International Issues in Data Management and Cooperation

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As noted in earlier chapters, remote sensing of Earth was in the 1960s and early 1970s nearly the sole province of the United States and the Soviet Union. During the late 1970s and early 1980s, Europe, India, Japan, China and other countries began ambitious remote sensing programs. Since the breakup of the Soviet Union, Russia has begun to open its remote sensing programs to cooperative efforts with other countries and with non-Russian private industry.

Until recently, U.S. technology and policy dominated the international scene in remote sensing, and U.S. practices established de facto international standards for remote sensing data policy and management. Now the expanding array of national and regional agencies involved in remote sensing has changed the ground rules for cooperation.[1] **International cooperation has long been the norm in civilian remote sensing, but the changing international environment demands a changing approach to cooperation. The** United States remains the leading player in remote sensing but is increasingly the first among equals. Because the United States is no longer in a position to dictate the terms of international space activities, it can exercise its leadership most effectively through negotiation, persuasion, cooperation, and possibly compromise.[2]

[1] This chapter uses the term agency to refer to any of the national government agencies involved in remote sensing, such as NASA and NOAA, as well as regional organizations such as the European Space Agency (ESA).

[2] John M. Logsdon, "Charting a Course for Cooperation in Space," Issues *in Science and Technology, vol. 10, No. 1,* fall 1993, pp. 65-72.

This chapter examines international issues in remote sensing data policy and management. It focuses on cooperative activities in the public sector, primarily in environmental research and weather forecasting, as well as related commercial issues.[3]

REASONS FOR COOPERATION

Nations seek to cooperate in space activities for scientific, economic, and political reasons (box 5-l). Economic motivations stem from the increasingly tight budgets for space activities worldwide. International cooperation offers the promise of reducing costs by reducing unnecessary redundancies between the remote sensing programs of different agencies, either by allowing greater specialization and division of labor between agencies or by permitting the development of joint satellite systems that meet the combined needs of several agencies. International coordination can also improve the effectiveness of remote sensing programs by bringing together the complementary strengths of different agencies and enabling them to identify and eliminate the gaps among their programs. These incentives for cooperation are reflected in increasing efforts to resolve disagreements over the international exchange of data and to coordinate programs of data management, both of which aim to increase the ability of various agencies to use each other data.

Remote sensing from space is an increasingly international activity. Increasing numbers of countries support remote sensing satellites, which are capable of providing data from around the world, and collecting those data often requires cooperation with receiving stations in many different countries. Furthermore, many applications of remotely sensed data are by their nature regional or global in scope. Modem weather forecasting requires global data to support increasingly capable computer forecasting models, and understanding changes in the global environment requires accurate information on the state of the atmosphere, oceans, and terrestrial ecosystems. **There is a long history of productive international exchanges of Earth data, including remotely sensed data, for these and other purposes.**

CHALLENGES OF COOPERATION

As more countries have become active in remote sensing they have taken a variety of approaches to data policy and management, which pose increasing challenges for established mechanisms of data exchanges. Some agencies have adopted policies that restrict who may have access to data or have decided to charge others for the use of their data. The international community has developed mechanisms that hold substantial promise of dealing with these conflicts, but their ultimate resolution remains uncertain.

As described in chapter 3, the prodigious quantities of Earth data produced by current and planned remote sensing systems poses a substantial challenge for data management. Recognizing this challenge, NASA has begun a concerted effort to develop the Earth Observing System Data and Information System (EOSDIS).[4] Other countries have taken different approaches to data management, and none have yet made a comparable commitment of resources.

International data management will require the development of systems for data transmission, processing, and storage that support international data exchanges. The requirements may vary widely depending on the applications. Operational activities such as weather forecasting require reliable networks for the prompt transmission of critical data worldwide, as provided by the World Weather Watch. Scientific research and monitoring require the maintenance of accessible high-quality archives that operate effectively together across national boundaries. Efficient international data management will require international coor-

[3] See ch. 4 for a discussion of international competition in the private sector.

[4] See ch. 3.

BOX 5-1: Political Motivations for Cooperation in Space

The political symbolism of cooperation can promote two closely related sets of goals First, cooperation in space can provide a highly visble symbol that reinforces broader political ties between the countries involved Second, cooperation on space projects can build support for those projects failure to live up to an International commitment could undermine the political relationships Involved [1]

At the 1972 Moscow summit, President Nixon and Soviet Premier Alexel Kosygln signed an agreement on peaceful cooperation in space [2] that culminated in the Apollo-Soyuz Test project of 1974-1975[3] Although both the United States and the Soviet Union maintained active military space programs, the 1975 rendezvous provided a highly visible symbol of the detente that characterized the U S -Soviet relationship at that time The ApoHo-Soyuz mlsslon didnot lead to further, highly visible cooperative missions, however, as the U S -Soviet relationship grew more strained

In 1984 President Reagan announced the U S commitment to building a permanently Inhabited space station and began to seek International partners to share the costs of this project, which came to be known as Space Station Freedom In 1988, the international partners in the space station—Canada, Japan, and the members of the European Space Agency—signed an Intergovernmental agreement [4] laying out their contributions to the International space station project, Despite several redesigns to reduce its cost, the space station became a symbol of U.S leadership of a unified western alliance during the Cold War, and the International commitment also became one of the leading arguments in Congress for continued funding of the space station

In 1993, President Clinton called for another redesign to reduce the cost of the space station This redesign left open the possibility of Russ Ian participation, which was eventually agreed to in November 1993 In addition to providing some needed components of the space station at relatively low cost, this agreement serves to dramatize the end of the Cold War and provides a symbol of Russias reintegration into the International community. Cooperation for political purposes carries the risk that the political considerations within either country could undermine cooperate agreements Indeed, the possibilty of political and economic instabiltyty in Russia makes this reintegration as much a hope as a fact, and poses risks to the space station if Russia is not able to meet its commitments

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[1] See app C of U S Congress Off Ice of Technology Assessment, *Civilian Space Station and the U S Future in Space* OTA-STI-241 (Washington DC U S Government Printing Office November 1984)

[2] The 1972 Intergovernmental Agreement on Cooperation in Exploration and Use Of Outer Space for peaceful puporses

[3] U S Congress Off Ice of Technology Assessment *U S -Soviet Cooperation in Space* OTA-TM-STI-27 (Washington DC U S Government Printing Off ce July 1985) pp 27-31

[4] The Agreement Among the Government of the United States of America Governments of Member States of the European Space Agency the Government of Japan and the Government of Canada on Cooperation in the Detailed Design Deve opment Operation and Utilization of the Permanently Manned Civil Space Station'

SOURCE Off Ice of Technology Assessment 1994.

dination that addresses worldwide data management needs in a systematic way.

International cooperation in remote sensing can also carrys ignificant drawbacks. First of al 1, it can complicate management and decision-making processes. leading to delays, inefficiencies, and a loss of flexibility that reduce the advantages of cooperation. Second, international cooperation can reduce U.S. autonomy in x-emote sensing, making the United States vulnerable to changes in policies or programs by foreign governments and limiting the ability of the United States to modify its programs in response to its own changing needs and circumstances. Finally, the open exchange of data internationally can undermine the ability of U.S. companies to compete in commercial data sales.

NATIONAL AND REGIONAL ACTIVITIES

As the number of agencies involved in remote sensing has grown (figure 5-1; app. A),[5] so has the variety of approaches to data distribution and management policies. These policies vary not just from country to country but from agency to agency and even from program to program within a single agency. In distributing remotely sensed data, NASA and NOAA follow the guidelines set out in Office of Management and Budget Circular A-130, making data available to users at or below the cost of reproduction. Non-U.S. agencies often view their data as valuable property, restricting access through licenses and charging substantially higher fees for access. Some agencies engage in value-added services for private customers while others, including U.S. agencies, leave this mostly to the private sector. In designing their data management systems, some agencies concentrate on managing data for their own internal purposes, while others invest in systems that provide access for a broader group of users.[6]

These variations in data policy and management have important implications for international data exchange. Agencies with restrictive access policies are often reluctant to exchange data with agencies that allow more open access, and sometimes provide data subject to restrictions on third-party access that add to the recepient's data management costs. Furthermore, the exchange of large amounts of data requires data access and transmission systems that are both compatible and have sufficient capacity to operate together effectively.

United States

The United States has the longest history in civilian remote sensing and its applications. With its early weather satellites and the first Landsats, the United States decided to make the data available to domestic and foreign users as cheaply as possible.[7] The marginal cost of open access was low, and it reinforced the ideal of free and open exchange of information as an element of U.S. foreign policy during the Cold War. During the late 1970s and 1980s the United States adopted a much more commercial approach to data access,[8] and this had a major impact on the emerging policies of other countries that were becoming active in remote sensing.

U.S. efforts at remote sensing now include NASA's Earth Observing System (EOS), which is the largest single component of the broader U.S. Global Change Research Program (USGCRP). The emergence of these programs prompted a review of data policy and management, with two important consequences. First, the Committee on Earth and Environmental Sciences (CEES) elaborated the Global Change Research Data Princ iples,[9] which reaffirmed policies of open data access and exchange[10] and the commitment to

[5] See app. D of 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) for a description of these activities.

[6] Ray Harris and Roman Krawec, "Some Current International and National Earth Observation Data Policies," *Space Policy,* vol. 9, No. 4, November 1993, pp. 273-285.

