be sufficiently compatible that users of one system can easily identify and obtain data held by another. This involves the development of agreed-upon standards for data and metadata[7] formats, computer-system interfaces, and data-processing algorithms. Discussions in CEOS have led to efforts to improve the compatibility of systems in the United States, Europe, and Japan, but much work remains to be done to ensure full interoperability of data systems. Coordination of algorithms for preprocessing data to extract physical information is particularly important for global studies that require comparable data from different regions of Earth.

[5] In the late 1980s, the Office of Management and Budget attempted to convince agencies that use Landsat data to help pay for a next-generation Landsat satellite, but the agencies refused to go along. See D. Radzanowski, *The Future of the Land Remote Sensing Satellite System (Landsat)*, 91-685 SPR (Washington, DC: Congressional Research Service, September 1991), p. 12. A similar difficulty arises with the U.S. Global Change Research Program (USGCRP), which NASA dominates in budgetary terms in large part because its overall budget is so much larger than those of other USGCRP agencies. See U.S. Congress, Office of Technology Assessment, *Global Change Research and NASA's Earth Observing System*, OTA-BP-ISC-122 (Washington, DC: U.S. Government Printing Office, November 1993), p. 24.

[6] U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, OTA-ISS-604 (Washington, DC: U.S. Government Printing Office, September 1994), ch. 3; National Research Council, *Panel to Review EOSDIS Plans, Final Report* (Washington, DC: National Academy Press, 1994).

[7] *Metadata* are descriptive catalog data that include such information as the time, geographic location, and quality of data and images and about how to obtain the actual data. See chapter 2 of *Remotely Sensed Data*, ibid.

SOURCES: U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, OTA-ISS-604 (Washington, DC: U.S. Government Printing Office, September 1994), ch. 5.

rope returned the favor when NOAA faced problems with its GOES program, lending Meteosat 3 to NOAA in place of GOES-East (see appendix B). Because the United States and Europe could rely on each other for backups, they avoided more serious disruptions in their operational programs while maintaining the deliberate pace of their satellite-development programs.

- ***Increasing effectiveness.*** The elimination of unnecessary duplication can also free up resources and allow individual agencies to match those resources more effectively with their missions. This reallocation of resources can eliminate gaps that would occur if agency programs were not coordinated. International discussions can be valuable even if they merely help to identify such gaps, but they can be particularly useful if they lead to a division of labor that reduces those gaps. Cooperation on data collection and exchange, especially for data collected in situ, can also provide important benefits.
- ***Sharing burdens.*** International cooperation can lead to a more equitable sharing of costs for existing remote sensing programs. One organization, the International Polar Operational Meteorological Satellite organization (IPOMS), was founded largely for this purpose. IPOMS was disbanded in 1993, having accomplished its mission with Europe's commitment to polar meteorological satellite programs, particularly the Meteorological Operational Satellite (METOP).[10] The growing interest and activity by other countries in remote sensing has also helped to equalize this burden. In 1993, U.S. programs accounted for roughly 40 percent of worldwide spending for civilian remote sensing (table 4-1).
- ***Aggregating resources.*** International cooperation can also provide the means to pay for new programs and projects that individual agencies cannot afford on their own. This has been the case in Europe, where the formation of the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) has allowed European countries to pursue much more ambitious and coherent programs than any of them could have accomplished alone. The need to aggregate resources is particularly great for remote sensing programs, such as the Earth Observing System (EOS), that are organized into large, multi-instrument platforms. In addition to aggregating financial resources, cooperation can also allow countries to combine complementary technical capabilities.

TABLE 4-1: International Civilian Remote Sensing Budgets, 1993

Agency or country[a]	Budget ($ million)
NASA	938
NOAA	320
DOD (Landsat and DMSP)	150
Total United States	1,408
ESA	354
Eumetsat	143
France	415
Germany	88
Italy	66
United Kingdom	127
Total Europe	1,193
Japan[b]	396
Canada	95
Russia[c]	228
China	128
India	90
Others[d]	39
Total	3,577

[a] NASA = National Aeronautics and Space Administration, NOAA = National Oceanic and Atmospheric Administration DOD =Department of Defense, DMSP = Defense Meteorological Satellite Program ESA = European Space Agency

b Including $150 million estimated for the Japan Meteoroloical Agency

[c] From Anser - $100 million estimated for Meteor

[d] From Anser

SOURCES National Oceanic and Atmospheric Administration/Natiiona Environmental Satellite Data and Information Service, 1994, Anser Corporation, 1994, Off Ice of Technology Assessment, 1994

10 The Coordination Group for Meteorological Satellites (CGMS) assumed the remaining coordination functions of IPOMS

- ***Promoting foreign policy objectives.*** Cooperation in space also serves important foreign policy objectives, as exemplified by the international space station program.[11] Important cooperative remote sensing activities grew out of the space station program[12] and from the agreements on space cooperation signed in 1993 by Vice President Albert Gore and Russian Prime Minister Viktor Chemomyrdin.[13] Cooperation on data exchange helped the United States promote the ideal of openness during the Cold War.

Risks of Cooperation

- ***Decreased flexibility.*** The planning, development, and operation of a major remote sensing project require a substantial long-term commitment of resources and do not allow a great deal of flexibility. International coordination could further reduce that flexibility y by making the decisionmaking process more complicated, leading to inefficient choices that limit the potential reductions in cost and risk.
- ***Increased management complexity.*** International cooperation can introduce an extra layer of complexity to the management of a remote sensing program. Not only does the decision-making process become more complicated, but the political and budgetary processes of cooperating agencies in different countries may be difficult to reconcile.
- ***Decreased autonomy.*** The commitment of a substantial portion of an agency's budget to international activities reduces its ability to modify its programs in response to changing needs or budgets. An agency may be forced to compromise on meeting its own requirements in order to meet the requirements of an international program, or it may have to defer desired programs of its own.
- ***Potential unreliability of foreign partners.*** Complementing the loss of autonomy is the concern over the reliability of foreign partners and their commitments. An attempt by one partner to reduce or withdraw its commitment to a joint program could jeopardize the entire program, including portions that had been proceeding steadily as separate national programs. This could pose particular difficulties when cooperation rests on political arrangements of uncertain stability, as is now the case with Russia. The reliability of U.S. commitments is also a concern to potential foreign partners. given recent uncertainties over U.S. commitments to the space station and other major international science and technology programs.[14]
- ***Decreased scope for private markets.*** As discussed in chapter 3. one way to meet the government's remote sensing data needs is to purchase data from the private sector. This has particular advantages when the aggregate demand for a certain type of data is large but no single agency can afford the satellite system. International agreements to fund remote sensing systems jointly could eliminate an important opportunity for the private sector. On the other hand, agreements to discuss common requirements and meet those requirements through coordinated data purchases could stimulate private-sector activities.
- ***Increased technology transfer.*** Although many countries now possess the technical ability to build remote sensing systems oft heir own, the United States maintains a substantial lead

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[11] U.S. Congress, Office Of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, op. cit., box 5-1.

[12] In particular, the Earth Observation International Coordination Working Group (EO-ICWG) grew out of the international polar platforms of the international space station program.

[13] White House, *Plan for Russian-American Cooperative Programs in Earth Science and Environmental Monitoring from Space* (Washington, DC: White House, Oct. 27, 1993).

[14] The cancellation of the Superconducting Supercollider may be instructive in at least two ways. First, the willingness of Congress to cancel a large ongoing project casts some doubt on the U.S. abi I ity to make the needed commitment to large cooperative programs. Second, uncertainty over the U.S. commitment to this project deterred other countries, particularly Japan, from taking part.

in several critical technologies. Cooperative programs require some sharing of technological information, and simply working together inevitably promotes the exchange of technological knowledge. This transfer could, in turn, undermine U.S. national security interests as well as the technological advantages of U.S. companies in the international market.

