ENVIROSAT—2000 Report

International Coordination of and Contributions to Environmental Satellite Programs

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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INTERNATIONAL COORDINATION OF AND CONTRIBUTIONS TO ENVIRONMENTAL SATELLITE PROGRAMS

ABSTRACT

This report examines international participation in the operational environmental remote-sensing satellite programs of the U.S. Government, as well as NOAA's participation in foreign remote-sensing programs. It also reviews the various mechanisms used for carrying out that participation.

The paper begins with an overview of U.S. policy on remote sensing. Next, the extensive international cooperation in U.S. Polar-orbiting Operational Environmental Satellites (POES) is described. This includes participation in the POES direct readout services program, and existing instrument contributions and commitments to the POES system. The opportunities and mechanisms for future contributions to POES, or to the polar platform component of the U.S. Space Station, are also examined.

Geostationary environmental satellites are operated by the United States, the European Space Agency, Japan, and India. These systems are described, and the Coordination on Geostationary Meteorological Satellites is discussed. Other international organizations used for cooperation and coordination in remote-sensing activities are outlined. These include the World Meteorological Organization, the Intergovernmental Oceanographic Commission, the International Council of Scientific Unions, and the Committee on Earth Observations Satellites. Contributions by the United States to planned foreign remote-sensing programs are addressed as well.

Finally, the report identifies and discusses three trends in remote sensing, and makes some concluding observations about the future of international remote-sensing activities. Appendix A lists the dates of all relevant documents, such as Memoranda of Understanding, Terms of Reference for international committees, and Minutes of Meetings of the principal coordinating groups. Plans for future NOAA satellites and onboard systems and an acronym list are presented in Appendices B and C, respectively.

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I. INTRODUCTION

This report addresses the international coordination of, and contributions to, environmental satellite programs. It reviews the background and history of international participation in civil satellite programs, describes current contributions to National Oceanic and Atmospheric Administration (NOAA) satellites and expectations for future contributions. It also examines other countries' related satellite programs, which are coordinated with those in the United States to enhance the world's global-observing capability. It illustrates the inherent international nature of environmental observations from space--in the establishment and operation of observing systems, in the reception and analysis of data from satellites, and in the exchange and application of complementary data among the nations of the world.

From its inception, the U.S. space program has had an international dimension. Public Law 85-568, the National Aeronautics and Space Act of 1958, created NASA and included the mandate to conduct international cooperative activities. Specifically, it stated that "the aeronautical and space activities of the United States shall be conducted so as to contribute materially to ... cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof."

The United States has also been committed to continuing the worldwide exchange of weather and ocean data, including data from civil and ocean environmental satellites. This policy is based on the understanding that substantial weather forecast benefits for domestic forecasts and national security result from the continuing international, nondiscriminatory, no-cost exchange of weather data. The United States provides a constant stream of satellite-derived weather data to the World Meteorological Organization's (WMO) member countries on a real-time basis via the Global Telecommunication System (GTS) in compliance with the 1950 World Meteorological Convention. Although the convention does not obligate any nation to provide specific volumes and qualities of data, the practice of providing maximum data on an open, nondiscriminatory, no-cost basis conforms to more than a century of international tradition.

NASA's guiding principles for international cooperation established a foundation for future civil space cooperation. In formulating its own policy for environmental satellite activities, NOAA has merged many of these principles with traditional meteorological data practices. These principles include:

- Central civilian government agency sponsorship and responsibility for each project
- Project rather than program cooperation, with technical agreement prior to political commitment
- Full financial responsibility of each party for its participation
- Scientific/technical value and mutual interest in each project
- Results made available publicly

The international perspective has been an important element since the start of the meteorological satellite program in 1960. Weather systems do not conform to political boundaries, and global data are required for accurate modeling and forecasting of meteorological conditions. The value of meteorological information is not diminished when it is shared with multiple users. In fact, the value of space observations is significantly enhanced by the broadest possible availability of ancillary, complementary observations from other sources, such as ground-based observations. It is of great domestic value to have an international observing and data exchange network in the areas of meteorology and oceanography to support the United States' global interests.

Within one year of the launch of the first weather satellite, the United States held an international workshop to expose foreign experts to the applications of space data to meteorology. This laid the foundation for the development of what is now truly an international network. Through technical workshops and courses sponsored solely by the United States or in conjunction with the WMO, thousands of foreign nationals have been trained over the past 25 years to develop skills in the reception, processing, and analysis of satellite data. This effort has improved the quantity and quality of global observations used in U.S. monitoring activities.

The U.S. civil weather satellites have included direct downlink transmitters operating continuously from the earliest days of service. This has enabled any nation or individual that invested in a moderately priced ground receiver to have real-time access to weather data at no charge. For many developing nations, the U.S. weather satellites provide the principal source of weather data.

The United States is committed to continuing the practice of providing satellite-derived or communicated weather data free of charge to individual foreign ground stations through direct readout, such as the Weather Facsimile (WEFAX) service, Direct Sounder Broadcast (DSB), Visible and Infrared Spin-Scan Radiometer (VISSR) broadcasts, Automatic Picture Transmission (APT), and High Resolution Picture Transmission (HRPT). Continuing direct readout is consistent with the President's 1982 National Space Policy (NSDS-42), which states:

> The United States...will support the public, non-discriminatory direct readout of data from Federal Civil Systems to foreign ground stations and the provision of data to foreign users under specified conditions.

Present NOAA/National Environmental Satellite, Data, and Information Service (NESDIS) policy reflects the awareness that NOAA is an agency with global interests and responsibilities in the oceans and atmosphere. NOAA's international partners play an essential role, and NESDIS programs could not be carried out without their assistance. Successful international programs involve sharing both benefits and responsibilities.

Like NASA, NESDIS international programs are developed based on technical merit and a no-exchange-of-funds arrangement, and are negotiated on a project-by-project basis. Unlike NASA, however, NESDIS also has standing commitments to support a variety of international organizations and programs on a long-term basis, both directly and through the National Weather Service (NWS). The U.S. civil environmental satellites have become an important source of global data for the World Meteorological Organization and its 159 member countries and territories. Several coordinating mechanisms have been established to facilitate international cooperation in environmental satellite activities. These include the Coordination on Geostationary Meteorological Satellites (CGMS) that involves current and committed operators of geostationary satellites; the Committee on Earth Observations Satellites (CEOS) that includes current and planned operators of space-based Earth observations systems; and the International Polar-Orbiting Meteorological Satellite (IPOMS) group that addresses future international cooperation in polar-orbiting satellites and space systems.

Virtually every nation in the world benefits from the global meteorological/environmental network to which the U.S. environmental satellites contribute, and the United States enjoys reciprocal benefits from foreign contributions to its own environmental data base through space segment, ground segment, and data exchange cooperation. The rest of this report describes the mechanisms for this cooperation and coordination, the kinds of contributions already made and planned, and the future directions of international participation in remote sensing from space.

II. INTERNATIONAL COOPERATION IN U.S. POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITES

The NOAA Polar-orbiting Operational Environmental Satellites (POES) provide operational coverage of the entire Earth four times a day. They are a principal source of environmental data for the 80 percent of the globe that is not covered by conventional data. The mission of these satellites is to make measurements of temperature and humidity in the Earth's atmosphere, surface temperature, cloud cover, water-ice boundaries, and proton and electron flux near the Earth. They have the capability of receiving, processing, and retransmitting data from balloons, buoys, and remote automatic stations distributed around the globe.

One of the most important elements of the POES system over the past 25 years has been the extensive international participation and cooperation. Many countries have taken advantage of the POES direct readout services program, and have also made specific contributions and commitments to the POES system. Although these indirect and direct forms of participation may appear distinct and unrelated, they are, in fact, connected parts of an evolutionary process. Worldwide direct readout has not only provided the data necessary for global meteorological monitoring, but has encouraged countries to integrate satellite observations into their regular weather forecasting and environmental monitoring activities. As countries have become more reliant on satellite data, the need for continuity of service and technological development has become increasingly apparent. Consequently, governments are more willing to contribute instruments or ground-segment services in support of the POES system. This internationalization is demonstrated by the amount and types of cooperative agreements that have been concluded and are being contemplated.

Section A of this chapter reviews international participation in the POES direct readout services program, section B looks at the current international contributions and commitments to the POES system, and section C examines the opportunities for future POES contributions.

A. INTERNATIONAL PARTICIPATION IN THE POES DIRECT READOUT SERVICES PROGRAM

The direct readout services program enables government agencies, academic and scientific institutions, commercial firms, and private citizens all over the world to obtain and use data from NOAA's environmental satellites without going through NOAA's own central data acquisition and processing facilities. These services include the APT, HRPT, and DSB services from polar-orbiting NOAA satellites, and the WEFAX and VISSR services from NOAA's geostationary satellites. The United States is firmly committed to the policy of providing these services on a worldwide basis.

There are at least 1,000 POES direct readout stations of one type or another operating in more than 120 countries. Operators of satellite direct readout receiving stations are under no legal, financial, or political obligation to any Federal agency in the United States to report the purchase, construction, or operation of a station to receive environmental satellite direct readout services. For this reason, the lists of countries having such capabilities may not be entirely complete.

The direct readout services are used for local and regional, operational public, aviation, maritime, and agricultural weather forecasting; sea and lake ice reconnaissance; snow cover and snow melt observations; ocean current and temperature studies; and many other purposes. They support, among other activities, locust control efforts in Africa; petroleum exploration in the Arctic; and river, lake, and ocean fishing activities around the world. In some developing countries, direct readout of environmental satellites provides the only opportunity for involvement in space activities. Often, a single readout station in such countries is the major source of environmental data. In the United States and elsewhere, a single commercial firm receiving data via direct readout may provide tailored satellite products to hundreds of customers, or to thousands of viewers through television links.

1. <u>Automatic Picture Transmission (APT)</u>

Automatic Picture Transmission services are provided by the polar-orbiting NOAA satellites and are copied by more than 1,000 users worldwide. Two channels of data are sent continuously by means of a VHF signal, as the satellite orbits Earth. The resolution of both visible and infrared APT data is 4 km. The signals can be received on very low-cost equipment and displayed as an image, or converted into digital products showing cloud, ocean, or land temperature values. Primary users are government meteorological agencies in developing countries, and ships or land stations in polar latitudes where geostationary satellite signals cannot be received and viewing angles are very poor.

The following countries and locations had APT-receiving capabilities in January 1985:

Afghanistan
Algeria
Antarctica
Argentina
Australia
Austria
Azores
Bahamas
Bahrain
Bangladesh
Barbados
Belgium
Bermuda
Bolivia
Brazil
Bulgaria
Burma
Cameroon
Canada
Canary Islands
Chile
China, People's Rep. of
Colombia
Costa Rica
Curacao
Czechoslovakia
Dominican Republic
Ecuador
Egypt
El Salvador
Ethiopia
Fiji
Finland
France
French Guiana
Gambia
German Dem. Rep.
Germany, Fed. Rep. of
Ghana
Greece
Greenland
Guadeloupe
Guatemala
Guyana
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Iraq
Israel
Italy
Ivory Coast
Japan
Jordan
Kenya
Korea, Rep. of
Kuwait
Madagascar
Malaysia
Mali
Malta
Martinique
Mauritania
Mauritius
Mexico
Mongolia
Morocco
Mozambique
Nepal
Netherlands
Netherlands Antilles
New Zealand
Nicaragua
Nigeria
Norway
Oman
Pakistan
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Romania
Saudi Arabia
Scotland
Senegal
Seychelles
Sierra Leone
Singapore
Somalia
South Africa
South Yemen
Spain
Sri Lanka
Sudan
Surinam
Sweden
Switzerland
Syria
Tahiti
Taiwan
Tanzania
Thailand
Trinidad and Tobago
Tunisia
Turkey
United Arab Emirates
United Kingdom
United States
Upper Volta
Uruguay
U.S.S.R.
Venezuela
Yugoslavia
Zaire
Zambia
Zimbabwe

2. High Resolution Picture Transmission (HRPT)

Like APT services, High Resolution Picture Transmission services are provided continuously from polar-orbiting NOAA satellites. Nevertheless, there are several differences between these services: five, rather than two, channels are sent on the HRPT, and the resolution of features is 1.1 km instead of 4 km. The HRPT data also are sent on a higher frequency, and much more expensive equipment is needed to receive and process the signals.