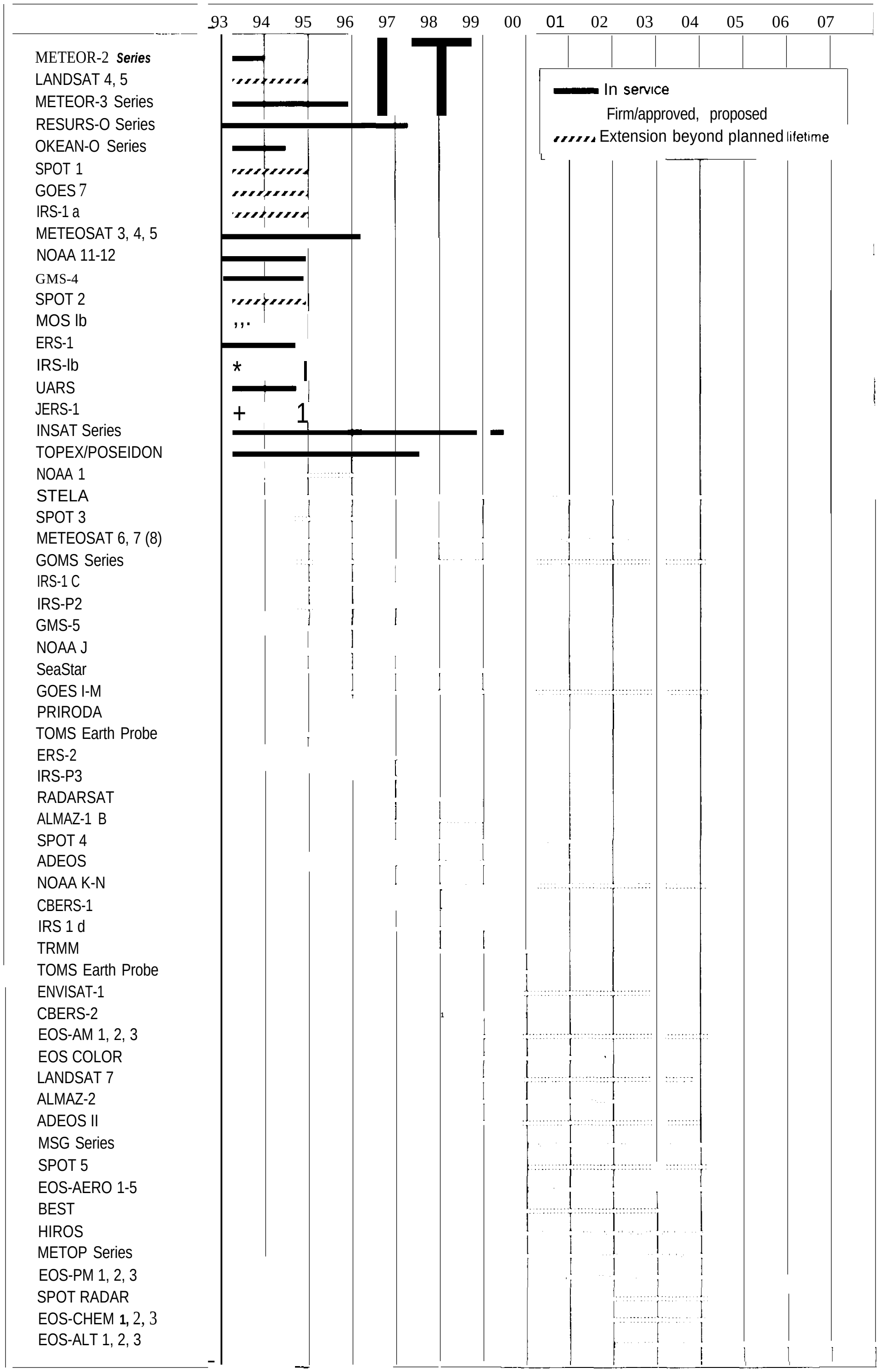
[7] Generally at no cost or at the cost of reproduction.

[8] See ch. 4 and David Radzanowski, The *Future of the Lund Remote Sensing Satellite System(Lundsal)91 -685* SPR (Washington, DC: Congressional Research Service, September 1991).

[9] Committee on Earth and Environmental Sciences, *The U.S. Global Change Data and Information Management Program Plan* (Washington, DC: National Science Foundation, September 1992). These principles were made public by OSTP Director D. Al Ian Bromley and became known as the Bromley Principles.

[10] This position was strongly influenced by data exchange principles of the ICSU World Data Centers. See Box 5-10.

FIGURE 5-1: Time Lines for Existing and Planned Earth Observation Satellites



SOURCE Commitee on Earth Observations Satelites 1993 adequate data management systems (box 5-2). Second, NASA made a major commitment to developing the EOS Data and Information System (EOSDIS) in order to manage effectively the huge quantities of data expected from EOS.[11]

Europe

Western Europe has emerged as an increasingly important player in satellite remote sensing. The European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological

BOX 5-2: U.S. Global Change Research Data Principles

In July 1991, the Office of Science and Technology Policy (OSTP) released the Policy *Statement on Data Management for Global Change Research,* which was elaborated on in a report by the Committee on Earth and Environmental Sciences.[1] This report forms the basis for U.S. policy on data access, exchange, and management The statement reads

"The overall purpose of these policy statements is to facilitate full and open access to quality data for global change research They were prepared in consonance with the goal of the U S Global Change Research Program and represent the U S Government's position on the access to global change research data

- The U S Global Change Research Program requires an early and continuing commitment to the establishment, maintenance, validation, description, accessibility, and distribution of high-quality long-term data sets
- Full and open sharing of the full suite of global data sets for all global change researchers is a fundamental objective
- Preservation of all data needed for long-term global change research is required For each and every global change data parameter, there should be at least one explicitly designated archive Procedures and criteria for setting priorities for data acquisition, retention, and purging should be developed by participating agencies, both nationally and internationally. A clearinghouse process should be established to prevent the purging and loss of Important data sets
- Data archives must include easily accessible Information about the data holdings, including quality assessments, supporting ancillary information, and guidance and aids for locating and obtaining the data
- National and International standards should be used to the greatest extent possible for media and for processing and distributing global data sets
- Data should be provided at the lowest possible cost to global change researchers in the Interest of full and open access to data This cost should, as a first principle, be no more than the marginal cost of filling a specific user request Agencies should act to streamline administrative arrangements for exchanging data among researchers
- For those programs in which selected principal investigators have initial periods of exclusive data use, data should be made openly available as soon as they become widely useful In each case the funding agency should explicitly define the duration of any exclusive use period "

[1] CEES, *The U S Global Change Data and Information Management Program Plan,* National Science Foundation, September 1992

SOURCE National Science Foundation, Committee on Earth and Environmental Sciences, 1992

[11] See ch. 3 for a discussion of EOSDIS.

Satellites (Eumetsat), '2 and the French space agency CNES (Centre National d'Etudes Spatiales) all have major remote sensing satellite programs with corresponding data receiving and distribution systems. Germany, Italy, and the United Kingdom maintain strong data analysis and applications programs. The European Space Research Institute (ESRIN) near Rome has principal responsibility for ESA'S Earthnet program, which manages ESA'S data archives, catalogs, and networks. The European Community (EC) has also taken an active interest in remote sensing, particularly in data management and in research on the application of remotely sensed data, 's and has joined ESA in developing the Centre for Earth Observation, but the management of data in Europe generally has been left to individual research institutes.

European data policies arose as the United States was attempting to commercialize the Landsat system. Europe's first land remote sensing satellite program, the French Satellite Pour Observation de la Terre (SPOT) 14 system, is operated as a commercial enterprise by the private company SPOT Image. Though more successful in data sales than EOSAT, SPOT Image still requires a substantial subsidy from the French government.[15] ESA has also arranged for the commercial sale of data from its research and operational satellites, beginning with ERS-[16] After initial problems caused by an incomplete data management system and by severe limitations on the quantity of data made available to researchers, ERS- 1 data are now available to users in the United States. Eumetsat is moving toward more restrictive policies for access to data from its Meteosat meteorological satellite system.

Russia

Russia is the main heir to the long Soviet tradition in civil remote sensing, but aside from imagery from its meteorological satellites, Russia did not begin making satellite data available outside the Soviet Union until the late 1980s. Several firms now market Russian remotely sensed data, Multispectral images are available in photographic form with resolutions as fine as 2 meters.[17] Attempts to sell photographic images and data from its Almaz synthetic aperture radar (SAR) commercially have met with only limited success because of difficulties in providing timely access to data, and inexperience with commercial markets. A shortage of funds is also inhibiting Russian efforts and has delayed the launch of the Geostationary Operational Meteorological Satellite (GOMS).[18] The United States and Russia signed an agreement on cooperation in civilian space activities in 199219 and have begun to develop plans for cooperation in Earth observations, including joint projects on data exchange and interoperabil-

[12] The evolving relationship between ESA and Eumetsat is similar to that between NASA and NOAA. ESA develops and launches the satellites, and Eumetsat processes and distributes the data.

[13] The Joint Research Centre at Ispra near Milan, Italy, is the main center for this research.

[14] SPOT was originally named Satellite Probatoire d'Observation de la Terre, indicating its experimental nature, but the name was later changed to reflect its current, operational status.

[15] CNES pays most Capital costs, including satellite development, and holds a 34 percent interest in Spot Image, S.A.

[16] The private company Eurimage was established to market remote sensing images by publicly owned ground stations within Europe, including data from Landsat, AVHRR, ERS - 1, and future systems. ERS - 1 data have not experienced strong sales to date. The Canadian Radarsat International has the North American marketing rights for ERS- 1, and SPOT Image has marketing rights in other parts of the world.

[17] See 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 1994), app. D, pp. 179-180.

[18] GOMS has been listed as ready for launch since 1992.

[19] *Agreement Between the Russian Federation and the United States of America on Cooperation in Peaceful Space Research and Exploration*, June 17, 1992.

ity of data systems.[20] The future of Russian involvement in cooperative remote sensing activities remains uncertain.

1 Japan

Four Japanese agencies play important roles in remote sensing: the National Space Development Agency (NASDA); its parent organization, the Science and Technology Agency (STA); the Ministry of International Trade and Industry (MITI); and the Japan Meteorological Agency (JMA). Both NASDA and MITI have undertaken joint programs with NASA.[21] Japan makes data available on a nondiscriminatory basis for nonmilitary applications, distinguishing only between research and nonresearch applications. NASDA distributes data to scientific users at or below the cost of reproduction through the Earth Observations Center (EOC) and receives royalties for data sold commercially through the Remote Sensing Technology Center (RESTEC). However, it has had serious problems in distributing data from its MOS and JERS-1 satellites and plans major improvements in data management for future satellite missions. Japan has also made proposals for greater international coordination of remote sensing data networks.

Canada

The Canadian Space Agency (CSA) plans to enter the remote sensing business with Radarsat, which promises to carry the first SAR to be used on an operational basis. Canada hopes to recover most of the operating costs of Radarsat through commercial data sales by Radarsat International, although most of the intended customers are foreign governments seeking data on sea ice cover. The Canadian government will receive free access to data, as will the U.S. government in exchange for NASA's launch of Radarsat.

India

India has developed an active remote sensing program, aimed mainly at domestic applications, but has refused to make satellite data regarding India available to other countries and, until recently, has not attempted to distribute satellite data for other countries. In October 1993, India's National Remote Sensing Agency (NRSA) and EOSAT announced an agreement under which EOSAT would market data from India's IRS satellites.[22]

Other

China has developed experimental weather satellites and has joined with Brazil to develop the China-Brazil Earth Resources Satellite (CBERS). South Africa is developing a land remote sensing satellite called Greensat, capable of gathering multispectral data of 16.25 meters resolution and panchromatic data of 2.5 meters resolution. A number of other countries have programs in remote sensing and operate ground stations that receive and process data from other countries' satellites.

These agency programs have substantial overlap and duplication, often because countries have pursued independent national space programs for reasons of national prestige and technological autonomy.

INTERNATIONAL TREATIES AND LEGAL PRINCIPLES

National, international, and commercial Earth observations from space take place in the context of an evolving system of international principles and legal regimes. The main forum for international agreements under the United Nations umbrella is

[20] *Plan for Russian-American Cooperative Programs in Earth Science and Environmental Monitoring from Space,* Oct. 27, 1993.

[21] These include the ASTER instrument, which MITI will supply for EOS AM-1, the joint NASA/NASDA Tropical Rainfall Monitoring Mission (TRMM) satellite, and NASA/NASDA instrument exchanges on ADEOS and EOS-Chem.