International cooperation offers many of the same benefits and risks as cooperation among U.S. agencies, with one important difference: International agreements have no central authority **like the U.S. federal government to set the agenda and adjudicate disputes.** Central authority in the U.S. government is relatively weak, and interagency discussions often resemble international negotiations, but national political decisions can intervene to resolve disputes. For example, the planned convergence of polar meteorological satellites was dictated by a Presidential Decision Directive NSTC-2 (appendix C), and NOAA and the Department of Defense (DOD) must answer to presidential and congressional authority in carrying out that decision.

Two areas that deserve special attention as potential constraints on international cooperation in remote sensing are the potential effects on emerging commercial markets and on national security. The next two sections deal with these issues in more detail.

INTERNATIONAL COMPETITION IN REMOTE SENSING

Countries compete in remote sensing for many reasons, including military power, technological prowess, and political symbolism. This section focuses on the more concrete issue of international competition in the commercial aspects of satellite remote sensing.

The United States dominated the development of scientific, operational, and commercial applications of remote sensing as part of the Landsat program in the 1970s and early 1980s. The Land Remote Sensing Commercialization Act of 1984 (P.L. 98-365) and the emergence of the French Systéme pour l'Observation de la Terre (SPOT) system in 1987 helped launch an international market in remote sensing. More recently, enterprises in Europe, Russia, and Japan have attempted to break into the commercial market, and several U.S. firms have announced plans to sell high-resolution land imagery (box 3-7).

Current markets for remotely sensed data are becoming more specialized, with the development of a variety of niche markets, each with its own requirements.[15] The growth in commercial data markets has been stimulated by the most rapidly growing sector: the value-added firms that convert raw data into usable information. European value-added firms are playing a growing role,[16] although U.S. firms continue to dominate the market for Geographic Information Systems (GIS).[17]

National governments continue to dominate both the supply and the demand for remotely sensed data. Because of this, national remote sensing policies play a major role in international data markets. To compete in international markets, U.S. firms must confront markets that are shaped in part by foreign governments. European coun-

[15] For example, agricultural users require moderate-resolution multispectral images with short revisit times. The mapping and planning market often requires high-resolution stereoscopic images, but timeliness is less important. For an outline of the differing requirements for some commercial markets, see U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markers,* op. cit., ch. 4.

[16] The countries of Eastern Europe have demonstrated their interest and capabilities in software development, particularly in analyzing data for operational purposes. See R. Armani, Managing Director of Vitro-SAAS Kft., testimony before the Senate Select Committee on Intelligence, November 1993.

[17] GIS are flexible, computer-based mapping software systems that allow users to manipulate and combine information of different types that comes from a variety of sources, including satellite images. For a more detailed discussion of GIS, see U.S Congress. Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets,* op. cit., ch. 4.

tries in particular have strikingly different policies from the United States on pricing and access to data from government-funded systems, as well as on the role of governments in commercial markets.[18]

Furthermore, government standards for data format and quality can have major effects—beneficial or detrimental----a data markets. They are beneficial when they reduce market risks by encouraging users to coalesce around a predictable set of data requirements, and they can be detrimental if they discourage the emergence of new markets that require different types of data.[19]

Recent events pose several dangers for U.S. firms in the international market. First, the failure of Land sat 6 has created great uncertain y over the continuing supply of Landsat-type data and has encouraged many users to seek other sources of supply, including SPOT data. Any interruption in the data supply could undermine established value-added firms and make it difficult for U.S. data suppliers to break back into a reshaped market.

Chapter 3 identified several options for mitigating these risks, including strengthening government support for continuation of the Landsat system, developing public-private partnerships for a possible Landsat successor or gap-filler, and using long-term data-purchase contracts. Alternatively, the United States could attempt to prevent any data gap by exploring the use of data from foreign satellite systems.[20]

The lack of a U.S. source for operational synthetic aperture radar (SAR) satellite data[21] also poses a danger for U.S. firms, particularly in the value-added market. Although heavy data-telecommunication and data-processing demands currently make SAR data too expensive for most commercial purposes. SAR systems could open up a range of new commercial applications.[22] Europe, Canada, and Japan all have experience operating SAR systems, and Europe has promoted the development of new SAR applications through public-private partnerships. Each of these countries has designated a specific firm[23] to market the data for commercial purposes, and these firms could have a particular advantage in the value--added market.

As described in chapter 3, the United States has several options in order to avoid being left out of the SAR data and value-added market, including deploying its own SAR and funding the purchase of SAR data for the development of commercial applications. In addition, the United States could push for international agreements on equal access to SAR data from foreign sources. Ideally, such agreements would prevent foreign countries from charging higher rates to U.S. commercial users or giving preferential access to designated companies.

Finally, U.S. firms could face obstacles in international markets because of the data policies and commercial subsidies that other governments provide to their national firms. These issues arise frequently in international trade negotiations. and a range of trade policy tools is available to address them.

[18] Ibid.. ch. 5.

[19] U.S. Congress, Office of Technology Assessment, International Security and Space Program, *Data Format Standards for Civilian Remote Sensing Satellites*, background paper (Washington, DC: Office of Technology Assessment, April 1993).

[20] The Indian Remote Sensing Satellite (IRS) system may be one of the closest to Landsat in its technical characteristics, but the Russian Resurs-O or the Japanese Advanced Earth Observing Satellite (A DEOS) sy stem could provide a usable substitute.

[21] The only U.S. space-based SAR system is the Shuttle Imaging Radar-C (SIR-C), which has flown on the Space Shuttle. SIR-C is a much more sophisticated radar than any of [he foreign systems, but fire\ only in frequently.

[22] The ability of SAR systems to "see" through clouds provides a particular advantage over optical systems in providing prompt and reliable imagery when timeliness is critical.

[23] Eurimage in Europe, Radarsat International rn Canada, and the Remote Sensing Technology Center (RESTEC) in Japan.

NATIONAL SECURITY ISSUES

National security concerns also pose constraints on the extent of international cooperation in remote sensing and on U.S. participation in global markets for satellite data and technologies. Remote sensing serves a variety of military and other national security purposes, including many that are similar to civilian applications, such as mapping and weather forecasting, and many that have no obvious civilian counterpart, such as arms control verification, reconnaissance, targeting, and damage assessment. Because the technologies and many of the applications are similar, a national strategy for civilian remote sensing must also consider national security concerns.

U.S. military strategy has long relied on technological superiority, including the superior information that comes from advanced remote sensing systems. The ability to obtain superior information and to deny it to an adversary can be decisive on the battlefield. For this reason, military approaches to remote sensing emphasize control over both technology and data. As discussed below, however, U.S. military requirements may change with the evolving international security environment and the increasing diffusion of technological capabilities.

International Issues in Convergence

The likely European role in a converged weather satellite system designed to meet both military and civilian requirements raises two related issues: control over the data stream, and U.S. reliance on foreign sources of data. DOD has an explicit requirement that it be able to deny the meteorological data stream to an enemy in a crisis or in wartime (chapter 3). Encryption of the broadcast data stream would accomplish this, while preserving the availability to broadcast cloud imagery to properly equipped troops in the field. On-board data storage would allow uninterrupted records for climate and land-use monitoring to be maintained.