There are at least 75 HRPT stations in operation around the world, 23 operated by U.S. Government or military services and 52 by other countries. Their primary application is to provide more sophisticated observations of meteorological, oceanographic, and geophysical phenomena than can be obtained with APT readout. Some specific HRPT applications include the monitoring of pastoral areas for plant growth and development in Senegal, the observation of surface currents in the Tasman Sea, and the study of desert locust breeding grounds in Italy. In the United States, HRPT data are received at NOAA's Command and Data Acquisition Stations in Alaska and Virginia, and at the Satellite Field Services Station (SFSS) in San Francisco, California. They are then relayed to Suitland, Maryland, for central processing. Hard copy imagery and computer-compatible tapes of the HRPT data are available from NESDIS archives.

The following countries had HRPT receiving capabilities as of July 1984:

Bangladesh	Indonesia	Singapore
Belgium	Iran	South Africa
Brazil	Italy	South Yemen
Canada	Japan	Sweden
China, People's Rep. of	Korea, Rep. of	Switzerland
Czechoslovakia	Malaysia	Taiwan
Denmark	Mongolia	Thailand
France	Netherlands	Tunisia
Germany, Fed. Rep. of	New Zealand	United Kingdom
Greenland	Norway	United States
India	Saudi Arabia	U.S.S.R.

3. Direct Sounder Broadcast (DSB)

Along with other types of observations, both the polar and geostationary satellites transmit real-time digital data via direct readout that can be converted into vertical atmospheric temperature and humidity profiles, or soundings. Only the data from the polar satellites are used operationally at this time; however, geostationary soundings are still being acquired experimentally, and operational transmissions are expected to begin in 1986. The instrument used to provide soundings from the polar satellites is the TIROS Operational Vertical Sounder (TOVS). The primary users are the national meteorological services of the United States and 16 other countries: Australia, Canada, Denmark, Federal Republic of Germany (FRG), France, Iran, Israel, Japan, New Zealand, Norway, People's Republic of China, Poland, Soviet Union, Sweden, Taiwan, and the United Kingdom.

Satellite atmospheric soundings, like their radiosonde counterparts, enable meteorologists to observe the major circulation patterns and stability of the atmosphere. Areas of instability, conducive to thunderstorm development, can also be detected. Large-scale air masses can be identified and tracked, and many other meteorological phenomena can be observed and studied.

Signal reception from instruments that provide the DSB services is a relatively easy task, but retrieval and processing of the data require sophisticated software and a comprehensive understanding of the physical processes that affect data reduction. The University of Wisconsin, as part of its cooperative arrangement with NOAA, has developed a software package for sounding data processing and is making this package available to interested users around the world. The exchange of results in applying and modifying the algorithms benefits both NOAA and international users in improving our understanding of sounding data.

B. CURRENT INTERNATIONAL CONTRIBUTIONS AND COMMITMENTS TO THE POES SYSTEM

The NOAA POES program presently receives instrument contributions or support from several foreign sources. These include France's Argos data collection and platform location system, the United Kingdom's Stratospheric Sounding Unit (SSU), and the French and Canadian equipment contributions to the Search and Rescue Satellite-Aided Tracking (SARSAT) system. The United Kingdom has also agreed to provide a component of the Advanced Microwave Sounding Unit (AMSU) as a future replacement for the SSU. All of these contributions and commitments are reviewed in the discussion that follows.

1. Argos Data Collection and Platform Location System

The Argos system was designed to provide an operational environmental satellite data collection, location, and dissemination service for the NOAA POES program. It was established under a 1974 Memorandum of Understanding (MOU) between NASA and NOAA for the United States, and the Centre National d'Etudes Spatiales (CNES) for France. The system became fully operational in 1979.

The Argos system currently includes:

- Approximately 400 fixed and moving platforms, from 17 countries, each equipped with sensors and a platform transmitter terminal (PTT)
- Two NOAA polar-orbiting environmental satellites, each equipped with an onboard data collection system (DCS) ensuring platform message reception, processing, and retransmission
- Ground data processing centers

The Argos instrument package is flown aboard the two NOAA polar satellites. The onboard DCS receives the message transmitted by PTTs within the view of the satellites. The processing performed by the onboard DCS consists of the identification of the PTT, the recording of the time of reception of the data contained in the message, and the measurement of the Doppler shift on the received signal. Since there are normally two satellites in operation, a minimum of four positions are obtained daily from a PTT in equatorial regions, and up to 28 positions daily in polar areas. In temperate latitudes, eight positions per day are typically provided because of orbit overlap at the higher polar latitudes.

Each time a satellite passes over one of three telemetry receiving stations (Wallops, Virginia; Fairbanks, Alaska; and Lannion, France), the satellite transmits the recorded information. The Argos data, along with other telemetry data received at the readout stations, are transmitted to the NOAA/NESDIS facility in Suitland, Maryland. In Suitland, the Argos data are separated and forwarded to the Argos Data Processing Center in Toulouse, France, via a commercial carrier. The following processing operations are performed at Toulouse:

- Decoding of the received PTT messages and conversion of data into physical units
- Accurate computation of the satellite orbit
- Computation of PTT positions from orbital data combined with Doppler shift data computed by the Argos instrument
- Storage of all these results on computer-accessible files for user access

Users requiring data in real time receive data directly from the satellite on the S-band or VHF beacon. Since each transmission is rebroadcast by the satellite as soon as it is received, anyone with a suitable receiver within range of the satellite can receive the data. Several of these receivers, which are called local user terminals (LUTs), are already being operated by some users, and one is operated in Toulouse by CNES.

Services provided by the system include:

- The relay of in situ observations of surface and upper level ocean conditions and surface weather conditions. The locations of moving platforms provide information on surface currents for buoys, or on middle or upper level winds for balloons.

- The capability to track the movement of oceanic research ships and marine life in research programs.

- The relay of environmental data from those platforms in the Arctic and Antarctic that are not observable from the data collection system on the Geostationary Operational Environmental Satellite (GOES). These data provide vital inputs for the analysis of weather patterns that transit the polar regions.

- The placement of Argos-equipped buoys in regions where ocean currents are expected to carry icebergs into shipping lanes. Also, buoys are attached to some drifting icebergs to verify berg-drift forecasts based on ocean current rates.

There are several ways in which the data collected by the Argos system can be obtained. They are available from computer files accessible by telephone, telex, or communication networks, generally within 4 hours after the receipt of data from the satellite. Processed data can be made available on computer-compatible tapes (CCTs) or printouts, either every 2 weeks or monthly. Appropriately formatted data also are distributed over the World Meteorological Organization's Global Telecommunication System (GTS).

NOAA's future polar-orbiting spacecraft plans call for changes to the instrument payload, for the advanced TIROS-N series through the NOAA M spacecraft. NOAA is considering an increase in power and platform area for NOAA K, L, and M. This increase is principally intended to support the AMSU (see following section). Nevertheless, sufficient reserve power and space remain for Argos to double its current system capacity.

CNES has projected system usage growth to expand to about 10,000 platforms by 1995. For this reason, CNES hopes to join NASA and NOAA in utilizing new developments such as the polar platform, a component of the NASA Space Station project.

2. <u>Stratospheric Sounding Unit/Advanced Microwave Sounding Unit (AMSU)</u>

Under an MOU signed in September 1974, the United Kingdom's Meteorological Office provides an SSU that NOAA flies on its polar-orbiting satellites, as part of TOVS. In exchange, NOAA transmits raw and processed TOVS data to the United Kingdom. The SSU is a three-channel instrument with 147 km resolution that measures temperatures in the stratosphere. When the SSU data are combined with the other elements of TOVS, they produce vertical temperature profiles that are used for global numerical modeling of the atmosphere.

The AMSU is scheduled to replace the SSU and the Microwave Sounding Unit (MSU) beginning with NOAA K, which has a 1990 launch date. The AMSU is a 20-channel radiometer designed to provide data that will be used to derive temperature soundings, water vapor profiles, and information on precipitation and ice. The instrument has two separate portions: a temperature sounding unit, AMSU-A, and the water vapor profiling module, AMSU-B. The AMSU-B module will be furnished by the United Kingdom and the AMSU-A will be provided by NOAA. The AMSU-B is a five-channel radiometer containing one channel each at 89 GHz and at 166 GHz, and three channels at 183 GHz. Its instantaneous field of view (IFOV) will be 15 km.

Data from the SSU, along with other TOVS channels that are requested by the United Kingdom's Meteorological Office, are transmitted via land line to the Meteorological Office as the data from each orbit are received in Suitland, Maryland. NOAA K will have a similar type of data transfer, with the data from the AMSU-B and AMSU-A stripped out early in the processing flow and transmitted to the United Kingdom. Satellite data transfer, via commercial satellite, will probably replace the present land line link after NOAA K. Since the United Kingdom furnishes an element of the total TOVS package, access to all data and derived products produced by the TOVS is available to its Meteorological Office.

3. <u>Search and Rescue Satellite System (COSPAS/SARSAT)</u>

The COSPAS/SARSAT program is a cooperative effort of the United States, the Soviet Union, Canada, and France (COSPAS/SARSAT partners)--along with Norway, Sweden, the United Kingdom, Bulgaria, and Finland (investigator nations)--to locate downed aircraft and surface vessels in distress. SARSAT refers to Search and Rescue Satellite-Aided Tracking, while COSPAS stands for Cosmicheskaya Sistyema Poiska Avariynich Sudov, the Russian name of a similar system. The U.S. interagency SARSAT team is composed of NOAA, responsible for incorporating SARSAT equipment provided by Canada and France on its POES; NASA, responsible for technology development; the U.S. Coast Guard, responsible for maritime search and rescue (SAR); and the U.S. Air Force, responsible for inland SAR coordination. The U.S. SARSAT team cooperates with the Department of National Defence of Canada and CNES, the French national space agency, to form the international SARSAT project team. This international team, in conjunction with the U.S.S.R.'s Ministry of Merchant Marine (MORFLOT), participates in a cooperative effort known as the COSPAS/SARSAT program.

The COSPAS/SARSAT system supports SAR operations by providing services from satellites that are in low-altitude, high-inclination orbits to facilitate the detection and location of distress signals. The detection and location are accomplished by relaying, via satellite, distress information from aircraft and ships to ground facilities, which complete information processing and transmit position locations to rescue services. Since the program began in 1982, the satellite system has contributed to saving more than 370 lives.

The COSPAS/SARSAT system is comprised of four basic elements:

- Emergency Locator Transmitter/Emergency Position-Indicating Radio Beacon (ELT/EPIRB). These small emergency transmitters are designed to transmit distress data to the COSPAS and SARSAT satellites on frequencies of 121.5 MHz, 243 MHz, and 406 MHz.

- Spacecraft. The system is composed of a constellation of four satellites--two Soviet and two United States. SARSAT instrumentation consists of a repeater provided by Canada and a processor provided by France. To date, three U.S.S.R. COSMOS-series navigational spacecraft equipped with COSPAS instrumentation and two U.S. advanced TIROS-N environmental spacecraft equipped with SARSAT instrumentation have been launched. The NOAA 8 spacecraft that failed in mid-June 1984 was replaced in October by NOAA 9. However, NOAA 8 was stabilized and "revived" on May 10, 1985. All instruments, including search and rescue, are operating satisfactorily except for the High Resolution Infrared Radiation Sounder (HIRS), which is inoperative. NOAA has plans to launch SARSAT packages on future environmental spacecraft.