[22] Ben Iannotta, "Landsat 6 Loss Opens Door to Other Imagery Suppliers," *Space News,* Nov. 1-7, 1994, p. 18.

the U.N. Committee on the Peaceful Uses of Outer Space (COPOUS), which negotiated four international agreements on space activities. The 1967 Outer Space Treaty establishes abroad framework for outer space law, encouraging scientific cooperation and prohibiting claims of sovereignty in outer space. Along with the 1972 Liability Convention and the 1975 Registration Convention, the Outer Space Treaty establishes the principle of national jurisdiction over satellites, including commercial remote sensing satellites, and includes the requirement that private companies obtain licenses for their satellites from their national government and that those satellites be listed in the U.N. Registry by that national government.

The 1987 U.N. principles on remote sensing express international ideals for the use of remote sensing, although observers disagree about how these principles should be interpreted. These principles embody the view that outer space is a resource for all humanity and should be used for the general benefit of all nations (box 5-3). The 1992 Landsat Act incorporated some of these principles into U.S. law (box 5-4).

INTERNATIONAL COOPERATION

The earliest efforts to promote international cooperation in remote sensing dealt with meteorological satellites. The World Weather Watch (WWW) is a cooperative program for collecting, process-

BOX 5-3: U.N. Principles on Remote Sensing

The United Nations Principles Relating to Remote Sensing of the Earth from Space (Principles) are contained in a 1987 resolution adopted by the General Assembly. As a resolution, the Principlesnnclples are not currently legally blinding but do provide the basis for a multilateral treaty. Much of the language and intent of the principles stems from the four major space treaties promulgated by the U N Committee on the Peaceful Uses of Outer Space (COPOUS) from 1967 through 1975 Of particular importance is the Treaty on Principles Governing the Actiities of States in the Exploration and use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty) This treaty, which has been in force for 26 years and to which the United States is a party, provides that outer space and celestial bodies are governed by international law and are not subject to national appropriation

The Princilples cite provisions of the Outer Space Treaty and the Convention on the RegistrationReglstratlon of Objects launched into Outer Space (Registration Convention) as applying to remote sensing actvities The Outer Space Treaty provisions cited mandate that outer space and celestial bodies are the “province of all mankind” and require that the exploration and use of space be for the benefit of all nations regardless of their degree of economic or scientific development

The provions cited also encourage international cooperation, require individual nations to oversee the space activitles of nongovernmental entities, and allow claims for damages to be presented in the courts of either the claimant or the launching state The Registration Convention provision cited in the Principles requires a state to provide information about space objects launched by it to the Secretary-General of the United Nations The information includes the name of the Iaunching state(s), a registra tion number, orbital parameters, date and location of launch, and the general function of each object.

The Principles augment the legal role of the United Nations in remote sensing by making it and its relevant agencies responsible for providing technical assistance and coordination The Secretary-General’s role includes being informed of national remote sensing activities and making relevant Information available to other states upon request

(contiued)

BOX 5-3: U.N. Principles on Remote Sensing (Cont'd.)

The Principles address access and distribution of data and information generated by national civilian remote sensing systems, Primary data are defined as the raw data delivered in the form of electromagnetic signals, photographic film, magnetic tape, or any other means. Processed data are the products resulting from processing primary data, and analyzed information means information resulting from interpreting processed data. Remote sensing activities addressed by the Principles include operations, data collection, storage, processing, interpretation, and dissemination.

As a whole, the Principles set a standard of international cooperation among states operating remote sensing systems (sensing states) and states whose territory is being observed (sensed states) while attempting to achieve a balance between the rights and interests of both groups. The needs of the developing nations are to be given special regard. Sensing states are encouraged to provide cooperative opportunities in a wide array of activities ranging from data collection to establishing and operating storage stations and processing facilities. If requested, a sensing state must consult with a sensed state to make participation opportunities available. Regional agreements are preferred wherever feasible.

Protection of the Earth's environment and of humanity from natural disasters are specific purposes promoted by the Principles, States participating in remote sensing activities that possess information useful for averting harmful phenomena are required to disclose the information to concerned states. If the potential harm threatens people, the obligation to disclose requires promptness and extends to processed data and analyzed information.

The relationship between sensed and sensing states—and the rights and responsibilities that issue from that relationship-are particularly addressed by Articles IV and X11 of the Principles, In political terms, the challenge of the relationship between sensed and sensing states is to reconcile the interests of economically and technologically advantaged and disadvantaged states, In legal terms, the challenge of the relationship is to provide governing standards for a whole activity with integral components occurring in legal regimes framed by different organizing principles. Sovereignty-the primary organizing principle on Earth—is prohibited in space. Articles IV and X11 stress both the nonexclusive right to use and explore space as well as respect for sovereignty of states over their own wealth and natural resources.

Article IV sets a legal standard for behavior among sensed and sensing states and Article Xll is a dissemination statute. Together, they provide a fluid legal regime for national remote sensing systems and activities that obliges sensing states to avoid harm to sensed states and to provide them with access to primary data and processed data concerning their own territory on a nondiscriminatory basis. Analyzed information available to sensing states is also to be available to the sensed states on the same basis and terms. In turn, sensed states are to meet reasonable cost terms and do not have access to analyzed information legally unavailable to the sensed states, for example, proprietary information.

The legal literature contains an ongoing debate as to whether the Principles add substantive value to the body of remote sensing law. One view points to the reiteration of Outer Space Treaty and Registration Convention provisions to demonstrate that the Principles are ambiguous and repetitious. From another view, it is pointed out that the Principles do contain new general principles, such as using remote sensing data for the protection of humankind and the Earth environment, thus expanding the law. From either perspective, the fact remains that the United Nations Principles Relating to Remote Sensing of the Earth from Space was the first major resolution to emerge from COPOUS in over a decade and represents persuasive authority that provides a foundation for the continued evolution of international remote sensing law.

SOURCE Joanne Gabrynowlcz, 1994

BOX 5-4: The Land Remote Sensing Policy Act of 1992 and the United Nations Principles

The Land Remote Sensing Policy Act of 1992 (Policy Act) has implications for international remote sensing activties because it sets regulations that can clarify the 1987 U.N. Principles Relating to Remote Sensing of the Earth from Space (Principles), As a major remote sensing nation, the domestic legislation of the United States has persuasive authority for the development of international remote sensing law, similar to the way that practices of strong maritime nations influenced the development of International Maritime law The Policy Act addresses some issues left ambiguous by the Principles Among them are protecting the Earth's environment through remote sensing, the role of the private sector in carrying out the Principles, and providing remote sensing assistance to developing nations

Protecting the Earth's environment through remote sensing

A driving force behind the repeal of the Land Remote Sensing Commercialization Act of 1984 (Landsat Act) was its lack of attention to the environmental value of remote sensing Replacing the Landsat Act with a law that focuses on the environmental value of remote sensing conforms with the Principles' positive duty that sensing states avoid harm to the Earth's natural environment.

Private sector obligations and the U.N. Principles

Prior to the Policy Act, U.S. officials took the position that Principle Xll, the dissemination statute, applied only to data from states, leaving open the obligation of a private entity under national jursdiction to make data available Now, timely access by an sensed state to at least one Principle Xll data category produced by the private sector—primary data—is required by the Policy Act Whereas the Landsat Act did not impose a time constraint on the operator as did the Principles, the Policy Act's licensing conditions do correspond to the Princple's time constraints by requiring that access occur as soon as data are available

The Policy Act also may require private operators, on a case-by-case basis, to make unenhanced data available on terms similar to that applied to the Landsat system or other government systems the value placed by the Policy Act on promoting widespread access to U.S. and foreign remote sensing data This, in turn, would allow the application of equitable principles to situations like protecting the Earth' environment, protecting humanity from natural disasters, and meeting the needs of the developing nations—all of which are contained in the Principles.

The Policy Act and developing nations

Landsat management responsibilities Include ensuring system operation IS responsive to the broad Interests of foreign users Landsat 7 data policy requires timely and dependable delivery of unenhanced data to foreign users. Federal agencies, particularly NASA, DOD, and the Departments of Agriculture and Interior have mandates to continue remote sensing research and development, which can extend to cooperation with foreign governments and International organizations. This authority can be exercised to develop the nature and extent of the obligations contained in the Principles, which include promoting International cooperation, creating opportunities for inteternational participation establishing and operating facilities for data collection, storage, and processing. promoting regional agreements, and providing technical assistance to states and the U N

Particular consideration of the needs of the developing nations, as required by Principle Xll, IS specifically authorized for U S government agencies, which the Policy Act encourages to provide remote sensing data, technology, and training to developing nations Agencies are also authorized to utilize excess government civilian remote sensing capabilities to carry out their missions which gives them access to technology that could provivide necessary infrastructure for Internationnal aid programs

SOURCE Joanne Gabrynowlcz 1994

ing, and disseminating meteorological data from satellites and other sources. WWW is the principal activity of the World Meteorological Organization (WMO), which also hosts satellite activities that involve both satellite operators and data users and aim to maximize the utilization of meteorological data from satellites. The Coordination Group for Meteorological Satellites (CGMS)[23] was established to coordinate technical standards among satellite operators.

A broader forum for international cooperation in remote sensing emerged in 1984, with the formation of the Committee on Earth Observation Satellites (CEOS). CEOS (figure 5-2) provides an informal and voluntary forum for discussing international issues remote sensing (box 5-5). The Earth Observation International Coordination Working Group (EO-ICWG) grew out of the international space station program and aims to coordinate selected remote sensing programs of the United States, Europe, Canada, and Japan into an International Earth Observing System (IEOS) (box 5-6).

Each of these organizations has important strengths. The WMO involves both users and suppliers of data who share a common interest in improving the effectiveness of operational meteorology. CEOS benefits from its informal, voluntary nature: participants share a commitment to cooperation and CEOS allows a substantial degree of flexibility. In dealing directly with operational matters, EO-ICWG provides a natural forum for coordinating ground data systems among the main remote sensing agencies.

These organizations have made substantial progress in promoting international exchanges of remotely sensed data through the harmonization of data policies and data systems. They have provided a forum that U.S. agencies have used to press for more open data access policies, but important obstacles remain. Some countries have been reluctant to accept the U.S. position. **Whether these international organizations can reach a working consensus on data exchange policies will have a major bearing on the ability of international cooperation to improve the effectiveness and reduce the cost of remote sensing programs.**

OPERATIONAL ENVIRONMENTAL APPLICATIONS

Weather forecasting is by far the largest operational application of remote sensing, both in terms of the scale of public investment and the level of international cooperation. Earth observing satellites also have begun to play a significant role in ocean monitoring, but apart from ocean meteorology most of these applications are experimental in nature. A number of operational uses exist or have been proposed for terrestrial data, including crop forecasting, forestry, and land use monitoring (appendix B).