The United States would like to be able to control the data stream from the European METOP platform as well, and has insisted on control over data from U.S.-supplied instruments. For METOP- 1, these include the most critical proven meteorological imaging and sounding instruments: the Advanced Very High Resolution Radiometer (AVHRR), the High-Resolution Infrared Sounder (HIRS), and the Advanced Microwave Sounding Unit (AMSU). Initially, Eumetsat has balked at this proposal, noting that data from these instruments is currently freely available by satellite broadcast.[24]

The Clinton Administration's convergence proposal calls for U.S. imagers and sounders to continue to fly on future generations of METOP satellites, but Europe will probably develop some of its own instruments. France and Italy are collaborating to develop the Interferometric Atmospheric Sounding Instrument (IASI), which could become a candidate to replace HIRS.[25] Similarly, ESA is developing a Multifrequency Imaging Microwave Radiometer (MIMR), which could replace the Special Sensor Microwave/Imager (SSM/I), although budget and satellite size constraints have led Europe to review both of these instruments.[26]

Operational users would prefer that compatible data come from the same instruments on METOP as are on the U.S. converged weather satellites. If Europe wanted to fly its own operational instruments, this compatibility could come into question. Alternatively, European instruments could fly on all three satellites, but this would raise con-

24 A. Lawler, "Data Control Complicates Weather Merger," Space *News*, June 20-26, 1994, p. 3.

25 The Atmospheric Infrared Sounder (AIRS) instrument currently under development by NASA for EOS PM-1 is another candidate to replace HIRS, as is the Interferometric Temperature Sounder (ITS) proposed by the Hughes Santa Barbara Research Corporation. Chapter 3 discusses the development of future meteorological instruments.

26 Europe currently has no plans to develop an imager to replace AVHRR.

cerns over U.S. self-sufficiency in basic meteorological systems.

The use of European imaging and sounding instruments on METOP would reduce U.S. leverage over access to and management of the METOP data. Even with a formal agreement on the conditions for restricting access to METOP data, DOD would lose direct control and would have less confidence in its ability to cut off the data flow during times of crisis. In part for this reason, the convergence proposal calls for the United States to operate two of the three operational satellites. Restricting the data flow from these two satellites-either by outright denial or, more likely, by delayed access—would reduce the value of the data from METOP alone. Controlling two of three satellites also limits DOD's reliance on foreign sources of data. The convergence plan calls for the United States to maintain the ability to launch a spare satellite on short notice, which further reduces U.S. reliance on European data sources.

Control over the data flow from a converged satellite system would not necessarily limit all access to comparable data sources. DOD has resisted attempts to make its meteorological imagery available operationally, especially the sea-surface wind data derived from SSM/I, although Europe has developed similar capabilities.[27] Russia also operates polar satellites in the Meteor series, which broadcast some data in the low-quality Automatic Picture Transmission (APT) format. and China has deployed experimental polar weather satellites as well. If these sources continue and improve, the United States could lose all ability to restrict access to high-quality meteorological data. However. maintaining open access (except in a crisis) to data from the converged satellite system could forestall this development by limiting the motivation of other countries to develop advanced meteorological instruments of their own.

Control of Data and Reliance on Foreign Sources

Military concerns over control of access to and management of U.S. data and reliance on foreign sources of data apply to issues beyond convergence. Data from government-run civilian land remote sensing systems have primarily civilian applications, although some types of data have significant military utility.[28] The U.S.-led coalition used data from Landsat and France's SPOT during the Persian Gulf War, and the United States and France restricted the flow of those data to other countries. DOD's Defense Mapping Agency now relies heavily on SPOT data, but may switch to U.S. commercial suppliers once their systems become operational.

The United States will remain a leader in providing satellite weather data and will have strong influence over the shape of cooperative agreements in that endeavor, but the situation could be quite different in other areas. For example, it may be difficult to establish a working partnership on ocean remote sensing that involves two of the leading players—Japan and the U.S. Navy—because of the Japanese policy to support remote sensing only for peaceful purposes. A lack of operational experience with civilian SAR systems could hamper DOD ability to make effective use of data from foreign SAR systems.

Although U.S. security policies have traditionally relied on superior intelligence and information, some people have argued that open access to satellite intelligence would provide greater security benefits than keeping access restricted. French and Canadian proposals in the 1980s, which were

[27] The Active Microwave Instrument (AMI) on board ERS-1 can function as a scatterometer, measuring sea-surface wind speeds.

[28] U.S. Congress, Office of Technology Assessment, *The Future of Remote Sensing from Space: Civilian Satellite Systems and Applications*, OTA-ISC-558 (Washington, DC: U.S. Government Printing Office, July 1993), ch. 6 and app. C.

never realized, called for an international satellite monitoring agency to help verify arms control agreements and promote openness in military deployments in order to defuse military tensions and deter surprise attacks.[29]

Licensing Commercial Data Sales

The differences in technical capability between military and civilian remote sensing systems are narrowing, particularly in the light of proposed high-resolution civilian systems. The Land Remote Sensing Policy Act of 1992 (P.L. 102-555) reiterated the authority of the Department of Commerce to license commercial sales of remotely sensed data. This act presumes that a license should be granted, with possible restrictions on data access. As noted in chapter 3, several firms have since applied for and received licenses to sell data with resolutions as high as 1 to 3 meters (m).

In March 1994, the Clinton Administration announced its policy on licensing the sale of remotely sensed data (appendix F). This policy requires the satellite operator to keep records so that the U.S. government can know who has purchased what data, and it authorizes the government to restrict the flow of data to protect national security interests during a crisis or war.

The principal considerations in permitting such data-sale licenses are: 1) the military sensitivity of the data in question and 2) the availability of comparable data through other channels.[30] Data with 1 -m resolution could certainly be used to identify targets for military attack, although restrictions on data access during a crisis or war could limit their use against mobile military targets. Data of similar resolution will soon be available internationally, from SPOT 4, with 5-m resolution,[31] from Russian satellites, with 2-m resolution or less,[32] and from the French HELIOS satellite.

Diffusion of Technological Capabilities

U.S. export-control policies have been designed to prevent the spread of technologies with critical military applications, including remote sensing. The United States leads the world in many specific sensor technologies, in the development of lightweight sensors and satellite systems, and in the hardware and software of signal process ing.[33] These advantages are important for the commercial competitiveness of U.S. industry as well as for national security. However, the spread of these technological capabilities as other countries pursue remote sensing programs has reduced these U.S. advantages substantially.

The United States no longer leads in all aspects of remote sensing technology, and increasing foreign investments in remote sensing technology are likely to narrow the gaps. For example, the United Kingdom is the world leader in active cooling of infrared sensors. For the type of technology involved in international remote sensing partnerships, technology transfer has become a more equal two-way process in which commercial control of proprietary technologies is more important than military control of sensitive technologies.

International partnerships often involve contractual restrictions that forbid those who receive technical information to support joint projects from using that information for other purposes. Another way to limit the transfer of sensitive technologies is to restrict cooperative programs to less sensitive activities. The imagers and sounders NOAA is providing for METOP-1 fall into this

29 This technical capability alone is not enough to prevent such attacks. U.S. intelligence satellites detected the Iraqi buildup on Kuwait's border in July 1990 but did not conclude that Iraq was planning to attack Kuwait until a few hours before the attack.

30 These are the normal considerations for all export controls.

31 SPOT *4* is scheduled for launch in 1996. See appendix B.

32 Russia has indicated that it might also sell images with resolution of less than 1 m.

33 See chapter 3 for a discussion of the role of technology development in the future Of remote sensing.

category. Finally, the use of "black box" arrangements can minimize the likelihood of inadvertent technology transfers. This entails providing as little detail as possible about the internal functioning of specific instruments while providing such essential information as their weight, power requirements, data quantity and format, and physical tolerances. Such arrangements are generally consistent with the standard engineering practice of modular design, making the components of an overall system as independent as possible.

With any cooperative project, some technology transfer is inevitable, even necessary. Having scientists and engineers work together is probably the most efficient way to transfer technological knowledge, particularly for system-level technologies such as bus design and spacecraft integration and for signal transmission and processing. The various instruments on a satellite generally share common data-communication channels, and the exchange of raw and processed data is essential to any cooperative arrangement.

National security concerns about technology transfer will continue to pose constraints on international cooperation in remote sensing. Given the increasing diffusion of technological capabilities, however, the desire to protect competitive advantages in international commercial markets may take on greater relative importance, and the ability to maintain these advantages through technology controls is likely to erode in any case.