- Local User Terminal (LUT). The LUT is a ground station that receives the satellite-relayed distress messages, processes the signals to determine the location of the party in distress, and subsequently transmits the information to a Mission Control Center (MCC). LUTs are now located in the United States (3), the Soviet Union (3), Canada, France, the United Kingdom (406 MHz only), and Norway. The goal is to develop a global SAR network by encouraging the establishment of additional LUTs in other countries to cover all regions of the world.

- System Control and Coordination. System control and coordination are accomplished by the MCC in each of the participating countries (United States, U.S.S.R., Canada, and France). The USMCC acts as the single point of contact for the SARSAT parties in coordinating system operations with the COSPAS MCC.

There are two coverage modes, regional and global. The regional mode provides coverage to those areas where the spacecraft is actually visible to an ELT/EPIRB and a LUT, an area approximately 4,000 km in diameter centered on the LUT location. In the regional mode of operation, the 121.5/243 MHz and the 406 MHz distress signals are relayed in real time to the LUT by the spacecraft. The LUT computes the location of the beacons, and the computed location data are then transmitted to the MCC. There they are sorted geographically and distributed to the appropriate Rescue Coordination Centers (RCCs), which function as the name implies. During a satellite pass, the maximum available mutual-visibility period is approximately 15 minutes. At least 4 minutes of mutual visibility is actually required to compute a location.

The SARSAT global mode operates only with the 406 MHz experimental ELT/EPIRBs. In this mode, a 406 MHz distress signal detected any place on Earth is processed and stored as data on board the satellite. When the satellite comes within the field of view of one of the NOAA Command and Data Acquisition stations located in Fairbanks, Alaska, and Wallops, Virginia, the stored data are played back on command. The data are relayed to NOAA's processing facility in Suitland, Maryland, for further processing, and are transmitted to the USMCC, where the location of the beacon is computed. The USMCC geographically sorts and distributes the information to the RCCs or other MCCs.

The COSPAS regional and global modes differ from SARSAT in that the COSPAS satellites transmit the stored 406 MHz signals to LUTs only. Also, COSPAS is not equipped to operate with 243 MHz beacon signals.

Under the current MOU signed Oct. 5, 1984, the space segment calls for a constellation of four search and rescue instruments in orbit through 1990, and allows for continuation beyond that into the indefinite future. The MOU contains agreements by the United States and the Soviet Union to maintain two search and rescue-equipped spacecraft each.

At the direction of the Office of Management and Budget (OMB), NOAA and NASA have been tasked to study alternative means of providing satellite search and rescue services should the U.S. proceed with only one POES. The alternatives being investigated include developing a dedicated satellite and placing a package aboard future commercial Landsat spacecraft.

The next three NOAA satellites, currently under construction, will be equipped with SARSAT instruments provided by Canada and France, offering full or partial coverage for the remainder of the 1980's. In addition, SARSAT instruments are included as requirements for the next generation of NOAA polar-orbiting environmental satellites. NOAA expects that Canada and France will provide these instruments. The Soviet Union already has two more satellites built that will maintain two-satellite coverage through 1986, and they are planning to build additional satellites to carry the program past 1990. Thus, current plans provide for continued complete search and rescue coverage for at least the next several years.

In the meantime, the COSPAS/SARSAT partners will explore mechanisms to ensure the continuity of this program. Emphasis will be placed on increasing international participation in, and contributions to, the system. Various options exist. Search and rescue packages could continue to "piggyback" on POES, on other polar-orbiting satellites, or on the polar platform component of the Space Station. A dedicated search and rescue satellite system could be developed and funded internationally. The COSPAS/SARSAT system could be integrated with an existing international organization, such as the International Maritime Satellite Organization (INMARSAT). In any case, broad international support is a necessary ingredient for the long-term success of COSPAS/SARSAT, and the system's participants are trying to establish permanent international arrangements as quickly as possible.

C. OPPORTUNITIES FOR FUTURE POES CONTRIBUTIONS

The seventh meeting of the Economic Summit of Industrialized Nations was held in June 1982, in Versailles, France. At that meeting, the heads of state established the Working Group on Technology, Growth, and Employment to identify areas for further cooperation among the summit members (Canada, FRG, France, Italy, Japan, the United Kingdom, the United States, and the European Communities). Satellite remote sensing was one of 18 topics chosen for discussion, which led to the formation of the Economic Summit Panel of Experts on Remote Sensing from Space. The United States was designated as the chair of this panel, and the assistant administrator for NOAA/NESDIS was chosen to be the U.S. expert point of contact.

The panel established the following initial objectives:

- To exchange information on remote-sensing programs and plans

- To coordinate remote-sensing programs and plans with a view to avoiding the duplication of efforts

- To foster the compatibility of activities to enhance the value of these to programs in addressing global phenomena

- To promote more efficient use of budget resources

In preparing for the 1983 to 1985 summit meetings, the heads of state commissioned reports for each of the 18 topics to be discussed. Within remote sensing, participants discussed potential collaboration in support of polar-orbiting meteorological satellites, participation in the SARSAT/COSPAS program, the coordination of present and future Earth observation satellites (including ocean satellites), and coordination of remote-sensing training. NOAA/NESDIS and its counterpart agencies continue to work on these cooperative projects and give reports on their efforts to the Working Group on Technology, Growth, and Employment.

1. <u>International Polar-Orbiting Meteorological Satellite (IPOMS) Group</u>

In addition to the activities discussed previously, the summit working group established the International Polar-Orbiting Meteorological Satellite group at the 1984 Economic Summit held in London. The decision to form the IPOMS group was based on several factors. The first was the recognition that meteorological observations from space play an essential role in the weather forecasting activities of the summit nations and of many other countries as well. As dependence on remote-sensing satellites has grown, continuity in the availability of such data has become of paramount importance. At the same time, the cost of polar orbiters, like the cost of aerospace equipment overall, has increased at a rate far exceeding the Consumer Price Index. These budgetary pressures, together with the appreciation of the indispensable functions performed by the U.S. two-satellite POES system, have made it necessary to explore ways of sharing the costs and responsibilities among its international beneficiaries. The IPOMS group, therefore, was founded to discuss technical, financial, and adminstrative/legal issues regarding international contributions to the U.S. POES, or an internationally developed system.

The IPOMS group met for the first time in November 1984, in Washington, D.C. Attending the meeting were representatives from Australia, Canada, France, the Federal Republic of Germany, Italy, Japan, Norway, the United Kingdom, the United States, the European Communities (comprised of Great Britain, the Federal Republic of Germany, France, Italy, Belgium, Netherlands, Luxembourg, Denmark, Ireland, and Greece) and the European Space Agency (ESA). Membership in the group is limited to those countries that participate in the Economic Summit and countries that are current or potential contributors to the U.S. polar-orbiting meteorological satellite system that may evolve from IPOMS. A contribution is defined as one or more components, subsystems, or systems for the space segment, financial support, or system-support ground segment facilities or services. The status of "observer" is open to countries that declare an intent to investigate possible contributions to the system and seek national approval for such contributions. Addition of new members and observers is subject to consensus of the group.

At the first meeting, the IPOMS group endorsed the need to continue a two-spacecraft system and to expand international participation. With regard to the maintenance of the two-spacecraft system, the group agreed that the future configuration would probably consist of a satellite/polar platform combination, or even of two (or more) platforms. With this in mind, the representatives identified four feasible options for a continued two-spacecraft system in the following descending order of likelihood:

- Two U.S. platforms with enhanced international contributions.
- One U.S. platform (afternoon orbit) and one internationally provided platform (or a constellation of other satellites that include relevant sensors).
- One U.S./non-U.S. polar platform and one non-U.S. platform. The non-U.S. platform could be a future ESA satellite. The U.S. would contribute instruments to non-U.S. platforms.
- Two platforms operated by an international organization.

In the area of expanded international participation in the U.S. POES, five representatives outlined specific contributions that they are either in the process of developing or are considering seriously.

Canada plans to continue to provide SARSAT repeaters and to operate two local user terminals. It is also considering developing the Brewer Spectrophotometer for ozone monitoring. Current plans call for the instrument to fly on the space shuttle in the late 1980's, so it is possible that it could be ready by the end of this decade for a polar satellite payload.

The United Kingdom is contributing the SSU to the current series of POES. The AMSU will be built jointly by the United Kingdom and the United States for NOAA K, L, and M. A U.K. LUT for the SARSAT program is also scheduled to be operational in 1985. In general, the United Kingdom intends to continue future participation in the POES system at a level of support equivalent to AMSU-B. Anything beyond that will probably be through a European-coordinated contribution.

France is presently providing Argos hardware for the POES. It also is contributing a SARSAT instrument, and provides ground reception and processing support for the SARSAT system. Negotiations are in progress for France to supply an improved Argos instrument for NOAA K, L and M, with greater capability to meet commercial market environmental data requirements. The establishment of an Argos processing center in the United States is being negotiated as well. Additional contributions to the POES system are under preliminary consideration. Any future contributions, however, will most likely be through a coordinated European effort.

The Federal Republic of Germany's remote-sensing program is specializing in the development of hardware for flight on the shuttle or on European satellites. Instruments that either have been flown or are being developed include the Modular Optoelectronic Multispectral Scanner (MOMS), the stereo MOMS, the Microwave Remote Sensing Experiment (MRSE), and the metric camera (ATLAS program). The FRG is considering one or more of four possible instruments: the Millimeter Atmospheric Sounder for ozone and water vapor measurements in the middle atmosphere; the Michelson interferometer for passive atmospheric sounding of 20 trace gases in the middle atmosphere; a stereo line scanner with laser radar for wind fields, cloud height, and sea and land surface temperatures; and a conical scan radiometer for measuring the Earth's radiation budget.

Italy is presently engaged in a pre-Phase A study of a passive microwave radiometer for the next generation of NOAA satellites. This would be a high-resolution, eight-channel, conical scan radiometer optimized for sea surface winds and soil moisture measurements. A cost study is due to be completed by the end of 1985. The Italian IPOMS representative noted the urgency of deciding on the type of future spacecraft that will be used (satellite or polar platform), as this will have an impact on the cost and capabilities of any proposed instrument.

Among the other countries and organizations participating at the first IPOMS meeting, Norway and ESA expressed an interest in providing future contributions to the POES system. Norway is currently operating a LUT for the SARSAT program and has an extensive drifting buoy program using the Argos system. In the future, Norway may contribute to POES through data reception, processing, and distribution. Although ESA's initial interest in IPOMS was to participate in an observer status only, the ESA representative noted that his organization supported the two-satellite system. Australia noted that the nature and extent of its potential contribution would be influenced by the WMO study on a future global meteorological satellite system. In the near term, jointly developed space hardware would be the most likely form for Australia's participation. Japan and the European Communities were noncommittal, but continue to have an active interest.

All those attending the first IPOMS group meeting agreed that two working groups should be established, one technical and the other administrative. A technical working group was established at that time. It was mandated to study all aspects of mission requirements of the polar satellites or platforms, the instrumentation discussed by each participant at the first meeting, the development of a proposed instrument complement, and the development of data/instrument requirements. The technical working group will meet in June 1985, and will report on the progress of its work at the second IPOMS group meeting in October 1985.

2. <u>International Participation in Polar Platforms</u>

There is a general international consensus, as reflected in the first IPOMS meeting, that the present POES system will be either augmented or replaced by one or more polar-orbiting, remote-sensing platforms in the coming decade. The technical and programmatic requirements of such platforms are now being reviewed by U.S. and other space agencies. In the United States, NOAA and NASA are discussing the polar platform as a component of NASA's Space Station program. The members of ESA, Canada, and Japan also are looking at the polar platform concept, both on an individual basis and collectively.

