Appendix B: Survey of National and International Programs

B

The level of international activity in remote sensing has grown steadily since the first TIROS weather satellite in 1960. The extent of cooperation among these agency programs has grown in tandem with the **increasing number** of national and regional agencies[1] that have undertaken remote sensing programs. Nations pursue remote sensing programs for both their direct utility and the technological development they stimulate. Remote sensing. therefore, also involves an element of international competition for technological advantage in national security, national prestige, and commercial markets for remote sensing systems and data.

NATIONAL AND REGIONAL PROGRAMS AND PLANS

This section focuses on the remote sensing programs of non-U.S. agencies (tables B-1 and B-2)[2]; see chapter 3 for descriptions of the main U.S. programs. Figure B-1 summarizes the existing and proposed U.S. and non-U.S. remote sensing systems.

Europe. The French space agency, CNES (Centre National d'Études Spatiales), has the largest national remote sensing program in Europe. CNES was the first European agency to develop and deploy a remote sensing system, the commercially operated

[1] Here OTA is using the term *agency* to refer both to national agencies such as NASA and NOAA and to regional organizations such as the European Space Agency and Eumetsat.

[2] For more details, see U.S. Congress. Office of Technology Assessment, *The Future of Remote Sensing from Space: Civilian Satellite Systems and Applications*, OTA-ISC-588 (Washington, DC: U.S. Government Printing Office, July 1993).

TABLE B-1: Operational U.S. and Foreign Remote Sensing Platforms

Platform	Country	Year	Function[a]
Landsat 4	United States	1982	Land remote sensing
Landsat 5	United States	1984	Land remote sensing
NOAA-1 1	United States	1988	Meteorology (polar)
NOAA-1 2	United States	1991	Meteorology (polar)
GOES-7	United States	1987	Meteorology (GEO)
GOES-8	United States	1994	Meteorology (GEO)
UARS	United States	1991	Atmospheric chemistry
SPOT 1	France	1986	Land remote sensing
SPOT 2	France	1990	Land remote sensing
SPOT 3	France	1993	Land remote sensing
Meteosat 3	Europe	1988	Meteorology (GEO)
Meteosat 4	Europe	1989	Meteorology (GEO)
Meteosat 5	Europe	1991	Meteorology (GEO)
Meteosat 6	Europe	1993	Meteorology (GEO)
ERS-1	Europe	1991	SAR and ocean dynamics
TOPEX/Poseidon	United States/France	1992	Ocean dynamics
GMS-4	Japan	1989	Meteorology (GEO)
MOS-1b	Japan	1990	Land and ocean color
JERS-1	Japan	1992	SAR and land remote sensing
IRS la	India	1988	Land remote sensing
IRS 1 b	India	1991	Land remote sensing
INSAT IIa	India	1992	Meteorology (GEO) and telecommunications
INSAT IIb	India	1993	Meteorology (GEO) and telecommunications
Meteor 2	Russia	1975 (series)	Meteorology (polar)
Meteor 3	Russia	1984 (series)	Meteorology (polar)
Okean-0	Russia	1986 (series)	Ocean
Resurs-0	Russia	1985 (series)	Land

[a]GEO = geostationary Earth orbit, SAR = synthetic aperture radar

SOURCE: *Committee on* Earth Observation Satellites (CEOS) 1993 Dossier--Volume A, 1993

SPOT (Systeme Pour l'Observation de la Terre) satellite system.[3] France is also developing the Helios reconnaissance satellite, which may have civil as well as military applications. Germany, Italy, and the United Kingdom also have substantial remote sensing programs.

A large portion of Europe's remote sensing activities take place through the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (Eumetsat; box 4-6). ESA currently operates ERS- 1 and is preparing ERS-2 for launch in early 1995. These are part of an ambitious long-term plan that includes Envisat-1, now under development for launch in 1998, and as yet unspecified future systems. Eumetsat operates the geosynchronous Meteosat weather satellite system and is developing the polar platform METOP-1 for launch in 2000