Licensing Satellite Sales

Some countries have expressed an interest in purchasing high-resolution remote sensing satellite systems from U.S. companies, and some U.S. companies have responded with proposals to sell "turnkey" systems for other countries to operate.[34] This type of transfer raises issues that go beyond concerns over the sale of data. Specifically, it would offer the recipient country the opportunity to gain experience in satellite operations and in data processing and management, while limiting the ability of the U.S. government to restrict the flow of data. U.S. policy continues to restrict the sale of these sensitive technologies (see appendix F).

Export Controls and Cooperative Projects

Cooperative remote sensing projects often involve foreign agencies providing instruments to fly on U.S. satellites or U.S. agencies providing instruments to fly on foreign satellites. The transfer of instruments for joint projects differs from more sensitive exports in several important ways. First, instruments can be transferred under a "black box" arrangement that minimizes the opportunities for technology transfer. Second, the sensors involved in joint projects generally have little or no specific military application. Finally, the United States usually undertakes joint projects with allies who often have comparable technical capabilities, so technology transfer is less of a concern (the placement of the Total Ozone Mapping Spectrometer (TOMS) instrument on a (then) Soviet satellite was a significant exception).

Currently, most satellite instruments are treated as munitions under export-control regulations.[35] For most joint projects, these controls are not applied at the time of transfer but at the time when the Memorandum of Understanding (MOU) governing a project is being negotiated. Such an MOU gives NASA the authority to license the necessary transfer of instruments.[36] Complete export control reviews are still required for certain countries, including Russia (although this may change in response to growing U.S.-Russian space cooperation). Another option being considered is to treat remote sensing instruments—at least those that do

[34] J. H. Frey, President of Itek Optical Systems, testimony before the Senate Select Committee on Intelligence, Nov. 17, 1993.

[35] They are listed on the U.S. Munitions List, which is administered by the Department of State.

[36] L. Shaffer, Acting Assistant Associate Administrator for External Coordination, Office of Mission to Planet Earth, NASA, personal communication, July 22, 1994.

not contain sensitive technologies—as dual-use technology items[37] rather than as munitions.

OPTIONS FOR INTERNATIONAL COOPERATION

The preceding sections considered the risks and benefits of international cooperation in remote sensing. This section applies those considerations to a range of options for increasing cooperation in the future.

Current plans for international projects and the agendas of international organizations call for a steady expansion of international cooperation in remote sensing over the next decade and raise the prospect of further long-term growth in international cooperation. This section analyzes three principal alternative approaches to the long-term future of international cooperation in remote sensing. Each of these approaches uses existing international organizations as models or building blocks,

- ***Develop an international information cooperative for environmental data,*** modeled on the World Weather Watch (WWW). The free and open exchange of data has been traditional both in operational meteorology and in the earth and environmental sciences but has come under increasing pressure from promoters of restrictive data-access policies.
- ***Develop formal specialization and division of labor,*** based on the Earth Observation International Coordination Working Group (EO-ICWG). The logical extension of current coordination efforts, this approach would develop formal commitments outlining specific roles for each agency.
- ***Create an international remote sensing agency,*** modeled on ESA or Eumetsat. The long-term need for efficient and reliable international arrangements could lead to a formal international organization for satellite remote sensing.

These options are not mutually exclusive, nor do they provide an exhaustive list of possible future arrangements. They do provide a framework for thinking about the long-term future of international cooperation in remote sensing. The variations on each of these approaches also illustrate possible paths for evolution toward greater cooperation.

International Information Cooperative

Modeled on WWW, an international information cooperative could develop broad institutional mechanisms for data exchange and for sharing responsibilities for data and information management. WWW (box 4-3) has three main functional elements: 1) a Global Observing System, consisting of the observational equipment whose data stream WWW member countries make available for broader use; 2) a Global Data Processing System of forecast centers operated by WWW members; and 3) a Global Telecommunications System for transmitting raw and processed data and forecast information among WWW members. The World Meteorological Council meets regularly to coordinate plans for these systems and for other purposes.

The most important feature of WWW may be its underlying assumption that the mutual benefit of open data exchange is greater than the costs of providing access to data. WWW members provide basic meteorological data and forecast information for the general use of all other members in real time and at no charge. In addition, all programs of the WWW are carried out through the voluntary cooperation of WWW members.

Information cooperatives have significant advantages over more-restrictive data-access mechanisms. Cooperatives are well-suited to modern information technologies that make it easy to provide access to data and information but difficult to control that access. They also allow for an informal sharing of the burden of data collection that does not require a strict accounting of costs and

[37] Controls on dual-use technology items are administered by the Department of Commerce under the Commerce Control List.

BOX 4-3: The World Weather Watch

The World Weather Watch (WWW) was established in 1963 as the operational weather information system of the World Meteorological Organization (WMO), affiliated with the United Nations. WMO itself grew out of the data exchanges of the International Meteorological Organisation, founded in the late 19th century. The purpose of WWW is to provide national and regional weather services with timely access to meteorological data and forecasts. WWW has since become the principal activity of WMO and remains the only worldwide program for international cooperation on operational meteorological data and information.

WWW has three main functional elements: the Global Observing System (GOS), the Global Data-Processing System (GDPS), and the Global Telecommunications System (GTS). GOS consists of a wide variety of components, including weather satellites and their associated ground stations, aircraft, and surface-based observing stations on land and at sea. This collection of meteorological instruments provides fairly complete weather data across the temperate latitudes but has significant gaps over the oceans and in the tropics. The quality of surface-based observations also varies substantially from region to region.

GDPS includes an array of global, regional, and specialized forecast centers. The three World Meteorological Centres—in Washington, DC, Moscow, and Melbourne—provide worldwide weather forecasts on a global scale. An additional 29 Regional and Specialized Meteorological Centres provide more detailed forecasts for specialized purposes; three of these centers are devoted to forecasting tropical cyclones as part of the Tropical Cyclone Programme. These centers use meteorological data and models to develop weather forecasts, which they provide to participating National Meteorological Centres. The forecasts vary from regional to global in scope and cover a range of time scales from a few days to over a week, with increasing emphasis on near-term warning of severe storms and on long-term forecasting.

GTS is a communications network for transmitting meteorological data collected by the Global Observation System and forecast information produced by the Global Data Processing System. The Main Telecommunication Network links the three World Meteorological Centres and 15 Regional Telecommunication Hubs on six continents, which then provide links to regional and national telecommunication networks. The maximum GTS data rate is currently 64 kilobytes per second (kbps), which is inadequate for the routine transfer of satellite imagery, but regional data are available through direct satellite broadcast.[1] GTS is used mostly for transmitting ground-station data, atmospheric soundings, and weather forecast data products. Current limitations on connectivity and data rates restrict the availability of surface weather data and access to useful forecast information in certain regions, particularly the tropics.

The World Meteorological Congress meets every 4 years to develop and revise its long-term plans. To a lesser extent, WWW also provides a vehicle for assisting developing countries in establishing modern weather forecast services. However, the implementation of WWW plans occurs through the Voluntary Cooperation Programme and depends on the willingness of WMO members and international development organizations to provide technical and financial assistance.

[1] There are some exceptions to this rule. India does not make cloud-cover data available directly from Insat, but it does provide derived cloud-motion wind-vector data to WWW. Eumetsat is developing plans to encrypt Meteosat data, but it will continue to make basic data available on GTS.

