PROCEEDINGS OF THE CONFERENCE ON

SPACE MONITORING OF GLOBAL CHANGE

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Conference Overview

"Space Monitoring of Global Change"

October 8–10, 1992 — University of California, San Diego

Since the early 1960s, satellites have provided platforms from which sensors of various sorts have obtained data about the Earth, its atmosphere and oceans. Technologies for obtaining the data have advanced greatly over the past three decades. In part, these were driven by national security concerns, but also by interest in the science of the Earth system and in operational satellites designed to secure data of value to such activities as weather prediction and resource evaluation. As the technology of remote sensing has moved forward, however, the institutional base for managing it has developed in a chaotic fashion. Early discussions in the 1970s and 1980s of a cooperative international effort were frustrated by the competitive Cold War atmosphere.

Currently some two dozen civilian satellites are in orbit, remotely sensing the Earth. In the next decade, this number is sure to more than double. As a result of the large number of satellites, both scientists and managers have questioned whether many sensors collect duplicative data. At the same time, there are significant gaps in Earth sensing measurements. For example, for several years the Earth Radiation Budget Experiment (ERBE) collected data on the radiative balance within the atmosphere—an area fundamental to problems of climate change. It has yet to be replaced, leaving a gap of several years before future satellites will continue these critical observations. Furthermore, in many cases, the data acquired from different satellites are incompatible. Different schemes for calibration, different instruments, and different patterns of observation lead to this incompatibility, lessening the potential value of the overall effort.

The current situation in remote sensing had its roots in times of Cold War tension and the resulting competitive environment. The end of the Cold War has decreased competition between East and West and now provides opportunities for multilateral cooperation and for increased attention to North-South problems. The lessening of tension also results in major dislocations in the military-industrial complex in both East and West, and possibly increased attention to civilian space activities. As a result, there is an opportunity to reassess the use of space technology and its management.

The end of the Cold War has also unleashed ethnic and nationalistic aspirations and animosities. The numerous local and regional conflicts pose new challenges to international political and economic institutions, but these need not stand in the way of a more effective international regime to manage the viewing of the Earth for scientific understanding and for the provision of essential services.

These changes in international relationships have coincided with the widespread recognition that the Earth is threatened by environmental problems that are not local or regional but global in their reach. Ground-based and satellite observations have established the thinning of the layer of ozone protecting the Earth from ultraviolet radiation in polar regions. Climate change due to increased concentrations of infrared-absorbing molecules in the atmosphere poses an additional threat. Civilization's activities on a worldwide basis have reduced the number of plant and animal species, thus endangering future genetic diversity. These global changes are of the kind that can often be best studied using data secured from sensors aboard satellites.

In response to these technological, political, and environmental developments, the University of California Institute on Global Conflict and Cooperation and the California Space Institute sponsored "Space Monitoring of Global Change," which convened October 8–10, 1992, at the University of California, San Diego. The goal of the conference was to examine institutional arrangements to manage future remote sensing.

CURRENT REGIME

At present, the United States, Russia, France, the European Community, Japan, India, and Brazil operate remote sensing satellites. These satellites are designed and structured to meet specific needs of the operating entity. Currently, three international structures for coordinating these activities are in place: the Committee on Earth Observation Satellites (CEOS), the Earth Observation International Coordination Working Group (EO-ICWG), and the Space Agency Forum on the International Space Year (SAFISY). These organizations are voluntary and have not been established by formal international agreements or treaties. They are designed to provide a forum for information exchange on remote sensing activities. Their goals are to avoid duplicative efforts through such information sharing and to promote cooperative planning.

CEOS serves as the principal coordinating mechanism. It developed as a result of a 1984 G-7 recommendation with respect to coordinating remote sensing activities from space. Since the G-7 represents the West's major industrial nations, the East and the developing world were not initially involved, although membership in CEOS has broadened since that time.

CEOS works both through a plenary session and through three working groups on sensor calibration, data, and geophysical calibration. The plenary and working groups provide a mechanism for information exchange,

which, it is hoped, will promote consensus on a variety of policy and technical issues with respect to remote sensing. There are, however, no mechanisms for achieving binding agreements, and in fact some participants have been reluctant to indicate longer-term plans and programs for remote sensing. This reluctance, based in part on a continuing competitive environment, has lessened the effectiveness of the information-exchange process.

EO-ICWG was formed in 1986 as a result of a U.S. National Aeronautics and Space Administration (NASA) initiative for coordinating activities related to the Earth Observing System (EOS). EOS is an effort to deploy a series of space platforms and scientific probes that will provide data of value for the scientific understanding of global change. The EO-ICWG's narrow focus on EOS restricts its influence on remote sensing.

SAFISY was established in 1988 to coordinate research and space activities for the International Space Year of 1992. Membership is open to civil national space agencies. Since the end of the International Space Year, there has been a move afoot to make the organization a permanent forum for exchanging information. It is unclear at present how SAFISY and CEOS would differ in their primary missions.

ALTERNATIVE MODELS FOR A REMOTE SENSING REGIME

Dissatisfaction with the current scheme of managing international remote sensing among scientists and government officials has led to the examination of alternative regimes that might serve as a model for a future remote sensing regime. One obvious model is the International Telecommunications Satellite Organization (INTELSAT), which was established in 1964 and became a permanent organization in 1971. Currently, 125 countries participate in INTELSAT activities, and any country that is a member of the International Telecommunications Union is eligible to join. Through its member organizations, INTELSAT supplies satellite and launch services, as well as overseeing the operation of the communication system.

Nations invest in and own shares in INTELSAT. The United States is represented in INTELSAT by COMSAT, a public-private satellite corporation created by Congress in 1962.

The International Maritime Satellite Organization (INMARSAT) is similar in format to INTELSAT, and provides member nations with satellite communications between ship and shore and ship and ship. More recently, several regional satellite communications organizations have been established that extend the services of INTELSAT, such as the European Telecommunications Satellite Organization (EUTELSAT), serving Western Europe, and ARABSAT, which serves the Arab nations.

Both INTELSAT and INMARSAT were launched with the recognition that satellites would play an important role in future telecommunications, and that the formation of an international organization to provide a global service through joint action would be more efficient than the fragmented structure that existed at the time. There were economies of scale and scope, and a relatively straightforward way in which standards for communications could be set. Both INTELSAT and INMARSAT featured shared funding arrangements, government structure, and practices ensuring heavy participation by industries in the member governments. While the principle of one nation, one vote dominates the assembly of INTELSAT, the influence of the organization was tied to the funding level through the activities of the working groups.

Two participants in the conference, John McElroy and John McLucas, have long promoted the concept of an Environmental Satellite Organization (ENVIROSAT). The basic notion of ENVIROSAT is to transfer the model and the lessons learned from INTELSAT and INMARSAT to the management of remote sensing. They argue that the economies of scale and scope previously found in communications could be achieved in remote sensing. Countries would still have experimental programs designed to test various sensors and explore specific scientific problems. However, remote sensing for operational use would involve a smaller number of satellites and could be managed by an international organization along the lines of INTELSAT or INMARSAT. Rather than each nation or region designing, developing, and operating its own remote sensing satellite, it would be more efficient to procure jointly a standard satellite and operating system. The procurement of a large number of identical communications satellites has proved to be cost-effective, and this could also be true for remote sensing satellites, including weather satellites.

SUMMARY

The participants commented in detail on the issues summarized above. In addition, the relationship of classified space activities to the civilian world received attention. Of special note were discussions of the relevance of the National Reconnaissance Office (NRO) as a model for future satellite activities. The existence of the office had been recently declassified, and several conference participants were familiar with its operations. Of particular interest were the similarities between the NRO's management scheme and the operation of INTELSAT-COMSAT. Issues related to the interaction between remote sensing satellites and national security were also discussed. While it is possible to envision future satellites that involve dual-use sensors with both environmental and security capabilities, there was general recognition that the current way of doing business would have to be altered significantly. However, the economic advantages of going to dual-use systems were widely acknowledged.

A major point of discussion was whether or not ENVIROSAT was the appropriate model for a future sensing regime. While there was general agreement as to the long-term desirability of constructing such an international organization based on considerations of economies of scale, there was disagreement as to the time scale over which this could be accomplished. Several of the participants felt that CEOS could be made to function more effectively, and that a voluntary, cooperative arrangement should be tried

until it becomes clear there are real commercial opportunities in remote sensing and a consequent need for new institutions. All participants agreed that the commercial viability of ENVIROSAT would require the guarantees of government to purchase certain products, such as weather services, from the international institution.

A further point of agreement was that a new regime, whether cooperative or formal, is very much needed to avoid duplication. The end of the Cold War and relaxation of competition between East and West opens up further opportunities for cooperation, and these opportunities should be grasped.

GORDON J. MACDONALD
Institute on Global Conflict and Cooperation

SALLY K. RIDE
California Space Institute

Twenty Years of Cooperation in Civil Earth Observation Activities

Paul F. Uhlir

Abstract

This background paper provides an overview of international cooperation in Earth observation activities and programs since 1972, the approximate date that the technology proliferated beyond the United States and the former Soviet Union. The paper focuses on the cooperative and competitive relationships among the different Earth observation system operators and their end users, and identifies some of the major issues associated with these relationships and activities.

1. INTRODUCTION

Before I begin the substance of this presentation, I would like to say a few words about the title. In discussing this conference with the organizers, it seemed to me it would be useful to begin with an overview of the cooperation that has taken place to date, since a knowledge of the relevant past is essential to fully understanding the present and to successfully planning for the future. I chose as a fairly arbitrary starting point the year 1972 for several reasons. It was the year that the first intergovernmental cooperative group for Earth observation activities, the Coordination on Geostationary Meteorological Satellites (CGMS), was formed. It was the year that the first LANDSAT satellite was launched, which opened up the era of civil land remote sensing and began a program that proved to be an immensely successful vehicle for educating the world on the potential benefits of this technology. The year 1972 also marked the signing of the first major cooperative civil space agreement between the United States and the former Soviet Union. Each of these three events initiated and symbolized what have since become significant trends in international cooperation regarding this technology.

Paul F. Uhlir is an associate executive director of the National Research Council.

I chose the next word in my title, "cooperation," for obvious reasons in light of the topic of this conference. It is important to note, however, that any discussion of cooperation must also include competition. Cooperation and competition are the yin and yang of human relationships and, by extension, of international relations. Each defines the other. This is a major theme of my presentation and, I hope, of the subsequent discussion.

The next word, "civil," also may seem obvious from the context of this conference. Because military and intelligence activities are inherently competitive, however, I would assert that a thorough understanding of international cooperation in civil Earth observations cannot be achieved without an understanding of classified Earth observation activities and their effect on the civil sector. Moreover, as I will point out, there are some important lessons that might be transferred from the classified to the civil sectors, and I hope that these also will be the subject of some discussion during the next few days.

By "Earth observation" I am referring to any sensing of our planet from space, including all activities associated with the support of such sensing and all data produced by it.

For the final word, I chose "activities" rather than "programs" because it is a more encompassing term. It is true that most international cooperation, especially on the governmental level, takes place within the context of official programs. Nevertheless, all such programs carry heavy bureaucratic baggage that reflect vested interests and significantly restrict options in decision-making. Although it is important to understand the institutional perspectives and constraints associated with international cooperation to date, it would be a mistake to confine our discussion over the next three days to existing organizational structures and programs. Given the rapid evolution of international organizations and cooperative arrangements over the past two decades, there is no basis for assuming that existing organizations and arrangements will suffice for the next twenty years, or even the next decade. It is the examination of new modes of cooperation and international management of Earth observation activities that I hope will form the primary topic of discussion here.

Having said all this, it is clear that this topic or set of issues is too complex to resolve or even comprehensively understand during this meeting, much less in the confines of my presentation. It is thus unavoidable for me to issue a few disclaimers. One is that I will obviously not be able to cover all that the title of my presentation seems to promise. I will necessarily be selective in the issues and events I choose to discuss, and this will no doubt reflect my own biases to some extent. My primary purpose is to provide a conceptual framework for discussion throughout this conference and to begin identifying some of the major issues that ought to be addressed.

The second caveat is that I will not be providing any descriptions or explanations of any programs, technologies, applications, or jargon I might use. This is a highly expert group and I will assume most of you will know most of the terms and acronyms that I use. To those of you who do not, I apologize.

The final disclaimer is obligatory: All of the views expressed in this presentation are my own and not necessarily those of my employer, the National Research Council.

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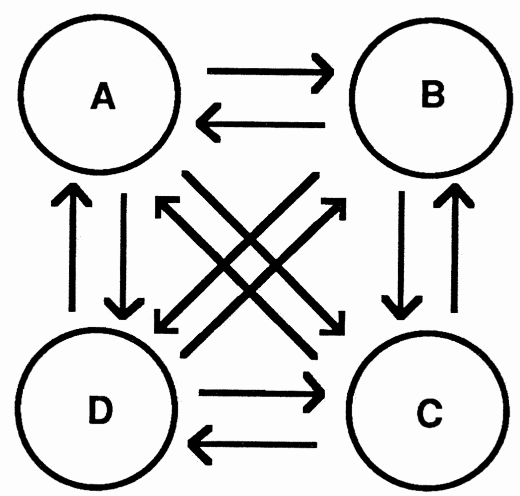
Over the past two decades we have seen a tremendous increase in the quantity and quality of Earth observation technology and participants. This growth in activity has been accompanied by a remarkable willingness on the part of most nations to coordinate their programs and to cooperate in attaining common objectives.

There are a number of ways to analyze these international cooperation activities. They may be viewed according to the type of operator; end-user applications; technological characteristics; socioeconomic, political, and legal considerations; and cooperative mechanisms or structures. In addition, I have provided a list of issues in the appendix to this presentation that are intended to help stimulate the discussion at this conference.

2. RELATIONSHIPS AMONG EARTH OBSERVATION SYSTEM OPERATORS



A — Military/classified
B — Civil government/R&D (experimental or research)
C — Civil government/operational
D — Private sector/commercial

There are four basic types of entities that operate Earth observation spacecraft, as indicated in the diagram. In general, it is accurate to assert that most civil government missions or programs are internationalized and managed on a cooperative or coordinated basis, whereas the military and commercial sectors are inherently competitive. It is the dynamics of the relationships among the various operational entities that are at the heart of any analysis of international cooperation. Following is a first-order characterization of these relationships.