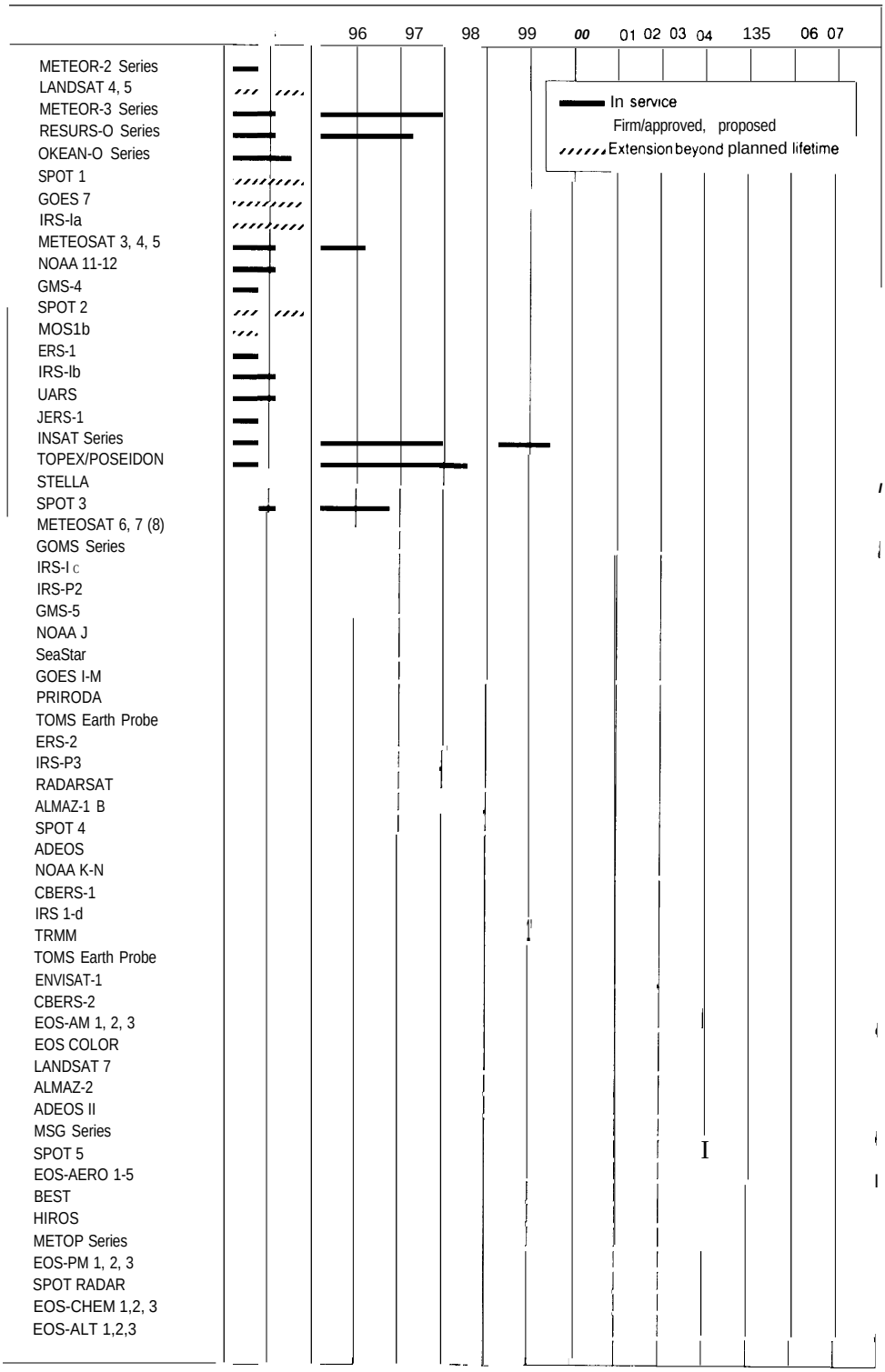
[3] Although SPOT is operated Commercially through SPOT Image, it continues to receive subsidies from CNES, which pays the costs of developing, procuring, and launching new satellites and owns a 40 percent share of SPOT Image.