A permanent, shuttle-tended, reserviceable platform in space could have a tremendous impact on Earth observation activities as they are known today. Current and planned remote-sensing satellite programs have established a plan for Earth observations well into the 1990's. The existence of these satellites, and their importance to the measurement of the Earth's land, oceans, and atmosphere and to an understanding of the Earth as a system, will increase the demand for the long-term, systematic acquisition of data. Polar platforms offer the optimum means for satisfying that demand. They will provide guaranteed continuity of environmental satellite data, establish multidisciplinary/multisensor coordination, improve data management capabilities, and foster international cooperation. Moreover, the increased remote-sensing capabilities will be provided with greater reliability and less cost than the present expendable satellite systems.

International cooperation in the development and operation of polar platforms has received official approval on both sides of the Atlantic. NOAA, NASA, ESA, and the national space agencies of several European countries, Canada, and Japan, are coordinating polar platform cooperation on both multilateral and bilateral levels. IPOMS has been NOAA's primary multilateral forum for these discussions. The foreign instrument contributions to the U.S. POES outlined in the previous section could be incorporated effectively into the polar platform component of the U.S. Space Station. In addition to those instruments, the United Kingdom has expressed an interest in providing a spacecraft bus within the purview of an ESA-sponsored platform. Although the manner and extent of hardware contributions has not yet been determined, international cooperation on polar-orbiting platforms is certain to continue.

III. INTERNATIONAL COORDINATION OF GEOSTATIONARY SATELLITE PROGRAMS

Whereas the polar-orbiting satellites discussed in the previous chapter provide daily global coverage, geostationary spacecraft are used for continuous coverage over a fixed geographic region. There are at present four geostationary environmental satellite systems operated by the United States, the European Space Agency (ESA), Japan, and India. In addition, the Soviet Union has stated its intention to launch a geostationary system. Taken together, the individual national systems, both polar-orbiting and geostationary, form a global observation satellite system.

The instrument technologies, capabilities, and functions of the various geostationary satellites are quite similar. In fact, U.S. contractors built the Japanese, Indian, and U.S. spacecraft, and the ESA system incorporated U.S. components and parallel technologies. All of these satellites use passive visible and infrared sensors, and data collection and dissemination systems. More specifically, they share the following capabilities:

- Routine observations (visible and infrared imagery) every 30 minutes to 3 hours
- Imagery in the visible and infrared ranges of the spectrum
- Spatial resolution ranging from 1.0 km to 2.5 km in the visible and 5 km to 8 km in the infrared spectral range
- Data collection system capability for receiving and retransmitting environmental information from remote ground platforms
- Direct broadcast of digital and analog data to ground stations free of charge

Of course, each system has unique capabilities as well. For example, the primary sensor on ESA's Meteosat spacecraft can acquire data in the water vapor absorption band, while the U.S. GOES satellite incorporates an experimental capability for vertical atmospheric temperature soundings. The similarities and differences among these spacecraft must be taken into account when considering the technological aspects of future cooperative endeavors.

Section A of this chapter summarizes the technical characteristics and international uses of the U.S. geostationary environmental satellite system, and briefly describes the geostationary satellite programs of the ESA, Japan, and India. Section B reviews the organizational structure and activities of the Coordination on Geostationary Meteorological Satellites (CGMS).

A. CURRENT GEOSTATIONARY ENVIRONMENTAL SATELLITE PROGRAMS

1. U.S. Geostationary Operational Environmental Satellites (GOES)

The GOES system is normally comprised of two spacecraft located in geostationary orbit over the Equator at 135° W. and 75° W. longitude. Currently, due to spacecraft failure, the United States has only one operational GOES. During the Atlantic hurricane season, it is positioned at 98° W.; otherwise, it is located at 108° W. The principal sensing instruments on the GOES satellites are the Visible and Infrared Spin-Scan Radiometer (VISSR), the VISSR Atmospheric Sounder (VAS), and the Space Environment Monitor (SEM). Major communication capabilities include the GOES Data Collection System (DCS), direct transmission of VISSR data, and the WEFAX. It is these three communication systems that link GOES directly with the international community. In addition, all GOES data products are available through the NESDIS Satellite Data Processing and Distribution Office in Suitland, Maryland.

a. GOES Data Collection System (DCS). The GOES DCS is a communication relay system that uses a transponder to relay UHF transmissions from data collection platforms (DCPs) by S-band to properly equipped ground stations. DCS products are in situ environmental measurements made by data collection platforms located in remote areas.

Examples of DCS uses include:

- Hydrology. River stages and flood forecasting.
- Data Buoys. Both near-shore and deep-ocean for operational and research purposes.
- Hurricane Reconnaissance. Automated and manual reports from "hurricane hunter" aircraft.
- Research. Storms Transfer and Response Experiment (STREX) ocean monitoring on ships of opportunity. Ships are instrumented with weather and oceanographic sensors.
- Tsunami Warnings. NOAA's research component is conducting a pilot experiment to develop, test, and evaluate a tsunami early warning facility for Valparaiso, Chile. The same technique may be used for tsunami warnings in the Pacific Basin in coordination with Japan's Geostationary Meteorological Satellite (GMS).

Twenty-four users in nine foreign countries operate GOES DCPs. In addition, five foreign direct-readout stations are equipped to receive the DCP messages directly from the spacecraft. The following is a list of the foreign DCS users, their applications of the system, and the dates of the Memoranda of Agreement (MOAs) between NOAA/NESDIS and the users as of April 1985:

<u>Country</u>	<u>User, MOA Dates, and Program</u>
Argentina	Comision Nacional de Investigaciones Espaciales (CNIE) (MOA being renegotiated) Relay of environmental data from Argentina and Antarctica to a direct readout station in Mendoza
Bolivia	Servicio Geologico de Bolivia (MOA 6/80-5/85, being renegotiated) Relay of meteorological and hydrological data from two remote sites in Bolivia
Brazil	Instituto de Pesquisas Espaciais (INPE) (MOA 7/82-6/92) Relay of hydrological data from 10 remote sites to a direct readout station
Canada	Alberta Environment (MOA 9/82-8/87) Relay of meteorological and hydrological data from more than 20 sites in British Columbia and Montana Atmospheric Environment Service (AES) (MOA 12/80-11/90) Relay of meteorological data from more than 20 remote sites British Columbia Hydroelectric (MOA 3/83-2/88) Relay of meteorological data from more than 20 remote sites for use in water management of rivers

Country	User, MOA Dates, and Program
Canada (cont.)	British Columbia Ministry of Environment (MOA 10/84-9/89)

Relay of environmental data to measure snow and to forecast stream flow conditions in major rivers

British Columbia Ministry of Transportation
(MOA 10/83-9/88)

Relay of meteorological data from two sites prone to avalanches

Canadian Department of Fisheries and Oceans
(MOA 8/81-7/91)

Relay of wave measurement data from oceanic areas adjacent to Canada

Dome Petroleum
(MOA 9/79-8/89)

Relay of meteorological data from stations on ice flows in Beaufort Sea to assist AES in supporting public forecasting in the Canadian Archipelago

Environment Canada Inland Water Directorate
(MOA 6/80-5/90)

Relay of hydrological data used in flood control and water management

ESSO Resources, Canada, Ltd.
(MOA 12/81-11/86)

Relay of meteorological and oceanographic data to assist AES in providing public forecasts in Davis Strait between Canada and Greenland

Ontario Hydroelectric
(MOA 4/80-3/85, being renegotiated)

Relay of hydrological data for use in flood control and management

Country	User, MOA Dates, and Program
Canada (cont.)	Ontario Ministry of Natural Resources (MOA 9/82-8/87) Relay of hydrometeorological data for use in river forecast system models used for flood forecasting and water management
	Petro Canada (MOA 11/80-10/90) Relay of environmental data from the Canadian Archipelago for AES use in providing public forecasts
	Quebec Environment (MOA 10/80-9/90) Relay of hydrometeorological data from remote areas in Quebec for use in water management
	Saskatchewan Research Council (MOA 4/80-3/85, being negotiated) Relay of environmental data used to monitor atmospheric and water contaminants near Dubawnt Lake, Saskatchewan
	Trans Canada Pipelines (MOA 9/82-8/87) Relay of meteorological data for AES use in providing public forecasts in the Arctic, and information for designing an Arctic port facility on Ellef Ringnes Island
Chile	University of Chile (MOA 6/83-6/88) Relay of environmental data from Chile and Antarctica to a direct readout station in Santiago
Dominican Republic	Instituto Nacional de Recursos Hidraulicos (MOA 11/84-10/89) Relay of hydrolological and meteorological data

Country	User, MOA Dates, and Program
Ecuador	Centro de Levantamientos Integrados de Recursos Naturales por Sensores Remotos (CLIRSEN) (MOA 10/83-9/88) A test, and later an operational program, to relay environmental data from remote areas to a direct readout station
France	Etablissement d'Etudes de Recherches Meteorologiques (MOA 3/85-2/86) Relay of meteorological data from an unmanned station on Clipperton Island in the eastern Pacific ocean
Mexico	Servicio Meteorologico Nacional (MOA 1984-1994) Relay of meteorological data from several remote islands to a direct readout station in Mexico City for use in improving weather forecasting services
Panama	Instituto de Recursos Hidraulicos y Electrificacion (MOA 6/83-5/88) Relay of hydrological data from remote river basins for use in water management
Peru	Servicio Nacional de Meteorologia y Hidrologia (MOA 3/85-4/90) Relay of meteorological and hydrological data
United Kingdom	British Antarctic Survey (MOA 10/82-9/87) Relay of meteorological data (surface, ship, upper air) from stations on or near the Antarctic Continent

b. Visible and Infrared Spin-Scan Radiometer (VISSR). The VISSR instrument on the GOES spacecraft provides high-resolution visible and infrared data approximately 20 minutes of each half hour. The resolution of the visible data is 1 km; for infrared data it is 8 km. When these data are displayed in image form, atmospheric circulation patterns, as revealed by cloud forms, can be observed and their motions can be predicted; wind vectors can be plotted; and sea and lake ice, and snow cover, can be mapped. Sea surface temperatures, ocean currents, cloud heights, and land surface temperatures (such as those important to citrus and coffee growers) can be displayed in digital formats.

At present, there are 21 active VISSR stations, 14 in the United States and 7 in other countries. The seven non-U.S. VISSR stations are in Argentina, Brazil, Canada, France, and Mexico, and are operated by their meteorological agencies.

c. Weather Facsimile (WEFAX). WEFAX services are provided through communication transponders on the GOES. Data are sent on a scheduled basis and include five different products: 1) processed images acquired from the GOES VISSR system; 2) images from the low-resolution, global area coverage system on the POES satellites; 3) selected National Weather Service weather charts; 4) operational messages; and 5) orbital prediction information for predicting the position of the polar satellites.

There are at least 200 stations in 34 countries receiving WEFAX broadcasts from the GOES system. About 60 of these are amateur stations; the rest are operated by U.S. and foreign government agencies or by commercial, scientific, and academic organizations.

Countries/Locations with WEFAX Receiving Stations
July 1984

Argentina	Curacao	Martinique
Australia	Dominican Republic	Mexico
Bahamas	Ecuador	Netherlands Antilles
Barbados	El Salvador	Nicaragua
Bermuda	Fiji	Paraguay
Bolivia	France	Peru
Brazil	French Guiana	Tahiti
Canada	Guadeloupe	Trinidad and Tobago
Chile	Guatemala	United Kingdom
Colombia	Guyana	United States
Costa Rica	Honduras	Uruguay
		Venezuela

2. European Space Agency (Meteosat)

The Meteosat system has a spacecraft located in geostationary orbit at 0^{o} longitude, and a control center at Darmstadt, West Germany. Meteosat-1 was launched in November 1977 and Meteosat-2 in June 1981. An operational agency, EUMETSAT, is being established to assume operational responsibility for future European meteorological satellites. The Meteosat spacecraft's payload contains:

- Visible and Infrared Scanning Radiometer. The principal scanning instrument provides near-continuous viewing in the visible and near-infrared bands at 2.5 km resolution, the thermal infrared wavelengths at 5.0 km resolution, and the water vapor bands at 5.0 km resolution.