SOURCES: World Meteorological Organization, 1994; Office of Technology Assessment, 1994.

benefits to each party. Furthermore, information cooperatives facilitate the development of information services in the private sector, such as Accu-Weather, by reducing the cost of raw data. Finally, the open data exchange that would occur under an international information cooperative is compatible with U.S. government data policies and practices.[38]

Information cooperatives also carry substantial disadvantages, however. Some agencies feel that they are bearing a disproportionate share of the costs of data collection and perceive relatively low benefits from the data they receive in exchange. Others will be tempted to act as free riders, using freely available data without contributing proportionately to the cost of collecting those data. **The greatest potential disadvantage of an information cooperative is that it impedes the emergence of a commercial market for data and of the financial mechanism of data sales that could give data users leverage over the data-collection system.**

Eumetsat has made the strongest objection to the free exchange of data: if Eumetsat makes its data freely available, nonmember countries will have little incentive to join Eumetsat and pay its operating costs. This is why Eumetsat plans to encrypt Meteosat data.[39] In addition, some developing countries have reduced their provision of in situ data from weather stations. The countries argue that the benefit goes mainly to developed countries, so developed countries should pay a greater share of the cost. These circumstances have raised fears for the future of the WWW system.

The possible erosion of the WWW system might not have a great effect on the availability of satellite data to NOAA. As the leading supplier of such data, NOAA would almost certainly retain access to other sources through bilateral exchange agreements. However, the erosion of the WWW system could undermine the exchange of in situ data as well as efforts to improve the collection of high-quality in situ data that are essential for understanding climate change and other aspects of global change. Furthermore, bilateral data exchanges usually entail restrictions on access by third parties, which could undermine the ability of private information services to obtain the data they need.

The International Council of Scientific Unions (ICSU) established an information cooperative that is similar to WWW, the World Data Centres (WDCS) (box 4-4), to support international collaboration in earth and environmental sciences and to archive data gathered during the International Geophysical Year in 1957. These centers, which hold both satellite and nonsatellite data, now constitute a valuable resource for global change research. WDCS are generally national data centers, but not all national data centers are WDCS. The WDC system provides open access to data on the basis of reciprocal data exchange among centers. Because of their desire to recover costs through data sales, however, some countries have reduced their contributions of data to the WDC system.[40]

The model of an information cooperative could also be applied to other areas, such as oceanic and terrestrial monitoring. Programs of the International Oceanography Commission (IOC) could provide the basis for operational exchanges of oceanic data, and programs of the Food and Agriculture Organization (FAO) and the United Nations Environment Programme (UNEP) could provide the basis for exchanging data about the

38 US policy elucidated in Office of Management and Budget Circular A-130, treats information owned by the federal government as being in the public domain and allows agencies to charge those requesting information only the marginal cost of fulfilling user requests.

39 L. Shaffer and M.L. Blazek ("International and Interagency Coordination of NASA's Earth Observing System Data and Information System," ERIM Symposium on Remote Sensing and Global Environmental Change, Graz, Austria, Apr. 4-8, 1993) argue that European countries already have substantial reasons to join Eumetsat, including national prestige and the opportunity to have a say in Eumetsat decisions. This may explain why 17 countries already belong to Eumetsat, although Austria's decision to join is generally attributed to Eumetsat's encryption policy.

40 For example, Canada has stopped providing geomagnetic data to the WDC for geomagnetism in Boulder, Colorado.

BOX 4-4: The ICSU World Data Centres

The International Council of Scientific Unions (ICSU), whose members are national scientific academies and international scientific unions, established the World Data Centre (WDC) system as a way to preserve data collected as part of the International Geophysical Year in 1957 and, more generally, to enhance the sharing of earth science data. WDCs serve as international archives for the preservation and exchange of a variety of earth science data.

As of January 1994, there were 44 WDCs in 11 countries, grouped into five geographic areas.[1] Most WDCs are located in National Data Centres (NDCs) established by host countries for their own purposes. The United States hosts 13 WDCs, operated by NOAA, NASA, the U.S. Geological Survey (USGS), the Department of Energy (DOE), and the Department of Defense (DOD).[2] NASA has proposed designating Distributed Active Archive Centers (DAACs) of the Earth Observing System Data and Information System (EOSDIS)[3] as World Data Centers, with the exception of the Alaska Synthetic Aperture Radar Facility, which holds data only from foreign sources.

The WDCs operate under a set of agreed-upon international principles. These principles call for a WDC to make data available to scientists in any country. A WDC should charge no more than the cost of filling the user's request, and WDCs generally share data among themselves on a reciprocal basis at no charge. A country or institution hosting a WDC agrees to provide the resources needed to operate the center on a long-term basis. Most WDCs are now located in national data centers and serve as liaisons to the international scientific community. In return, taking part in the WDC system makes it easier for these national centers to gain access to international data. Very few NDCs existed when the WDC system was established, and the WDC system played an important role in encouraging their formation. In addition, scientists argue that the open exchange of data provides benefits that far outweigh the costs of maintaining a WDC.

WDCs generally have limited resources and depend on their host institutions for these resources and for the services they provide to data users. This limits their ability to undertake initiatives of their own. They also depend for their data holdings on voluntary submissions, which are becoming less frequent as a result of pressures to reduce costs by selling data commercially. The future of the WDC system may depend on the reemergence of more open exchange of scientific data through such international bodies as the Committee on Earth Observation Satellites and the International Earth Observing System.

[1] These regional groups are designated A, B, C1, C2, and D. WDC-A comprises 13 centers in the United States; WDC-B, four in Russia; WDC-C1, nine in Europe; WDC-C2, eight in Japan and one in India; and WDC-D, established in 1988, comprises nine centers in China.

[2] See S. Ruttenberg, "The ICSU World Data Centers," *EOS Transactions* 73(46):494-495, Nov. 17, 1992.

[3] For further information on EOSDIS, see U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, OTA-ISS-604 (Washington, DC: U.S. Government Printing Office, September 1944), ch. 3.

SOURCE Off Ice of Technology Assessment 1994

terrestrial environment. However, interest in the operational use of these types of data has been relatively weak and fragmented, so these exchange mechanisms remain largely unexploited for operational purposes.

Alternatively, the Committee on Earth Observations Satellites (CEOS) could provide the basis for a more comprehensive information cooperative involving satellite data of all types. A broad-based information cooperative may be difficult to achieve at a time when many agencies are emphasizing cost recovery and potential commercial applications of satellite data. **Congress may wish to monitor international negotiations that address the challenge of maintaining open access and exchange of data for operational me-**

teorology programs and for global change research.

International Specialization and Division of Labor

Rather than pursue comprehensive remote sensing programs that go far beyond their means, most agencies have little choice but to specialize in one way or another. In some cases, such as NOAA and Eumetsat, this specialization reflects the scope of an agency's missions, but frequently, it reflects deliberate decisions about where to focus limited resources, particularly in relatively new programs. These decisions are based on a variety of factors, including national and regional needs, technological strengths and opportunities, and the potential for commercialization.

For example, ESA'S nonmeteorological remote sensing programs place special emphasis on atmospheric chemistry and the development of SAR technology and applications. Japan has emphasized observations of ocean color and dynamics and of coastal zones. Canada has focused on the application of SAR to monitor snow and ice cover on land and at sea. Even EOS, which the National Aeronautics and Space Administration (NASA) originally planned as a comprehensive system, has been "rescoped" in response to budget constraints in order to focus on observations related to climate change.[41] Although most agencies have activities outside these core areas, the tendency toward specialization is real and significant.

This specialization arose in part through the coordination activities of CEOS and the Earth Observation International Coordination Working Group (EO-ICWG) and, more importantly, in part from the independent choices of independent agencies. Even this informal division of labor allows the participants to receive the benefits of a comprehensive remote sensing system without any one group bearing all the costs. For example, NASA has been able to reduce its costs for EOS based on the commitment of other agencies to perform some of its functions. Specifically, NASA has eliminated or deferred instruments, such as a SAR and HIRIS, based in part on the fact that Europe, Japan, and Canada are flying similar instruments, though these instruments are less capable and less expensive than those NASA would have flown.[42] NASA could also benefit from the coordination of atmospheric chemistry missions between NASA's EOS Chem and ESA'S Envisat.[43] Even with some division of labor, however, the United States may prefer not to rely too heavily on foreign sources of data, especially in technologically promising areas such as SAR and hyperspectral land sensing.[44]

Relying on the current division of labor without formal commitments from foreign agencies carries significant risks. These risks are twofold. First, an agency could eliminate or substantially modify its plans so that it no longer meets U.S. needs. Second, even if the program continues, the data it produces might not be readily available to users in the United States. Although formal agreements can also collapse, they at least provide assurance of an agency intention and make it more difficult politically for that agency to change direction.