A. Military/Classified

International cooperation within the military and intelligence sector has been highly classified and defined by Cold War enmities and alliances. Until recently, the United States and the former Soviet Union dominated this field and the terms under which classified remote sensing information was shared within their respective spheres of influence. Even before the breakup of the Soviet empire, however, this duopoly over the most advanced aspects of the technology began to be challenged. China developed its own classified systems in the 1980s and Israel has been reported to be doing so. France, in cooperation with Italy and Spain, has also been developing high-resolution systems, and the Western European Union has been discussing an arms control monitoring system for its members. Other such cooperative monitoring systems have been proposed over the years, notably the International Satellite Monitoring Agency, advocated by the French in the United Nations in the late 1970s, and the PAXSAT and ACCO systems, proposed by Canada and Sweden, respectively, in the 1980s.

As the Cold War has abated, the threat of a nuclear exchange between the United States and the former Soviet Union has been replaced by the threat of nuclear proliferation and of distributed regional conflicts. At the same time, the concept of national security is being expanded from purely military terms to include economic and environmental considerations, and a greater emphasis is being placed on collective security and international stability. These new developments in the world order, coupled with the growth in the number of nations with sophisticated remote sensing capabilities, suggest that the time may be propitious to revisit some of the previous proposals for verifying and enforcing collective security on a global scale.

A —> B, C, & D. In the past, there has been little if any cooperation between the operators of classified systems and civil government or commercial programs in the international context. Any such cooperation generally has been limited to program coordination on the national level, such as the Defense Meteorological Satellite Program (DMSP) and the NOAA Polar-orbiting Operational Environmental Satellites (POES), or various DOD research satellites (such as GEOSAT or CRRES) operated in coordination with NASA. In the United States, as elsewhere, the Defense Department and intelligence agencies have traditionally sought to prohibit the use of classified satellite data for civil applications—whether operational or research—and have tried to integrate the technological advances and operational capabilities of the civil sector into the national security apparatus to the greatest extent possible. Also not surprisingly, there have been systematic attempts to limit the level of technological sophistication used by the civil government and commercial operators in the open international context.

In the last few years, however, there have been significant changes in the technology and data allowed to be used by the U.S. government in the public domain. Ironically, some of these pressures came from the Soviet government in the late 1980s, when previously classified data were sold on the international open market under the Gorbachev policy of glasnost. Other more significant pressures have come from the increasingly competitive commercial systems in Western Europe, Japan, and Canada. Finally, the post–Cold War era has led to a reassessment of the role of classified remote sensing. For instance, a detailed examination of the potential use of retrospective classified data for environmental research is currently underway at the instigation of [Senator at the time of writing, now] Vice President Al Gore.

Although it remains unlikely that defense or intelligence agencies will become sponsors or members of any new or existing cooperative organizations for Earth observation activities, the changes that have recently taken place—unthinkable less than a decade ago—open up new possibilities and opportunities for international cooperation among civil government and commercial operators. Furthermore, as I discussed at some length at the 1991 conference sponsored by this institute, the classified arms control monitoring and verification paradigm could be successfully transferred to the monitoring and verification of international environmental agreements, except on an open basis.

B. Civil Government/R&D

The broad level of international cooperation in experimental and research Earth observation programs may be largely attributed to the efforts of NASA for over three decades. Almost every Earth observation mission or program ever undertaken by NASA has had a significant cooperative element, either directly through contributed hardware elements or indirectly through the sharing of data for research purposes. Virtually all NASA Earth observation missions are now thoroughly internationalized.

NASA's leadership in open cooperation over the years has served as a model for other government operators of experimental and research satellites. The agency has also led in the creation of bilateral and multilateral cooperative mechanisms and structures, and these are discussed in subsequent sections.

Perhaps the most important civil government research organization for international cooperation in Earth observations, at least in the context of this workshop, is the European Space Agency (ESA). This too is reviewed in more detail later on.

B —> A. As already noted, the relationship of classified operators to civil sector operators has been restrictive, with most forms of cooperation in the civil sector viewed with suspicion. With the trend toward liberalizing the restrictions on the civil sector, however, new technologies and data are certain to become available for international research.

B —> C. Historically, there has been a close coupling between the civil research and operational sectors, as exemplified by the NASA–NOAA and ESA–EUMETSAT relationships. In theory, the research agencies are supposed to develop and test Earth observation technologies—both space and ground systems—for which the operational agencies (or the commercial sector) then are to assume responsibility in providing continuous services.

In practice, this has worked reasonably well to date in the weather satellite context, but not without a number of well-publicized problems, such as what technology should be transferred, when such transfers should occur, and at whose expense. It is important to note, however, that problems have occurred principally between NASA and NOAA or ESA and EUMETSAT, rather than between those agencies and foreign contributors to their programs.

Although the civil and operational sectors maintain their own set of independent bilateral and multilateral cooperative relationships, they also participate together in the most important multilateral fora, such as the United Nations' World Meteorological Organization (WMO) and the Committee on the Peaceful Uses of Outer Space.

In recent years there has been a hybridization of the R&D and operational functions, with the R&D agencies assuming tasks such as continuous monitoring and the flying of operational sensors and the operational agencies involved increasingly in research applications. This is a significant trend in the context of future cooperation and the international organization of such activities.

B —> D. A major organizational purpose of government R&D agencies is to develop technologies for commercial exploitation by the nation's industries and for broad application by the private sector. This is certainly true in the context of NASA's Earth observation R&D programs, as well as other nations' space agencies. Whereas NASA over the past decade has emphasized the cooperative environmental research aspects, most other national space agencies, including ESA, have placed a premium on commercial applications and on maximizing economic return from their R&D investments.

The need for inexpensive and unencumbered flow of data for environmental research is difficult to adequately reconcile, however, with the economic, legal, and policy restrictions that must accompany the successful commercialization of the technology and sale of the data. This tension is similar to the one between the civil R&D and defense sectors, in which the latter seeks to restrict the free and open flow of environmental data, albeit for completely different reasons. Some of the most difficult issues facing existing and future international cooperation are raised by this research-commercial interface.

C. Civil Government/Operational Sector

As in the case of NASA, NOAA has been the leader of international cooperation in the civil government operational sector for the past 30 years through its Polar-orbiting Meteorological Satellite (METSAT) program, and for the past two decades with its geostationary METSAT program. NOAA was the organizer in 1972 of the first multilateral governmental forum for any Earth observation activity, the Coordination on Geostationary Meteorological Satellites (CGMS). The agency also established in 1984 the first intergovernmental coordination mechanism for polar-orbiting METSATs, the International Polar-orbiting Meteorological Satellite (IPOMS) group. These, and several other cooperative organizations, notably the European Meteorological Satellite Organization (EUMETSAT) and the Committee on Earth Observation Satellites (CEOS), the successor organization to IPOMS, have been the principal intergovernmental coordinating bodies.

Also as in the case of NASA, NOAA has led by example in conducting both of its operational meteorological satellite programs in an open, cooperative manner, including the continuous direct broadcast of data from its polar orbiters to anyone who wishes to deploy a receiving ground station. This method of operation has been adopted by China as well in its polar orbiting meteorological satellite program.

C —> A. Cooperation between the civil operational and military sectors has understandably been limited to the national level. In the United States, this cooperation has consisted of the sharing of some data and providing mutual backups for the NOAA POES and DOD DMSP systems. In other nations, notably India and the former Soviet Union, operational civil government systems, whether meteorological or land remote sensing, have been treated more as national security assets, with concomitant restrictions on cooperation with other nations and on the open distribution of their data.

C —> B. See the discussion under *B —> C.*

C —> D. Civil government operators may be viewed as competitors of private sector operators. Both provide a technologically mature set of services that could be offered either cooperatively as a public commodity or competitively as a private one. In the case of meteorological satellite systems, the nations that operate them have concluded it is in their best interest to maintain them as a public service to assure continuity of observations and equal distribution of the information to all citizens to enhance their safety and help minimize property damage. Most nations have also followed NOAA's lead in the open sharing of weather satellite data internationally, through the WMO and other means. Efforts to privatize METSAT operations have been rejected, and it would be fair to conclude that the cooperative arrangements of both the government R&D and operational sectors have served to undermine the growth of private sector operators.

In the case of land remote sensing, the only civil government operational agency that has tried to transfer such a system to the private sector has ended as a dismal failure. What I am referring to, of course, is NOAA's privatization of the LANDSAT system, which was initiated under the Reagan administration and is in the process of being returned to the public sector. The most interesting aspect of this government reacquisition of LANDSAT in the context of the current discussion is that the program will be operated jointly by a civil R&D agency, NASA, and the Department of Defense. Thus, in the relatively short span of two decades, the LANDSAT program will have been operated by all four types of operators. The implications of this new arrangement of LANDSAT operation by strange bedfellows should receive some attention at this conference, particularly in the context of international cooperation.

D. Private Sector/Commercial

There has, in fact, been precious little purely private sector involvement in operating Earth observation systems to date. In fact, there have been no instances of private sector operators without large government subsidies and involvement. Both the LANDSAT and SPOT programs have been of this variety.

A large, independent private sector industry has developed, however, in the commercial exploitation of the data from various civil government systems, including LANDSAT and SPOT. This is the so-called "value-added" industry, which provides commercial information services for a broad range of applications.

D —> A. The relationship between the private and classified sectors has been mostly one way; that is, the defense and intelligence agencies procure technologies and services from the private sector, but have imposed stringent limitations on the level of technology that the private sector can sell or operate on a commercial basis.

LANDSAT and SPOT, as the only existing commercial operators, have had a divergent influence on the classified sector, with the notable exception that both provide collateral and backup data for classified purposes. In the case of SPOT, the technology is being adapted for the classified Helios system.

D —> B/C. The relationship of the private sector to the civil government R&D and operational sectors has already been reviewed to some extent. Of greatest interest to this conference, I think, will be a discussion of potential hybrid arrangements that link or integrate civil government R&D or operational entities more closely with the private sector, perhaps as an international consortium. The case for that model is made by John H. McElroy later in this volume.

3. END-USER APPLICATIONS

If the relationships among all the operators seem complex and confusing, they become vastly more complicated when end-user applications are considered. On the simplest level, we have individual operators and the narrow constituencies they consider to be their primary users or customers.

Within the military and intelligence sector we have a small class of primary users strictly delimited by high-security clearances. Included in this elite group are data technicians, military commanders, intelligence analysts, and select civil government policymakers. This restricted set of users is closely associated with the primary intended applications, which include various intelligence functions, arms control verification and monitoring, early warning of military attack, and strategic and tactical military support. Until recently, there was very little secondary use of any of these systems, with the exception of some highly specialized research using selected retrospective data.

Within the civil R&D sector, the primary users traditionally have been the scientists and engineers who design experimental instruments, or who

have specific research interests in the data. Similarly, within the civil operational sector, the primary users of weather satellites have been government meteorologists, whose task it is to process, interpret, and disseminate the weather data to the media and the broader public.

As the technology has matured and proliferated, however, the number of applications and secondary end users have increased as well. Each operator has thus developed a very large and diverse set of constituencies, which can place similarly diverse and even contradictory requirements on the operator. These competing demands posed by different end users overlay the relationships among the four types of operators, adding to the complexities of adequately addressing all legitimate concerns in any international cooperative endeavor.

Despite the continually evolving demands on operators from the user communities, the civil government operators will always serve their primary users first, consistent with their agency mission and specific program goals. This often leads to inadequate attention or even complete disregard for the needs of the secondary users.

Perhaps some examples would help illustrate this problem. For many years, METSAT operators devoted most of their resources and programmatic concerns to supporting operational meteorological forecasting with real-time or near-real-time data availability. Little attention was paid to carefully calibrating sensors or to properly archiving data sets. As the global change research program has evolved from a set of related concepts to a comprehensive research plan, it has become quite obvious that the long-term continuous data sets collected by the METSATs could have important climate research applications. Unfortunately, the poor sensor calibration and improper archival methods have severely circumscribed the value or even accessibility of the earlier data to the research community.

To take another example from the R&D operators, current planning in the United States for the global change research program focuses almost exclusively on scientific research, with little attention or resources devoted to developing commercial applications. This is practically the reverse of the situation in the 1970s, when commercial applications were promoted at the expense of the research user community.

Such shifts in focus and operator-user relationships are difficult enough to address within the boundaries of an individual nation, but they become even more nettlesome in the international context. In any analysis of international cooperation projects, it is therefore important to carefully consider not only the relationships among the different operators but also among the operators and end users, particularly when contemplating new arrangements.

Finally, it should be noted that operator-user relationships in the private sector are not subject to the kinds of stresses experienced by secondary users in the civil government sectors, since in commercial enterprises everyone is a primary user because the customer is king. This factor should not be overlooked in assessing the relative merits of international organizational structures.

4. TECHNOLOGICAL CHARACTERISTICS

In the civil government cooperative sectors, there are numerous technological characteristics that require standardization, or at least close coordination, to make the most efficient and effective use of Earth observation systems. For those missions that have multiple partners contributing hardware, the various spacecraft components and sensors must, of course, be fully compatible and manufactured to agreed specifications. This is the most difficult and complex level of cooperation.

However, even among similar programs operated separately, such as the geostationary meteorological satellites, technical standardization and coordination are essential for significantly enhancing the scientific and operational applications. For instance, coordinated orbital parameters for obtaining maximum observational coverage has been an effective yet low-cost measure. Advance agreement on sensor designs can either augment, fill gaps, or provide prudent redundancies in covering portions of the electromagnetic spectrum, depending on need. Mutual calibration of similar sensors and the careful validation of their data is an essential prerequisite not only to the accuracy of the individual sensor's data set but to allowing comparative uses of related data sets from separate sensors. Advance agreement on telemetry and band width in the direct transmission of data can make effective use of existing ground receiving stations.

The advent of new sensors with very high data rates coupled with a constant increase in the number of operators and archived data have produced a daunting data management challenge. To derive maximum use out of all the data collected it is essential to cooperate closely and in many cases to standardize approaches in the various technical functions of the data management process, including reception, processing, formatting, cataloging, storing, distributing, and archiving of data and data products. These complex and expensive technical problems are exacerbated by legal and policy constraints.

For private sector operators, such issues have a narrower relevance, since their interest is in satisfying their customers' needs—the end users—rather than in cooperating with other operators. Even here, however, the private sector programs are driven in many respects by the standards and requirements established by civil government operators for the technology generally, and by the fact that the government agencies are still the largest customers.

5. SOCIOECONOMIC, POLITICAL, AND LEGAL ASPECTS

This will necessarily be a very cursory discussion because of time constraints, the broad scope of these issues, and the fact that the other speakers will be addressing all of these areas in much greater detail. The

appendix to this presentation raises some questions that need to be considered in these contexts.

The only topic I would briefly like to touch upon here concerns some of the broad international political themes that have emerged in this decade and are certain to create global problems for the foreseeable future. These themes are the effects of the end of the Cold War and accelerating environmental degradation. Both have far-reaching significance to the future organization and purpose of Earth observation activities.