- Data Collection System. This communication system relays environmental data transmitted from ground collection platforms in formats similar to the GOES DCS.

- WEFAX. Meteosat and GOES imagery are provided in analog form, including cloud-top height analyses and selected weather charts. The NESDIS Assessment and Information Services Center uses Meteosat WEFAX data to supplement NOAA satellite data in producing subsistence crop yield assessments.

3. Japanese Geostationary Meteorological Satellite (GMS)

The GMS satellite, operated by the Japan Meteorological Agency, is located in geostationary orbit at 140° W. longitude. GMS-1 was launched in July 1977, GMS-2 in August 1981, and GMS-3 in August 1984. Its primary instruments include:

- Visible and Infrared Scanning Radiometer. This scanning sensor provides data on a near-continuous basis in the visible spectrum at 1.25 km resolution and the infrared channels at 5.0 km resolution. The sensor also measures the temperature of the Earth's surface and atmosphere.

- Space Environment Monitor. The SEM monitors solar activity and the space environment by measuring the flux of solar protons, alpha particles, and electrons.

- Data Collection System. This communication system relays environmental data acquired by data collection platforms, such as land stations, buoys, ships, and airplanes.

- WEFAX. Imagery is transmitted every 3 hours in a form compatible with the other WEFAX services. The U.S. receives the GMS WEFAX signals in Honolulu and transmits the data to NOAA's Central Data Distribution Facility (CDDF) in Camp Springs, Maryland, for public dissemination.

4. Indian National Satellite System (INSAT)

INSAT-1 is a multipurpose operational satellite system for a variety of telecommunication services, and for Indian national meteorological and Earth observations. It was planned as a two-satellite system with a primary spacecraft in geostationary orbit at 74° E. and an active in-orbit backup at 94° E. longitude. INSAT-1B, located at 74° E., was launched in August 1983 after the deactivation of INSAT-1A in September 1982, because of the failure of its attitude control system. INSAT-1C is being procured as a replacement for 1A, and is expected to be launched by NASA's space shuttle in June 1986.

INSAT's primary meteorological instrument is the Very High Resolution Radiometer (VHRR), which senses in the visible channel at 2.75 km resolution and in the infrared channel at 11.0 km resolution. VHRR data are used to derive the direction and speed of upper winds over India and adjoining oceanic areas, as well as sea surface temperatures. Full-frame images are available every 30 minutes. INSAT also has a data collection system used to collect meteorological, hydrological, and oceanographic data from data collection platforms in remote land and sea locations.

INSAT data currently are scarce to users outside India because of a limited ground processing capability. The Indian Meteorological Department, responsible for processing, utilization, and dissemination of INSAT meteorological data, will soon be receiving some computer equipment from the National Science Foundation under the Indo-U.S. Science and Technology Initiative. This will increase its capabilities for handling the data. Direct reception is possible only in India because the spacecraft transmits the meteorological data on a narrow, focused beam. Nonetheless, it is possible that communication links with the INSAT ground station can be established to retransmit data outside India in near-real time in the future.

B. COORDINATION ON GEOSTATIONARY METEOROLOGICAL SATELLITES (CGMS)

The first discussions regarding coordination of nationally and regionally operated remote-sensing satellites began in September 1972, when representatives of the United States (NOAA), the European Space Research Organization (now the European Space Agency), and Japan (Japanese Meteorological Agency) met to consider complementarity and compatibility among these agencies' planned geostationary meteorological satellites. This initial meeting led to the establishment of an informal technical group known as the Coordination on Geostationary Meteorological Satellites. CGMS has served as a forum through which individual plans can be informally rationalized and harmonized to the point where participating agencies can pursue the development of complementary and compatible space segments. Among the practices currently endorsed by the CGMS are:

- International sharing of data on a no-cost basis
- Standardization of data products
- Sharing of a common WEFAX transmission frequency
- Coordination of coverage zones to minimize overlap and maximize global coverage

Participation in the CGMS is limited to those countries that have initiated development of, or are presently operating, geostationary meteorological satellites. This currently includes the United States, the European Space Agency, India, and Japan as operators, and the U.S.S.R., as having initiated development. Because decisions made by the CGMS participants are advisory and are not binding on national authorities, no formal vote is taken; however, consensus must exist for formal CGMS recommendations.

The work of the CGMS since 1973 has been carried out principally through two technical working groups that work closely together. The Operations Working Group is concerned with the operational aspects of the programs, especially data processing and dissemination. It reflects knowledge of user needs in identifying possible areas where commonality among planned systems would be of value to users worldwide. Matters such as coordinated data formats, standard transmission frequencies, compatible data collection platform standards, and complementary orbits have been discussed by this group. The System Engineering Working Group has considered the technical feasibility of suggestions developed by the Operations Working Group. It has developed possible means of instituting those suggestions it considers likely to be implemented from the point of view of policy, cost, and schedule. The reports of both working groups are reviewed by the plenary CGMS body.

Management of member countries' satellite systems remains with national/regional agencies because the CGMS does not have management or administrative authority. Participants recommend adoption or implementation of only those items that are determined to be in each country's interest, and that can be supported from the point of view of cost, schedule, and technical feasibility. Final acceptance of any recommendation is indicated by an exchange of correspondence among program/project managers after formal approval is obtained within the parent organization or nation.

The results of each CGMS working group meeting, as well as of the meetings of senior officials, have been compiled in the form of brief technical reports. This information also is contained in a consolidated report, updated periodically, which summarizes the technical results of the CGMS meetings. ESA has served as the unofficial secretariat for the CGMS. All of the participants share the work of preparing technical studies in support of the CGMS meetings.

The United States has already derived several benefits from the CGMS, including the following:

- Data is received from foreign geostationary satellites on a continuous, no-cost basis. For example, data from the European geostationary satellite (Meteosat) over West Africa and from the Japanese GMS position over New Guinea support several U.S. activities.

- Geostationary satellites share a common WEFAX transmission frequency, providing near-global weather information for U.S. commercial shipping and aviation, military operations, and weather forecasting.

Another accomplishment through the CGMS was an agreement by NOAA to lend ESA one of its standby geostationary satellites (GOES-4) as a substitute for ESA's failing Meteosat-1 spacecraft. The NOAA satellite will perform a data relay function for ESA.

NOAA began moving GOES-4 westward, by 4 degrees per day, on April 15, 1985. It will be located at its new station, at 10° W. longitude, by mid-June. The GOES-4 spacecraft will perform its data relay mission until ESA launches a replacement satellite, which is expected to occur in June 1986. This agreement is an example of international cooperation that is not yet commonplace but will help in laying the groundwork for future exchanges of satellites and data.

The initial successes of the CGMS are likely to be expanded upon in the near future. According to the 1984 Consolidated Report of CGMS Activities, the Soviet Union is planning to launch a Geostationary Operational Meteorological Satellite (GOMS), perhaps as early as 1987. The characteristics of the GOMS equipment for data collection and dissemination will be to conform to CGMS guidelines. The People's Republic of China may soon be applying for membership in the group. Also, Europe's first weather satellite organization, EUMETSAT, is expected to be ratified in 1986. EUMETSAT will provide the cooperative framework for 17 European countries to manage and operate meteorological satellites. This organization is certain to make significant contributions to the CGMS and to worldwide geostationary satellite capabilities in general.

IV. INTERNATIONAL COORDINATION OF OTHER SATELLITE PROGRAMS

Chapters II and III examined international participation in NOAA's polar-orbiting environmental satellite program and the international coordination of geostationary environmental satellites. This chapter considers other international organizations and cooperative mechanisms that deal with remote-sensing space systems, including the non-U.S. systems currently planned through the turn of the century in which the United States may participate.

A. MECHANISMS FOR COORDINATION

1. World Meteorological Organization

The World Meteorological Organization (WMO) is a specialized agency of the United Nations. It was created:

- To facilitate international cooperation in the establishment of networks of stations and centers that provide meteorological and hydrological services and observations
- To provide the establishment and maintenance of systems for the rapid exchange of meteorological and related information
- To promote standardization of meteorological and related observations, and to ensure the uniform publication of observations and statistics
- To further the application of meteorology to aviation, shipping, water problems, agriculture, and other human activities
- To promote close cooperation between meteorological and hydrological services
- To encourage research and training in meteorology and, as appropriate, in related fields

As remote-sensing technology has matured and proliferated, it has come to provide the primary means of fulfilling many of the WMO's objectives. Virtually all national and international meteorological remote-sensing systems support WMO activities in some way. At the same time, the WMO serves as a truly international forum for coordinating all those systems and expanding their application throughout the world.

NOAA/NESDIS support of WMO activities includes transmitting satellite data on the Global Telecommunication System (GTS) on a routine basis, participating in the work of the technical commissions, serving on the Executive Council Panel of Experts on Satellites, preparing and contributing to WMO documents, publishing climatic world and regional data, and producing a cloud climatology global data set for the International Satellite Cloud Climatology Project.

The following describes the principal WMO programs that NOAA supports:

a. World Weather Watch (WWW). The WWW is the basic program on which nearly all other programs of the WMO depend. It is a coordinated global system designed to make observational data and processed information available to WMO members for both operational and research purposes. The primary benefit gained by the U.S. through its participation in WWW activities is the significant international goodwill generated by NOAA's direct broadcast and data services.

The WWW is composed of three principal elements. The observational data are supplied by the Global Observing System (GOS), which includes in its space-based subsystems the polar-orbiting and geostationary satellites of the member states, including the NOAA POES and GOES. The Global Data-Processing System (GDPS) provides the required processed information. Finally, the GTS offers the facilities for the rapid and reliable collection, exchange, and distribution of the observational data and processed information.

As part of the U.S. commitment to the WWW, NOAA has assumed the responsibility for routinely generating and transmitting the following satellite data on the GTS:

- Satellite sea surface temperature (SST) observations, transmitted twice daily.

- Satellite wind observations (picture pair winds). These are exclusively low-level, 900 mbar winds.

- Satellite image-derived wind vectors, produced three times daily and relayed to 20 foreign countries. The wind vectors are primarily for mid- and high-level winds, and are obtained over the tropical and subtropical oceanic areas within view of the GOES spacecraft.

- Satellite-derived soundings.

- Satellite tropical disturbance summaries, issued on a routine basis for all tropical ocean areas.

- Tropical storm weather bulletins, based on satellite imagery and analysis in the tropical portions of the

Indian and western Pacific Oceans, and issued as required to affected countries.

- APT Predict (TBUS) bulletins containing information on polar satellite Equator crossings and other orbital data.

In addition to the preceding responsibilities, NOAA/NESDIS provides to the Agency for International Development (AID) a daily summary of precipitation for North Africa and the Caribbean islands based on the interpretation of U.S. and ESA satellite imagery. Information on the location, strength, and movement of tropical weather systems also is provided.

b. World Climate Program (WCP). The WCP was established in 1979 as one of the major programs of the WMO. Its basic objectives are to take advantage of man's increasing knowledge of climate, to take steps to improve this knowledge significantly, and to foresee and to prevent potential manmade changes in the world's climate that might be adverse to the well-being of humanity.

NOAA's satellite data are used in three WCP subprograms:

- Working Climate Research Program. The objectives of this program are to determine the extent to which climate can be predicted and the extent of man's influence on climate.