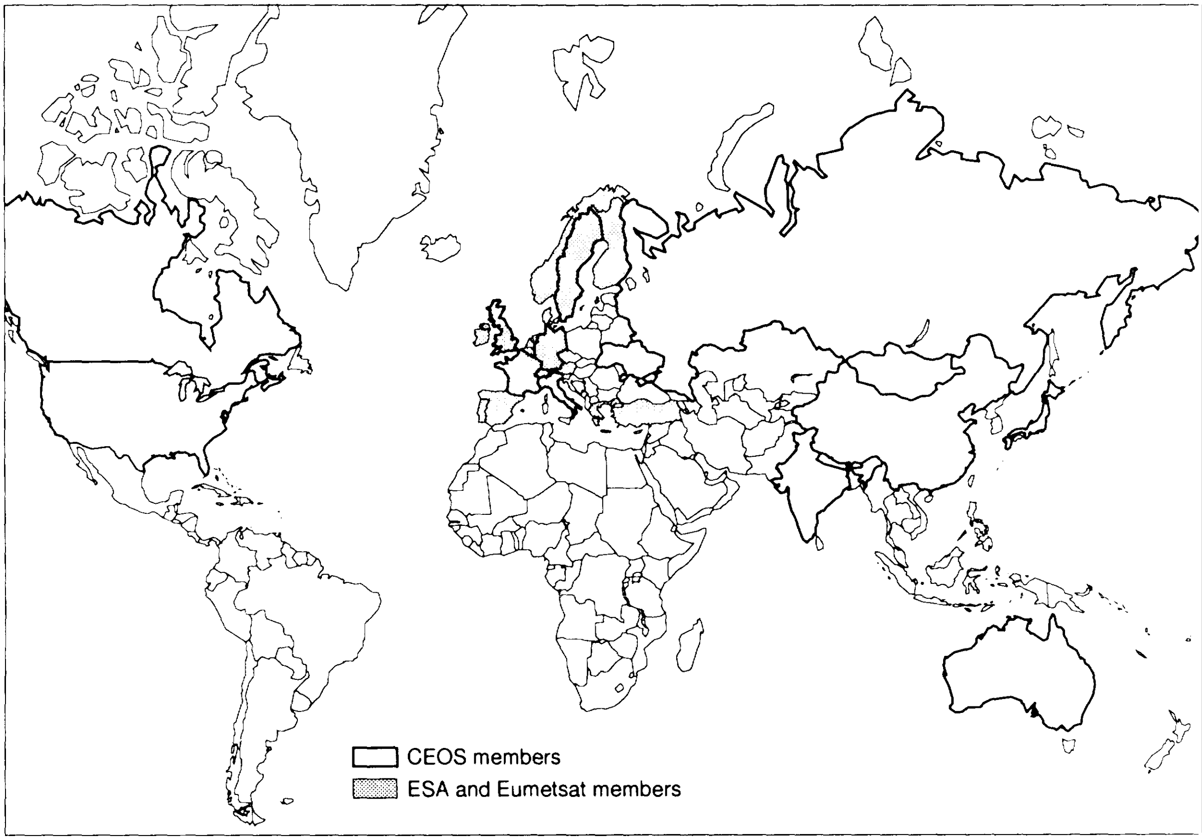
As discussed below, operational applications have much in common with scientific monitoring of the environment,[24] but there are also substantial differences, as illustrated by the difference between weather forecasting and climate monitoring. What distinguishes operational applications of remote sensing is the use of the data to support timely decision-making, either in response to environmental changes or for the management of natural resources.

The exchange of data for operational purposes requires international data systems for timely data collection, transmission, processing, and dissemination. These systems necessarily involve sharing the burden of data collection and communication, and they also benefit from a division of labor in data processing; current limits on data communications and processing capabilities dictate that much of the raw data must be processed into a

[23] CGMS was founded in 1972 as the Coordination of Geosynchronous Meteorological Satellites group.

[24] See box 5-9 and 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), pp. 34-36.

FIGURE 5-2: Committee on Earth Observations Satellites membership



SOURCE Committee on Earth Observations Satellites 1994

more usable form before it can be shared on an international network.

The establishment of operational data networks involves some technical issues of compatibility and capability, but these issues are less important than the establishment of an institutional commitment to data exchange. Of the three primary operational domains, meteorology, ocean monitoring, and terrestrial monitoring, meteorology has by far the most extensive activities and the most established mechanisms for international data exchange. Although many of the issues apply generally, this section focuses on weather forecasting, which has both the strongest need and the best established mechanisms for international data exchange. The final report in this assessment discusses operational activities in ocean and terrestrial monitoring.

WEATHER FORECASTING

Modem computer models for weather forecasting require high-quality data from a variety of sources. Instruments based on land, at sea, and in the atmosphere provide the most detailed information, but often have limited scope. Satellite data and images are essential in providing broad coverage to fill in the gaps between in situ measurements.[25] Furthermore, weather is a global

[25] For a description of current weather satellite programs, see ch. 3 of *The Future of Remote Sensing* from *Space.*

BOX 5-5: The Committee on Earth Observation Satellites

The Committee on Earth Observation Satellites was established in 1984 as an outgrowth of a summit of the Group of Seven,[1] and provides a forum for voluntary cooperation among its 19 members, five observers, and nine affiliates. The members and observers are national and regional agencies involved in remote sensing, and the affiliates are international organizations of data users (table 5-1). CEOS has come to play a critical role in developing an international consensus on policy related to remote sensing,

Most CEOS activities take place through established working groups and their subgroups, with major decisions ratified in regular and ad hoc Plenary Meetings. All CEOS working groups have responsibility for data issues. The Working Group on Calibration and Validation deals with the calibration of sensors to insure a consistent relationship between sensor readings and the physical quantities being measured, The Working Group on Data deals with ground networks, data catalogs, data formats, and coordination of specific cooperative projects. At its seventh Plenary Meeting in November 1993, CEOS agreed to establish an ad hoc Working Group on Networks to facilitate the coordination and integration of data networks. CEOS has held several ad hoc plenary-level meetings on data policy.

CEOS distinguishes among four types of data use:

- scientific research on global environmental change;
- operational uses for the public benefit, including environmental monitoring,
- other research; and
- other uses, including commercial use,

Of these, CEOS has focused mainly on global change research. The Sixth CEOS Plenary Meeting in December 1992 adopted a revised Resolution on Satellite Data Exchange Principles in Support of Global Change Research,[2] Although these principles call for data to be made available to global change researchers at the cost of filling the request, they reflect a clear tension between this goal and the desire to recover costs through the sale of data. An ad hoc CEOS data policy meeting in April 1994 developed tentative data principles in support of the operational use of satellite data for the public benefit,

CEOS also provides a forum for CEOS affiliates-international organizations of users of remotely sensed data—to discuss their needs with the agencies that collect those data. These affiliates include organizations devoted to global change research and to operational environmental monitoring Discussions between CEOS members and affiliates have influenced the implementation of CEOS data policies for global change research and led to the preparation of an Affiliates Dossier describing the data needs of the affiliates, the counterpart to the CEOS Dossier, which describes the remote sensing systems of CEOS members.

(continued)

[1] The Group of Seven consists of the United States, Canada, Japan, France, Germany, Italy, and the United Kingdom

[2] See the Minutes of the Sixth CEOS Plenary Meeting, available from the CEOS secretariat through ESA, NASA, and NASDA

SOURCE Off Ice of Technology Assessment, 1994,

BOX 5-5: The Committee on Earth Observation Satellites (Cont'd.)

TABLE 5-1: Participants in CEOS

Members

National Aeronautics and Space Administration (NASA)
National Oceanographic and Atmospheric Administration (NOAA)
Canadian Space Agency (CSA)
European Space Agency (ESA)
European Organisation for the Exploitation of Meteorological Satellites (Eumetsat)
Centre National d'Etudes Spatiales (CNES)/France
British National Space Centre (BNSC)
Deutsche Agentur fur Raumfahrtangelegenhelt (DARA)/Germany
Agenzia Spaziale Italiano (ASl)/ltaly
Swedish National Space Board (SNSB)
Science and Technology Agency (STA)/Japan
Russian Space Agency (RSA)
Russian Committee for Hydro- meteorology and Environment Monitoring (Roskomgidromet)
National Space Agency of Ukraine
Chinese Academy of Space Technology (CAST)
National Remote Sensing Centre of China (NRSCC)
Indian Space Research Organisation (ISRO)
Commonwealth Scientific and Industrial Research Organisation (CSIRO)/ Australia
Instituto Nacional de Pesequias Espaciais (lNPE)/Brazil

Observers

Norwegian Space Centre (NSC)
Belgian Office of Science and Technology (BOST)
Commision of the European Community (CEC)
Canada Centre for Remote Sensing (CCRS)
Crown Research Institute (CRl)/New Zealand

Affiliates

International Council of Scientific Unions (ICSU)
International Geosphere-Biosphere Programme (IGBP)
World Climate Research Programme (WCRP)
Global Climate Observing System (GCOS)
Global Ocean Observing System (GOOS)
United Nations Environment Programme (UNEP)
Intergovernmental Oceanographic Commission (IOC)
World Meteorological Organisation (WMO)
Food and Agriculture Organisahon (FAO)

SOURCE Committee on Earth Observations Satellites, 1994

BOX 5-6: The Earth Observation International Coordination Working Group

The Earth Observation International Coordination Working Group 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 5-2) 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, Including coordination of payloads, interoperability of ground systems, and harmonization of operations.

TABLE *5-2:* Members of EO-ICWG and IEOS

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

SOURCE National Aeronautics and Space Administration, 1994.

EO-ICWG is developing a set of IEOS Data Exchange Principles. Like CEOS, these principles distinguish between four types of data use, although the categories are slightly different

- scientific research, including global change research,
- noncommercial operational uses for the public benefit, including environmental monitoring and meteorology,
- applied research and development of new applications of remote sensing; and
- other uses, including commercial uses.

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 non-discriminatory basis and in a timely manner,” and that data will be available for non-commercial uses at no more than the cost of reproduction, So far, however, Europe has committed to include only one of its planned polar platforms—Envisat-l —in IEOS to be subject to these rules, although other platforms may be incorporated later.

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.

SOURCE Off Ice of Technology Assessment, 1994 phenomenon —the weather in one location is influenced by conditions around the globe, Long-range forecasting, in particular, requires systematic monitoring of weather in distant locations with both space-based and in situ measurements. Therefore, effective weather forecasting requires international cooperation in data collection and benefits greatly from a formalized division of labor in data processing and dissemination. **International data exchanges are essential to maintain and improve the quality of weather forecasts.**

A number of international organizations have arisen to meet the need for international cooperation in weather forecasting and meteorological data exchange. Foremost among these is the World Meteorological Organization and its operational program, the World Weather Watch. The WMO has limited resources of its own, and relies on the voluntary cooperation through the national weather services of member countries to carry out its agreed programs.

The WMO provides a forum for both satellite operators and users of satellite data to coordinate operational weather satellite programs. These activities have the principal objectives of improv ing the standardization of satellite instruments and measurements, ensuring continuity of satellite measurements, and promoting the more effective use of these data by WMO members. WMO formalized these actions in 1993 by forming the Working Group on Satellites within the WMO Commission on Basic Systems.