The end of the Cold War has set several macro-scale trends in motion. The most obvious is the enormous opportunities for cooperation between East and West that have suddenly been made available. The end of bipolar confrontation also provides opportunities for multilateral cooperation and for a shift in focus from East-West to North-South issues and problems. The new accommodation between East and West has also caused major dislocations in the military-industrial complex on both sides, with resulting reassessments of purpose and the creation of economic problems of global proportions. Finally, the reduction in political control exercised by the two adversaries over their respective spheres of influence has unleashed ethnic, religious, and nationalistic aspirations and animosities. These have resulted in numerous local and regional conflicts that pose new challenges to policy-makers and international political and economic institutions.

The other major trend with obvious implications for Earth observation activities is the global environmental crisis that is creeping upon us. I will not belabor the facts, with which you are all familiar. However, if the end of the Cold War has suddenly left us without significant political enemies on which to focus, the rational management, preservation, and remediation of the global environment provides a worthy challenge. In what may prove to be a watershed election in the United States this year in more ways than one, it has been suggested for the first time that the global environment could provide the central organizing principle in the post–Cold War international community. Whether or not environmental issues take on such grandiose proportions in the near term—though I am convinced that they ultimately will—the role of Earth observations in that process will be central.

In short, both of these major international political forces will impact and be impacted by Earth observation activities in both the near and long term. They must therefore be carefully considered in any analysis of existing or new international cooperation efforts.

6. MECHANISMS AND STRUCTURES FOR INTERNATIONAL COOPERATION

As is the case with most types of technologies, international cooperation in Earth observation activities spans a broad range of arrangements. By mechanisms, I refer to instruments through which cooperation is effectuated. At the most complex governmental level, this involves formal bilateral or multilateral treaties among operators. The analog in the private sector is a contract. At the next level of decreasing complexity in the intergovernmental context are Memoranda of Understanding or Agreement, also known as executive agreements in the United States. This class of cooperative instruments is used to make agency-to-agency or institution-to-institution commitments regarding some specific operator or end-user activities. Within the U.S. government, such agreements are considered less binding than treaties because they do not have the full advice and consent of the Senate and because they are subject to annual congressional appropriations. Beyond this there are various ad hoc cooperative mechanisms used by both operators and users, down to the most informal individual-to-individual contacts.

By structures I am referring to the implementation of cooperation, which is generally through some organizational entity. International organizations provide one of the primary vehicles for pursuing cooperative goals, and this is the focus of my discussion. International organizations may be formally or informally constituted; international, regional, or bilateral; governmental or nongovernmental; with limited or open membership; focused on operations or research issues; and have Earth observation as either a primary organizational goal or merely as an important extraneous activity.

Over the past twenty years we have seen practically every permutation of these characteristics reflected in international organizations established for the operation or use of Earth observation technology. In fact, these groups are so numerous that it is not possible to review them all individually in this presentation. For a comprehensive listing and description of these kinds of institutions and groups, I suggest that you refer to the *1991 Earth Observations Directory: A Worldwide Listing of Government Institutions and Related Groups*, edited by Uhlir and Shaffer (Washington, D.C.: American Institute of Aeronautics and Astronautics, SP-012-1990).

Appendix

Issues for Discussion

1. INTRODUCTION

This appendix contains a list of issues raised by my presentation in various contexts, including: relationships among different types of Earth observation system operators; end-user applications; technological characteristics; socioeconomic, political, and legal considerations; and cooperative structures and mechanisms. These issues are not comprehensive, but provide some basis for subsequent discussion at the conference.

2. RELATIONSHIPS AMONG EARTH OBSERVATION SYSTEM OPERATORS

General Issues

• What are the principal characteristics of the relationships of all four types of operators in the international context?

• How do the relationships among existing operators impact international cooperation? In particular, how do the competitive sectors (A and D) affect the cooperative sectors (B and C)?

A. Military/Classified

• Are there any operational or organizational paradigms that can be transferred from the military sector to the civil cooperative sectors?

• Does the current trend toward greater openness in the military/intelligence sector pose any special opportunities in international cooperation—in terms of hardware, data, or cooperative arrangements?

• What limitations on international cooperation are likely to continue?

B. & C. Civil Government/R&D and Operational Sector

• How does the expanding number of nations and organizations with their own Earth observation capabilities impact existing relationships within and between the R&D and operational sectors?

• What are the notable successes and failures experienced within and between the R&D and operational sectors in cooperating on the international level? What lessons can be drawn for future cooperation?

• What is the impact of intergovernmental cooperation on private sector activities or on governmental commercialization efforts?

D. Private Sector/Commercial

• Where does cooperation end and economic competition begin in any given cooperative organization or mechanism?

• How do private sector interests impact intergovernmental cooperation?

• How do governmental commercialization programs affect intergovernmental cooperation?

• What are the notable successes and failures experienced by the private sector and governmental privatization/commercialization to date? What lessons can be drawn in terms of international cooperation prospects?

• Which elements of Earth observation activities are most appropriate for private sector/commercial development and which are best managed on an intergovernmental cooperative basis?

• What are the necessary conditions for cooperation within the private sector on the international level? Would an international cooperative venture or consortium in the private sector be a better model for managing Earth observation activities than an intergovernmental model?

3. END-USER APPLICATIONS

• Who are the end users and what are the relationships of the end users of Earth observation technology to the operators in the different sectors?

• What requirements do the end users impose on the operators, and how can international cooperation address those requirements?

• What types of applications are particularly suitable for international cooperation and why? Which ones are not, and why?

4. TECHNOLOGICAL CHARACTERISTICS

• What technological parameters require coordination or standardization in order to obtain the most efficient and effective use of the technology (i.e., on spacecraft, sensors, ground stations, and data systems)?

• Are technological advances promoted better through international cooperation, or through competitive means?

5. SOCIOECONOMIC, POLITICAL, AND LEGAL ASPECTS

Socioeconomic Issues

• What are the public good (cooperative) and private good (competitive) aspects of Earth observation activities, and how do they apply to the international context?

• What are the costs and benefits associated with various forms of cooperation?

• Are national social and economic goals furthered more by cooperative or competitive relationships?

• What are all the data pricing options and what are their strengths and weaknesses?

Political Issues

• What are the most important international political factors influencing cooperation in Earth observation activities?

• Which nations should be involved and at what level?

• What are the principal political motivations for cooperation at the national level?

• Can international cooperation be structured in a way that maximizes the stability of the agreed relationships, while providing for sufficient flexibility of action?

Legal Issues

• What are the major elements of international law that govern international relationships in Earth observation activities?

• What are the most significant national laws affecting international cooperation?

• What changes should be made to the existing legal regime?

6. MECHANISMS AND STRUCTURES FOR INTERNATIONAL COOPERATION

• What are the possible mechanisms and structures for international cooperation in Earth observation activities?

• What are the major international organizations (IOs) or groups that have been used for such cooperation over the past twenty years? What have been some of the most important lessons learned from these cooperative activities?

• Are existing IOs adequate for effectively coordinating all current and planned government programs? Do the functions of existing IOs need to be revised or should new IOs be created?

• If a new IO is necessary, what is the most appropriate model? What are the strengths and weaknesses of various options?

International Cooperation in Satellite Remote Sensing: Organizational and Structural Issues

Ray A. Williamson

Abstract

Once the province of only the United States and the former Soviet Union, remote sensing from space has become a truly international activity. Some remotely sensed data (e.g., from EOSAT, SPOT Image, Soyuzkarta) have considerable value in the marketplace. Data from planned global change research satellites may also prove to have economic value. This paper discusses the international considerations of pricing and distributing remotely sensed data from satellites. In particular, it summarizes the debate within the U.S. Congress over pricing of data from LANDSAT 6 and 7. It also explores issues surrounding nondiscriminatory data pricing and distribution policies in the international marketplace.

I take as demonstrable that the world community needs some sort of broad-based international partnership in space-based remote sensing to tackle issues of global environmental change, rural development, and other topics of broad international interest. Scientists and policymakers lack critical information concerning the nature and extent of natural and anthropogenic changes to the world's climate and ecological systems. Global data sets from space-based systems and other sources will be needed to provide appropriate information to the international community. For some areas of the world, such as the South Pacific, the Indian Ocean, or central South America, satellite measurements are nearly the only data available on a routine basis. Yet, conditions in these areas may have a marked affect on the evolution of weather patterns elsewhere. However, before jumping immediately to questions concerning the form such cooperation should take, we should step back and review the set of boundary conditions and other assumptions that form the cooperative equation.

Ray A. Williamson is a senior associate in the Office of Technology Assessment of the U.S. Congress and project director for the OTA's Earth Remote Sensing Systems.

The United States and other countries have participated in various forms of international cooperation in remote sensing for about three decades. The most extensive and successful of these have involved sharing weather data from both the geostationary and polar-orbiting systems.[1] More often than not, however, these cooperative programs have been developed in response to opportunities of the moment instead of proceeding from a balanced, inclusive consideration of the benefits and drawbacks, incentives and impediments associated with proceeding on an international basis. Furthermore, such cooperative ventures have often evolved in the context of strong nationalistic desires to become players in the development and operation of high-technology space systems. Hence, the world has a wide variety of sensors and systems with overlapping capabilities already in place. There is, therefore, a strong technical basis upon which to form a cooperative organization.

Although troublesome technical barriers exist in setting standards, integrating systems, and sharing data, they are minor compared with the difficulties of overcoming the organizational, structural, and political impediments to devising a broadly based international remote sensing organization. Once such an organization is in operation, it may face continual barriers as a result of the political sensitivity of data that it gathers. Thus, an international regime must take account of a variety of political and economic issues that attend the collection and interpretation of data. Several experts have urged creation of international remote sensing organizations—for weather and climate, for land remote sensing, and for global change research.[2] Each of these suggestions has considerable merit and would bring some benefits to the world. The implementation of such cooperative institutions would also face various impediments. In the following paragraphs, I have outlined the issues I believe should be addressed in assessing possible modes and means of international cooperation. I have grouped the issues in four broad categories: (1) first questions; (2) organizational and structural concerns; (3) operational questions; and (4) data management, distribution, and analysis.

FIRST QUESTIONS

What interest is there in an international regime for remote sensing? Why do it?

The world now has a crazy quilt of sensors, satellites, organizations, and types of data either in existence or planned. In looking over the collection of sensors, systems, and institutions, one might even question whether the countries of the world have the will to cooperate more extensively in a permanent system. After all, the ability to launch and operate remote sensing systems gives a country a certain economic and political edge over its neighbors. In addition, in the United States, despite the end of the Cold War, the relaxation of East-West tensions, and the widespread proliferation of space technologies, fears of technology transfer are still strong. Some U.S. officials raise concerns that establishing tighter international cooperative arrangements will lead to a drain of U.S. technologies to foreign firms, who will use them to compete with U.S. firms.

At the same time, the straitened circumstances of the world's economies suggest that international cooperation in remote sensing will become increasingly important as the competition for global resources increases. Remote sensing systems are expensive to build and operate, and no single country has the resources to develop a complete system alone, given the existing set of national priorities for space. In the United States, after several years of sharp budget increases, NASA's overall budget has remained nearly flat since 1991. In real terms, it has even decreased slightly.[3] Congress has signaled that future NASA budgets will remain just as constrained. Over the next five years, the gap between NASA's commitments for funded programs and a level budget of $14.3 billion per year totals $15.1 billion, or about 21 percent.[4] NASA is severely overcommitted[5] and will therefore have to find savings in all of its programs, a task that will be extremely difficult.

The state of the space budget of the Commonwealth of Independent States (CIS), which is dominated by Russian spending, is even more severely constrained. By 1992, the CIS space budget had fallen an estimated 40 percent from its peak spending in 1988.[6] To keep its space program going, Russia has been forced to market some of its valuable technologies. It is no longer seen as a political competitor of the U.S. space program. The European Space Agency (ESA) has also recently faced a serious budget crisis that has led to the sharp reduction or cancellation of some development programs, although "the Member States are strongly in favor of strengthening the Agency's activities in the pursuit of a greater understanding of the Earth's environment."[7] The programs for the polar-orbiting satellites ENVISAT-l, ERS-l, ERS-2, and METOP-l, as well as the second-generation geostationary METEOSAT, emerged with strong support.

Although fiscal concerns will be a strong motivator for increased cooperation among nations, the additional science that can be pursued through wider cooperation will also play a strong role. Science issues may vary considerably from nation to nation and region to region. Scientists from different countries therefore come to these issues with varied scientific perspectives, which could strengthen the value of the research performed.

What impediments exist?

In general, countries now operating remote sensing systems clearly have mixed interests they must balance as they decide whether or not to engage in a cooperative remote sensing regime. Some of these interests raise impediments to the development of a cooperative regime.

The existing structure. Probably the greatest impediment is the set of systems and institutions now in place. Institutional inertia and the protection of bureaucratic machinery will make the development of a new organization, or even the extension of an existing one, extremely difficult. The extensive cooperative arrangements now in place for meteorological data could even slow the development of a new, more extensive cooperative program. In the United States, the existing structure is also firmly rooted in the rhetoric of the Cold War, where across-the-board leadership, indeed preeminence,[8] in space technology has been of great concern. Despite the fact that political competition based on conspicuous displays of technological might began to diminish well before the Berlin Wall came down and the Soviet Union dissolved,[9] proponents of increasing space budgets have tended to retain the old rhetoric. As recently as 1991 proponents of the Space Exploration Initiative (SEI) used the argument that embarking on a vigorous, expensive program to revisit the Moon and send humans to Mars would restore U.S. leadership in space.[10] The U.S. approach to space leadership has colored its space program and set the terms for any cooperative program, making changes in that approach (to one, for example, in which the United States plays a less dominant role) very difficult.

Economic concerns. Remote sensing activities contribute to the national economy in two primary ways. First, developing and operating space systems contributes to the development and/or maintenance of the high-technology aerospace industry. The industries that develop these systems learn important skills that find application elsewhere in the economy. Thus, by building and owning their own satellite systems, countries are able to foster development of industries that produce products based on advanced technology.[11] Hence, most countries, including the United States, are reluctant to give up the momentum they have built in pursuing these systems for fear of losing economic and political clout in the global marketplace. For example, U.S. industry might oppose a strongly cooperative program on the grounds that it would harm U.S. business, which currently dominates the world aerospace industry, by shifting development contracts to firms in other countries.