TABLE B-2: Planned U.S. and Foreign Remote Sensing Platforms

Platform	Country	Year	Function[a]
NOAA-J	United States	1-994 '--	Meteorology (polar)
NOAA-K	United States	1996	Meteorology (polar)
NOAA-L	United States	1997	Meteorology (polar)
NOAA-M	United States	1999	Meteorology (polar)
NOAA-N	United States	2000	Meteorology (polar)
GOES-J	United States	1995	Meteorology (GEO)
GOES-K	United States	1999	Meteorology (GEO)
GOES-L	United States	2000	Meteorology (GEO)
TOMS Earth Probe	United States	1995	Atmospheric chemistry
EOS AM-1	United States	1998	Climate, atmospheric chemistry, ocean color, land remote sensing
EOS PM-1	United States	2000	Climate and meteorology
EOS Aero-1	United States	2000	Atmospheric chemistry and aerosols
EOS CHEM	United States	2002	Atmospheric chemistry, solar ultraviolet, trace gases, ozone
EOS Color	United States	1998	Ocean color
Landsat 7	United States	1998	Land remote sensing
SeaStar	United States	1995	Ocean color
WorldView	United States/ Commercial	1994	High-resolution land remote sensing
TRMM	United States/ Japan	1997	Climate and tropical precipitation
Meteosat 7	Europe	1995	Meteorology (GEO)
Meteosat 8	Europe	2000	Meteorology (GEO)
METOP	Europe	2000	Meteorology (polar)
SPOT 4	France	1996	Land remote sensing
ERS-2	Europe	1994-95	SAR, ocean dynamics, atmospheric chemistry
Envisat- 1	Europe	1998	SAR, atmospheric chemistry, ocean dynamics and color
Radarsat	Canada	1995	SAR
GMS-5	Japan	1994	Meteorology (GEO)
ADEOS	Japan	1996	Oceans, climate, and atmospheric chemistry
GOMS	Russia	1994	Meteorology (GEO)
Almaz-1B	Russia	1996	SAR
Almaz-2	Russia	1999	SAR
IRS-1 c	India	1994	Land remote sensing
IRA-1 d	India	1996	Land remote sensing
MECB SSR-1	Brazil	1996	Land remote sensing (vegetation)
MECB SSR-2	Brazil	1997	Land remote sensing (vegetation)

[a] GEO= geostationary Earth orbit SAR = synthetic aperture radar

SOURCE *Committee on Earth Observayion Satellites (CEOS)* 1993 Dossier—Vohxne *A, 1993*



SOURCE Committee on Earth Observations Satellites, 1993

TABLE B-3: METOP-1 Instruments and Sources

Instrument	Agency or government[a]
AATSR-Advanced A-long-Track Scanning Radiometer	U. K., Australia
AMSU-A—Advanced Microwave Sounding Unit	N O M
ASCAT—Advanced Scatterometer	ESA
AVHRR/3—Advanced Very High Resolution Radiometer	N O M
GOMI—Global Ozone Monitoring Instrument	ESA
HIRS/3—High Resolution Infrared Sounder	N O M
IAS1—infrared Atmospheric Sounding Interferometer	CNES/ASl
MHS—Microwave Humidity Sounder	Eumetsat
MIMR—Multifrequency Imaging Microwave Radiometer	ESA
ScaRaB—Scanner for Earth's Radiation Budget	CNES/DARA
SEM—Space Environment Monitor	N O M

[a] NOAA = National Oceanic and Atmospheric Administration, ESA = European Space Agency, CNES/ASl = Centre National d'Études Spatiales/Agenza Spaziale Italiana, CNES/DARA = CNES/Deutsche Agentur fur Raumfahrtsangelegenhelit.

SOURCE *Committee on Earth Observation Satetellites (CEOS) 1993 Dossier—Vo/ume A, 1993*

(table B-3). The European Union is also involved in remote sensing applications and data management.

Japan. Japan launched its remote sensing programs with the Geosynchronous Meteorological Satellite (GMS) series, which began in 1977. Since then, Japan has concentrated on ocean remote sensing, with the infrared and ocean-color sensors on the Marine Observation Satellites (MOS-1) and the imaging radar on the Japan Earth Resources Satellite (JERS-1).[4] Japan's remote sensing plans include the Advanced Earth Observation Satellite (ADEOS), with an international suite of instruments for observing the oceans, atmospheric chemistry, and land surface, and the joint Tropical Rainfall Measurement Mission (TRMM) with NASA.

Canada. Canada has contributed search-and-rescue instruments to NOAA polar satellites and plans to deploy Radarsat, its first remote sensing satellite, in 1995. Radarsat will provide synthetic aperture radar (SAR) data for operational purposes—mainly for monitoring sea ice cover—and for research. The Canadian Space Agency hopes to recover some of its operational costs through commercial data sales to foreign governments, although the United States will receive free access to Radarsat data in exchange for providing launch services.