For the most part, the operational World Weather Watch program (box 5-7) has been effective at making meteorological data available for weather forecasting around the world, but the program also manifests some weaknesses, especially in collecting in situ data. High-quality surface data are scarce for the oceans, deserts, and tropical regions. With current computer models for weather forecasting, the ability to make long-range forecasts is limited by the quality and coverage of available data, not computing power. WWW long-term plans have consistently called for an expansion of these surface-based observations, but these plans frequently go unrealized because they rely on voluntary commitments from countries. Some developing countries have reduced their provision of weather station data, which they see as providing the greatest benefit to developed countries, and developed countries generally do not provide the financial support necessary to operate these stations.[26] To **improve the quality of data for long-range weather forecasting as well as climate monitoring, Congress may wish to boost the priority of technical assistance on weather monitoring and forecasting in bilateral and multilateral foreign aid programs.** Even with improved satellite instruments, in situ observations will still be necessary both to complement and to calibrate and validate satellite data.[27]

Several other international coordinating groups deal specifically with meteorological satellites, The Coordination of Geosynchronous Meteorological Satellites (CGMS) group was founded in 1972 as a forum for technical discussions to promote common operating procedures and standards among the operators of meteorological satellites, in part for the joint WMO/ICSU Global Atmospheric Research Programme, complementing the activities of the WMO.

The International Polar Orbiting Meteorological Satellite group (IPOMS) was established in 1984 primarily to promote a more equitable sharing of the burden of maintaining polar orbiting meteorological satellites. NOAA's polar satellites have long been the principal source of Automated Picture Transmission (APT) imagery for users around the world,[28] and the sole source of higher quality High Resolution Picture Transmission (HRPT) data. Both types of data are broadcast and

[26] The section below on Remote Sensing and International Development discusses several related issues.

[27] For example, of atmospheric chemistry, temperature, pressure, and wind speed.

[28] The Russian Meteor satellites also broadcast images in APT format.

BOX 5-7: The World Weather Watch

The World Weather Watch (WWW) was established in 1963 as the operational weather information system of the World Meteorological Organisation (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 W is to provide national and regional weather services with timely access to meteorological data and forecasts. W has since become the principal activity of WMO, and remains the only worldwide program for international cooperation on operational meteorological data and information.

W has three main functional elements: the Global Observing System (GOS), the Global Data-Processing System (GDPS), and the Global Telecommunications System (GTS). The Global Observing System consists of 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.

The Global Data Processing System includes an array of global, regional, and specialized forecast centers. Three World Meteorological Centres—in Washington, 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 short-term warning of severe storms and long-term projections.

The Global Telecommunication System 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 kbps, which is inadequate for the routine transfer of satellite imagery, but satellite data within any region are available directly from the satellites.1 GTS is used mostly for transmitting ground station data, atmospheric soundings, and weather forecast data products. The NOAA polar orbiters provide more limited global coverage by collecting sounding data[2] and storing them for later transmission to the ground. On the so-called "blind" orbits, these satellites do not pass over the United States, and the data are transmitted to the ground station in Lannion, France, which relays them to the United States. Current limitations on connectivity and data rates restrict the availability of surface weather data and access to useful forecast reformation in certain regions, particularly the tropics.

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

[2] These infrared and microwave soundings are converted into temperature and moisture profiles in the air column along the satellite ground track

(continued)

BOX 5-7: The World Weather Watch (Cont'd.)

W also encompasses a number of planning, support, and other specialized functions, The Committee on Data Management works to improve the integration and utilization of the elements of the W system GOS, GDPS, and GTS The Instruments and Methods of Observation Programme attempts to improve the quality and standardization primarily of surface-based meteorological observations System Support Activities provide technical support, advice, and training especially to developing countries

W's Tropical Cyclone Programme provides information about hurricanes, typhoons, and other tropical storms in order to minimize loss of life from these severe storms. Because they are large and slow-moving, tropical storms are particularly amenable to a coordinated international response. The Tropical Cyclone Programme integrates the forecasting of tropical storms with flood prediction as well as disaster prevention and preparedness measures

Weather is a global phenomenon, and W provides an essential service in planning and coordinating the collection, processing, and transmission of meteorological data and Information The World Meteorological Congress meets every four years to develop and revise its long-term plans, To a lesser extent, W also provides a vehicle for assisting developing countries in establishing modern weather forecast services, However, the Implementation of W 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.

SOURCE Off Ice of Technology Assessment, 1994

freely available to anyone with the appropriate receiving equipment. IPOMS was disbanded in 1993, its principal mission accomplished with the commitment by Eumetsat to deploy its own polar platform, Metop, which would take over the mission currently filled by NOAA's POES-AM platform.[29]

CEOS and EO-ICWG also deal with operational meteorological satellites in a broader context that includes their capacity to provide meteorological data for nonmeteorological purposes such as global change research, as well as the ability of other satellites to provide data that are useful for meteorology.

The European organization Eumetsat represents a significant step beyond voluntary cooperation and coordination to a regional intergovernmental consortium with shared budgetary responsibility based on a fixed percentage of gross domestic product. Eumetsat was established through a formal intergovernmental convention in 1986 to provide an institutional mechanism for aggregating national resources within Europe to support a weather satellite program, and specifically to support the operation of the geostationary Meteosat satellites and their data systems (box 5-8). Eumetsat and the European Space Agency have a relationship similar to that between NASA and NOAA in the United States—ESA develops, procures, and launches satellites and Eumetsat has overall operational responsibility—although Eumetsat has a narrower charter than NOAA. The national weather services of Eumetsat member countries share the responsibility for collecting data from surface stations and other instruments, and for weather forecasting.

[29] Metop is a cooperative effort involving NOAA, ESA, and the national space agencies of France, Italy, and Canada as well as Eumetsat.

BOX 5-8: Eumetsat

The European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) grew out of satellite programs of ESA and its predecessor, the European Space Research Organisation (ESRO). ESA launched the first two experimental satellites in the Meteosat series in 1977 and 1981. The national weather services of Europe established Eumetsat in 1986 in order to continue this program, and Eumetsat now serves as the responsible agency for the Meteosat Operational Programme (MOP). Eumetsat has since grown to 17 members and 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 NOAA over the provision of instruments for this satellite.

Eumetsat headquarters are located 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 onboard 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 five months, but Eumetsat intends to take over permanent responsibility for these archives when it assumes responsibility for Meteosat operations.

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[1] See the Eumetsat brochure *EUMETSAT: The European Organisation for Meteorological Satellites* (Darmstadt, Germany: Eumetsat, 1992) As of May 1994, the members of Eumetsat are 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

SOURCE Off Ice of Technology Assessment, 1994.

OPERATIONAL DATA EXCHANGE ISSUES

Operational monitoring poses two principal issues regarding access to data and information: who should receive the data on an operational basis—soon enough to support operational use—and what price should they pay. These questions apply both to commercial users and to the use of data by other government agencies. The United States has followed the tradition of placing operational data into the public domain, allowing unrestricted access for all users.[30] This policy is based on the theory that the government must provide these data for its own use, and serving additional users does not add significantly to overall system costs. The United States receives essential foreign data in return. To the extent that data exchanges can reduce costs for each participating agency, such exchanges provide one mechanism for sharing costs internationally.

Others agencies, particularly in Europe, argue that an equitable sharing of costs requires that the agencies using the data bear some of those costs. For example, Britain's Meteorological Office charges the Civil Aviation Authority and the Department of the Environment for the use of weather and climate data, and Canada plans to recoup some of the costs of operating Radarsat through commercial data sales to foreign agencies. Such policies on data pricing can provide a formal mechanism for sharing the burden of remote sensing systems. This approach might lead to a fairer distribution of costs in the long run, but it could also make data exchanges more difficult and undermine established exchange mechanisms that rely on less formal notions of reciprocity.

European agencies argue that requiring data users to pay a substantial share of system costs results in a more rational allocation of costs. They also argue that it gives data users—most of whom are value-added service providers—greater influence over the evolution of remote sensing programs and moves closer to the goal of user-operated remote sensing programs. This argument raises the question of how mature these remote sensing applications are and what price to charge to give users leverage without stifling development of new applications.

A second concern in data exchange policy stems from differences over the proper boundaries between public and private sector activities: which services provide a broad enough public benefit that they should be undertaken in the public sector, and which provide such narrow benefits that the costs should fall more narrowly on those who use them. The U.S. government makes raw data and general forecast information freely available but leaves it to others to provide more specialized services. Many weather services in Europe are under pressure to generate revenues and recover operating costs through value-added services. For example, the British Meteorological Office charges oil companies for forecasts essential to the operation of drilling platforms in the North Sea.[31]

Eumetsat has announced its plans to use encryption to restrict the availability of Meteosat data beginning in 1994. This move serves at least two purposes: encouraging nonmember countries in Europe to join Eumetsat and contribute to paying its system costs[32] and protecting European national weather services from potential commercial competitors. These restrictions should increase the ability of Europe national weather services to recover some of their operating costs.[33] Initially, Eumetsat will make all data available to NOAA and weather services outside western Europe that now receive them, but will impose some restrictions on access by third parties. For example, NOAA would not redistribute Meteosat data to

[30] This policy does not apply to data from the Defense Meteorological Satellite Program (DMSP), which are broadcast in encrypted form. Low-resolution data and up to 30 percent of high-resolution data are stored and transmitted to DMSP ground stations, from which they are available to NOAA and the Department of Defense. A limited set of DMSP data—the temperature and moisture soundings-are made available operationally through the WWW, but with delays and potential restrictions that may make them unsuitable for operational use. All DMSP data are unclassified and are being archived at the National Geophysical Data Center in Boulder, Colorado.

[31] With these and other activities, the British Meteorological Office was able to recover 36 percent of its operating costs in 1992 through interagency transfers and commercial sales. Commercial sales alone accounted for 11 percent of operating costs.

[32] Austria joined Eumetsat in December 1993 for this reason.

[33] There has been some debate in Europe between those who worry that governments will use their control over meteorological data to gain an unfair advantage over private companies and those who worry that free access to data will give private companies—which do not have to bear the costs of data collection systems-an unfair advantage over government agencies.

companies that provide aviation weather forecasts in Europe.[34] Eumetsat plans to continue to make basic meteorological data and products available through direct broadcast and the World Weather Watch,[35] and will continue its bilateral relationship with NOAA for the full exchange of more detailed operational data.

The United States is likely to retain free access to data from foreign weather satellites, in part because it will remain a leading provider of satellite weather data, and in part because meteorological data exchange is essential to all countries. Other countries would probably continue to provide data on the basis of reciprocal exchanges, although possible restrictions on data access by third parties could complicate U.S. data management. NOAA is also negotiating with Eumetsat over the possible provision of instruments for Europe's Metop polar satellite, insisting that data from U.S. instruments be broadcast unencrypted for all users. These negotiations provide added leverage for influencing Eumetsat data policies.

Other countries have chosen to restrict data for a variety of reasons. Most notably, India does not make available any images of its territory, including cloud imagery from Insat, although it does provide the WWW with wind vector data derived from these images.