Second, working with the data and adding value to them contributes to a country's ability to manage its resources more wisely. Hence, for important economic reasons, countries understandably are reluctant to give up even a small measure of control over the systems they operate. In structuring a cooperative regime, its designers must account for the economic interests and needs of each participating country. The fair-return principle of the European Space Agency, in which the industries of participating countries are able to claim a share of the development contracts roughly equivalent to their country's financial contributions, provides a good example of accommodating the economic realities of cooperative structures.[12]

Participating in a cooperative Earth monitoring program could free some U.S. funds now spent for remote sensing on other space activities. Alternatively, by cooperating with other countries and spending the same on remote sensing, the United States could potentially develop a broader, more effective remote sensing program.

National security interests. The United States and Russia operate a variety of classified satellite systems to serve national security needs. France has a high-resolution military imaging system called Helios under

development. Because the individuals who have grown up with the development and expansion of these systems tend to view international cooperative institutions with suspicion, they are unlikely to support them. In some cases, such as high-resolution land remote sensing, they might actively oppose it on the grounds that they would then begin to lose control over the data collection and distribution system and over the technology.[13] In the 1970s and early 1980s, for example, it was widely believed that secret U.S. policy forbade the development of a U.S. civilian system having a ground resolution of 10 meters or better. In the mid-1980s, the successful operation of the French SPOT satellite system, which carries a 10-meter panchromatic band, made any such policy obsolete. The recent Russian announcement that data of 2-meter ground resolution are available for purchase, effectively undercuts policies specifying controls over resolution.[14] Even in the absence of a formal policy regarding system capabilities, however, the national security community of any country is likely to exert considerable influence over the extent to which a country cooperates with others.

Environmental satellite systems that serve primarily military requirements, such as the U.S. Defense Meteorological Satellite Program, would not likely be made part of an international system. The presence of such a system, however, is also not likely to impede international cooperative arrangements because it operates independently of the civilian systems.

What goals and objectives should an international regime have?

The world's civilian remote sensing satellite systems serve the public good by supplying a wide variety of data for routine weather forecasting, climate research, the management and exploitation of natural and cultural[15] resources, and more recently, scientific studies of global change.

Routine environmental monitoring. The most compelling long-term need is for the provision of environmental data that are now provided by the "operational" environmental satellites operated by the U.S. National Oceanic and Atmospheric Administration (NOAA), the Russian HYDROMET Office, the European EUMETSAT, and the Japan Meteorological Agency. To be most effective in weather and climate prediction, these data should be available on a routine basis and, to provide better input into predictive models, they should have better calibration than previously provided.

The United States and Europe have for several years engaged in discussions over the development of a cooperative polar meteorological satellite program in which Europe would supply the morning orbiter for a two-satellite system and the United States would continue to supply the afternoon orbiter. The November 1992 ESA *ministerium* meeting, in which ESA agreed to build an operational polar orbiter called METOP[16] as well as a research polar orbiter called ENVISAT, has brought that prospect much closer to reality. METOP-1, which will be operated by EUMETSAT, will serve as the morning orbiter[17] in a pair of orbiters that make up the complete system now supplied by the United States. NOAA will continue to operate the afternoon orbiter but will phase out its existing morning orbiter. Extension of this arrangement to a wider sphere of countries could serve as the basis of a global operational satellite system.

Global change research. Satellite systems are becoming of increasing importance to global change research, which will require prodigious amounts of well-calibrated data from a variety of platforms and instruments, delivered over time scales of months to decades. Satellite systems built for systematic, routine data collection, if designed with research questions in mind, can provide many of these data needs. Necessary design parameters include, among others, careful attention to calibration and instrument drift.

Yet, instruments designed for "operational" monitoring are seldom appropriate to gathering the detailed data sets required to answer research questions involving specific processes, or even for long-term monitoring of subtle climatic changes. The instrument design requirements may be overly specialized or complex to serve broad-based monitoring functions. However, accommodation can often be made on a monitoring satellite for research instruments supplied by others, if weight, power, and size requirements can be met. For example, many of the research instruments now part of NASA's Mission to Planet Earth are able to fly in polar orbit with either morning or evening equator crossings. In addition, once a data distribution network is in place, the research communities in several countries might wish to contract with an international consortium to supply the necessary data.

Moderate- to high-resolution surface data collection. The data provided by the LANDSAT, SPOT, and JERS-l multispectral optical instruments, or the Almaz,[18] ERS-1, JERS-1, and RADARSAT synthetic aperture radar instruments, fall into a somewhat different category from the data generated by the environmental satellites by virtue of their market value. In addition to serving the public good directly, remotely sensed surface data have value to the extraction industry, forestry companies, agribusiness, fishing industry, and shipping companies, among many other profit-making applications.[19] When incorporated in geographic information systems (GIS) and integrated with other spatial data, these data provide a cost-effective means of analyzing surface conditions on land, coastal waters, and the oceans. Hence, the appropriate cost of these data and the rules for distributing them become matters for discussion and occasional dispute.[20]

In principle, an international consortium could readily gather and sell these data along the lines by which they are already sold by EOSAT and SPOT Image, the marketing agents for LANDSAT and SPOT data, respectively.[21] The market in remotely sensed land data, though small, is growing and might by the end of the century provide sufficient income to support the development and operations costs of a satellite system. However, even though the market is unlikely to support more than one such system, the very existence of the LANDSAT and SPOT satellite systems, which were developed in part to demonstrate the technological capabilities of the United States and France, respectively, inhibits the development of an international structure to provide such data.

Nevertheless, the development of a successful international structure to collect and distribute environmental data internationally might in time make the inclusion of moderate- (10–30 meters) to high-resolution (1–5 meters) instruments on the polar orbiters acceptable.[22] First, it would provide the necessary institution and work out many of the operational mechanisms for that institution. Second, if successful, its very existence might undercut the current resistance to an international institution for collecting and distributing remotely sensed land data. Although surface data have considerable market value when integrated in GIS, government sales still make up the largest market segment.

ORGANIZATIONAL AND STRUCTURAL CONCERNS

How should it be structured? Which countries should be involved?

Deciding how an international regime should be structured must necessarily involve decisions about which countries should be involved at the outset and how to make the transition from existing structures to a new one. Organizers must also take into account the self-interest of the participating countries. In establishing a new international cooperative structure, the existing systems and infrastructure of space-capable nations serve as important initial assets, although, as noted earlier, these same assets may also inhibit international system development by adding bureaucratic inertia to the system. In some cases they may provide a logical path to the future. Including existing national assets in a global system will allow each participating country to have a strong role in the management and operation of the organization.

For example, NOAA, ESA, and EUMETSAT will learn important lessons in setting up and working with the cooperative agreement for operating the joint European/U.S. polar orbiter system at the beginning of the next century. However, if the international community wishes to create a truly international system, it must extend beyond this to include other countries. By eventually bringing other space-capable nations such as Japan, Russia, China, or India[23] into that arrangement, the United States and Europe could potentially reduce their costs and/or improve the capabilities of these polar-orbiting systems. Of more importance, such a move would involve these countries in a scientific union that is likely to be of great importance in improving the stewardship of Earth's resources. Russia, in particular, would be an obvious candidate for inclusion in an expanded cooperative venture because it already operates the Meteor polar-orbiting system, which operates in polar orbit and carries both visible and infrared scanning spectrometers. In addition, the United States already has a small cooperative program with Russia. Normally, two or more Meteor satellites are in operation at a time. A Meteor 3 polar orbiter, launched in August 1991, carries an American Total Ozone Mapping Spectrometer (TOMS).

The geostationary systems under the control of EUMETSAT, Japan, and the United States could also be more tightly integrated than they are today. Although the system operators coordinate with each other and share data, they could work toward the development of common instruments.[24] This would help reduce system costs and increase the usefulness of sharing resources in the event a satellite fails. Recently, EUMETSAT agreed to move one of its geostationary satellites toward the west to provide backup to the only remaining U.S. GOES satellite, which is currently positioned over the central part of the United States.[25]

Eventually, if Russia manages to recover sufficiently from its current economic difficulties, it may even be able to join the existing geostationary system, which could then provide complete coverage of the globe between 60° N and 60° S latitudes. The former Soviet Union has planned for several years to launch and operate a geostationary environmental satellite. Here, as with the polar orbiters, Russia has the capability to make a major technical contribution to a global system.

If a cooperative arrangement involving space-capable nations is hammered out and put into operation, then other countries could be included in the organization by contributing other skills, in much the same way that COSPAS/SARSAT, the international search and rescue organization, is structured. In COSPAS/SARSAT, Canada, France, Russia, and the United States provide the satellites and instruments. Receivers capable of picking up distress signals from a standard emergency transmitter fly on the Russian and U.S. polar orbiters. Other participating countries—Bulgaria, Finland, Norway, and the United Kingdom, among others—provide ground receivers for the distress signals relayed from the polar orbiters and other system infrastructure. In the case of a global remote sensing system, countries unable to contribute instruments, satellites, or launch vehicles might wish to develop a regional data archiving, distribution, and analysis center, a capability that would not only assist local economies directly but also help develop additional expertise in information technology.

The framework I have laid out above could operate, with some difficulty, as a voluntary coordinating organization, such as the Committee on Earth Observation Satellites (CEOS). However, in order to provide a firm organizational basis for collecting and distributing data, eventually it must evolve into a more tightly structured organization that would set remote sensing priorities and develop appropriate new sensors and satellites.[26] As John H. McElroy has suggested,[27] INMARSAT or INTELSAT would make plausible models, insofar as both organizations have the appropriate technical capabilities and the financial resources to purchase what they need. However, both organizations have substantial income that derives from sales of communication transponder capacity to governments and commercial entities. As noted above, except for moderate- to high-resolution imaging data, the data produced by a system of environmental satellites would have relatively small commercial value. Hence, funding would most likely have

to be provided by annual contributions from the participating members. As long as the organization generated data of value to the participating countries, it could operate very much like INTELSAT, in which voting shares are proportional to the investment in the system.

The time scale for developing a global remote sensing system is likely to extend a decade or more, not only because the development cycles for space systems are so long and reaching agreement on technical standards takes time but also because the economic and political issues are so difficult. Among other things, proponents of such a system will have to sell their respective governments on the importance of participating in a global monitoring system. However, because so many of the building blocks are already in place, the world does not have to wait until a fully participatory structure is in place to realize certain benefits. CEOS and the International Earth Observing System (IEOS) serve an important function by coordinating the operations of existing and planned systems. Although neither organization has an independent budget or operating staff, each is able to bring the participating countries and organizations much closer than they have been. Within a decade or so, however, these organizations either will have to evolve into permanent structures in which the organization as a whole makes resource decisions or be replaced by a permanent structure.

What is the role of the private sector?

Although satellite remote sensing systems are almost entirely funded and operated by governments, private industry, academia, and nongovernmental organizations have had major roles in remote sensing. First and foremost, private industry has had its greatest effect in processing raw data and adding value to them by merging them with other data and developing usable products. The so-called "value-added" sector is large and growing, thanks in part to the development of powerful GIS technologies, which make using remotely sensed data relatively easy to interpret and to merge with other spatial data sets.[28]

In the future, the private sector may increasingly function as data provider. Although governments have provided the requirements and the funding for satellite remote sensing systems, the systems themselves have been largely built by private industry. Hence, private industry already has the skills to build a privately launched and operated system. However, a large gap exists between the development, launch, and operational costs of the system and the income that data sales would provide. If industry can find innovative ways to lower the price for building and operating a system to a level that can be supported by data sales, private data providers might be able to earn a profit. The arrangement that NASA has made with Orbital Sciences Corporation, in which NASA has agreed to purchase a certain amount of data for an agreed price, provides an interesting test case for this proposition.

An international consortium might buy data from one or more private systems, thereby avoiding the cost of building and operating its own systems. It could also act as a market consolidator for certain kinds of data sets.

How extensive should an international regime be?
What should the major drivers be?

On the simplest level, the organization should be as broadly construed as it needs to be. For practical reasons, it should probably start relatively small and grow over time as countries gain experience with it. At the start the organization could, for example, include only the polar-orbiting satellites; if successful, it could grow to include the geostationary satellites and eventually satellite systems that need to be in other orbits. The TOPEX/Poseidon ocean altimetry satellite, for example, follows an orbit inclined by 66° in order to spend most of its time over the mid-latitudes where it can track the effects of tidal flows. I am suggesting that the organization should follow an evolutionary, not revolutionary, path, driven by scientific and operational needs for data and the costs and benefits of providing them.

OPERATIONAL QUESTIONS

How would the system providers recover the costs of the system?

System operators would incur three primary costs—the cost of the initial space and ground systems; the operational cost of providing data; and the cost of developing new sensors and systems. The organization could recover these costs in two primary ways—by charging each member of the organization a participation fee, or by charging for data, either on a piecemeal basis or for the privilege of tapping a data stream at its ground stations. Probably both methods would be needed. Some countries are too poor to contribute directly to the organization, although they might be purchasers of data.

Basic data, such as that transmitted by the U.S. and Russian polar orbiters to Automatic Picture Transmission (APT) stations, could continue to be provided free. Hundreds of these APT stations exist around the world, providing basic, but quite important, weather data to thousands of users.

The organization could also provide raw data at modest cost[29] to value-added firms, which would then provide additional services by interpreting the data in much the same way as they do today. I interpret modest cost to mean the cost of reproduction plus an additional small surcharge to help amortize the cost of building and operating the system. Alternatively, firms could be charged a royalty on profits earned from adding value to the data. Selling private firms data at modest cost should encourage them to market enhanced data products and to find innovative uses for the data.

Because the organization's satellites may have greater platform capacity (power, mass, size) than they actually need to carry out basic functions, they might be able to carry additional research sensors from time to time. In such cases, the organization wishing to fly such a sensor would pay an access fee and additional fees for special services, thereby defraying the cost of providing data services beyond their basic mission.

Who will set the standards of operation and how?

The principal members of the organization should set the data type, formats, and other standards, such as instrument calibration. Here the experience of INTELSAT or INMARSAT will be extremely useful, both in how to approach setting standards and in what to avoid in a remote sensing organization. A voting scheme, for example, in which each member country has a vote proportional to its investment in the system might provide the most equitable approach. Officials of the organization might wish to establish an operators forum, in which the whole range of technical issues could be discussed openly. The experience CEOS has had in setting standards and discussing other technical issues will be of great interest in arranging an appropriate structure for addressing these matters.

What is the role of the private sector?

As noted, private industry, academia, and nongovernmental organizations might provide important contract services, both in assessing new approaches to systems development and in finding new applications for the data. Also as noted earlier, private industry could act as a data provider, assuming that it is successful in developing a viable, self-sustaining remote sensing system. Because of these roles, private firms might serve an advisory role in such an organization.