Under a formal division of labor, agencies would agree to take on specialized functions not only for their individual benefit but for the collective benefit of all cooperating agencies. This

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[41] U.S. Congress, Office of Technology Assessment, *The Future of emote Sensing from Space*, op. cit., app. B.

[42] The Japanese Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) will fulfill some of the functions of the canceled HIRIS (High-Resolution Imaging Spectrometer), and the SAR instruments on Europe's ERS-1, ERS-2, and Envisat and Canada's Radarsat will fulfill some of the functions of the canceled EOS SAR.

[43] Recommendation of the EOS Payload Advisory Panel Report, Office of Mission to Planet Earth, National Aeronautics and Space Administration, Dec. 17, 1993, p. 11.

[44] See the earlier section on international competition.

BOX 4-5: The Earth Observation International Coordination Working Group

The Earth Observation International Coordination Working Group (EO-ICWG) was established to coordinate the remote sensing activities associated with the international space station program. Now independent of the space station program, EO-ICWG aims to coordinate a selected set (table 4-2) of programs of the United States, Europe, Canada, and Japan into an International Earth Observing System (IEOS). The current focus of EO-ICWG is to develop an IEOS Implementation Plan to make the IEOS missions as effective as possible, which includes coordinating payloads, making ground systems interoperable, and harmonizing operations.

EO-ICWG has focused much of its effort on developing a set of IEOS Data Exchange Principles. The current draft of the IEOS Data Exchange Principles states that "all IEOS data will be available for peaceful purposes to all users on a nondiscriminatory basis and in a timely manner" and that data will be available for noncommercial uses at no more than the cost of reproduction. So far, however, Europe is committed to including only one of its planned polar platforms—Envisat-1—in IEOS to be subject to these rules, although other platforms may be incorporated later. ESA has stated its intention to include future systems in IEOS, but Eumetsat has made no commitment regarding METOP.

Unlike CEOS, EO-ICWG deals directly with operational matters. The IEOS Implementation Plan is expected to address a wide range of data issues, including access, formats and standards, archives, networks, catalogs, and user services. Current plans do not yet amount to an IEOS Data and Information System comparable to NASA's EOSDIS, although they represent a major step in that direction.

SOURCES: National Aeronautics and Space Administration, 1994; Office of Technology Assessment, 1994.

would permit each agency to limit the scope of its programs with some confidence that it would not at the same time narrow the range of data it might receive or the applications it might pursue.

A formal division of labor would require a structured mechanism for negotiating and reaching agreement on the roles of individual agencies. EO-ICWG provides an example of how this might work (box 4-5). In its ongoing efforts to coordinate selected agency programs (table 4-2) into an International Earth Observing System (IEOS), EO-ICWG provides a framework that facilitates the implementation of instrument exchanges and joint projects. The mandate of EO-ICWG is quite broad and includes coordinating plans for future remote sensing programs. This broad mandate would allow the formation of a joint planning group responsible for coordinating agency plans.

The option of a formalized division of labor raises two principal issues. First, can one agency rely on others to meet its data requirements? For example, can NOAA rely on ESA, Eumetsat, and

TABLE 4-2: International Earth Observing System Members and Platforms

Country or region	Agencies[a]	Satellites
United States	NASA, NOAA	EOS-AM, EOS-PM, EOS-Chem, EOS-Alt, EOS-Aero, POES
Europe	ESA, Eumetsat	Envisat-1
Japan	NASDA, JEA, JMA, MITI	ADEOS, ADEOS-2
Canada	CSA	Contributor to Envisat-1
Japan, United States	NASA, NASDA	TRMM

[a]NASA - National Aeronautics and Space Administration: NOAA - National Oceanic and Atmospheric Administration, ESA - European Space Agency NASDA National Space Development Agency, CSA = Canadian Space Agency

SOURCE National Aeronautics and Space Adminitration, 1994

Japan's National Space Development Agency (NASDA) for atmospheric and oceanic data? The long history of convergence efforts for NOAA and the Defense Meteorological Satellite Program (DMSP) polar systems shows the difficulties of building confidence even among agencies of the U.S. government.[45] To build that level Of Confidence, a formal division of labor requires a formal process through which the agencies that develop and operate remote sensing systems can address the requirements of those who use the data.

The risks of relying on foreign agencies for remotely sensed data are greatest when the data requirements are the most demanding, particularly in terms of operational timeliness and reliability. Therefore, the challenge of international coordination grows with the transition from research and demonstration to operational monitoring, whether for global change research, weather forecasting, or environmental management.

To meet particularly critical needs, an agency may provide in-kind contributions of instruments or share responsibility for data management. For example, NOAA is contributing imagers and sounders to the European METOP platform. NASA is providing a scatterometer to measure sea-surface winds for the Japanese Advanced Earth Observing Satellite (ADEOS) platform and taking responsibility for processing the data from this instrument. Cash contributions are also possible, but nations usually prefer to make in-kind contributions in order to develop and maintain their own technological capabilities.

The willingness of agencies to continue bearing the costs of maintaining and operating a system they have developed can also be an issue, especially if these costs stand in the way of pursuing new programs. Eumetsat has moved toward a more restrictive data policy in large part to spread its costs more broadly. Under a formal division of labor, it would be clearer what each country received in return for its contributions and there would be a mechanism for addressing the division of costs, but it would be difficult to avoid the tendency for each agency to value its own contributions more highly than what it receives in return. Furthermore, some agencies have relatively narrow charters and would not benefit from the data they receive from others. For example, Eumetsat might not be willing to make data from METOP freely available to Japan in return for ocean data from ADEOS, which would have relatively little value to Eumetsat's meteorological mission.

Finally, a division of labor might spread the burden too narrowly among the participating agencies, and the pressure would remain to spread the burden more broadly by restricting data access and charging others for the use of data.

International Remote Sensing Agency

Over the years, several authors have proposed establishing an international satellite remote sensing agency or consortium.[46] These proposals generally envision an organization that is broad-based both in the international scope of its membership and in the functional scope of its observations and their application. It would collect contributions from national governments and, in turn, make data and information available to those governments. This section considers the assumptions that underlie these proposals and summarizes some alternative approaches.

Many proposals cite the International Telecommunications Satellite Corporation (Intelsat) as a model for an international satellite monitoring consortium. Intel sat provides a mechanism for national telecommunications services to combine resources to pay for satellites that provide international telecommunications links. National ser-

45 See chapter 3 for a discussion of convergence.

46 J.H. McElroy, '. INTELSAT, INMARSAT, and CEOS: Is ENVIROSAT Next?" In *Space Monitoring of Global Change,* G. MacDonald and S. Ride (eds.) (San Diego, CA: Institute on Global Conflict and Cooperation, University of California, 1993); J. McLucas and P.M. Maughan, "The Case for Envirosat," *Space Policy* 4(3):229-239, *1988,*

vices receive access to these links in proportion to their investment in Intelsat. The International Maritime Satellite Organization (Inmarsat) plays a similar role for mobile and maritime communications.

The Intel sat model may not be directly applicable to remote sensing because of the nature of the service Intelsat provides. It is much more difficult for remote sensing than for telecommunications services to distribute the benefits of a satellite system in proportion to contributions. Weather forecasting and global change research provide information as a public good. Furthermore, investors in Intelsat recoup their costs by charging users for the telecommunications service they provide.

Other organizations created for international cooperation in the noncommercial applications of space technology, such as the European organizations ESA and Eumetsat (box 4-6), may provide more appropriate models than Intelsat for an international remote sensing organization. Further experience with interagency cooperation through the Integrated Program Office, planned as part of the convergence of the Polar-orbiting Operational Environmental Satellite (POES) and DMSP systems, may also provide important lessons for structuring such an organization.