In the future, governments may choose to purchase data for operational purposes from commercial satellite operators. The relationship between NASA and Orbital Sciences in developing the SeaWiFS system provides an example of how this might occur (box 4-2). However, commercial data access policies can conflict with the need for international data exchanges, and government agencies will have to exercise care if they are to ensure that commercial data purchases do not undermine international cooperation in the operational use of those data. A related issue arose in the early 1980s when the Reagan Administration attempted to privatize U.S. weather satellites. Congress decided that the provision of weather data should remain a government activity, and included provisions in the *Land Remote Sensing Commercialization Act of 1984*[36] and again in the *Land Remote Sensing PolicyAct of 1992*, forbidding the transfer of these functions to the private sector.

The proposed convergence of U.S. civilian and military weather satellite programs raises several issues relevant to the international exchange of weather satellite data. The National Performance Review led by Vice President Gore proposed consolidating the DMSP and NOAA weather satellite systems,[37] and President Clinton recently directed NOAA, DoD, and NASA to implement the convergence of NOAA, DMSP, and relevant NASA satellite programs.[38] These proposals raise the issues of access to data currently supplied by DMSP satellites and the reliance of the Department of Defense on foreign meteorological data sources. These issues and convergence in general are treated in the final report in this assessment.

INTERNATIONAL COOPERATION ON GLOBAL CHANGE RESEARCH

Space agencies around the world have made major commitments to remote sensing systems to improve understanding of changes in the global en-

[34] Any company providing commercial services in Europe would have to pay for the use of this key or purchase decrypted data from national weather services in Europe.

[35] The WMO charter calls for the exchange of "basic meteorological data and products."

[36] Public Law 98.365 (98 STAT. 45]), 15USC 429] : "Neither the president nor any other official Of the Government shall make any effort to lease, sell, or transfer to the private sector, commercialize, or in any way dismantle any portion of the weather satellite systems operated by the Department Of Commerce or any successor agency."

[37] Recommenda ion" DOC12 in Office of the Vice president, *From Red Tape to Results.. Creating a Government that Works Better and Costs Less, Report of the National Performance Review*, September 1993.

[38] The White House Presidential Decision Directive/NSTC-2, convergence of US. Polar-Orbiting Operational Environmental Satellites, May 5, 1994.

vironment. Individually, these agencies are taking part in national and international programs of environmental research. Collectively, through CEOS and EO-ICWG, they are coordinating their remote sensing programs and implementing data policies to support that research.[39]

I Scientific Programs

Established in 1990, the U.S. Global Change Research Program (USGCRP)[40] plays a leading role in environmental research worldwide, with other countries also making important contributions. Because they can provide consistent measurements with global scope, remote sensing satellites are critical to obtaining the data needed for these research programs. NASA's Mission to Planet Earth made up over *70* percent of the $1.446 billion appropriated for the USGCRP for fiscal year 1994.

These national research efforts are largely organized around the agendas of three major international research programs (box 5-9): the World Climate Research Programme (WCRP), which studies physical aspects of climate change; the International Geosphere-Biosphere Programme (IGBP), which studies biogeochemical aspects of global change and their relationship with climate change; and the Human Dimensions of Global Environmental Change Programme (HDP), which studies socioeconomic processes and their interaction with the global environment.

Although national governments take part in these programs, the programs are planned and organized by international organizations—intergovernmental agencies affiliated with the United Nations and international organizations of scientists. The International Council of Scientific Unions (ICSU) is an organization of national scientific academies around the world, with the National Academy of Sciences (NAS) as the U.S. member. Similarly, the Social Science Research Council (SSRC) is the U.S. member of the International Social Science Council (ISSC), which is an organization of social science academies. NAS, SSRC, and their international counterparts have varying degrees of independence from and influence over their respective national governments. The Intergovernmental Oceanographic Commission, United Nations Environment Programme, United Nations Educational, Scientific, and Cultural Organization, and World Meteorological Organization also help in planning these international research efforts. **Existing international programs of global change research depend almost entirely on informal mechanisms to persuade national governments to support research agendas developed by the international scientific community.** These mechanisms include personal contacts with national government agencies and participation in informal intergovernmental coordinating bodies like CEOS and the International Group of Funding Agencies for Global Change Research (IGFA).

Data from various countries' satellites and from in situ measurements contribute to both process-oriented research and long-term environmental monitoring. Process-oriented research aims to improve the understanding of the key environmental processes and develop improved models of global change. Scientific monitoring of the environment aims to develop systematic records of critical environmental variables in order to document the state and rate of change to compare observations of the environment and with global

39 Committee on Earth Observation satellites, "The relevance of satellite missions to the study of the global environment," presented at the United Nations Conference on Environment and Development, Rio de Janeiro, June 1992. Chapter 3 discusses the more general aspects of data management for global change research.

resee Committee on Earth and Environmental Sciences, *Our Changing Planet: The FY 1993 U.S. Global Change Research Program*, (Washington, DC: National Science Foundation, 1993) and U.S. Congress, Office of Technology Assessment, *Global Change Research and NASA's Earth Observing System*, OTA-B P- ISC- 122 (Washington, DC: Government Printing Office, November 1993).

BOX 5-9: International Global Change Research Programs

A number of international research programs (table 5-3) have been established to improve our understanding of various aspects of change in the global environment. Despite their diverse agendas, these programs share one remarkable feature: instead of national governments and their research programs, they involve an independent organization of natural and social scientists and international bodies in the United Nations system. As such, these programs do not have the financial authority to sponsor research projects, but rely on their authority within the scientific community to convince national governments to take part.

The oldest of these programs is the World Climate Research Programme (WCRP), established by the International Council of Scientific Unions (ICSU) in 1979. WCRP has since grown into a joint program with the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO), which hosts the WCRP Secretariat, With its focus on understanding the physical aspects of climate change, WCRP began with three main research projects. Tropical Ocean and Global Atmos-

(continued)

TABLE 5-3: International Global Change Research Programs

Acronym	Name	Description
UNEP	United Nations Environment Programme	
WMO	World Meteorological Organisation	The U.N. meteorological organization,
Ioc	Intergovernmental Oceanographic Commission	The U.N. oceanographic organization, affiliated with UNESCO.
Icsu	International Council of Scientific Unions	An international association of scientific academies, The National Academy of Sciences is the U.S. representative,
Issc	International Social Science Council	An international association of social science organizations. The Social Science Research Council is the U.S. representative.
IGBP	International Geosphere-Biosphere Programme	The international global change research program of ICSU.
WCRP	World Climate Research Programme	A joint climate research program of IGBP and WMO.
HDP	Human Dimensions of Environmental Change Program me	The global change research program of ISSC.
START	System for Research and Training	A project of IGBP, WCRP, and HDP to promote global change research in the developing world.
GCOS	Global Climate Observing System	A joint program of WMO, ICSU, IOC, UNEP,
GOOS	Global Ocean Observing System	A joint program of IOC, ICSU, UNEP.
GTOS	Global Terrestrial Observing System	A proposed program of ISSU, IGBP, UNEP,
GEMS	Global Environmental Monitoring System	A program of UNEP,
GRID	Global Resource Information Database	A program of UNEP.
IGFA	International Group of Funding Agencies for Global Change Research	A forum for coordinating national and international research programs,

SOURCE National Aeronautics and Space Administration, 1994

BOX 5-9: International Global Change Research Programs (Cont'd.)

phere (TOGA), aimed at understanding the El Nino/Southern Oscillation phenomenon,[1] the Global Energy and Water Cycle Experiment (GEWEX), and the World Ocean Circulation Experiment (WOCE) The U S Global Change Research Program (USGCRP) explicitly supports U.S. participation in these international projects [2] WCRP has since added three new projects, Climate Variability and Predictability (CLIVAR), Stratospheric Processes and their Role in Climate (SPARC), and the Arctic Climate Systems Study (ACSYS), and is planning a fellow-on to TOGA

Recognizing that global change, including climate change, also depends on complex blologlcal, geological, and chemical processes, ICSU established the International Geosphere-Biosphere Programme (IGBP) in 1986 IGBP has five core projects now underway: International Global Atmospheric Chemistry (lGAC), Global Change and Terrestrial Ecosystems (GCTE), Biospheric Aspects of the Hydrological Cycle (BAHC), the Joint Global Ocean Flux Study (JGOFS), and Past Global Changes (PAGES) Two additional projects are currently under development Land-Ocean Interactions in the Coastal Zone (LOICZ), and the Global Ocean Euphotic Zone Study (GOEZS), In addition to these empirical research projects, IGBP supports three major cross-cutting activities the task force on Global Analysis, Interpretation, and Modeling (GAIM), the System for Analysis, Research, and Training (START) to promote global change research in developing countries, and the IGBP Data and Information System (IGBP-DIS) [3]

IGBP-DIS has three main foci The first of these is the development of critical data sets. An example is the global 1 -km resolution AVHRR data set proposed by IGBP-DIS to meet the need for systematic records of land cover and land use This comprehensive proposal included a survey of existing archives of high-resoluhon AVHRR data, proposals for filling the gaps with additional ground stations (fig 5-1) and data exchange agreements, and for several additional data sets derived from the AVHRR data,[4] and was adopted as one of the Pathfinder data sets for EOSDIS.[5]

The second focus of IGBP-DIS is to ensure the establishment of effective systems to manage the data needed for IGBP's core research projects This Involves defining the data management needs of IGBP projects, developing data and operating standards that facilitate interoperability, and convincing government agencies or research Institutes to act as hosts and commit themselves to maintaining the needed data systems and standards

The third focus of IGBP-DIS is to act as an International liaison with other organizations This includes coordination with other organizations revolved in global change research, as well as with organizations that collect the necessary data As part of this acstivity, IGBP-DIS represents IGBP as an affiliate to CEOS

(continued)

[1] The El Niño Southern Oscillation is a periodic change in atmospheric circulation and ocean temperatures in the tropical southern Pacific Ocean and is correlated with widespread changes in rainfall in other regions

[2] National Science and Technology Council Committee on Environmental and Natural Resources Research, *Our Changing Planet* the fiscal year 1995 U S *Global Change Research Program 1994*

[3] *See* IGBP report No 12, *The International Geosphere-Biosphere Programme A Study of Global Change The Initial Core Projeels* (Stockholm IGBP 1990) and *Reducing Uncertainties* (Stockholm IGBP, 1992)

[4] See IGBP report No 20

[5] See ch 3

BOX 5-9: International Global Change Research Programs (Cont'd.)

The International Social Science Council (ISSC) established the Human Dimensions of Global Environmental Change Programme (HDP) in 1990 to improve understanding of the human environment and the mutual influences between human activities and the natural environment. HDP involves a number of research projects, including a joint project with IGBP on land use and land cover One major emphasis of HDP is improving the quality and management of data, which often involves combining socio-economic and environmental data, much of it obtained through remote sensing, using Geographic information Systems (GIS). The HDP Data and Information System (HDP-DIS) is currently involved in a joint project with the Consortium for International Earth Science Information Network (CIESIN) and its Socio-economic Data and Applications Center (SEDAC) to develop an international data network for social science workers.