- Working Group on Satellite Observing Systems for Climate Research. This working group reviews requirements for satellite observations and measurements.

- International Satellite Cloud Climatology Project. The goal of this project is to create a cloud climatology data set for the years 1983-87, using the global coverage provided by international polar-orbiting and geostationary meteorological satellites.

For more information on NOAA's involvement in the WCP and its programs, see the Envirosat-2000 Report: Operational Satellite Support to Scientific Programs. This report examines the role of operational environmental satellites in science programs that study the Earth system.

c. Other WMO Programs. NOAA's and other nations' remote-sensing satellites form an integral and indispensable part of many other WMO projects and programs. Among the more important of these are:

- Commission for Marine Meteorology, Working Group on Marine Climatology. NESDIS processes, formats, and exchanges surface marine observations with seven foreign processing centers and 40 countries.

- Commission for Atmospheric Sciences. NESDIS participates in the Group of Rapporteurs on Use of Satellite Data for Research.

- Background Air Pollution Monitoring Network. NESDIS produces an annual publication containing data on turbidity, precipitation chemistry, carbon dioxide, and suspended particulate matter from reports received from international stations in the network.

- Global Ozone Research and Monitoring Project. NESDIS provides ozone data from its POES.

Since 1964, NOAA has been actively involved in providing meteorological satellite training to the international community, frequently in conjunction with the WMO. Training is provided that shows how satellite data can be used for tropical storm detection and forecasting, winter storm intensity detection, and precipitation estimation. Other topics are covered that are of direct benefit to aviation, marine, and agricultural interests.

2. Intergovernmental Oceanographic Commission

The Intergovernmental Oceanographic Commission (IOC) is the leading United Nations organization for marine scientific affairs and related ocean services, training, and mutual assistance. Many of the organization's cooperative programs are greatly assisted by the remote-sensing systems of its members.

One of the major ongoing programs carried out by the IOC is the International Oceanographic Data Exchange (IODE). The major objective of the IODE is to collect, process, archive, retrieve, and exchange oceanographic data and information on a worldwide basis with the aim of rendering services to the scientific community, to the offshore industry, and to the governments of member states. The working committee of IODE has the task of adopting practices to facilitate the exchange of oceanographic data and information internationally. The working committee approach uses task teams, groups of experts, and discipline-oriented rapporteurs to deal with specialized problems affecting international oceanographic data and information exchange. NOAA/NESDIS participates in 15 activities of the working committee, most of which require the use and international coordination of remote-sensing satellite data. Other IOC programs that use and coordinate such data include the activities performed by responsible National Oceanographic Data Centers, the Aquatic Sciences and Fisheries Information System, and the Tsunami Warning System.

3. International Council of Scientific Unions

The International Council of Scientific Unions (ICSU) is an international, nongovernmental scientific organization comprised of 18 international scientific unions, 65 national members, 17 scientific associates, and 4 national associates. Its principal objective is to encourage international scientific activity for the benefit of mankind by initiating, designing, and coordinating scientific research projects.

NOAA/NESDIS participates in ICSU, and coordinates remote-sensing activities and data with the following ICSU programs:

- Panel on World Data Centers (Geophysical and Solar). This panel provides guidance for the operation of all WDCs and promotes international cooperation in data exchange.

- Committee on Data for Science and Technology (CODATA). The purpose of CODATA is to improve the quality, reliability, and accessibility of scientific and technological data.

- Committee on Space Research (COSPAR). NESDIS participates in the Advisory Committee on Data Problems and Publications to promote the efficient exchange of space-related data.

- Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). NESDIS is involved in the Steering Committee for Monitoring the Sun-Earth Environment, the Analysis Phase International Magnetospheric Study, and the Middle Atmosphere Program Steering Committee.

- International Union of Geodesy and Geophysics (IUGG). NESDIS participates in the International Association of Geomagnetism and Aeronomy, the Inter-Union Commission on the Lithosphere, the Historical Seismic Data Project, and the Federation on Astronomical and Geophysical Services.

- International Union of Geological Sciences (IUGS). NESDIS is a member of the Commission on Storage, Automatic Processing, and Retrieval of Geological Data.

- International Union of Radio Science (URSI). NESDIS is involved in two working groups, the International Network

Advisory Group and the Task Group on International Reference Ionosphere.

- International Astronomical Union (IAU). NESDIS helps coordinate solar-terrestrial physics observations, and provides forecasts and solar activity alerts.

- Global Atmospheric Research Program (GARP). This ongoing activity was begun in 1967 by the ICSU and the WMO to study the physical processes of the atmosphere.

4. Committee on Earth Observations Satellites

At the 1984 meeting of the Panel on Remote Sensing from Space, the members agreed to replace the existing Coordination on Land Observing Satellites (CLOS), the Coordination on Ocean Remote-Sensing Satellites (CORSS), and the multilateral meetings on long-term planning for remote-sensing satellites with one unified group--the Committee on Earth Observations Satellites (CEOS). The overall objective of CEOS, as stated in the committee's terms of reference, is to enhance the benefits of space-borne Earth observation for members and the international user community. Toward this end, CEOS will serve as a forum for the exchange of technical information to encourage complementarity and compatibility among space-borne Earth observation systems that are currently in service or development. Improved complementarity and compatibility will be sought through cooperation in mission planning and the development of compatible data products, services, and applications. Appendix B lists the planned launches of NOAA's POES and GOES through the year 1994, and the sensors those satellites will carry.

CEOS met for the first time in Washington, D.C., in September 1984. The meeting was chaired by NOAA/NESDIS. In attendance were representatives from Brazil, Canada, France, India, Japan, the United States, and the European Space Agency. Membership is open to international, national, or regional organizations responsible for a space-borne Earth observation program that is currently operating, or is at least in Phase B or an equivalent stage of system development. New members can be added only with the concurrence of all existing members. CEOS will convene in plenary session at least once every 2 years. The second meeting of CEOS is scheduled to be hosted by the European Space Agency in 1986.

Two working groups were established at the first CEOS meeting. NOAA/NESDIS chairs the Working Group on Data, and ESA chairs the Working Group on Intercalibration and Performance Verification. Among the items discussed at the first meeting were ocean satellite systems, data issues, commercial and government programs, regional user meetings, and training.

The topic of greatest importance and interest at the initial CEOS conference was the future coordination of ocean satellite systems. Between now and 1991, more than 1 billion dollars worth of satellite sensors designed for oceanic measurements are planned for launch by the summit countries: the Japanese Marine Observation Satellite (MOS-1, 1986), the U.S. Navy Remote Ocean Satellite System (N-ROSS, 1990), the U.S./French TOPEX/Poseidon mission (1991), the ESA Remote-Sensing Satellite (ERS-1, 1989), and the Canadian Radarsat satellite (1991). These programs will make a significant contribution to experimental and operational global weather forecasting, marine operations, and oceanographic and environmental monitoring. For example, data from N-ROSS and ERS-1 will increase operational winds, wave, and sea ice measurements from their present report level of 2,000 to 4,000 per day to more than 2 million per day by 1990. In the future, ocean-observing capabilities could increase even further with the use of polar platforms.

This vast increase in information just from ocean satellite systems will pose a tremendous challenge for data management. It will require extensive international cooperation in such forums as CEOS, WMO, and other organizations to ensure data complementarity and compatibility. Only through adequate cooperation will NOAA be able to derive global data sets on an operational basis from different national systems.

5. Executive Agreements

Thus far, this report has reviewed the principal international organizations and programs used to coordinate the activities and data products of remote-sensing environmental satellites. All of these cooperative mechanisms were established either by treaties or executive agreements. NOAA/NESDIS uses the executive agreement, usually referred to as a Memorandum of Understanding (MOU), to pursue specific multilateral or bilateral cooperative projects. An example of the multilateral agreement is the COSPAS/SARSAT MOU; an example of the bilateral agreement is the Argos agreement, or any of the bilateral agreements discussed in the next section.

This report reviews all of the major multilateral and bilateral MOUs that NOAA/NESDIS has entered into with regard to remote-sensing systems. Certain agreements have been left out of the discussion because they are of marginal relevance. Appendix A lists all remote-sensing MOUs to which NOAA/NESDIS is a party.

B. U.S. CONTRIBUTIONS TO PLANNED FOREIGN PROGRAMS

The preceding sections have described how the expansion in remote-sensing space technologies of other nations has enabled them to contribute directly to the remote-sensing programs of the United States. This section looks at the remote-sensing systems planned by other countries through the turn of the century and at the technological contributions, assistance, and coordination that the United States either has committed to make, or is planning to make, to those foreign systems.

1. European Space Agency

ESA currently is planning at least two space systems--a remote-sensing satellite (ERS-1) and a polar-orbiting space platform--that could include direct U.S. participation and coordination.

In March 1982, ESA formally began the initial design phase for the first European remote-sensing satellite. ERS-1 objectives call for:

- Providing all-weather imagery of oceans, coastal waters, ice fields, and land areas
- Advancing knowledge in the fields of oceanography, glaciology, and climatology
- Developing and promoting economic applications related to a better knowledge of ocean parameters and sea-state conditions

The sensor payload planned for ERS-1 includes the following:

- Active Microwave Instrumentation (AMI) to combine the functions of three sensors: a synthetic aperture radar, a wave scatterometer, and a wind scatterometer. The information gathered by the AMI will be used for the measurement of wind fields, wave spectra, and all-weather imaging.
- Radar Altimeter (RA) to be used primarily for the measurement of significant wave height.
- Along-Track Scanning Radiometer (ATSR) to make infrared measurements of sea-surface temperature and microwave measurements of water vapor in the lower atmosphere.
- Precise Range and Range-Rate Equipment (PRARE) to be a tracking system for determining precise orbits.

ERS-1 is scheduled for launch on Ariane in April 1989. It will have a near-polar, sun-synchronous orbit at an altitude of 650 km. A direct readout capability to multiple ground stations is planned.

Discussions are underway between NOAA, NASA, and ESA regarding the coordination of ERS-1 data handling and usage with the planned U.S. Navy Remote Ocean Sensing System (N-ROSS). NOAA will be the civilian agency responsible for distributing data from N-ROSS, which is due to be launched in 1990. The agencies are exploring collaborative activities for validating the data from ERS-1 and N-ROSS to ensure maximum compatibility between the two programs. NOAA and NASA also are interested in receiving both recorded and real-time data from ERS-1 at the Fairbanks, Alaska, ground station and in exchanging data with ESA for research purposes. This will ensure the availability of near-real-time global data for both U.S. and European users.

2. France

CNES currently is planning to develop the Poseidon ocean remote-sensing instrumentation. Poseidon's mission goals are to measure the surface topography of the oceans for at least 3 years to determine the oceans' general circulation and mesoscale variability. The measurement of sea ice dynamics, marine geodesy, and cartography are additional objectives. In conjunction with the Poseidon mission, NASA is planning to contribute a satellite bus and complementary instrumentation known as TOPEX. NASA and CNES completed a joint feasibility study toward this end in 1983. At this time, TOPEX is under consideration as a NASA new start, with the earliest potential launch in 1991.

3. Canada

The Canadian Government began Phase B activities on the synthetic aperture radar remote-sensing satellite (Radarsat) in January 1985. Radarsat's science mission requirements are being studied in four areas--ice, oceans, renewable land resources, and nonrenewable land resources. The launch is scheduled for 1991.

The Canadians presently are soliciting hardware contributions from several countries, including the United States. NOAA is considering providing a scatterometer and an AVHRR.

Discussions are also continuing between the Canadian Radarsat project team and NOAA and NASA officials regarding U.S. ground segment support. The Canadians are interested in using NOAA's Fairbanks, Alaska, station for the readout of recorded and real-time scatterometer data, which is expected to be handled by the NOAA/Navy/Air Force shared processing system. In this system, NOAA will process all sounding data, the Navy will process oceanic parameters and products, and the Air Force will process and map all visible and infrared imagery.