In general, an international remote sensing organization requires a closer, more formal cooperative structure that could increase both the benefits and the risks of cooperation. Compared with an information cooperative or a formal division of labor, an international organization offers a greater ability to share costs broadly and equitably[47] and a more formal method for meeting international requirements. It could also lead to the most cumbersome administrative arrangements. An international agency also requires the greatest degree of trust among its participants.

The effectiveness of an international monitoring agency will depend on how it deals with several issues:

- ***How much does each member contribute?*** For example, members of Eumetsat contribute a percentage of their gross domestic product (GDP). Members of ESA contribute to so-called mandatory programs (mostly operations and overhead) on a percentage-of-GDP basis and to other programs on a voluntary basis.
- ***What are the procedures for making decisions?*** ESA and Eumetsat generally require consensus among member agencies. which often impedes decisionmaking. In contrast, Intelsat makes decisions like a corporation, on the basis of a majority of share ownership. The decisionmaking process is particularly important in establishing system requirements and matching those requirements to available resources.
- ***What are the policies on data access, for member and nonmember governments as well as for private organizations?*** To create incentives for membership, ESA and Eumetsat give preferential access—providing data at reduced cost, in a more timely manner, or in a more complete form-to member governments.
- ***What should the agency buy-satellite systems or data-and from whom?*** Under its "juste retour" policy, ESA spends contract money in a member country in proportion to that country's voluntary contribution to ESA. This policy has been criticized as cumbersome and inefficient, but it aims to provide technological and economic benefits in proportion to national contributions. Intelsat and Eumetsat have no such policies. For now, the absence of rules on procurement sources would benefit U.S. aerospace firms, which hold the technological lead in many areas. But in the long run, this approach might not guarantee a continuing role for U.S. companies in providing the systems they currently produce.
- How ***comprehensive should the agency's mission be?*** Eumetsat focuses on weather and c1i-

47 In principle, such an organization could lead to an unfair distribution of costs. However, it is unlikely to impose a greater relative burden than current arrangements do on the United States.

BOX 4-6: Eumetsat

The European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) grew out of satellite programs of the European Space Agency (ESA) and its predecessor, the European Space Research Organisation (ESRO). ESA launched the first two experimental geosynchronous satellites in the Meteosat series in 1977 and 1981. The national weather services of Europe established Eumetsat in 1986 to continue this program, and Eumetsat is now responsible for the Meteosat Operational Programme (MOP). Eumetsat has since grown to 17 members and has taken on an increasingly important role in data transmission, data processing, and nonsatellite observations.[1] Eumetsat is also developing the polar platform METOP for launch in the year 2000 and is negotiating with ESA and the National Oceanic and Atmospheric Administration (NOAA) over the provision of instruments for this satellite and over participation in a converged polar satellite system with the United States.

Eumetsat headquarters are in Darmstadt, Germany, which also hosts ESA's European Space Operations Centre (ESOC). Many of the ground-segment functions of Eumetsat are currently performed at ESOC, including satellite operations and control, data downlinks, data processing, and data archiving, but Eumetsat is building its own operations center in Darmstadt and plans to take over satellite and data operations in 1995. Raw Meteosat data are preprocessed for radiometric calibration, geographic referencing, and quality control before being distributed by satellite relay through Meteosat. These data are available in full digital form to Primary Data User Stations (PDUS) and in reduced analog form to Secondary Data User Systems (SDUS). As of 1990, there were 119 PDUS in 25 countries and 1,127 SDUS in more than 75 countries, mostly in Europe and Africa.

Eumetsat also collects data from other sources, including satellite data from the U.S. GOES-East[2] and polar NOAA satellites and in situ data from Eumetsat's Data Collection System. This system consists of an array of automated data-collection platforms on land, at sea, and on board commercial aircraft, which relay data to ground stations through Meteosat transponders.

Eumetsat maintains a complete digital archive of Meteosat images at ESOC, dating back to the first Meteosat data collected in 1979. Currently, responsibility for these archives is transferred to ESA after 5 months, but Eumetsat intends to take over permanent responsibility for these archives when it assumes responsibility for Meteosat operations.

[1] See the Eumetsat brochure *EUMETSAT: The European Organisation for Meteorological Satellites* (Darmstadt, Germany: Eumetsat, 1992). As of December 1993, the members of Eumetsat were Austria, Belgium, Britain, Denmark, Finland, France, Germany, Greece, Ireland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and Turkey.

[2] When a launch failure and delays in the GOES-Next program left the United States with a single operational geosynchronous meteorological satellite, Eumetsat reactivated Meteosat 3 in 1991 and made it available to the United States in place of GOES-East.

SOURCES: Eumetsat, 1994; Office of Technology Assessment, 1994.

mate observations, for example, but most proposals envision a comprehensive agency that encompasses all aspects of operational remote sensing. A comprehensive international agency offers several advantages. Because of (he synergies between different types of measurements and because measurements often serve multiple purposes, it makes sense to consider the requirements of multiple applications simultaneously.[48] Defining a program too nar-

[48] See chapter 2. NASA originally planned to make EOS a comprehensive system but has since narrowed the intended scope of EOS to focus on climate. EOS is meant to be a research program rather than an operational one, although some of its elements may lead to long-term operations.

rowly may make it more difficult to pursue applications that have been left out, and it may ultimately be simpler to administer a single international program under a single set of procedures than to allow special-purpose organizations to proliferate.

But a comprehensive international agency also carries significant drawbacks that limit its feasibility for the near term. By maximizing the scope of the proposed agency, one also maximizes the disadvantages that come with cooperation: administrative complexity and loss of autonomy. Furthermore, some of the participating national agencies have more restricted missions and would not be willing to take part in an international organization with a broader scope.

Options for a More Specialized International Remote Sensing Agency

A narrowly focused international remote sensing agency could concentrate its cooperative efforts on those areas where cooperation may offer greater benefits, with less risk of disrupting existing national programs. Over time, such an agency could broaden its mandate if member governments saw an advantage in doing so.

The main drawback of embarking on a more focused mission is that it could fail to take advantage of the synergies between various remote sensing missions and capabilities. For example, an ocean monitoring agency might not give adequate weight to monitoring ocean processes that affect the climate system. However, in the context of currently emerging mechanisms to address these issues in other ways, this drawback may not be critical. The following are several possible international agencies with more limited scope:

- ***An international weather satellite agency.*** Like NOAA's satellite programs, this kind of agency could include both polar and geostationary satellites. The polar satellite component might grow out of a future converged U.S.-European system based on POES, DMSP, and METOP. Because these satellites cover the entire planet, however, the agency that supports them might seek a broad global membership incorporating systems from Russia, Japan, and, possibly, China, although this might make it difficult or impossible to exercise control over data for national security purposes. The funding formula and benefits of participation could be designed to encourage the broadest possible membership and to discourage free riders. and the administrative procedures would have to be relatively simple. For example, the international agency might simply contract with the United States, Europe, or Russia to provide polar satellite services. much like the way Inmarsat, early in its operation, built on preexisting capabilities, leasing communications channels from satellite operators.

  Geostationary satellites have a more limited scope and, therefore, present slightly different issues. Rather than contributing to a worldwide agency, members might contribute to regional agencies centered on the current U. S., European, and Japanese programs. The central Asian region presents a problem because India has not allowed access to its data, and Russia and China have encountered problems in deploying satellites of their own.[49] An interregional coordinating body could establish minimum agreed standards for these satellites and simplify data exchange across regions.