WCRP, IGBP, and HDP are aimed at understanding the basic processes that underlie global environmental change, like cloud formation, ocean circulation, and evapo-transpiration in plants, In addition to research on these basic processes, it is also important to monitor the state of processes and related environmental variables, both to develop a baseline understanding of the state of the global environment but also to detect and measure the scope of changes in that environment and to support the development of more accurate and comprehensive theoretical models of Earth systems This need is the main motivation behind the formation of a number of Global Observing Systems (table 5-3): the Global Ocean Observing System (GOOS),[6] the Global Climate Observing System (GCOS),[7] and the proposed Global Terrestrial Observing System (GTOS) [8] As with WCRP, IGBP, and HDP, these Global Observing Systems rely on the voluntary cooperation of national governments. In one likely scenario they would build on the operational monitoring programs of those governments For example, GCOS could collect data from operational weather satellites and surface-based meteorological stations, with the relatively modest additional investment required for Improving the quality of the data for scientific applications and the maintenance of systematic archives, GTOS would probably have to be a significant exception to this, in that few operational programs exist for monitoring terrestrial processes, In part, the GTOS proposal aims to stimulate the establishment of such programs,

There is one intergovernmental organization that deals with the funding of global change research, On the initiative of the FCCSET Committee on Earth and Environmental Sciences (CEES), the international Group of Funding Agencies for global change research (IGFA) was established in 1990 as an informal forum to exchange information on national research programs. IGFA has no formal intergovernmental mandate and no authority to determine overall budgets, but it offers the opportunity for coordinating environmental research programs internationally and provides an intergovernmental base of support for national and international programs.

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6 National Oceanic and Atmospheric Administration, *First Steps Toward a U S GOOS. Report of a Workshop on U.S. Contributions to a Global Ocean Observing System,* October 1992 (available from Joint Oceanographic Institutions, Inc , Washington, DC)

7 GCOS Joint Planning Office, c/o WMO, Case Postale 2300, ch- 1211, Geneva, Switzerland

8 *Towards a Global Terrestrial Observing System (G TOS) Detecting and Monitoring Change in Terrestrial Ecosystems,* O William Heal *et al*, eds (Paris UNESCO, June 1993)

9 Generally, science quality data must be systematic and well -calibrated, attributes that are not as important for operational use Temperature measurements with an accuracy of one degree may be adequate for operational purposes, but not for detecting climate changes of a few tenths of a degree

SOURCE Off Ice of Technology Assessment, 1994 change models. **An effective international research program on global environmental change requires a balance between process-oriented research and long-term monitoring.**[41]

Concerned over the need for a greater commitment to long-term monitoring, the scientific community is developing plans for the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the proposed Global Terrestrial Observing System (GTOS) (box 5-9). Scientific monitoring has much in common with operational applications of remote sensing; both require reliable and consistent data streams. While operational applications place heavy demands on the timely distribution of data, scientific monitoring emphasizes high-quality and consistent y calibrated data. As currently conceived, GOOS and GTOS would combine operational and scientific monitoring functions.

Climate monitoring presents more complicated choices. Marginal improvements in instrument performance and data management for weather satellites would meet many of the requirements of climate monitoring.[42] But other variables, such as atmospheric chemistry, aerosols, and radiation balance, are less important for weather forecasting. These could be measured with additional instruments on weather satellites, or by developing separate, dedicated satellite systems. Furthermore, both operational and scientific monitoring programs require high-quality in situ data from around the world, with effective mechanisms for international data exchange.

A central purpose of these research programs is to inform and influence national policies and international agreements on environmental management. The effective use of this knowledge requires an institutional mechanism to assess the state of understanding of environmental problems and inform policy makers .43 The Intergovernmental Panel on Climate Change (IPCC) provides a model for this process at the international level. IPCC completed its first full assessment of the state of the global climate in 1990, with an update in 1992 and a full reassessment planned for 1995, and has played a critical part in motivating and informing the Intergovernmental Negotiating Committee in developing the Framework Convention on Climate Change, which entered into force in March 1994. **The IPCC provides a model for the scientific assessment of international environmental problems that could be applied to other issues currently under international discussion, such as biodiversity, forest conservation, and desertification.**

As discussed in chapter 3, environmental research and monitoring places heavy demands on data management systems. These include the large quantity of raw and processed data, the high quality control standards in data processing, and the need to maintain long-term records of environmental change. Making the best use of improved scientific models or data processing algorithms could require the reprocessing of large quantities of archived data.

Many countries have substantial archives of Earth data, some of them from satell ites. These archives are of uneven quality.[44] Some of these archives belong to the ICSU system of World Data Centres (WDCS), established in 1957 to preserve and exchange data from the joint research pro-

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41 See IGBP Report 20 *Improved Global Data for Land Applications: A Proposal for a New High Resolution Global Data Set, Report of the Land Cover Working Group of IGBP-DIS* (Stockholm: IGBP, 1992) for a discussion of these two types of data use. See also, 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) for a discussion of the need for greater attention to monitoring within the USGCRP.

42 As an example of this synergy, Eumetsat is moving toward incorporating scientific climate monitoring as part of its miss ion.

43 See Office of Technology Assessment, *Global Change Research and NASA's Earth Observing System*, pp. 6-7 and 43-45.

44 The data may be stored on poorly maintained media, may be recorded using obsolete formats and technologies, and may be calibrated in undocumented ways, if at all. See ch. 2.

grams of the International Geophysical Year. The WDC system now consists of 44 centers in 11 countries (box 5-10), repositories of a wide variety of Earth science data that are made available without restrictions at the lowest possible cost to users. The WDC commitment to the free exchange of scientific data, which persisted through many international crises, set an important precedent that is reflected in U.S. policies (box 5-2) and in those of the international remote sensing organizations such as CEOS and EO-ICWG.

The international scientific community has become concerned over restrictions on access to Earth data. In response to these concerns, ICSU established an Ad Hoc Working Group on Data Policy Issues. Its greatest concern is that commercial and other restrictive policies for data access could effectively put much essential data beyond the reach of working scientists. For example, because of national cost recovery programs, several countries have reduced their voluntary data submissions to the WDC system.[45] In order to obtain data, scientists often have to agree not to redistribute it, which forces them to choose between their contractual obligations and the normal scientific process of data sharing. Second, scientists need meteorological and other data sets of higher quality than now available from many sources. Finally, scientists believe that countries need to make greater investments in data management systems. As noted in chapter 2, the technology is available and growing cheaper, but the demands of data management are also growing rapidly.

INTERNATIONAL COORDINATION OF DATA POLICIES

The international organizations for cooperation in remote sensing have made the coordination of data policy for global change research a top priority. Both CEOS and EO-ICWG have agreed that Earth science data should be made cheaply and readily available for global change research (box 5-5 and box 5-6), and are taking actions to implement these agreements.

CEOS plays a unique role in providing a forum for data users to discuss their requirements directly with the operators of Earth observing satellite systems. This includes international scientific organizations, who are active as CEOS affiliates. As part of a pilot project coordinated through CEOS to make multispectral land imagery available for IGBP projects, NASA, CNES, and NASDA have agreed to make data from Landsat, SPOT, and MOS available at reduced cost to IGBP researchers. Many scientists who use remotely sensed Earth data are hopeful that CEOS will be effective as a forum for discussing the needs of scientists and improving their access to remotely sensed Earth data.

Data access depends as much on effective data management systems as it does on formal policies. The U.S. government has recognized the need for such systems and is attempting to meet that need through the EOSDIS and GCDIS programs.[46] Other countries have also recognized this need, but are in earlier stages of developing plans for data management systems.

Superficially, Europe's Earthnet data management system resembles NASA's EOSDIS, with Processing and Archive Facilities (PAFs) corresponding to the U.S. Distributed Active Archive Centers (DAACs), and the European Space Research Institute (ESRIN) in the role of the EOSDIS Core System. In fact there are significant differences. In Europe, research programs are generally managed through research institutes rather than through grants to individual investigators, and European data management plans reflect this. The PAFs are located in research centers and serve primarily to meet the needs of those centers.

[45] M. Chinnery and S. Ruttenberg, personal communications. Canada has stopped providing geomagnetic data, for example.

[46] Ch. 3 describes existing U.S. data archives and discusses plans for EOSDIS and GCDIS.

BOX 5-10: The ICSU World Data Centres

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

As of May 1994, there are 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, USGS, DOE, and DOD (table 5-4)[2]

TABLE 5-4: ICSU World Data Centres in the United States

U.S. National Data Center	World Data Centre(s)
National Geophysical Data Center (Boulder, Colorado)	Glaciology
	Marine Geology and Geophysics
	Solar-Terrestrial Physics
	Solid Earth Geophysics
	Paleoclimatology
National Climate Data Center (Asheville, North Carolina)	Meteorology
National Oceanographic Data Center (Washington, DC)	Oceanography
National Earth Information Center (Golden, Colorado)	Seismology
U.S. Naval Observatory (Washington, DC)	Rotation of the Earth
Oak Ridge National Laboratory (Oak Ridge, Tennessee)	Trace Gases
EROS Data Center (Sioux Falls, South Dakota)	Remotely Sensed Land Data

SOURCE National Oceanic and Atmospheric Administration, 1994.

(continued)

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

[2] See S Ruttenberg, 'The ICSU World Data Centers, *EOS Transactions,* VOl 73, No 46, Nov. 17, 1992, pp 494-495

They are not well equipped to meet the needs of outside users or the demands of other data applications.

The main focus of ESA'S Earthnet data management system is managing SAR data from ERS-1. This system overcame severe inadequacies at its beginning, and still suffers from a lack of standardization and interoperability among the PAFs. Because of different data processing techniques, data from different PAFs are dificult to compare. ESA is in the preliminary stages of developing management plans for data from its global change system, Envisat-1, and it remains unclear what level of support these planned data systems will receive and how effective y they w ill serve outside users.

Japan's principal data management center for scientific users is NASDA'S Earth Observations Center (EOC) in Tokyo. This center has principal responsibility for managing SAR data from JERS-1, but has experienced serious problems in meeting the data requests of scientific users. Recognizing the need for improved data systems, Japan is planning an Earth Observation Information System (EOIS), built around the EOC. This system would include three main components, a Data

BOX 5-10: The ICSU World Data Centres (Cont'd.)

The WDCS operate under a set of agreed international principles. These principles call for a WDC to make data avaible to scientists in any country. A WDC should charge no more than the cost of filling the data 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 a liaison 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 catalyzing the formation of those national centers Most scientists believe that the open exchange of data provides benefits that far outweigh the costs of maintaining a WDC,

From the beginning, WDCS have attempted to adopt the most modern practical data and information technologies. WDC data are becomming increasingly available on electronic networks at high data rates and on emerging media standards such as CD-ROM. In the past, the WDC system has devoted a major effort to developing standardized data formats, but the development of more flexible software capable of using data in a variety of formats has greatly reduced the need The challenge of providing efficient methods for searching and browsing data may also be eased by increasing network capacity and the emergence of network search software [3] These capabilities are only available to those with sufficient computing and communications capabilities, which are not available in many parts of the world, especially in developing countries.