Russia. Russia continues several series of satellites inherited from the Soviet Union for observing weather, oceans, and land. This includes the Meteor-2 and Meteor-3 series of polar weather satellites, the Okean-O series of low-resolution ocean observing satellites, and the Resurs-F and Resurs-O series of moderate-resolution land remote sensing satellites. These series have been quite stable, although the satellites often have short lives or use old technologies. Russia has also deployed the Almaz-1 radar satellite and is preparing a follow-on Almaz-1b. Since 1992, Russia has listed its first Geosynchronous Operational Meteorological Satellite (GOMS) as ready for launch, but funds for this launch have not been forthcoming.

Russian enterprises have attempted to sell data from the Resurs-F and Resurs-O series and from Almaz-1 but have had difficulty meeting commercial demand for timeliness and reliability. Russia has also begun offering 2-m resolution land imag-

4 JERS-1 encountered problems with its antenna and power systems and produces low-quality data.

ery from intelligence satellites and is reportedly considering offering still higher-resolution imagery.[5]

India. India has the most active remote sensing program among developing countries. Telecommunications satellites in the Insat series carry a Very High Resolution Radiometer (VHRR) for cloud cover and infrared images. The Indian Remote Sensing (IRS) satellite series, similar to Landsat but with lower resolution and fewer bands, is part of India's commitment to technological self-sufficiency. Except for wind data derived from Insat, these data have not been available outside India, but the Indian Space Research Organization (ISRO) recently signed an agreement with the U.S. firm EOSAT to market IRS imagery outside India.[6]

China. China has deployed the FY-1 (Feng Yun—''Wind and Cloud") series of experimental polar weather satellites and has developed a geosynchronous weather satellite (FY-2) as well, but neither has been very successful.[7] In 1988, China and Brazil signed an agreement to develop two China-Brazil Earth Resources Satellites (CBERS-1 and 2) for observing land and vegetation, but no firm plans have yet emerged.

Brazil. In addition to working with China on CBERS-1 and 2, Brazil has deployed a data-relay satellite for collecting environmental data from remote ground stations and is developing a follow-on satellite with a camera for vegetation monitoring.

South Africa. South Africa is developing the lightweight Greensat for commercial sale, with both civilian and military applications.

Ground Segment. Many countries are active in the applications of remote sensing through the operation of ground stations for collecting and processing satellite data from Landsat, SPOT, ERS-1, and JERS-1. Hundreds of ground stations around the world receive data of various kinds from polar and geostationary meteorological satellites.

JOINT SATELLITE PROJECTS

Joint satellite projects are a growing form of international cooperation in remote sensing. Typically, these projects involve one agency providing instruments for a satellite being developed by another agency. Joint satellite projects have paved the way for many countries to enter the field of remote sensing through relatively modest initial steps, which, over the years, has led to more equal international partnerships. Other forms of partnership include providing launch services and cooperating on data management. The partnerships also require coordination in such areas as export controls, the operation of satellite ground stations, and the exchange of data.

NOAA Polar Series. Canada, France, and Britain have contributed instruments to NOAA polar satellites for search and rescue, data relay, and stratospheric temperature soundings.

TOMS. The Total Ozone Mapping Spectrometer was developed by NASA and has flown on a variety of platforms, including the Russian Meteor 3 series. It will also fly on the planned Japanese ADEOS satellite and a future Meteor 3. The negotiations for placing the first TOMS on Meteor were complicated by export restrictions on radiation-resistant electronics included in TOMS.

TOPEX/Poseidon. This joint mission between NASA and CNES provides accurate measurements of ocean topography and, indirectly, ocean current. NASA and CNES provided instruments and NASA built, assembled, and operates the spacecraft, which was launched by a French Ariane rocket.

TRMM. Japan's National Space Development Agency (NASDA) is providing a Precipitation Radar for NASA's Tropical Rainfall Measurement Mission.

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5 B. Ionatta, "Russia Expected To Raise Ante in Satellite Image Market," *Space News*, Apr. 18-24, 1994, p. 18.

6 EOSAT press release, Feb. 28, 1994.

7 China's polar satellites all failed within a few months of launch, and its first geosynchronous satellite was destroyed during ground testing.