DATA MANAGEMENT, DISTRIBUTION, AND ANALYSIS

What sort of marketing function should it have?

As noted earlier, private firms are generally more efficient and more innovative at marketing than governments. This was part of the rationale behind the decision of the French government to establish SPOT Image, S.A., a corporation to market data from SPOT, and the decision of the U.S. government to grant marketing rights to a private corporation for LANDSAT data. EOSAT was awarded the contract to sell LANDSAT data and to license the foreign LANDSAT ground stations to collect data.[30] Although the market for remotely sensed land data has not grown fast enough to support the construction and operation of a nonsubsidized system, SPOT Image and EOSAT have increased the market for these data substantially. Hence, the international organization's framers probably would be wise to establish arrangements with private firms to market the data.

What should the distribution policy be?

The only distribution policy that makes sense for an international structure funded largely by governments is one that sells or otherwise provides data on a nondiscriminatory basis to all buyers. The United States has followed this policy for LANDSAT and for data from the NOAA satellites on the grounds that to discriminate in selling data from publicly funded systems would undercut other U.S. policies supporting the international free flow of information. France and other countries have followed suit with sales of data from their systems.

On the other hand, because moderate-resolution data have military value, some attention will need to be given to countries that use the organization's data to support aggression against their neighbors. During the 1991 Gulf War, SPOT Image and EOSAT refused to sell images of the gulf on the grounds that they contained information that could aid the Iraqi military. If the international organization gathered and distributed data of similar capabilities, it would have to develop a policy for dealing with equivalent situations.

How much analytic capacity should an international organization maintain?

Private firms have demonstrated a remarkable ability to develop powerful analytic software and to lower dramatically the cost of processing raw data and converting them to information. In addition, most countries maintain their own facilities for analyzing the data and incorporating them into predictive weather and other models. Hence, there apparently is little to gain in spending precious resources on providing a large analytic facility and staff.

OBSERVATIONS AND CONCLUSIONS

This short essay was meant to raise some of the most important issues that will need to be addressed in structuring an international remote sensing organization. It is not an exhaustive list. If such an organization is pursued, the organizers will certainly have to address a host of other technical, political, and economic issues.

The breadth and depth of information we now need about the physics, chemistry, and biology of Earth systems and their interactions, coupled with declining government investment in space activities, requires a new look at international cooperation. However, before designing a cooperative international venture, the United States and other countries need to develop more clarity about their national and international approaches to remote sensing. The United States, for example, has not developed an integrated strategy for its remote sensing capabilities.[31] NASA, DOD, and NOAA now operate remote sensing systems that could feed instruments, satellites, and/or data into an international system. In addition, the DOE laboratories have expressed a desire to contribute expertise to the construction and operation of space-based remote sensing systems.

In general, policymakers need to think through the entire system from data requirements to instruments and satellites to the delivery of information. Although many experts have recognized the value of a cooperative remote sensing organization and have urged its creation, there have been no comprehensive analyses of such an organization in the context of the national programs now in place.

We live in a complex, confusing, conflict-filled world in which space systems serve both scientific, profit-making, and political ends. This argues for adopting an evolutionary approach to an international remote sensing regime. After all, modest gains are gains nonetheless.

NOTES

The views expressed in the preceding paper are the author's own and do not necessarily reflect the views of the Office of Technology Assessment, the Technology Assessment Board, or the U.S. Congress.

1. The World Meteorological Organization (WMO) has supported the international sharing of weather data since it began in 1853. In addressing the United Nations on September 25, 1961, U.S. President John F. Kennedy proposed intensified cooperation on global weather issues. Strongly supported by the United States, U.N. Resolution 1721 (XVI), December 20,1961, which called for increased efforts to "advance the state of atmospheric science and technology," led eventually to research and operational weather programs under WMO sponsorship. See Patrick Hughes, "Weather Satellites Come of Age," *Weatherwise* 37, 2 (April 1984): 69–75.

2. John H. McElroy, "ENVIROSAT for Observing Earth," *Space News*, February 18–24, 1991, p. 16.; John McLucas and Paul M. Maughan, "The Case for ENVIROSAT," *Space Policy*, 4, 3 (August 1988): 229–239; Neal Helms and Bert Edelson, "An International Organization for Remote Sensing," paper presented at the 42d Annual Meeting of the International Astronautical Federation, Montreal 1991, IAF-91-112.

3. NASA's 1992 budget was $14.35 billion, a 3.4 percent boost over the fiscal year 1991 budget. Its 1993 budget is $14.32 billion, a decrease in real terms of some 3 percent.

4. U.S. Congress, General Accounting Office, *NASA Programs Planning*, GAO/NSIAD-92-278 (Washington, D.C.: General Accounting Office, June 1992).

5. Ronald Brunner, "Overcommitment in NASA." Paper presented at the 39th Annual Meeting of the American Astronautical Society, San Francisco, December 1992.

6. Donald Blersch and Robert Usher, *Decision-Maker's Guide to International Space* (Washington, D.C.: Anser, August 1992), p. 45.

7. European Space Agency, "European Space Agency Given Mandate for the Coming Years," ESA News Release, November 10, 1992.

8. This was clearly the intent of President John F. Kennedy's challenge to the nation on May 25, 1961, that before the decade was out the United States could put a man on the Moon and return him safely.

9. The former Soviet Union, for example, has had working space stations for over a decade.

10. Synthesis Group, *America at the Threshold* (Washington, D.C.: The White House, June 1991), pp. 104–111.

11. The development of regional satellite communications systems, despite the existence of INTELSAT, illustrates that countries or regional consortia that do not possess the means to manufacture their own satellites nevertheless desire to own space systems for the control and international prestige ownership imparts.

12. U.S. Congress, Office of Technology Assessment, *International Cooperation and Competition in Civilian Space Activities*, OTA-ISC-239 (Washington, D.C.: U.S. Government Printing Office, July 1985), chap. 3.

13. William J. Broad, "Private Cameras in Space Stir U.S. Security Fears," *New York Times*, August 25, 1987, pp. C1, 12.

14. William J. Broad, "Russia Is Now Selling Spy Photos from Space," *New York Times*, October 4, 1992, p. 10.
15. Cultural resources generally include any results of human activity, including paths, agricultural fields, roads, bridges, cities, and archaeological sites.
16. Planned for launch in 2000.
17. So called because it crosses the equator in the morning.
18. Almaz no longer operates. It deorbited and was destroyed by atmospheric heating in October 1992 after running out of station-keeping fuel.
19. U.S. Congress, Office of Technology Assessment, *Remote Sensing and the Private Sector*, OTA-ISC-TM-239 (Washington, D.C.: U.S. Government Printing Office, April 1984).
20. U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data from Space: Distribution, Pricing, and Applications* (Washington, D.C.: Office of Technology Assessment, July 1992).
21. Neal Helms and Bert Edelson, "An International Organization for Remote Sensing," paper presented at the 42d Annual Meeting of the International Astronautical Federation, Montreal, 1991, IAF-91-112.
22. The requirements for time of equator crossing can affect the desirability of putting surface remote sensing instruments on satellites optimized for collecting meteorological data. Nevertheless, instruments for moderate- to high-resolution surface monitoring are appropriate for satellites that cross the equator in the morning.
23. U.S. technology transfer concerns are likely to be greater for China and India than for Japan and Russia because the latter already are much farther along in acquiring strong capabilities in aerospace technologies.
24. Note, however, that differences in weather patterns over the region each system covers may dictate instruments with different characteristics. For example, Europe does not have nearly the need for simultaneous imaging and sounding in tracking and predicting the paths of severe storms that the United States has. Hence, EUMETSAT is unlikely to want to use instruments similar to the Visible Atmospheric Sounder, which will be the primary instrument on GOES-Next, because it has more capability than EUMETSAT needs and is much more costly than the Visible and Infrared Imaging Scanning Radiometer it now uses in the METEOSAT satellite.
25. Normally, NOAA operates two GOES satellites, one positioned at 135° W and one at 75° W longitude.
26. Brent D. Smith, Linda V. Moodie, Betty Howard, Lisa R. Shaffer, and Peter Backlund, "Coordinating Earth Observations from Space: Toward a Global Earth Observing System," paper presented at the 41st Congress of the International Astronautical Federation, Dresden, October 1990.
27. John H. McElroy, "INTELSAT, INMARSAT, and CEOS: Is ENVIROSAT Next?" This volume.
28. U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data from Space: Distribution, Pricing, and Applications* (Washington, D.C.: Office of Technology Assessment, July 1992).
29. As the debate in the U.S. Congress over how to charge for LANDSAT data illustrates, determining the appropriate cost for data can be extremely difficult. See U.S. Congress, Office of Technology Assessment, *Remotely Sensed Data from Space: Distribution, Pricing, and Applications* (Washington, D.C.: Office of Technology Assessment, July 1992).
30. The EOSAT contract has other provisions that go far beyond the marketing of data, which are designed to promote the transition of the LANDSAT system to the private sector. Concern over the continued provision of LANDSAT data recently led to Public Law 102–555, mandating the transfer of the LANDSAT system from NOAA, which was overseeing the contract with EOSAT, to DOD and NASA.
31. U.S. Department of Commerce, Office of the Inspector General, *National Strategy for Satellite Remote Sensing Is Needed*, unpublished report, February 1991.

Collective Goods and National Sovereignty: Conflicting Values in Global Information Acquisition

Molly K. Macauley

Abstract

The increasing internationalization of natural resources is likely to heighten tension between national sovereignty and international cooperation. While sovereignty and cooperation are not necessarily mutually exclusive, traditional means of accommodating both, such as maintaining sovereignty through geographic jurisdictional limits specified in international agreements, may be increasingly challenged. The tension is perhaps greatest in the case of acquiring comprehensive global environmental data (about human activity and oceanic, atmospheric, and land processes). Such data have been deemed vital to understanding global climate change, and are also likely to be useful if not critical in monitoring compliance with international environmental treaties. In the interests of sovereignty (economic or otherwise) or in anticipation of adverse international reaction, nations may not want to make available detailed information about activities (e.g., greenhouse gas emissions, industrial pollution, rates of deforestation) fundamental to scientific and environmental understanding. Yet virtual unanimity in international willingness to provide information may be required to maintain the scientific integrity of databases in the case of climate change or other environmental study and to achieve environmental goals in the case of treaty compliance.

Molly K. Macauley is a fellow of Resources for the Future and associate professor in the Department of Economics at Johns Hopkins University.

This paper conceptualizes sovereignty and international cooperation as determinants of reaching virtual unanimity in global environmental data acquisition, offers a stylistic approach to empirically consider which countries may refrain from participation, and suggests strategies for accommodating the hold-out countries. The paper is intended to provoke further interdisciplinary research and to aid policymakers in negotiating agreement on global environmental data activities.

INTRODUCTION

The management of natural resources, including scientific inquiry to improve understanding of resource and environmental processes, and the collection of data to monitor these processes, is becoming increasingly international. Transboundary air and marine pollution, stratospheric ozone depletion, the preservation of species to maintain biological diversity, and most recently, climate change are all concerns which arise in a truly worldwide context. Remotely sensed data, such as that collected from satellites or aircraft, may significantly contribute to understanding some of these concerns. A high degree of cooperation will be required among countries in both the acquisition and use of such data to adequately address these issues.

Yet such cooperation may well constitute an unprecedented threat to national sovereignty. While tension between sovereignty and cooperation has been reconciled in many remote sensing activities in the past, these activities have tended to focus on developing hardware (for example, new sensors) or improving data interpretation and applications at an abstract level rather than using the data to make decisions that affect countries politically, financially, or otherwise controversially.[1] Resource and environmental concerns inextricably link countries, however, and actions that affect resource allocation (such as the development of new environmental agreements or improved monitoring of existing agreements) may well thus effectively heighten tension between sovereignty and cooperation.[2]

This paper focuses on a situation where the tension might be most acute: the acquisition, and use in decision-making, of comprehensive global environmental data. Scientists have deemed these data vital to fundamental understanding and development of responses to climate and environmental change processes, and plans for data acquisition constitute the centerpiece of significant United States efforts during the next decades.[3] The data are intended to contain a vast amount of information about oceanic, atmospheric, and land processes, as well as information about the spectrum of human activity that directly and indirectly influences these processes. Examples include direct or indirect information about industrial emissions of greenhouse gases, contaminated waste, and air toxins; rates of deforestation; and patterns of population density, growth, and distribution.

It is probable and highly important to note that maintaining the scientific integrity of such a database permits only a few (if any) gaps in the data, as the success of the effort rests on obtaining data so comprehensive as to fully characterize the interrelationship of Earth processes. For example, one expert has noted that "the transitional movement of weather phenomena and the process of weather forecasting make it impossible for any country, including the largest, to forecast for its territory without access to global data" (White, cited in McElroy 1986, p. 8). Other experts have said the same for atmospheric and oceanic data, citing the need to thoroughly characterize the ocean's interface with the atmosphere (see McElroy, op. cit.).

Yet the nature and extent of such information may well be perceived as unacceptably threatening to a host of national values fundamentally related to concepts of national sovereignty—economic standing, levels of industrial development (including polluting activities), technical capabilities, natural resources, political interests, legal precedent, cultural norms, religious tenets, concern about the environment. Indeed, sovereignty traditionally has been "invoked to shield nations from external intrusion" (Caldwell 1990, p. 151); thus, even if the information ultimately is useful in the pursuit of a greater good such as environmental protection, such interests may preclude its acquisition. It has also been observed that "the permeability of national borders to invisible agents (such as disease) has never been remedied by declarations of national sovereignty" (Caldwell, p. 129).

Space-based observations to which political boundaries are invisible are another case in point. The concern is not new; in regard to the first space-based civil remote-sensing satellite, the space scientist Wernher von Braun is quoted as having said that "effective use of the new capability will call in the talent of the statesmen, program administrators, economists, lawyers, political and social scientists, and educators to settle all the vexing questions ranging from the sovereignty of nations to the rights of land-owning individuals. A global Earth resources management system is a very promising challenge for applying here at home what we have learned in space, namely that we are all inhabitants of a rather small and limited planet" (McElroy, p. 1).

International cooperation and national sovereignty have been reconciled in many previous space-related activities, including activities involving remote sensing. Since a global environmental database—and, in many cases, effective responses to information gleaned from the data (such as steps to protect environmental quality)—will require virtual unanimity in international willingness to participate in the effort, even just a few hold-out nations may undermine data collection and responses. Accordingly, this paper seeks to raise questions that might contribute to understanding of the forces that shape near-universal agreement in the provision and use of collective goods, such as information related to the environment. The paper focuses on the relationship between national sovereignty and international cooperation in the case of information acquisition and use and highlights several distinct issues that arise in this setting.