Shared data processing will provide mutual access and backup among all three agencies.

In addition, Canada is interested in gaining timely access to other data from N-ROSS, GEOSAT, and ERS-1 that will be available from the shared processing system. The readout of synthetic aperture radar data at the University of Alaska is an issue that will be addressed later by NASA, NOAA, and the Radarsat project team.

4. Japan

The Japanese National Space Development Agency (NASDA) is developing two different polar-orbiting, remote-sensing satellite systems: the Marine Observation Satellite (MOS) and the Japanese Earth Resources Satellite (JERS). The objective of the MOS series is to develop a fundamental marine remote-sensing capability, including the measurement of sea-surface color and temperature, atmospheric water content, and some limited land observation. The first satellite in the series, MOS-1, will carry a Multispectral Electronic Self-Scanning Radiometer (MESSR), a Visible and Thermal Infrared Radiometer (VTIR), a Microwave Scanning Radiometer (MSR), and a data collection system. NASDA's launch date for MOS-1 is scheduled for 1986. MOS-2 through -5 are expected to be launched before the year 2000.

The JERS series is the result of the merger of two earlier remote-sensing projects, NASDA's Land Observation Satellite and the Ministry of International Trade and Industry's (MITI) Mineral and Energy Resources Satellite. The JERS mission objective is to establish land remote-sensing technology for the exploration of nonrenewable resources. More specifically, the JERS will monitor land and coastal zones, and will be used for geologic exploration, land use classification, and vegetation analysis. The JERS-1 sensors will include a visible and near-infrared radiometer and a synthetic aperture radar. NASDA expects to launch JERS-1 in 1990, and JERS-2 and -3 before the end of the century.

Both the MOS and JERS series will be built and launched primarily with Japanese technology. Nevertheless, the two systems could operate in the context of a coordinated global environmental satellite system. Toward this end, discussions are already underway on a multilateral basis in CEOS and bilaterally with the United States. NASDA has stated, in principle, that data from the MOS program will be available on a nondiscriminatory basis and that foreign direct readout will be possible. Although data management policy for the future JERS system has yet to be announced, it is anticipated that the conditions for data availability will be similar to the MOS program.

5. India

India plans to launch the first Indian Remote-Sensing Satellite (IRS-1A) in mid-1986. The spacecraft will be used for the survey and management of Indian natural resources in the areas of agriculture, forestry, geology, and hydrology.

The IRS-1A will be a semioperational, three-axis-stabilized satellite with a design life of 3 years. It will have a 904 km polar, sun-synchronous orbit with a repetition cycle of 22 days. The spacecraft will carry one 72.5 m and two 36 m resolution linear-imaging, self-scanning cameras. Four spectral bands will provide images in the visible and near-infrared bands.

Future plans include the 1988 launch of IRS-1B, which will carry a 15- to 20-m high-resolution camera. Launches of IRS-1C and IRS-1D are scheduled for 1990 and 1992, respectively. Plans for the IRS-2 series include new spectral bands in the middle and thermal infrared regions. The availability of data on an international basis from either of the IRS series has not yet been established. India has requested tracking support for the IRS-1A mission from NOAA's Fairbanks station. Such support would be handled on a cost-reimbursable basis.

6. People's Republic of China

The People's Republic of China (PRC) has been launching Earth observation satellites with varying capabilities since 1975. According to a 1984 report, Global Disaster Early Warning System Policy Planning, prepared for the U.S. Agency for International Development by Resources Development Associates, Inc., Chinasat-1 through -7 carried limited remote-sensing capabilities, Chinasat-10 and -11 were meteorological satellites, and Chinasat-12 had an 80 m resolution sensor. The Chinese Government is in the process of developing, or has developed, a multispectral scanner, a linear array sensor with 11 channels, and a synthetic aperture radar system. In general, information about the PRC space program is very scarce, especially with regard to future planned activities and capabilities.

NOAA has had some limited cooperation with the PRC in the remote-sensing area since 1979. During that year, NOAA signed two bilateral agreements, the Protocol on Cooperation with the People's Republic of China in Atmospheric Science and Technology and the Protocol on Cooperation with the People's Republic of China in the Field of Marine and Fishery Science and Technology. Under these two agreements, some meteorological and oceanographic satellite data have been exchanged, and NOAA has provided training on satellite data processing and interpretation to several Chinese specialists. This level of cooperation is likely to continue for the foreseeable future.

7. Soviet Union

The U.S.S.R. has had an active remote-sensing space program since the 1960's. The Soviets primarily have used the Meteor series polar orbiters to obtain environmental data. More recently, they have added the Meteor-Priroda series and several Cosmos satellites to augment their remote-sensing capabilities. Both NOAA and NASA had fairly extensive bilateral cooperative arrangements with the Soviets between 1973 and 1980, particularly with regard to environmental data exchanges and scientific projects. NOAA has tentatively expressed an interest in conducting exploratory discussions concerning the possible U.S.-Soviet exchange of some remote-sensing satellite data.

8. Brazil

Brazil's remote-sensing program is being developed under the Brazilian Complete Space Mission (MECB). The MECB calls for the design, manufacture, launch, and operation of four satellites by the early 1990's. The first two satellites will be devoted to environmental data collection. These spacecraft will carry UHF to S-band transponders to retransmit environmental data from data collection platforms, possibly in cooperation with the United States and other countries. The third and fourth satellites of the MECB will carry remote-sensing instruments in a near-polar, sun-synchronous orbit.

Brazil is planning to test a prototype of one of its remote-sensing satellite sensors on a U.S. space shuttle flight in mid-1987. Among the objectives of this experimental flight will be the acquisition of data over Brazil in the greatest possible variety of operational conditions to help establish the specifications for the final instrument. A Brazilian payload specialist also may accompany this experiment.

9. Indonesia

The Indonesian Institute of Aeronautics and Space (LAPAN) has entered into discussions with the Netherlands' Agency for Aerospace Programs to jointly develop a Tropical Earth Resources Satellite (TERS). The proposed TERS would fly in an equatorial orbit and would acquire images of Earth areas between 10° N. and 10° S. latitudes--primarily Southeast Asia, central Africa, northern South America, and the Caribbean. The satellite would orbit the planet 11 times daily, at an altitude of 1,680 km, thus allowing four or five daylight overpasses. TERS would fly a charge-coupled, three-band (visible spectrum) "pushbroom" sensor with 20 m resolution.

The imaging process also would include an onboard computer that would combine remote-sensing programming and control with information from a forward-looking cloud detector. Such a system would make possible the selective and optimal imaging of land areas frequently obscured by a heavy cloud cover.

Preliminary technical studies on the TERS system were completed in 1984 and confirmed the project's feasibility. Economic and financial evaluations are still underway. The ultimate extent of cooperation or coordination with the United States, if any, is unknown.

V. THE OUTLOOK FOR FUTURE INTERNATIONAL PARTICIPATION

This report has reviewed the international participation in the operational environmental remote-sensing satellite programs of the U.S. Government as well as our Government's participation in foreign remote-sensing programs. It also has examined the various mechanisms used for carrying out that participation.

Chapter II looked at the extensive international cooperation in U.S polar-orbiting environmental satellites. Foreign participation in the POES direct readout services program is one form of such collaboration. The other form of cooperation is direct contributions and commitments to the POES system, including: the French Argos data collection and platform location system; the United Kingdom's Stratospheric Sounding Unit and the planned Advanced Microwave Sounding Unit; and the SARSAT search and rescue satellite system, which is a cooperative effort between the United States, Canada, and France. Opportunities for future POES contributions are being coordinated by two international groups, the Panel of Experts on Remote Sensing from Space and the International Polar-Orbiting Meteorological Satellite group. International contributions of several remote-sensing instruments are expected for either the POES or the polar platform component of NASA's Space Station project.

Chapter III described the international geostationary environmental satellite systems operated by the United States, the European Space Agency, Japan, and India, and the coordination of those systems, which is being carried out by the Coordination on Geostationary Meteorological Satellites.

Chapter IV discussed the coordination of other satellite programs. Existing mechanisms for cooperation include international organizations such as the World Meteorological Organization, the Intergovernmental Oceanographic Commission, the International Council of Scientific Unions, the Committee on Earth Observations Satellites, and both bilateral and multilateral agreements. The United States either has committed to make, or may make, technological contributions or other forms of assistance to the planned remote-sensing systems of the European Space Agency, France, Canada, Japan, India, and Brazil.

This chapter identifies and describes three trends in remote sensing, and makes some concluding observations about the future of remote sensing from space.

A. FUTURE TRENDS IN REMOTE SENSING

There are three distinct, yet interrelated, trends that can be identified with regard to international remote-sensing activities. They may be referred to as internationalization, utilization, and specialization. Each trend is described separately in the following discussion; the final section draws attention to some of the ways in which they are interrelated.

1. Internationalization

The focus of this report has been on the international dimensions of remote sensing. It is inherently international, not only because many nations are now engaged in it, but because it is an activity that takes place in an international environment and transcends national boundaries.

Remote sensing has provided us with the unprecedented capability of recording and analyzing the Earth and its environment on a global scale. The atmospheric and meteorological conditions sensed by satellites determine the weather patterns around the globe and are vital to forecasting in any location. The oceanic and land conditions that are identified and monitored with satellite remote sensing are in most cases not unique to a particular nation, but are typical of a region or larger geographic area. The vast amount of data that is now continuously collected from all corners of the world requires significant international scientific cooperation for effective management and analysis. The high cost associated with developing and operating new remote-sensing technologies also tends to encourage cooperation. Finally, the great variety of information derived from remote-sensing satellite data promotes the internationalization process in terms of scientific/technological, political, economic, and social perspectives.

2. Utilization

Another trend points toward increasing use of remote-sensing technologies on a worldwide basis. The greater use of remote sensing may be divided into two areas, the technology development process and the use of the data products generated by satellite systems.

The technology development process will be driven by much the same forces as other capital-intensive, advanced technologies. The key players in this regard will be governments and the aerospace industries. Governments will use the remote-sensing technology development process to further traditional policy objectives, such as improving the industrial base, advancing science and technology, creating products for export to improve balance of trade, and augmenting national security.

Whereas the technology development process tends mostly to be competitive in nature in the international context, the development and end use of the data products and services will be largely cooperative, at least with regard to government-operated environmental satellite systems. Remote-sensing satellite data already have wide international applicability. Uses range from scientific research in environmental and life sciences, with long-term goals and effects, to more immediate applications, such as renewable and nonrenewable resource management, weather forecasting and natural disaster warning, pollution monitoring and control, and humanitarian services (e.g., search and rescue). There is no doubt that these and many other new uses, beneficial to all countries, will continue to multiply as the technology matures. International cooperation enhances the use of remote-sensing satellite data through the coordination of data formats, processing approaches, and distribution mechanisms.

3. Specialization

We are certain to see the continued specialization of remote-sensing technology. The current surge in individual programs outlined in Chapter IV reflects nationalistic tendencies to develop indigenous technological capabilities and to satisfy domestic informational needs without having to rely on foreign sources. Another factor that influences specialization is the existence of "gaps" in international capabilities or coverage. For instance, the Indonesian-Dutch Tropical Earth Resources Satellite (TERS), discussed in Chapter IV, is motivated by a gap in equatorial coverage and not merely by the political prestige associated with deploying such a system. The process of specialization is a characteristic of all developing technologies.

Although the trend toward specialization is not inherently cooperative, the large costs associated with autonomous technological development ultimately encourage cooperative programs. By joining forces to fly independently developed instruments on a common spacecraft, an international division of labor is achieved. The cost of the entire system is shared among several countries and the benefit of having access to the system's data accrues to all. The polar platform components of the Space Station are a significant step in this regard.