ADEOS. In addition to NASA's TOMS instrument. the Japanese ADEOS will carry a NASA scatterometer and the POLDER instrument provided by CNES to measure greenhouse gases and acrosols.

ASTER. The Japanese Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). a moderate-resolution land imager, will fly on EOS AM-1.

METOP. Eumetsat plans for METOP grew out of international discussions on sharing the cost burden of polar weather satellites. Because of the need to coordinate with NOAA and because of Eumetsat's relative inexperience in satellite development, METOP will be the most heavily international remote sensing satellite in history, with instruments provided by eight separate national and European agencies (table B-3). Plans for cooperation depend on future agreements between NOAA and Eumetsat about data-access policy and encryption.[8]

INTERGOVERNMENTAL ORGANIZATIONS

Several organizations have arisen to promote cooperation between government agencies in remote sensing. Some of these organizations address remote sensing comprehensively, while others deal with specific applications of remote sensing. Though they operate with varying degrees of formality, they all offer mechanisms for voluntary cooperation among the national and regional member agencies. [9]

CEOS. The Committee on Earth Observation Satellites (box B-1: figure B-2) grew out of a 1984 summit of the Group of Seven Industrialized Nations. It was created to improve coordination among those countries' remote sensing programs. Its membership has since expanded to include all the major remote sensing agencies in the world (table B-4). CEOS is a voluntary association, with no legal authority over its members, and works to achieve consensus on a range of issues that focus on data policy. The committee also provides a forum for its members to discuss these and other issues with its affiliates, which are international organizations of users of remotely sensed data. In recent meetings, CEOS has focused on data policies designed to promote global change research and operational uses for remote sensing.

EO-ICWG. The Earth Observation International Coordination Working Group (box 4-5) grew out of remote sensing programs originally associated with the international space station program but has since become independent of that program. It aims to coordinate the details of selected major Earth observation platforms of its member agencies (table 4-2) into an International Earth Observation System (IEOS). EO-ICWG has reached formal agreement on data policics for these IEOS platforms, which would form the basis for binding agreements applying to specific joint projects. These policies do not apply to platforms such as METOP that are not part of IEOS, although such platforms could be included at a later date.

WMO/WWW. The World Weather Watch of the World Meteorological Organization is a cooperative program for worldwide sharing of meteorological data and information. It operates through the voluntary cooperation of its members to collect, transmit, and process meteorological data from satellites and a variety of in situ sources and to disseminate meteorological forecast products. The WWW depends on a longstanding tradition of open and timely sharing of meteorological data (box 4-3).

CGMS. The Coordination Group for Meteorological Satellites was founded in 1972 to harmonize the operations of geosynchronous meteorological satellites in connection with the WMO'S

[8] See chapter 4.

[9] See U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, OTA-ISS-604 (Washington, DC U. S. Government Printing Office, August 1994), ch. 5, for more detailed descriptions of many of these organizations.

BOX B-1: The Committee on Earth Observations Satellites

The Committee on Earth Observations Satellites (CEOS), established in 1984 as an outgrowth of a summit of the Group of Seven,[1] 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. 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. The working groups have particular responsibility for data issues. The Working Group on Calibration and Validation deals with the calibration of sensors to ensure 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 general data policy issues. At its seventh Plenary Meeting in November 1993, CEOS agreed to establish a 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 has devoted much of its attention to data policy in support of global change research. The Sixth CEOS Plenary Meeting on 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.

[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.