ISSUE 1: THE PROBLEM OF UNANIMITY

The role of unanimity in the case of participation in global data acquisition is rather unusual as a practical problem. Unlike the situation of many other resource-related international agreements, in the case of constructing a global data set it is difficult to substitute information to compensate for nonparticipation of other parties. For example, in the situation of pollution controls, reaching global emissions targets within some range might be feasible even if some countries refuse to reduce emissions, provided other countries compensate by increasing their own cutbacks. In the case of building a global database of resource and environmental information, however, such substitution is less workable, as the data typically involve unique information (e.g., about climatic zones, ecosystems, atmospheric gradients specific to particular geographic areas).

It is important to note that data about environmental change, particularly that related to anthropogenic impacts, differ from, say, meteorological data that reflect only naturally occurring or stochastic phenomena. The type of "quid-pro-quo" data sharing that has worked well in the case of the World Meteorological Organization (WMO) and other weather monitoring activities (or in the case of scientific exchange in other areas) may not be as agreeable to countries because of this difference in information content.[4] This disagreeableness may be especially true, for example, if the information directly or indirectly reveals a country's industrial and other economic processes. Conclusions in a recent report (U.S. Congress, GAO 1992) on international environmental agreements lend some support to this observation. The report notes (p. 12) that some nations believe that if the compliance mechanisms in the agreements were more stringent or enforceable, then fewer nations would participate [in the agreement].

That some nations may have reservations about data collection gives rise to these questions: What determines willingness to participate in the data acquisition project? What are the consequences for the quality of the data of nonparticipation? If the consequences are large, how can participation be encouraged?

The literature related to bargaining and consensus building sheds some light on these questions; for example, see Isard (1988), Raiffa (1982), Swanson (n.d.), Young (1989), Burtraw and Toman (1992), and references therein. The discussion of Issue 4 below, which addresses the problem of inducing participation, elaborates on how these frameworks might be used. The question then follows as to whether the withholding of information by particular countries critically threatens the scientific value of the data. There is indication that data gaps may be critical; for example, the science community has long been concerned that data are unavailable or of poor quality for large areas of certain countries (e.g., China, the former U.S.S.R., some developing countries) and nonagricultural ecosystems.[5]

ISSUE 2: THE "INVASIVENESS" OF INFORMATION COLLECTION PER SE AND AS A MONITORING ACTIVITY

As alluded to above, one feature of global data acquisition is its dual role as an information base and a technology for monitoring. This dual role arises because the act of data collection itself offers a glimpse (or in some situations, a long, studied look) that reveals information about the nature and extent of a host of natural and industrial activity. The monitoring capability means that such information gathering may be perceived as invasive, particularly when conducted from space-based or aircraft remote sensing that operates without regard for political or other boundaries. As such, the activities may well threaten the privacy of economic and other activity and national sovereignty.

There is already strong evidence of resistance by some nations to space-based information collection. The 1967 Outer Space Treaty permits open dissemination of information from remote sensing satellites, just as remote sensing and information dissemination by ships outside territorial waters or by aircraft outside national airspace has been permitted.[6] But some countries claim that national sovereignty should prevail over space-gathered data intended for use on Earth. Recently, and of direct relevance to global environmental data collection, the "Group of 77" developing countries has held that dissemination of data obtained from space should not be done without the prior consent of the sensed country. The reluctance of industry to report pollution emissions data to international agencies has also become apparent.[7]

Another related issue that may bear on national willingness to participate in global data collection is that even with the Outer Space Treaty, some countries continue to press for limits on transborder flows of data, ranging from intracorporate international transactions to satellite broadcasting of mass media.[8] The former concern relates to the exertion of sovereignty over data flowing above a country's airspace; the latter claim reflects the purported concern that broadcasting from other countries can undermine national cultural identity. In both cases, control of the technology has been a focal point of international debate.[9]

Monitoring has generally figured little, if at all, in the case of past international resource and environmental agreements. Rather, compliance has tended to be voluntary and, if verified, then verified by self-reporting. For example, the 1992 U.S. Congress General Accounting Office report cited above observes that "because no supranational enforcement body exists, peer or public pressure . . . is generally the primary mechanism for enforcing multilateral agreements" (p. 2). The report also notes that "[some] international environment experts have proposed measures to strengthen international oversight as well as parties' capability to comply with agreements" (p. 3), but that "additional monitoring may not be readily accepted by some nations. . . ." (p. 5).[10]

An issue inextricably linked with monitoring concerns, but which seems to be inadequately addressed in discussion of global data collection, is what actions might ultimately be taken in response to monitoring information. Interpretation and use of the data presumably could lead to some responsive action, possibly including calls for sanctions or restrictions on activities that affect the environment.[11] If individuals, businesses, or nations as a whole perceive themselves to be victims rather than beneficiaries of the actions taken in response to the information revealed, then these concerns will severely challenge the workability of international cooperation. An example might be "cleaner" countries demanding that "polluting" countries reduce industrial emissions, on the basis of information obtained during the process of assembling the global database.[12]

Several sources of indirect observation offer insights into how the role of monitoring and subsequent actions might be perceived by various nations. One source is the public record of nations' expressed concerns about remote sensing, data dissemination, and transborder data flows. The record permits some hypotheses about how these concerns may impede willingness to agree to international data collection, and how the concerns might be mediated through provisions to restrict or limit data access, safeguard national identity in scientific use of the data, or otherwise accommodate concerns.[13] Of key importance also are the potential "winners" and "losers" in actions taken in response to environmental information, assuming that these actions may influence participation. The growing literature on the distributional burden related to environmental action, particularly mitigating greenhouse gases, offers some clues.[14]

ISSUE 3: THE ROLE OF TECHNOLOGY

A third special issue related to collecting global data centers on the technology likely to be employed. Advanced technologies, including space-based remote sensing and sophisticated computer management and data analysis, are key components of proposed plans. The space-based vantage point of these systems permits them to gather detailed information on natural global processes as well as activities such as industrial emissions, deforestation, and other indicators of demographic and economic change. Also for these reasons, technology is a key determinant of the enforceability that might render environmental agreements effective (say, monitoring agreements to reduce emissions).

At the same time, technology (particularly space and information technologies) can be an instrument for demonstrating national technological prowess and leadership—highly visible manifestations of national sovereignty. Such arguments have traditionally strongly figured in nations' justifications for developing autonomous national space programs. This is the case both among developed countries (the United States, Europe, Japan, the former U.S.S.R.) and developing countries (India and Brazil, for instance, allocate sizable resources to civil space technology).[15]

This dimension of sovereignty may have significant implications for negotiating and organizing global data gathering. Nations that have the technology may seek to use the activity as a means of asserting technological expertise, demanding that their technologies be chosen or that they share in construction and operating contracts.[16] At the same time, the significant invasive capability of the technology may make nations without it reluctant to agree to participate. Countries may also demand that technology be transferred to them in exchange for permitting information collection within their borders.[17]

The role of technology suggests several questions: How does ownership and operation of technology as a means of demonstrating technological prowess influence nations' willingness to participate in a global, advanced technology-based data collection effort? Will they require ownership of some (or all) components of the technology? If a nation has an ownership share in the technology, then might it be less inclined to complain about the invasiveness of sensing? What are the disadvantages and advantages of various types of linkage (sharing construction contracts, operating a technology transfer fund) as possible answers to "what if" questions about the role of technological sovereignty?

ISSUE 4: RECONCILING NATIONAL SOVEREIGNTY AND INTERNATIONAL COOPERATION

One interpretation of the concepts of national sovereignty and international cooperation borrows heavily from political science, law, and philosophy.[18] These schools of thought identify the set of individual and collective values that contribute to the strength of attitudes toward sovereignty and cooperation. (Most frequently cited are cultural norms, historical experience, vested political interests, economic concerns, religious persuasions, and legal precedent). The literature is less clear about exactly how these values become aggregated and ultimately represented in national positions, although it notes generally that the aggregation takes place through the political process. Current events—such as the difficulty obtaining approval for the Maastricht Treaty in Europe and the ethnic contention and violence in Estonia, Bosnia, and other countries—raise new questions about tensions between sovereignty and nationalism.

Some of the literature suggests that sovereignty and cooperation need not be at opposite ends of a continuum demarcated "going it alone" at one end and the subsuming of national identity for the sake of cooperation at the other. In practice, it does appear that some mechanisms established through international negotiation accommodate both sovereignty and cooperation—they are not necessarily mutually exclusive. One straightforward example whereby extensive cooperation has been achieved and sovereignty maintained is in the case of setting international standards (for example, in labeling pharmaceuticals and in standardizing some units of engineering measurement). Examples abound, however, in which standard setting has failed to take place precisely because it cannot accommodate sovereign economic and other interests—instances include the marketing codes for infant formula and health and environmental standards for pesticides and toxic chemicals. Thus the question arises as to why standardization is accepted in some cases but not in others.

Another mechanism might be structuring agreements to give one entity or group of entities a leadership role, even though all parties make financial contributions. Historically, however, financial considerations have been contentious. A cost-redistribution mechanism of some type probably is essential to achieve broad-based participation, but experience indicates that no mechanism seems superior (whether for United Nations' or specialized U.N. agency funding, environmental agreements, or international space cooperation, where disputes have arisen over the allocation of spacecraft construction contracts among members of the European Space Agency, for example, and the allocation of membership shares in the International Telecommunications Satellite Organization [INTELSAT]).[19]

This discussion suggests that specific questions focusing on sovereignty and cooperation in relation to global data collection include the following: Are sovereignty and cooperation indeed the dominant national attitudes that must be accommodated in agreeing to collect international data? If so, what motivates cooperation in pursuit of a collective good like environmental data? Must the activity offer mutual gain to all parties? Could cooperation be driven by the desire to redistribute the benefits and costs of environmental protection? How can uncooperative attitudes be anticipated and reconciled? Can attitudes change during negotiation?

In translating concepts of sovereignty and cooperation into practice, these concepts become manifested in both economic/utilitarian and political/institutional influences on negotiating behavior and willingness to form agreements. From the former literature it appears that the degree of impatience for realizing the benefits of agreement, attitudes toward risk, and the nature of options available in the event of disagreement all affect negotiation incentives. The incentives expressed by negotiators reflect a variety of attitudes expressed by individuals and groups within individual societies. Those attitudes in turn reflect the state of scientific knowledge, political circumstances, and many other factors.[20]

Political/institutional constructs raise similar issues while focusing somewhat more on the process of agreement. For example, Young (1989) identifies several factors that, if present, contribute to the formation of an international cooperative regime. Roughly speaking, these factors include (1) an emphasis on discovering common interests versus deadlocks over distributional quarrels; (2) the feasibility of acceptably fair (even if imperfect) outcomes; (3) the existence of focal points to guide bargaining; (4) the feasibility of straightforward compliance mechanisms; (5) motivation for agreement due to urgent needs or crisis; and (6) the presence of effective leadership.

In the case of data acquisition, both of these literatures can clarify the role sovereignty may play as one of the determinants of initial focal points around which beginning bargaining postures are framed. It may also then be possible to consider some of the influences that may alter the focal points during the course of bargaining, including shifts in attitudes toward sovereignty. Examples might include changing public awareness of Earth ecosystems and processes, the arrival of new scientific information about the effects of human activity on these processes, and national economic growth.

A pragmatic and essentially inferential approach to assessing these factors observes how countries have behaved in recent resource-related negotiations, in the conduct of their own and international space and other advanced technology activities, and in assuming public positions on remote sensing, the exchange of scientific data, and transborder data flows. The roles of economic and to some extent political interests as influences on negotiating behavior and in motivating cooperation are also relevant.

Given this level of aggregation, such an approach masks many of the underlying determinants of these attitudes. Nevertheless, it does allow a focus on factors that might be more readily accommodated within the sphere of influence of negotiators (for example, structuring an agreement to accommodate economic interests in contrast to bringing about change in a nation's cultural norms). Examples in the case of global information might include accommodating sovereignty through providing for limited legal jurisdictional authority (perhaps limiting data access or assigning priority to access); the allocation of voting rights or the stipulation of voting procedures (such as majority voting and veto power); the geographic location of data management facilities; the sharing of financial responsibility; and the linkage of national participation to technical assistance or other forms of aid.[21] Examples specifically related to the collection of space- or remotely-sensed data may include agreements that limit the spectral, temporal, or resolution characteristics of the data. Each of these possibilities, and the options for the agreement process itself, must be scrutinized to consider its contribution to equity in allocation, procedural fairness, and political viability.[22]

A STYLIZED EXAMPLE

Table 1 contains a stylized example of this approach. The table lists by country or group of countries attitudes toward sovereignty and cooperation in several settings, including postures taken toward advanced technologies (predominantly space technology), remote sensing, transborder data flows, and the global environment.[23] Reading across any row of entries in the table indicates significant variation across countries and groups of countries. In almost no case is either sovereignty or cooperation alone consistently marked. (Rather, the rows are combinations of these attitudes).

One implication of the entries in the table is that countries willing to cooperate on environmental issues may also be quite protective of their own efforts to assert technological prowess. If so, these countries might want the

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Illustration of Conflicting Attitudes Underlying Willingness to Participate in Global Environmental Information Acquisition and Monitoring

	ADVANCED TECHNOLOGY PROGRAMS		REMOTE SENSING		TRANSBORDER DATA FLOWS		GLOBAL ENVIRONMENT	
	National Sovereignty	International Cooperation	National Sovereignty	International Cooperation	National Sovereignty	International Cooperation	National Sovereignty	International Cooperation
United States	++	+	-	++	-	++	+	+
Japan	++	-	?	?	-	+	++	-
China	++	--	+	-	++	--	++	+
France	++	-	+	+	++	-	?	?
India	++	-	++	-	++	?	++	-
Brazil	++	+	++	-	+	-	++	+
Canada	+	+	+	-	+	-	+	++
United Kingdom	?	?	?	+	-	+	++	++
Australia	+	?	?	?	-	+	?	?
Former U.S.S.R.	++	-	+	++	++	--	++	-
Czechoslovakia	?	?	+	?	+	-	++	+
Poland	?	?	+	?	+	-	++	+
Bulgaria	?	?	+	?	?	?	?	?
Hungary	?	?	+	?	+	-	++	+
Sierra Leone	?	?	?	?	+	-	?	?
Argentina	?	?	+	?	?	?	?	?
Chile	?	?	+	?	?	?	?	?
Egypt	?	?	+	?	?	?	?	?
Indonesia	?	?	+	?	?	?	?	?
Mexico	?	?	+	?	?	?	?	?
Group of 77	++	?	++	-	++	-	++	+
Europe	++	+	+	+	++	-	+	++
NGOs	++	+	?	++	?	?	--	++

KEY:

++ figures prominently in actions and public statements

- figures less prominently in actions and public statements

+ figures somewhat in actions and public statements

-- does not figure in actions and public statements

Sources: See text.

lead in building or operating the technologies related to global information acquisition (and thus would want their own satellites or computing facilities used). Other countries might hold out national sovereignty concerns over being sensed as a rationale for transferring high technology to them.