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 CEOS and IEOS

[3] See ch 2

SOURCE Off Ice of Technology Assessment 1994.

Acquisition and Processing System, a Data Analyzing System, and a Data Managing and Distribution System, but the plans are still under development and funding remains uncertain.

International efforts are under way to coordinate these data management plans. At its seventh Plenary meeting in November 1993, CEOS created a working group on international data networks. EO-ICWG has begun to address the issue of forming and coordinating IEOS data management systems. Discussions await the commitment of resources and the development of a planning process in other agencies participating in IEOS, with a view toward forming an IEOS Data and Information System, or IEOSDIS.

Some elements of an international data system are essential for effective data exchange mechanisms. First of all, the individual national data systems must have archives that provide adequate quality control and standardization of data[47] and

[47] See U.S. Congress, Office Of Technology Assessment, *Data Format Standards for Civilian Remote Sensing satellites,* OTA-BP-ISC-114 (Washington, DC: Office of Technology Assessment, May 1993).

readily usable systems for searching metadata sets. Second, the various data management systems must be sufficiently compatible to operate effectively together, allowing users of one system to access data held by another in a relatively transparent manner.[48] In practice, this could involve the routine exchange of metadata among designated archive centers. The CEOS International Directory Network has links between Europe, Japan, and the U.S. Global Change Master Directory[49] at its core (fig. 5-3). Finally, the international data system must have the capability to provide data to users, either through electronic transmission or through the exchange of physical storage media like magnetic tapes or CD-ROM.[50]

The simplest approach to international data management is to build on national and regional data systems and plans by establishing basic requirements for compatibility and interoperability. This approach has the advantage of flexibility, allowing different agencies to meet their various needs in the manner they deem appropriate. In an era when information technology is rapidly evolving, such flexibility is particularly important. The principal disadvantage of this approach is that it makes it easier for some agencies to give inadequate attention to data management and create "weak links" in the international network, with corresponding gaps in data availability.

An alternative approach is for the international community to collaborate on the definition and implementation of data management requirements. EO-ICWG in particular could consider this approach in developing plans for IEOSDIS. This would allow for a greater degree of harmonization and interoperability of systems, but it could prove cumbersome and inflexible.

A complementary option would be to share the burdens of data management systems and pursue a division of labor and specialization in data management as in satellite systems. The European ground segment plans, for example, rely heavily on indigenous European resources to acquire data from Envisat- 1. This includes the use of onboard data storage on satellites and data relay satellites to transmit data directly to ground stations in Europe. An alternative would be to rely on ground stations located in other countries to acquire the data and use other communications links to transmit the data to Europe if that is desired. So far, the various national and regional agencies do not appear to have given great attention to managing data from other agencies' satellites or relying on other countries for data acquisition.

REMOTE SENSING AND INTERNATIONAL DEVELOPMENT

Social and economic conditions in many parts of the world are poor and often stagnant or even deteriorating. Over the years concern has grown that the mismanagement of natural resources and the environment is contributing to these poor conditions and vice versa. The United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, in the summer of 1992, solidified international support for the concept of sustainable development-economic development that improves human conditions in the short run while preserving environmental resources to make those gains sustainable in the long runs The United States and other industrialized countries have established national and international programs of financial and technical assistance to developing countries, and have

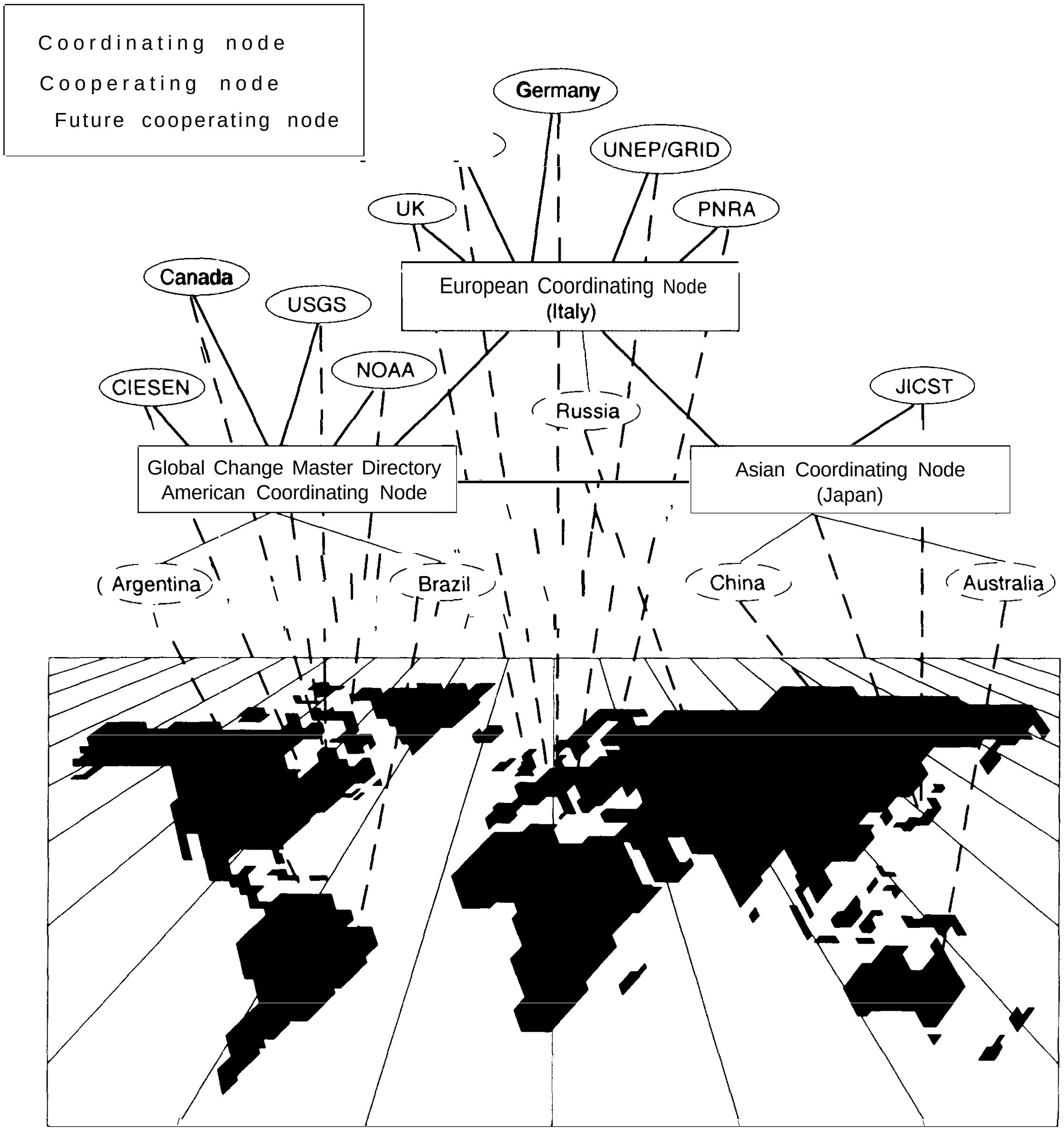
[48] NASA and ESA are testing the interoperability of NASA's Information Management System (IMS) and ESA's User Interface Terminal (UIT), and NASA and NASDA are undertaking similar tests.

[49] See ch. 3.

[50] See ch. 3 for a discussion of these requirements in the context of EOSDIS.

[51] K. Dahle, "Environment, development, and belief Systems," *Futures*, December 1993, pp. 1070-1074.

FIGURE 5-3: The CEOS International Directory Network



SOURCE Committee on Earth Observations Satellites, 1994

committed themselves to the principle of sustainable development, although the degree of support for its implementation remains to be seen.

The concept of sustainable development is based on the view that current patterns of development **in many cases pose unsustainable burdens** on the natural and human environments. The reasons for this include inefficent economic structures, rapid population growth, and a lack of knowledge and capacity to implement more sustainable practices. **Satellite remote sensing can contribute to more sustainable development by**

providing some of the knowledge necessary for a more efficient management of natural resources. For example, satellites can: observe the burning of forests and other biomass and the resulting deforestation,[52] can help monitor the condition and vegetative cover of vulnerable arid lands,[53] and can support the monitoring of land use, and of air and water quality.[54]

Developing countries often lack the capability to make use of data from Earth observing satellites for these or other purposes.[55] This shortage has many related aspects, and presents a complicated challenge to those who seek to develop this type of capability. First, many countries lack the technical resources+ computers and communications equipment—for data collection, transmission, processing, and analysis. Second, they face shortages of trained personnel who know how to use such systems or even have the necessary background to learn how to use them, Finally, they often lack the public and private institutions to make use of the information provided through remote sensing.

Financial and technical assistance from developed countries can help overcome these obstacles, but the effective use of remotely sensed data requires a comprehensive approach and a long-term commitment from both donor and recipient. This comprehensive approach would have to include startup funding to develop the required data and information systems, as well as sustained support for the supply of data and long-term training in the use of these systems and data.[56] Geographic Information Systems can make these tasks much easier, but they cannot eliminate the need for long-term follow up to support the initial investment. Another way to promote the development of related capacities is to support the development of indigenous scientific expertise in developing countries through programs like the START initiative (box 5-9). This would allow those countries to develop an independent understanding of their particular needs in environmental research, monitoring, and resource management, A variety of international principles, including the U.N. Principles on remote sensing (box 5-2) and the UNCED agreements, call for this type of technical assistance.

Decisions on foreign assistance are based on the level of public interest, both on humanitarian grounds and national self-interest. For example, the United States has long supported weather services in the Caribbean region as a way to improve the ability to track hurricanes and tropical storms. A broader vision of national interest might include a national commitment to global environmental monitoring, which might require support for programs of in situ monitoring in developing countries. A decision on whether or not to support the use of satellite data for international development would also depend on an assessment of the effectiveness of that type of assistance in comparison with other forms of assistance.[57]

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[52] See app. C, D. Skole and C. Tucker, "'Tropical Deforestation and Habitat Fragmentation in the Amazon; Satellite Data from 1978 to 1988," *Science*, vol. 260, June 25, 1993, pp. 1905-1910. Direct observation of biomass burning requires a highly sensitive instrument such as the Optical Linescan Sensor (OLS) on the Defense Meteorological Support Program (DMSP) satellites.

[53] C.J. Tucker et al., "Expansion and Contraction of the Sahara Desert From 1980 to 1990," *Science,* vol. 253, No. 5017, July 19, 1991, pp. 299-301.

[54] See *New Technologies: Remote Sensing and Geographic Information Systems*, Environment and Development Brief No. 3 (Paris: UNESCO, 1992).

[55] India is a notable exception to this rule, with an active remote sensing program that includes both satellites and programs to analyze and use the data they produce.

[56] U.S. Congress, Office of Technology Assessment, Working Group on Approaching Sustainable Development, meeting held Dec. 7, 1993, in Washington, DC.

[57] The Office of Technology Assessment is currently engaged in an assessment of science and technology, renewable resources, and international development, which will address this issue in a broader context.