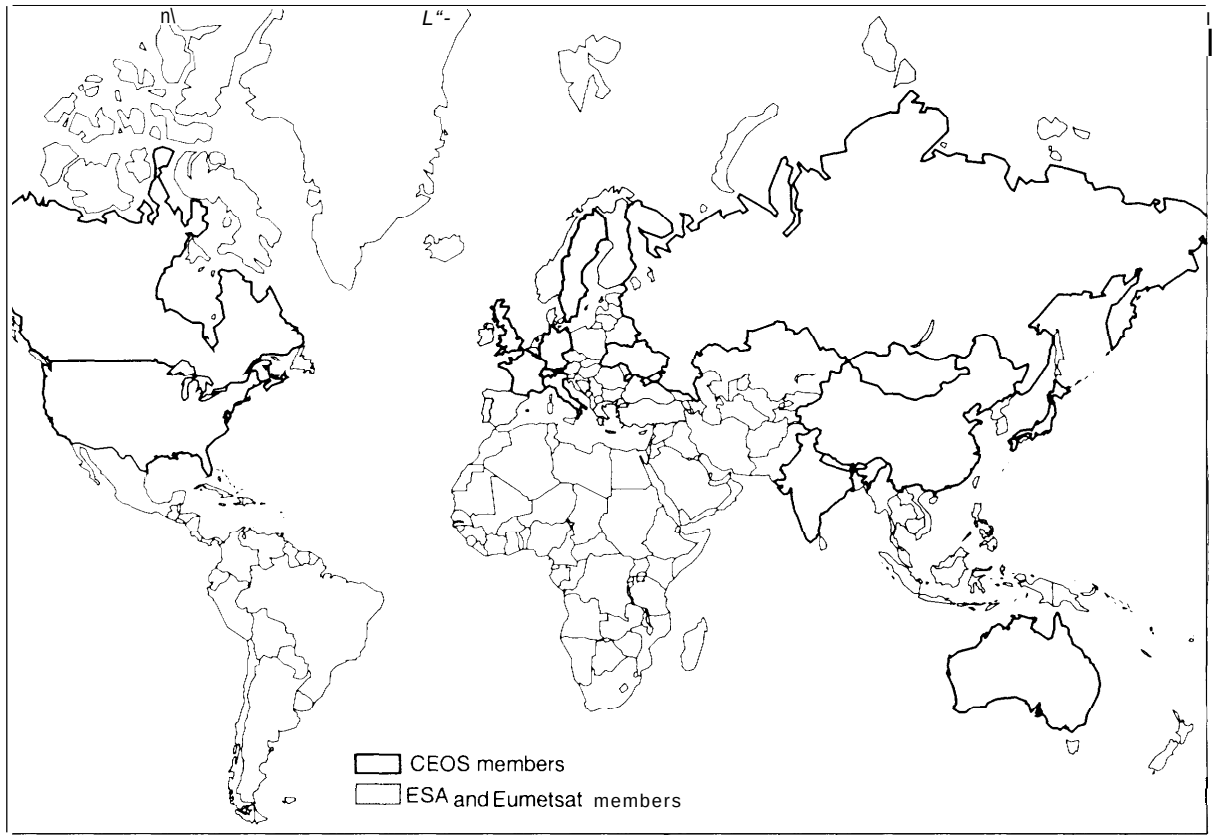
SOURCES: National Oceanic and Atmospheric Administration, 1994 Office of Technology Assessment, 1994.

Global Atmospheric Research Program (GARP). The mandate of CGMS has since expanded to include polar satellites as well. [10] CGMS provides a forum in which international issues in the convergence of weather satellites can be addressed.

IOC. The Intergovernmental Oceanographic Commission is a U. N.-affiliated organization that promotes international cooperation in oceanographic research. Several data centers around the world serve as archives for oceanographic data,

[10] The original name of CGMS was the Coordination of Geosynchronous Meteorological Satellites group. For more details, see U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets,* OTA-ISS-604 (Washington, DC: U.S. Government Printing Office, September 1994).

FIGURE B-2: Committee on Earth Observations Satellites Membership



SOURCE Committee on Earth Observations Satellites, 1994

including remotely sensed data, and take part in the Intergovernmental Oceanographic Data Exchange (IODE) program.

UNEP. The United Nations Environment Programme supports two related programs that use remotely sensed data. The Global Environmental Monitoring System (GEMS) collects information to support international environmental protection and management programs. The Global Resource Information Database (GRID) serves as an archive with 10 centers on five continents that provide environmental data to natural resource managers around the world. Although they frequently use satellite data, GEMS and GRID do not have the resources to support operational satellite data-gathering activities.

FAO. The U.N. Food and Agriculture Organization also supports programs that use remotely sensed data in agriculture, forestry, and environmental monitoring. The Global Information Earl y Warning Network uses satellite imagery and national crop reports to provide early warning of possible famine conditions. The Forest Resource Assessment program aims to provide an updated inventory of tropical forests every 10 years.