In addition, national postures may change over time. Indeed, changes in national leadership or in public and scientific understanding, economic developments, and other factors may reorient these perspectives. These factors would influence the type of information in the table.[24]

What might be the consequences for the scientific value of data "withheld" by countries or regions for which national sovereignty appears to weigh heavily? Participation could be withheld if sensors had to be turned off over nonparticipating countries, or if ancillary ground-based data about population, natural resources, industrial emissions, or other information necessary to interpretation were withheld or, where possible, physically concealed (say, by enclosing industrial facilities so they can't be observed from the air). As noted earlier, there is some information about the relative importance of data; for instance, there are large gaps in data about non-agricultural ecosystems in particular and certain countries and regions in general. Based on Table 1, countries such as the former U.S.S.R., China, India, Poland, and Hungary could be critical hold-outs.

What institutional mechanisms might induce the participation of countries whose withholding of information is particularly critical? The mechanisms might be formal or informal, and economic, legal, or based on "moral suasion." Their consideration is key to the efficacy of international arrangements that loosely "coordinate" autonomous systems (e.g., the Committee on Earth Observation Satellites [CEOS]—see Gibson 1992) or more formally institute a global consortium (see McLucas 1985; McElroy 1986).

NOTES

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1. For a discussion of cooperative activities, see Lauer (1990) and references to ground-based cooperative activities related to NASA's Earth Observation Programs in NASA (1984). The Committee on Earth Observation Satellites (CEOS), created in 1984 as a result of the International Economic Summit of Industrialized Nations, serves to coordinate space-related Earth observation activities but has primarily focused on technical issues of standards and compatibility of systems rather than decision-making in response to information generated by the activities.

2. Certainly experience in negotiating international resource agreements such as the Law of the Sea Agreement, the Outer Space Treaty, the Antarctic Treaty, and the recent Montreal Protocol (to reduce production and use of chlorofluorocarbons) has demonstrated sharp conflict between attitudes toward cooperation and sovereignty. For example, see the discussion in Akehurst (1982), Alexander (1969), Burtraw and Toman (1992), Caldwell (1990), Epstein and Gupta (1990), Grubb (1989), Jamieson (1991), Mericq (1987), Morrisette et al. (1991), Sagoff (1988), Sand (1990), Shapley (1985), and Swanson (n.d.).

3. More than 60 percent of an annual $1 billion U.S. budget allocated to global climate change during fiscal years 1990 through 1992 was targeted at information collection and management, principally the construction of a proposed space-based Earth-observing system ("EOS") and new computing and data storage and analysis facilities.

4. A similar argument applies to why organizations such as the International Telecommunications Satellite Organization (INTELSAT) or the International Maritime Telecommunications Satellite Organization (INMARSAT) are not good paradigms. INTELSAT and INMARSAT involve the devices to communicate the information (that is, the transponders), not the information itself.

5. See the detailed discussion in Sombroek (1990), Bolin et al. (1979), and Mathews (1987).

6. The treaty defines out space itself as a *res communis humanitatus* regime, or the common heritage of mankind, but the nature of activities conducted in outer space has remained a significant issue. (National sovereignty extends over air as opposed to outer space; international air transport occurs by way of a network of bilateral treaties giving permission to fly through national air space.) See the discussion in Akehurst (1982), Christol (1986), Florini (1988), U.S. Congress OTA (1984), and Glaser and Brender (1986).

7. See Ember (1992).

8. Most recently, see Jones (1992) for a discussion of governments' desiring control over international satellite broadcasts into Japan, Indonesia, China, Singapore, Malaysia, and other Asian countries.

9. See papers in Nordenstreng and Schiller (1979), especially Pool, and in Lundstedt (1990–book), especially De Stefano and Ajami. See also Dizard (1986).

10. The report reviewed 8 out of 168 international environmental agreements in which the United States participates or has significant interest. These eight concerned problems of global or regional impact: the Montreal Protocol (ozone depletion); the Nitrogen Oxides (NOx) Protocol (acid rain, air pollution); the Basel Convention (hazardous waste disposal); the London Dumping Convention (marine pollution); the International Convention for the Prevention of Pollution from Ships (MARPOL); the Convention on International Trade in Endangered Species (CITES); the International Whaling Convention; and the International Tropical Timber Agreement (deforestation). See also Grubb (1989) and the discussion in Morrisette et al. (1991), especially about voluntary compliance in European agreements to mitigate acid rain. Note that remote sensing could play a role in monitoring all of these activities.

11. In this regard, the data acquisition project becomes linked to international negotiations on the environment.

12. Smith and Justus (1990) are among the first to acknowledge that actions anticipated as an outcome of global data acquisition may be a disincentive for countries to agree to the data activity. Burtraw and Toman (1992) analyze a related issue, that of fairness as perceived as an outcome of negotiations to take action to reduce greenhouse gas emissions. See also the brief discussion of the relationship between space remote sensing and actions that ultimately challenge individual privacy and national sovereignty in Macauley (1990) and Florini (1988). Macauley and also Russell, Harrington, and Vaughan (1986) describe the interaction of information collection and subsequent action; they recount the surfacing of constitutional issues in the United States when the Environmental Protection Agency used aircraft photography of a corporate site to monitor and enforce compliance with environmental legislation. The U.S. Supreme Court held in 1986 that aerial photography of an industrial plant from navigable airspace is not a search prohibited by the Fourth Amendment. See "Second Aerial Surveillance

Case Accepted," *New York Times*, June 11, 1985, p. A16, and "Supreme Court backs the EPA in Dow Dispute," *Wall Street Journal*, May 20, 1986, p. 4.

13. Also of importance here are the consequences of instituting preferential data access within the science community if some members compete to be the first to publish research based on the data.

14. For example, see Manne and Richels (1990); Epstein and Gupta (1990); Nordhaus (1990); Grubb (1989); Chapman and Drennen (1990); and Morrisette et al. (1991). Branscomb (1985) and Cleveland (1985) offer related discussion about the value placed on "rights to know" and information as "empowerment"—both reasons why limiting data access might be controversial.

15. For additional discussion, see Business–Higher Education Forum (1986); Cleveland (1985)—especially for discussion of empowerment provided by information technologies; Committee on Space Policy (1989); De Stefano (1990); Dickson (1987a and 1987b); Florini (1988); Greenhouse (1989); Whitehouse (1986); Gavaghan (1987); Macauley (1990); and "Watch this space," *Manchester Guardian Weekly* (1987). In the United States, the initiative to undertake a large-scale Earth observation program has been both justified and criticized on the basis of the technological challenges posed by designing and operating satellites and computer systems to manage and interpret the satellite data. McElroy (1986) provides detailed discussion.

16. The issue may be much less important, however, if duplicative efforts by more than one nation to own and operate a global information system do not significantly raise costs relative to a single international system. See Macauley and Toman (1990).

17. Technology concerns have to date figured less visibly in international discussion of other environmental issues, although, as noted earlier, technology transfer funds to accommodate treaty compliance have been linked with agreements in several cases. As technologies for environmental protection, monitoring, and compliance develop, such considerations might be expected to play a larger role. For example, a provision in the new U.S. Clean Air Act establishes tradable emissions permits to control sulfur dioxide emissions of utilities. Experts note that such a provision has been made possible only by the development of low-cost, continuous emissions–monitoring technology. To date, technology has been most prominent as a consideration in the development of international agreements on arms control, with the nature of the agreements strongly determined by developments in remote-monitoring technology (spy planes, satellites).

18. For example, see Caldwell (1990), Akehurst (1982), Cleveland (1985), Francis (1991), Huntington (1973), Lundstedt (1990), Nordenstreng and Schiller (1979), and Sahlins (1972). The economic literature on the provision of collective goods and cooperation in their provision is also relevant. This literature is huge; especially useful examples directly or indirectly relevant to the context of information acquisition include Kindleberger (1986), Cornes and Sandler (1986), Swanson (n.d.), Isard (1988), Raiffa (1982), and Cooper (1986). Also relevant is the literature on honest preference revelation in cooperation, e.g., Myerson (1979).

19. For a discussion of U.N. funding, see "Bush vetoes foreign aid bill . . . " (1989), MacQueen (1985), Knight (1992), and "How Japan missed the boat" (1990). Zurer (1992) reports on argument over the control and size of multilateral funds for helping developing countries finance ozone-safe technology.

20. Discussion specifically in the context of environmental negotiations is offered by Morrisette et al. (1991) and Burtraw and Toman (1992).

21. Examples of such provisions include establishing sovereign territory (such as coastal zones in the Law of the Sea Agreement or national air space as demarcated in international law), reconciling the timing of treaty compliance (as the Montreal Protocol does in phasing in restrictions rather than immediately banning pollutant emissions, to mitigate economic dislocation), providing funds to transfer new technologies to countries to assist them in complying with treaties (as in the Montreal Protocol), and linking alternative forms of compensation to treaty acceptance (such as debt-for-nature) swaps. See also Burtraw and Toman (1992) for a discussion of linkage in international negotiation over carbon dioxide reduction.

22. For example, while linkage among related aspects of the same issue is conventional advice by bargaining theorists as a mechanism to expand gains from trade, in actual practice linkage in international negotiation has particularly controversial connotations. In the context of negotiations to address global climate change it has been suggested that a preliminary topic in discussions be a restriction of the agenda to prevent coercive linkage.

23. Entries were determined based on government position papers, excerpts from speeches of national leaders, newspaper and other accounts of national activity (in advance technology areas), and voting records and other records of positions on environmental agreements and terms of treaties (including the Outer Space Treaty and reports from meetings of the Committee on the Peaceful Uses of Outer Space, a United Nations organization, especially discussion addressing remote sensing and transborder data flows—for example, see the chapters in Christol [1982] on satellite television broadcasting and remote sensing). In some cases we draw directly from policy statements (typical examples are statements emphasizing sovereignty as a driver of space or other technology activities). In many cases we draw our own conclusions based on our perception of the tenor of the discussion.

24. Jamieson (1991) emphasizes the role of environmental information as communicated between the science community and the public and between the public and decision-makers. His discussion provides additional structure for considering the role information interpretation and communication may play in influencing the entries in Table 1 at different points in time.

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INTELSAT, INMARSAT, and CEOS: Is ENVIROSAT Next?

John H. McElroy

Abstract

When the nations of the world were faced with the large capitalization costs for international satellite telecommunications, INTELSAT was born. Shortly later, a similar challenge for satellite maritime telecommunications led to the formation of INMARSAT. Over the next decade, approximately fifty Earth observation satellites will be launched by the spacefaring nations of the world. They represent an investment on the order of at least $12 to $15 billion. Most of these satellites will be "one-of-a-kind'" ventures with no commitment for follow-on services, yet they will stimulate an appetite for further Earth observation data, both among the users participating in the missions and the bystanders who may look with envy on the results.

Today there remains a premium on painting a nation's flag on the bulkhead of a satellite as a sign of national technological prowess and as an implication of potent capabilities in other arenas. The stimulation of pride will wane, while the need for data will grow. At some point, the nations of the world must face the question of the efficient implementation of a global observing system, or at least no more than a few, that serves in an economically efficient manner all of their needs. Countries unable to afford their own satellite may well be willing to participate in a shared-ownership system. The ability to rely upon a continuing stream of data will inspire confidence among and expand the user base for Earth observation data. The present response of the spacefaring nations is the voluntary Committee on Earth Observation Satellites (CEOS), which can provide no guarantees of continued data availability, although commendable collaborations on particular missions do indeed result. These voluntary efforts might better be supplanted by a formal international consortium that I have dubbed ENVIROSAT.

John H. McElroy is dean of engineering at the University of Texas at Arlington.

The view of the Earth from space began with the tumbling camera payloads launched from White Sands on captured V-2 rockets and continued with cameras carried by balloons and the X-15 rocket craft. However, the first practical applications of this view came from the higher "tower" of the artificial Earth satellite and the early weather satellite of 1960. In the intervening thirty-two years, automated spacecraft have imaged the entire Earth for weather, ocean, and land applications serving both the civil and military communities. Piloted spacecraft in earthly and lunar orbit have given momentary glimpses of the Earth with good resolution but without continuity or consistency. Aircraft continue to play a role also, but for localized phenomena and in situ measurements of atmospheric constituents. Gaining the continuous global synoptic view is the exclusive province of the automated Earth satellite.

Putting aside the inspirational perspective of the "big blue marble" viewed from lunar orbit and also putting aside the similarly inspirational urge to explore new lands, space is a rather mundane matter, although of course it is really the absence of matter. It provides merely a convenient vantage point, one higher than any available through other means. From this vantage point, the visibility of great areas makes using communication and navigation repeaters and transmitters easier; more to the point of this paper, it makes possible the continuous monitoring of natural and anthropogenic changes on planet Earth.

Having gained this new perspective on Earth, humankind will not willingly retreat from it. The urge to explore Earth remains but is preempted by the pressing need to understand its changes. The observation of the Earth from space has become an accepted, even mandatory aspect of the programs of the spacefaring nations. In Europe, for example, the demise of the piloted Hermes spacecraft project is accompanied by a European Space Agency Council decision to make Earth observations a permanent part of its program. All spacefaring nations give high priority to Earth observations, and all users of space-derived data rely increasingly upon it for the support of routine daily activities.

Application of the technologies for observing the Earth from space is arguably the greatest single achievement of the Space Age. Yet with this success come problems and complexities. The appetite for Earth observation data has been created. How shall it be satisfied?

THE PAST

The first weather satellites quickly proved useful in serving human needs. While their contribution to short-term weather forecasting remained controversial for decades and even remains so for some investigators today, the synoptic images they provide give indispensable insights regarding the paths of severe weather. Inaccessible regions of the Earth, notably in the Southern Hemisphere, are routinely analyzed using weather satellite data, where once only sparse ship reports existed.

The United States, both in the civil and defense sectors, moved rapidly to capitalize on this new data source. The Tiros and Defense Meteorological Satellite Program (DMSP) satellites became continuing operational systems, and were soon joined by others from the former U.S.S.R. They were soon followed by geostationary weather satellites deployed first by the United States and then by Europe, Japan, and India. Today, European nations have created an operational weather satellite organization, EUMETSAT, and have agreed to the provision of a polar-orbiting satellite in addition to the geostationary METEOSAT spacecraft.