4. Interaction Among the Trends

The internationalization of remote-sensing activities has been the key theme of this report. It has been shown that the inherent characteristics of remote-sensing technology lead to international cooperation and coordination on the public level. Cooperation is especially important for the effective use of remote-sensing space systems and the vast amounts of data generated by them. Increasing technological specialization can be exploited profitably, in a cooperative framework, to the benefit of all.

Despite the strong trend toward internationalization and cooperation, competitive forces must not be overlooked or underestimated. Cooperation between governments is never an altruistic exercise. Every government pursues vital national interests when entering into a cooperative endeavor, and those interests occasionally conflict or compete with the national interests of other participants. Technological specialization, although potentially useful in a cooperative context, is essentially driven by national self-interest and competitive goals.

A dynamic equilibrium exists, therefore, between the cooperative and competitive aspects of these trends. This equilibrium is influenced to a great extent by the public policies of the governments involved. As additional foreign environmental satellite systems join those already deployed by the United States, competitive and nationalistic considerations could become dominant factors in remote-sensing activities. The challenge for the United States and for NOAA/NESDIS in particular is to shape those trends and forces with policies that serve U.S. national interests, as well as those of the world.

B. CONCLUDING OBSERVATIONS

Up to now, NOAA/NESDIS has been the focal point for operational remote sensing, and has provided indispensable services to this country and the entire international community. At the same time, the growing technological capabilities of other nations have significantly contributed to our environmental remote-sensing programs. The cooperative mechanisms that have been established can provide a framework for continued international coordination and assistance. Should international remote sensing become more explicitly competitive or exclusivist, it may be necessary for the United States to assure adequate access to foreign data systems through political and diplomatic channels.

The ocean remote-sensing systems scheduled for launching before the end of this decade and the Space Station's polar-orbiting platforms planned for the 1990's promise greatly enhanced capabilities and services. The polar platforms will revolutionize remote sensing from space while the international dimensions are certain to become increasingly complex.

Many of the decisions made today will not bear fruit for a decade or even longer. It is of paramount importance, therefore, that we do not neglect our long-term responsibilities for short-term advantages as we move toward the 21st century and beyond.

APPENDIX A

INTERNATIONAL ENVIRONMENTAL SATELLITE COOPERATION: MAJOR DOCUMENTS

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INTERNATIONAL ENVIRONMENTAL SATELLITE COOPERATION: MAJOR DOCUMENTS

This appendix gives the names and dates of major documents concerning international environmental satellite cooperation to which NOAA/NESDIS is a party. The documents include the Terms of Reference and Minutes of Meetings of international groups for satellite coordination and cooperation, and all existing bilateral and multilateral satellite agreements.

Documents of International Groups for Satellite Coordination and Cooperation:

1. Coordination on Geostationary Meteorological Satellites (CGMS): Minutes of Meetings, annual, 1972-85; Consolidated Report (updated annually).

2. Economic Summit Working Group on Technology, Growth, and Employment, Panel of Experts on Remote Sensing from Space: Minutes of Meetings, 1983-85.

3. Committee on Earth Observations Satellites (CEOS): Terms of Reference, 1984; and Minutes of 1984 Meeting.

4. International Polar-Orbiting Meteorological Satellite (IPOMS) Group: Terms of Reference, 1984; and Minutes of 1984 Meeting.

5. COSPAS/SARSAT Steering Group: Minutes of Meeting, semiannual since 1979.

Bilateral and Multilateral Satellite Agreements:

1. Memorandum of Understanding Between NASA, NOAA, and Centre National d'Etudes Spatiales (CNES) for the TIROS-N Satellite Data Collection System (Argos), effective Dec. 10, 1974; modified May 13, 1984.

2. Memorandum of Understanding Between the Meteorological Office of the United Kingdom Ministry of Defence and NOAA, Together with NASA, effective Sept. 6, 1974; extended for 6 years on Sept. 6, 1982.

3. Memorandum of Understanding Between NOAA, the Department of Communications of Canada, and the Centre National d'Etudes Spatiales of France Concerning Cooperation in an Experimental Satellite-Aided Search and Rescue System (SARSAT), effective Sept. 28, 1984.

4. Memorandum of Understanding Among NOAA, the Ministry of Merchant Marine of the U.S.S.R., the Department of Communications of Canada, and the Centre National d' Etudes Spatiales of France Concerning Cooperation in a Joint Experimental Satellite-Aided Search and Rescue Project (COSPAS/SARSAT), effective Oct. 5, 1984.

5. Memoranda of Agreement Between NOAA/NESDIS and (country) concerning the use of GOES Data Collection Platforms. All existing agreements are listed in Chapter III.

Other Reports:

1. International Meteorological Satellite System: Issues and Options, 1983.

2. NESDIS International Activities, 1984.

3. NESDIS Programs-NOAA Satellite Operations, 1985.

APPENDIX B

FUTURE NOAA SATELLITES AND ONBOARD SYSTEMS

Future NOAA Satellites and Onboard Systems

Sensor/System	Satellites and Planned Launch Dates(1)														
	NOAA D 1986	NOAA G 1986	GOES-G 1986	GOES-H 1986	NOAA H 1987	NOAA I 1988	NOAA J 1989	GOES-I 1990	GOES-J 1990	NOAA K 1990	NOAA L 1991	NOAA M 1992	GOES-K 1991	GOES-L 1994	GOES-M 1994
AVHRR	X	X			X	X	X			X	X	X			
TOVS															
HIRS	X	X			X	X	X			X	X	X			
SSU(2)					X	X									
MSU	X	X			X	X	X								
AMSU										X	X	X			
OCI(3)												X			
SBUV(2)					X	X				X		X			
Radiation Budget	X	X			X	X	X			X	X	X			
GOES															
Imaging channels			2	2				5	5				5	5	5
Vis			X	X				X	X				X	X	X
IR			X	X				X	X				X	X	X
Sounder (GOES)			X	X				X	X				X	X	X
WEFAX			X	X				X	X				X	X	X
Search and Rescue		X	X	X	X	X	X	X	X	X	X	X	X	X	X
DCS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SEM															
X-ray sensor			X	X				X	X				X	X	X
Magnetic field			X	X				X	X				X	X	X
Solar particles	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Solar flux	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

(1) Launch dates listed are subject to change (2) Afternoon satellites only (3) Not yet approved

APPENDIX C

GLOSSARY OF ACRONYMS

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GLOSSARY OF ACRONYMS

AES	-	Atmospheric Environment Service (Canada)
AID	-	Agency for International Development
AMI	-	Active Microwave Instrumentation
AMSU	-	Advanced Microwave Sounding Unit
APT	-	Automatic Picture Transmission
Argos	-	Argos Data Collection and Platform Location System
ATSR	-	Along-Track Scanning Radiometer
CCT	-	Computer Compatible Tapes
CDDF	-	Central Data Distribution Facility
CEOS	-	Committee on Earth Observations Satellites
CGMS	-	Coordination on Geostationary Meteorological Satellites
CLIRSEN	-	Centro de Levantamientos Integrados de Recursos Naturales por Sensores Remotos (Ecuador)
CLOS	-	Coordination on Land Observing Satellites
CNES	-	Centre National d'Etudes Spatiales (France)
CNIE	-	Comision Nacional de Investigaciones Espaciales (Argentina)
CODATA	-	Committee on Data for Science and Technology
CORSS	-	Coordination on Ocean Remote-Sensing Satellites
COSPAR	-	Committee on Space Research
COSPAS	-	Cosmicheskaya Sistyema Poiska Avariynich Sudov (U.S.S.R.)

DCP - Data Collection Platform

DCS - Data Collection System

DSB - Direct Sounder Broadcast

ELT - Emergency Locator Transmitter

EPIRB - Emergency Position-Indicating Reporting Beacon

ERS - *European Remote-Sensing* Satellite

ESA - European Space Agency

EUMETSAT - European Meteorological Satellite Organization

FRG - Federal Republic of Germany

GARP - Global Atmospheric Research Program

GDPS - Global Data Processing System

GEOSAT - Geostationary Operational Environmental Satellite

GHz - Gigahertz

GMS - Geostationary Meteorological Satellite

GOES - Geostationary Operational Environmental Satellite

GOMS - Geostationary Operational Meteorological Satellite

GOS - Global Observing System

GTS - Global Telecommunication System

HRPT - High Resolution Picture Transmission

IAU - International Astronomical Union

ICSU - International Council of Scientific Unions

IFOV - Instantaneous Field of View

INMARSAT - International Maritime Satellite

INPE - Instituto de Pesquisas Espaciais (Brazil)

INSAT - Indian National Satellite

IOC	-	Intergovernmental Oceanographic Commission
IODE	-	International Oceanographic Data Exchange
IPOMS	-	International Polar-Orbiting Meteorological Satellite
IR	-	Infrared
IRS	-	Indian Remote-Sensing Satellite
IUGG	-	International Union of Geodesy and Geophysics
IUGS	-	International Union of Geological Sciences
JERS	-	Japanese Earth Resources Satellite
JMA	-	Japan Meteorological Agency
LAPAN	-	Lembaga Penerbangandan Angkasa Nasional (Indonesia)
LUT	-	Local User Terminal
MCC	-	Mission Control Center
MECB	-	Brazilian Complete Space Mission
MESSR	-	Multispectral Electronic Self-Scanning Radiometer
Meteosat	-	Meteorological Satellite (ESA)
MHz	-	Megahertz
MITI	-	Ministry of International Trade and Industry (Japan)
MOA	-	Memorandum of Agreement
MOMS	-	Modular Optoelectronic Multispectral Scanner
MORFLOT	-	Ministry of Merchant Marine (U.S.S.R.)
MOS	-	Marine Observation Satellite
MOU	-	Memorandum of Understanding
MRSE	-	Microwave Remote Sensing Experiment
MSR	-	Microwave Scanning Radiometer

MSU	-	Microwave Sounding Unit
NASA	-	National Aeronautics and Space Administration
NASDA	-	National Space Development Agency (Japan)
NESDIS	-	National Environmental Satellite, Data, and Information Service
NOAA	-	National Oceanic and Atmospheric Administration
N-ROSS	-	Navy Remote Ocean Sensing System
NWS	-	National Weather Service
OCI	-	Ocean Color Instrument
OMB	-	Office of Management and Budget
POES	-	Polar-orbiting Operational Environmental Satellite
PRARE	-	Precise Range and Range-Rate Equipment
PTT	-	Platform Transmitter Terminal
Radarsat	-	Synthetic Aperture Radar Remote-Sensing Satellite
R&D	-	Research and Development
RCC	-	Rescue Coordination Center
SAR	-	Search and Rescue
SARSAT	-	Search and Rescue Satellite-Aided Tracking
SCOSTEP	-	Scientific Committee on Solar-Terrestrial Physics
SEM	-	Space Environment Monitor
SFSS	-	Satellite Field Services Station
SPOT	-	Systeme Probatoire d'Observation de la Terre (France)
SST	-	Sea Surface Temperature
SSU	-	Stratospheric Sounding Unit

STREX - Storms Transfer and Response Experiment

TBUS - APT Predict Bulletins

TERS - Tropical Earth Resources Satellite

TIROS - Television and Infrared Observation Satellite

TOVS - TIROS Operational Vertical Sounder

UHF - Ultrahigh Frequency

URSI - International Union of Radio Science

USMCC - United States Mission Control Center

VAS - VISSR Atmospheric Sounder

VHF - Very High Frequency

VHRR - Very High Resolution Radiometer

VISSR - Visible and Infrared Spin-Scan Radiometer

VTIR - Visible and Thermal Infrared Sensor

WCP - World Climate Program

WEFAX - Weather Facsimile

WMO - World Meteorological Organization

WWW - World Weather Watch