TABLE B-4: Participants in CEOS

Members	Observers	Affiliates
National Aeronautics and Space Administration (NASA)	Norwegian Space Centre (NSC)	International Council of Scientific Unions (SCU)
National Oceanic and Atmospheric Admmistration (NOAA)	Belgian Office of Science and Technology (BOST)	International Geosphere-Biosphere Programme (IGBP)
Canadian Space Agency (CSA)	Commission of the European Community (C EC)	World Climate Research Programme (WCRP)
European Space Agency (ESA)	Canada Centre for Remote Sensing (CCRS)	Global Climate Observing System (GCOS)
European Organisation for the Exploitation of Meteorological Satellites (Eumetsat)	Crown Research Institute (CRI)/New Zealand	Global Ocean Observing System (GOOS)
Centre National D'Études Spatiales (CNES) (France)		United Nations Environment Programme (UNEP)
British National Space Centre (BNSC)		Intergovernmental Oceanographic: Commission (IOC)
Deutsche Agentur fur Raumfahrtangelegenheit (DARA) (Germany)		World Meteorological Organisation (WMO)
Agenzla Spaziale Italiano (ASI) (Italy)		Food and Agriculture Organization (FAO)
Swedish National Space Board (SNSB)		
Science and Technology Agency (STA) (Japan)		
Russian Space Agency (RSA)		
Russian Committee for Hydrometeorology and Environment Monitoring (Rosgidromet)		
National Space Agency of Ukraine		
Chinese Academy of Space Technology (CAST)		
National Remote Sensing Centre of China (NRSCC)		
Indian Space Research Organisation (SRO)		
Commonwealth Scienific and Industrial Research Organisation (CSIRO) (Australia)		
Instituto Nacional de Pesequias Espaciais (INPE) (Brazil)		

SOURCE Committee on Earth Observations Satellites

INTERNATIONAL RESEARCH PROGRAMS

In addition to the intergovernmental and U. N.-affiliated organizations that use remotely sensed data. international scientific organizations' have developed research programs involving the use of remotely sensed data. Although these programs often involve U. N.-affiliated organizations, they rely for their effectiveness on personal contacts and an international imprimatur to influence the research agendas of national research agencies. [12]

The World Climate Research Programme (WCRP), founded in 1972, focuses on geophysical aspects of climate change. WCRP projects such as the World Ocean Circulation Experiment (WOCE), the Global Energy and Water Cycle Experiment (GEWEX), and the Tropical Oceans Global Atmosphere (TOGA)[13] form the core of the U.S. Global Change Research Program. The International Geosphere-Biosphere Programme (IGBP) was founded in 1986 to address the gaps in WCRP (specifically, the biogeochemical interactions that are critical to understanding the effects of climate change, the feedbacks] [4] that could amplify or moderate climate change, and other important areas of global change). IGBP projects and proposals are beginning to influence national research programs. The Human Dimensions of Global Environmental Change Programme (HDP), founded in 1991. studies the interactions between environmental change and human conditions and activities.

In addition to these process-oriented programs, scientists are pursuing several international programs to address the related need for long-term monitoring to assess the state of the global environment and its rate of change. [15] These programs would also address the needs of natural resource managers around the world for operational satellite data. The evolving concepts for the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS) will involve a mixture of improvements in existing operational systems and the development of dedicated new systems.

11 These are the International Council of Scientific Unions (] CSU), which includes national science academies such as the U.S. National Academy of Sciences as members, and the International Social Science Council (ISSC), which include, national social science organizations such as the U.S. Social Science Research Council.

12 See U.S. *Congress,* Office of Technology Assessment, *Remotely Sensed Data: Technology, Management, and Markets*, op. cit., box 5-9 for more information on these research programs.

13 TOGA aims to monitor and model the El Niño phenomenon.

14 The potential magnitude of Warning fro_m the emission of greenhouse gases depends on a variety of feedback effects, some of which involve the reaction of natural ecosystems to changes in climate and atmospheric chemistry. See U.S. Congress, Office of Technology Assessment, OTA-BP-ISC-122, *Global Change Research and NASA'S Earth Observing System* (Washington, DC: U.S. Government Printing Office. November 1993).

15 Process-oriented research aims t. understand the basic physical, biological, and chemical processes that underlie global environmental change. Research monitoring aims to provide high-quality measurements to detect subtle change\ in the critical indicators of global change. Operational monitoring aims to use the data for day-to-day environmental and resource management decisions.