- ***An international climate monitoring agency.*** Climate monitoring depends on much of the same information as weather forecasting but requires more precise meteorological measurements as well as a broader range of in format ion. For example, satellite measurements must be validated by comparison with well-calibrated in situ measurements from around the world. Climate depends on a range of ocean and land processes, so climate monitoring requires ob-

[49] The Russian Geostationary Operational Meteorological Satellite (GOMS) has reportedly been ready for launch since 1992 and may be awaiting foreign funding. The Chinese FY-2 satellite, scheduled for launch in April 1994, was destroyed during ground testing.

servation of these processes as well. Climate also depends on information about atmospheric chemistry—the concentration of aerosols and greenhouse gases—which is not essential for most other applications of remote sensing.[50]

A climate monitoring agency, which might evolve from the proposed Global Climate Observing System, could function in several ways. It could operate satellites to collect only those data unique to climate studies, such as atmospheric chemistry measurements, while maintaining archives of high-quality meteorological data and related land and ocean data obtained from other sources. This would require the cooperation of other agencies or programs, which would collect those data. Alternatively, climate monitoring could be carried out by a weather forecasting agency; Eumetsat is considering expanding its mandate to include climate monitoring. Given the broad national commitments to climate research and the scope of international cooperation in global change research, however, such an agency may not be needed.

- ***An international ocean satellite agency.*** This differs from the weather satellite case in that no operational systems now exist, except as adjuncts to meteorological systems. An international agency could facilitate the establishment of an operational program by aggregating resources from the various interested agencies. Because proposed requirements led to high costs, the United States has been unable to make a commitment to an ocean observing satellite system, but U.S. participation in an international system should be more affordable.[51] Like an international weather satellite agency, however, an international ocean satellite agency would make it more difficult to control data for national security purposes.

  An ocean monitoring agency poses some unique problems. One is how to determine national contributions. An island nation such as Japan is naturally more interested in oceanic information than is a landlocked country such as Austria, although both could be concerned about the influence of oceans on climate. This suggests that a division of labor based on varying degrees of' interest may be more appropriate than an international agency. However, the formation of an international agency could sidestep the potential problems of direct cooperation between Japan and the U.S. Navy, given Japan's policy to support only nonmilitary applications of remote sensing.
- ***An international land remote sensing agency.*** Internationally as well as nationally, the problem of aggregating demand is particularly acute for terrestrial monitoring, which involves a variety of national and local government agencies having overlapping but often quite different requirements (see chapter 3). Harmonizing these requirements into a mutually agreed to and affordable basic set presents a considerable challenge. Terrestrial monitoring also faces the greatest overlap between public and private-sector interests,[52] as well as civilian and military interests. An international agency could also stifle the development of commercial ventures in land remote sensing.
- ***An international data-purchase consortium.*** Instead of organizing resources to develop and operate satellite systems, any international remote sensing agency could accomplish its mission—whether narrow or comprehensive—through the purchase of data from commercial

50 other satellite instruments can also provide important climate information. These include the Earth Radiation Budget Experiment (ERBE), which measures the balance between incoming solar and outgoing thermal radiation from Earth, and the Active Cavity Radiometer Irradiance Monitor (ACRIM), which measures the total energy flux from the sun.

51 For a discussion of U.S. options for ocean monitoring, see chapter 1.

52 The public sector tends t. be more interested in Landsat-type imagery (high spectral resolution, moderate spatial resolution) while the private sector may be more interested in high-spatial-resolution imagery prov ided by SPOT and other proposed commercial ventures, but there is no clear line of demarcation between the two.

suppliers. NASA is testing this relatively novel arrangement with its purchase of data from the Sea-Viewing Wide Field Sensor (SeaWiFS) (chapter 3). A data-purchase consortium would then operate a data-management, -processing, and -distribution system to serve its members, but its greatest challenge could be to aggregate and coordinate its members' data requirements and to match the needs of its members with the available resources. The principal advantage of this type of agency is that it would stimulate international private-sector activity by demonstrating a guaranteed demand for the data in question, rather than competing with and potentially crowding out private-sector activities. A data-purchase consortium would raise the question of data access by third parties, that is, nonmember governments and private companies or individuals.

Any of these proposed organizations could function independently, with varying degrees of cooperation with other programs. They could also provide manageable steps on the road toward a more comprehensive international remote sensing agency.

International Convergence Processes

All of these cooperative arrangements-an information cooperative, a formal division of labor, or an international agency—face several common challenges. In each case, decisionmakers must consider the tradeoff between the perceived advantages of cooperation—increased effectiveness and reduced costs—and the drawbacks—reduced autonomy and the risks of relying on others.

These approaches to international cooperation also provide alternative methods of dealing with the tradeoff between maintaining a manageable organizational structure and ensuring a fair allocation of the burden of paying for it. An information cooperative requires the least formal structure but allows for the greatest inequity in sharing costs. A formal international division of labor could reduce but not eliminate these perceived inequities and could restore the attractiveness of open information sharing. An international agency would formalize the distribution of costs but would require careful design to avoid becoming excessively bureaucratic.

Over the years, international cooperation in remote sensing has steadily expanded. Initially, the open sharing of meteorological and other environmental data from U.S. satellites strengthened the WWW information cooperative. The entry of other countries with more restrictive data policies threatens to undermine this tradition, but it could also lead to a more equal partnership based on an international division of labor. Such a partnership offers substantial improvements in cost-effectiveness, providing the participants can accept a relatively open exchange of data.

An international agency seems unlikely under current international conditions, but the growth of mutual trust that could emerge from intermediate stages of cooperation might make it seem feasible or even inevitable in the future. Because remote sensing systems and programs take decades to develop and mature and because some setbacks and disagreements are inevitable, cooperative relationships will probably evolve through gradual, measured steps.

Intergovernmental cooperation stands in contrast to the alternative of relying on the private sector for data and allowing individual agencies to fend for themselves in the private-data market. In principle, these markets should provide an efficient system of sharing costs without a cumbersome organizational structure. As discussed previously, however, private markets for remote sensing take time to develop and mature and have not yet demonstrated that they are economically viable. Furthermore, reliance on private markets can discourage investments in remote sensing as a public good.

Cooperation with Russia

The United States and Europe have sought to expand technological cooperation with Russia, for both practical and political reasons. This cooperation is a symbol of Russia's reintegration into the international community[53] and provides financial support to maintain the Russian economy and Russia's skills in science and technology. But Russia's future, including the stability of its political relationships and its ability to maintain an ambitious space program, remains uncertain. This situation increases the risk of relying on Russia for important remote sensing needs and imposes limits on the scope of current cooperative efforts.

In 1993, Vice President Gore and Russian Prime Minister Chernomyrdin signed several agreements on U.S.-Russian cooperation in space activities. Although these agreements emphasized Russian participation in an international space station, they also included agreements to expand cooperation in earth science and remote sensing.[54] Russia has a long history and important capabilities in civilian remote sensing.

Building on past cooperative efforts, these agreements include several possible projects:

- Strengthening Russia's data-management capabilities.
- Encouraging Russian participation in international projects of global change research.
- **Arranging future flights of U.S. TOMS and Stratospheric Aerosol and Gas Experiment (SAGE) instruments on future Russian spacecraft.**[55]

Congress may wish to explore ways for Russia to contribute to improving the robustness of existing operational satellite programs. For example, Russia's Meteor satellites could provide valuable backup capability for a converged U.S. and European satellite system. Similarly, Russia's RESURS-O satellites could help fill in possible gaps in the U.S. Landsat system.

These projects could provide the basis for Russia's gradual integration into international cooperative programs in remote sensing. But this integration must overcome major obstacles and withstand the test of time. Expanding cooperation with Russia on remote sensing depends on steadily growing mutual confidence in Russia's political relationships and its ability to mainlain its programs through difficult economic limes.

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53 U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, op. cit., box 5-1.

54 White *House Plan for Russian-American Cooperative Programs in Earth Science and Environmental Monitoring from Space*, *op. cit.*

55 The United States *and Russia have agreed in* principle that a TOMS instrument will fly on a future Meteor satellite, and negotiations fOr the placement of a SAGE instrument are under way.