However, the application of satellite data to other Earth applications came more slowly as budget authorities vigorously resisted the further proliferation of Earth observation satellites. In the face of strong opposition from budget authorities, aided by those who favored aircraft measurements or feared the revelations that might flow from civil systems that intruded where only classified systems had existed, the LANDSAT program was born, although with a crippled data system that budget authorities ensured could serve no application requiring rapid data.

Despite severe handicaps and unenlightened oversight, the LANDSAT program continues to make contributions and grow in importance. The U.S. program was joined first by the very capable French SPOT system, then by systems from Japan, Europe, and elsewhere. The feasibility of making land cover maps from space, aiding in the exploration for resources and monitoring pollution and its effects, has now been proved.

After the land satellites came the ocean satellites. These have tended to rely upon passive and active microwave measurements, but they employ some visible wavelength electro-optical measurements as well. Sea surface topography, sea state, significant wave height, sea surface temperature, and ocean color are some of the principal measurements that have been made. The short-lived SEASAT gave way to Nimbus-7, military satellites, and civil satellites from Russia, Japan, and Europe.

Alongside these developments came the workhorse Tiros satellites, which have proved their utility in complementary measurements of ocean, lake, and land conditions. They also have become a convenient platform for data collection systems, solar activity monitors, and search-and-rescue transponders.

By the 1990s, many players were involved in Earth observations as providers and users of data. National and regional facilities in space and on the ground served national, regional, and even worldwide users. The weather event detected in one region quickly becomes the burden borne by adjacent regions. Shared facilities make affordable capabilities that would otherwise be unavailable, as when a satellite receiving station in Thailand serves much of Southeast Asia. The ash cloud of a major volcano rapidly produces global effects and an El Niño event off the western coast of South America produces its own worldwide ripples of severe weather. Collaborative efforts have proved both desirable and necessary.

THE FUTURE NEEDS

No technology is static, and Earth observation technology is no exception. In this instance, however, it is driven by the rapidly expanding needs of growing populations, increasing pollution, the escalating data needs of a complex society, and dwindling natural resources. Technology barely keeps pace with human needs and may not prove feasible or affordable in the long term. Nations and agencies often can muster the resources needed to orbit a single research mission, but the commitment to provide a permanent capability and continue its evolutionary advancement requires far more resources.

In a broad sense, the future needs for Earth observation data are quite evident. The details of instrument design, the optimization of the payload for a given satellite, and other technical details may be controversial, but such disputes must not be allowed to obscure the broader agreements. There can be no dispute that the Earth must be mapped. A 1:100,000 map does not exist and is badly needed. A 1:25,000 map could be used today, but will be vital in the future. Global land cover maps and their periodic update are another readily evident need. The atmosphere must be measured for its slow changes in chemical makeup and for its rapid, dynamic changes governing meteorology. The ocean must be monitored as well over varying time scales. Ocean pollution may be slowly evolving or the result of a sudden event. Surface dynamics are important to mariners, but the characterization of the ocean-atmosphere interface is likewise increasingly important to the modelers predicting the weather several days in advance.

However evident the needs may be, the technology and the systems employing it must be affordable. A rush of national enthusiasm may support the development of a sui generis system as evidence of technological prowess, but the day-to-day drudgery of providing consistent, continuous data can tax that enthusiasm. A nation's pride in having its flag painted on the side of a new satellite may wane when the fifteenth or twentieth expensive satellite is launched. If a nation still requires the data, it may find that sharing the pride with another nation or group of nations in exchange for a lower cost is a desirable action.

CEOS AND ITS LIMITATIONS

Collaboration among agencies and nations is common in Earth observations. Weather data are exchanged, and even satellites have been diverted to meet the needs of another region. Satellite builders are guided by agreements on data formats that allow many countries to enter into the purchase of expensive ground equipment with the assurance that the data stream to be analyzed will not suddenly change in character or format. Within their capabilities, agencies coordinate the deployment of their missions to maximize the utility to all. Nations also provide instruments for flight on other nations' spacecraft. The Tiros spacecraft, for example, carries instruments from Canada, France, and the United Kingdom.

In the next decade or so, the nations of the world will be orbiting approximately fifty satellites devoted to Earth observations. If each satellite costs an average of $300 million or more, including launch costs, the total investment is $15 billion or more. In many if not most cases, the cost per satellite would be much higher. A comparable amount will be invested in ground facilities.

Nearly a decade ago, as a part of the work accompanying the annual Economic Summit of Industrialized Nations, I founded and served as the first chairperson for the Committee on Earth Observation Satellites (CEOS). The primary objectives of CEOS (paraphrased slightly from "the relevance of satellite missions to the study of the global environment," CEOS background paper prepared for the United Nations Conference on Environment and Development [UNCED], Rio de Janeiro, 1992) are as follows:

- to optimize the benefits of Earth observations from space through cooperation in mission planning and in the development of compatible data products, formats, services, applications, and policies;
- to serve as the focal point for international coordination of Earth observations from space, including activities relating to global change;
- to exchange policy and technical information to encourage complementarity and compatibility among Earth observation systems currently in service or development and the data received from them;
- to address issues of common interest across the full spectrum of Earth observation satellite missions.

These are commendable and necessary objectives. They are, however, not sufficient. The CEOS framework that was established for cooperation has no authority. The participating nations have done splendidly to date, but in a climate where each was able to persuade the relevant budget officials to proceed unilaterally or as part of a regional consortium. Though discussions with budget officials are never easy, nevertheless the nations were able to describe the pioneering nature of the measurements to be made and the contribution the program would make to enhancing the capabilities of high-technology industry. These arguments work best for the initial spacecraft in a program; they grow less persuasive as the program becomes more established and consequently more routine.

As nations move beyond the early, exploratory Earth observation missions, two needs will have to be reckoned with: (1) the need to guarantee the continued availability of Earth observation data upon which the nations have come to rely, and (2) the need to obtain the data at an acceptable national cost. Neither of these needs is adequately met within the framework of a voluntary organization. CEOS cannot assure nations that their reliance upon another's programs is warranted. Nations participating in CEOS are still free to adjust their missions (approval, schedule, payload, etc.) according to their own national processes—and without regard to international consequences. A nation that has come to rely upon the availability of certain data, and that has no assurance that it will be reliably available from an international partner, will find it necessary to provide the data through its own systems.

THE MARKET

There are many myths plaguing the discussion of Earth observations. Among the most troubling are those related to markets. Markets are sometimes assessed in terms of potential sales of computer-compatible tapes or CD-ROMs of geolocated, radiometrically calibrated data. Concern is then expressed at the slow growth of the market for such products and the inability of the market to fund the space segment. Attention is then directed to barriers to adoption of the new data source. Such discussions are badly misguided and fatally flawed. Such satellite data have little value in that form. They may gain some value through comparison with past satellite data, where change detection is sought, but in general they gain value only in their merger into GIS and GIS-like information systems that merge the satellite data with many other data sources and apply specialized processing techniques to them. The processing techniques may be proprietary or simply so demanding of computer capability that they can be done only at a few locations. Equally important, the intended application of the final analysis is highly likely to be a governmental one, whether national, state, or local.

Markets are sometimes assessed according to land, atmosphere, or ocean data products—or even according to whether the data arise from a LANDSAT, METSAT, or SEASAT. The idea of having Earth observation satellites tailored to particular "spheres" (e.g., hydrosphere, lithosphere, biosphere, or atmosphere) had some utility in the early days of remote sensing. It helped focus the approval processes for the missions and it was consistent with the payload capacities of the spacecraft that could be built with existing technology. However, electro-optical sensors in a given orbit provide data of utility to understanding all of the "spheres." Microwave sensors explore vegetation cover and ice sheets with equanimity. The need to provide frequent sampling of changing conditions leads to morning and afternoon satellites, and the differing scene lighting conditions affect some of the choices of instruments to fly on spacecraft in a given orbit. The need for securing reliable measurements leads to employing a degree of redundancy in providing spacecraft with instruments. Such terms as "land," "weather," and "ocean" satellites are nonsensical. From a particular orbit, certain features of the Earth can be observed. Those features are related to the parameters of the orbit, the relationship of the orbit to the Sun, perhaps the thermal inertia of the observed objects, and so forth.

Therefore, the current divisions separating land satellites from weather satellites and weather satellites from ocean satellites are artificial and promote wasteful and inefficient system designs. Proper systems analysis would

optimize the deployment of carriers of Earth observation instruments into orbits appropriate to the use of those instruments.

Markets are also often subdivided according to whether they are public or private. Public markets are frequently discarded as being somehow of lesser value. Governments buy paper to conduct their business; they buy computers to carry out their analyses; they buy motor vehicles to transport people and goods. The funds come from governmental appropriations, but no one challenges the validity of including these government purchases as a legitimate market. In some cases, as in the instance of NOAA, the "purchase" is less direct, in that the governmental appropriation funds the securing of certain data. However, the relationship between the appropriation and the desired data is quite direct. The purpose of the appropriation is to obtain particular data the nation has determined is worth a given "price," where the "price" is the size of the appropriation. Therefore, whether the government buys the data from an outside source or buys from itself, as in the case of NOAA, the true measure of the market is the appropriation.

If this assertion is accepted, then the true market for Earth observation data is robust and very large, because it is measured not by the paltry sales of a few computer tapes, CD-ROMs, or photographs, but by the willingness of governments to appropriate funds for this purpose. This suggests further that these funds might be available to support an international collaborative effort, particularly if the collaborative effort could provide enhanced services at reduced national cost.

INTELSAT AND INMARSAT

The nations of the world have been faced with a similar challenge on two past occasions. They responded by creating the International Telecommunications Satellite Organization (INTELSAT) and the International Maritime Satellite Organization (INMARSAT). In both instances, governmental action precipitated the formation of a new international organization to provide a global service that could be more efficiently provided by joint action. There were obvious economies of scale and scope, and a relatively straightforward way in which standard communications products could be defined.

Among the features of INTELSAT and INMARSAT germane to this discussion are the shared funding arrangements, governance structures, and practices regarding industrial share. Influence in the organization is tied to funding level, but the bodies overseeing operations employ both a representational and a weighted voting.

On a regional scale, there are still other examples: EUMETSAT and EUTELSAT. The conclusion of any such review is that nations have a number of existing models that might be employed in providing a better and more authoritative oversight of Earth observations.

TELECOMMUNICATIONS VS. EARTH OBSERVATIONS

There are both similarities and dissimilarities between telecommunications and Earth observations. Both require extensive space and ground systems. System usage is not uniformly distributed geographically, nor is the capability to participate in the manufacture of system elements. Both can benefit from economies of scale in the procurement of the space segment. Sufficient expertise exists to permit reasonable industrial share practices in either instance, although there are longstanding complaints regarding this issue in both telecommunications organizations.

A significant difference is the balance between governmental and private services. The telecommunications industry has a major public role but is largely financed via its commercial operations. INTELSAT benefited from an early government contract but its revenues are now dominated by private services, although the party with which agreements are made is in most cases a governmental agency (PTT).

In Earth observations, the balance will be tipped in the other direction. Most functions supported by Earth observations are governmental functions (weather forecasting, land-use planning, disaster assessment, mapping, environmental assessments, etc.). Even functions such as crop forecasting have strong governmental roots, though there are some private activities. As a result, government subscriptions would be an Earth observation entity's principal source of revenues. Furthermore, the U.S. practice of employing a commercial entity to represent it in international satellite telecommunications may not be as appropriate in Earth observations. In the past I have advocated the use of a commercial entity, namely EOSAT, but that may not be an appropriate policy. A small governmental group charged with aggregating requirements and securing the governmental appropriation via the Office of Management and Budget and the Congress may prove to be a better choice.

ENVIROSAT

I chose the name ENVIROSAT nearly a decade ago to describe an international consortium for Earth observations. Others have also described similar consortia, most notably John McLucas and Paul Maughan. The most plausible organizational structures address all aspects of Earth observations and ignore the artificial distinctions between weather, ocean, and land observations noted above.

The governance structure would be derived from the experience that has been gained with INTELSAT, INMARSAT, EUMETSAT, and others. It would, of necessity, be treaty-based to avoid the weaknesses of lesser degrees of commitment. The initial participants would be those currently playing a role in CEOS, with a near-term emphasis on the spacefaring nations. The expansion to data-using nations and the role they might play would be a subject for the consortium to address.

ENVIROSAT would provide both the geostationary and low-altitude space segments and the ground systems that control and monitor them. Standard geostationary and low-altitude spacecraft buses would offer manufacturing economies. ENVIROSAT would also provide data processing facilities to serve those client governments or entities that have no such capability. ENVIROSAT would probably enter into licensing agreements with regional facilities for the global distribution of data. The experience with the LANDSAT Ground Station Operators Working Group and the Global Telecommunications System for the exchange of weather data both provide useful examples.

A major issue would be to ensure continuing advances in technology. Earth observation remains an evolving technology. The same was true also of telecommunications during the formation of INTELSAT and INMARSAT. In both instances, major advances in telecommunications technology have occurred and been incorporated.

EVOLVING TOWARD ENVIROSAT

The formation of such an organization cannot occur rapidly. There are major issues of national policy to be addressed by all participants. The concerns of defense agencies will have to be calmed. However, the world has come a very long way toward ENVIROSAT in the numerous and highly successful collaborative efforts that have developed since 1960. Some would say, "Why not leave collaboration to these informal arrangements?"

The current arrangements rely upon voluntary compliance and are largely dominated by project-oriented space agencies. Space agencies, for all their good qualities, are project-focused and tend to become bored easily—or their funding sources become bored easily. The continuing assessment of the Earth's environment and its changes is a permanent function that nations require. It is not a scientific exploration consisting of a single experiment that yields a definitive answer. Rather, the answers regarding global change and its consequences will emerge slowly and with considerable pain. Ensuring the collection of consistent, calibrated, long-term data sets on global change is a challenging task. Deploying and operating successive generations of highly capable space systems to monitor the Earth's short- and long-term dynamics requires a dedicated entity that single-mindedly pursues these laudable activities. It will employ space hardware simply as a means to an end, not as the end in itself. Understandably, that is not a characteristic of space agencies.

It is my contention that ENVIROSAT will indeed be next, that it will be the logical outgrowth of CEOS. The time scale is uncertain. Nations must satisfy their chauvinistic political objectives; they must demonstrate they have the expertise to design, manufacture, and operate Earth observing systems. Once, however, they recognize the permanence of the task—and the permanence of the task's claim on national resources—the move toward the efficiencies and economies of an ENVIROSAT will prove inevitable.