A Global Satellite Observation System for Earth Resources:

Problems and Prospects

A Report to the National Science Foundation on the Application of International Regulatory Techniques to Scientific/Technical Problems

by

Valerie Hood
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PREFACE

This report is part of the first stage in a two-stage research effort under NSF Grant No. GI 41472. The overall purpose in this research effort is to select, survey and explore the possibilities of actively applying the spectrum of existing international management and regulatory techniques to the practical solution of six selected scientific and technological problems requiring international action, and to suggest in a systematic way circumstances and conditions under which these various techniques might be applied toward the resolution of specific technology-related transnational policy issues. A major political-technological challenge of the future is to develop approaches, policies and institutions capable of coping with the burgeoning number of issues and problems that cannot be successfully managed within the confines of individual nations.

There has developed over the last few decades on the international scene a spectrum of regulatory procedures, techniques and approaches that are employed in a fragmentary way by various international entities concerned with widely differing, but generally highly specialized and non-political subjects. These regulatory and management techniques have not been subject to a thorough evaluation of the dynamic forces relating to their development and application, nor to the development and testing of working hypotheses regarding the conditions of an effective or ineffective regulatory regime and the conditions which influence the transferability of regulatory and management techniques to other problem areas.

The first stage of the project concentrates on problem-oriented research focused on six technology-related transnational policy problems, one of which is the subject of this report. The other five are pesticide residues in food, food reserve systems, the international regulation of pharmaceutical drugs, marine transport systems and regional fishing arrangements. In each of these six areas, an attempt is being made to grasp and project a decade ahead the evolving pattern of international scientific/technological relationships and to suggest a framework for their analysis that explores the range of possibilities for international action in each. In this problem-oriented report, and in the five others to be produced in this project, we are:

(a) Describing and analyzing the legal, political, economic and scientific/technological dimensions of the policy area examined;

(b) Defining the priority problems in the policy area for the ensuing decade;

(c) Evaluating the adequacy of existing institutions, and putative institutions, for coping with current and prospective problems;

(d) Identifying and evaluating alternative programs.

The research in the first stage is directed towards producing information, analysis and recommendations which will be of direct use to US decision-makers.

Once the first stage of this project has been completed, David Kay, the Principal Investigator, will, using the data collected in this first stage, begin the construction of a paradigm of international regulatory activity that will have explanatory power and analytical usefulness for the policy-maker and scholar. In this stage he will be seeking to describe the range of techniques operative at the international level and to analyze these techniques with a view to proposing and initiating testing of working hypotheses concerning the conditions associated with:

(a) Norm creation

(b) Allocation of costs and benefits

(c) Compliance with agreed standards

(d) Expansion of management, control and regulatory functions

(e) Transferability of management, control and regulatory techniques among scientific/technological areas.

In connection with the writing of this report, we are indebted to the personnel of the National Aeronautics and Space Administration and the United States Geological Survey's EROS Program for their patient help on all aspects of this report and for library facilities; the National Oceanic and Atmospheric Administration, especially the National Environmental Satellite Service for their advice and assistance; the Canadian Centre for Remote Sensing (Ottawa) and the Canadian Department of External Affairs for their assistance in the early stages of the project and for providing the satellite photograph of Lake St. Clair; the Australian Embassy for information on the use of LANDSAT imagery in the courts; the United Nations Committee on Peaceful Uses of Outer Space for the provision of documents, ideas and library facilities; the United Kingdom Mission and the United States Mission to the United Nations for copies of speeches; and the European Space Agency and the World Bank for the reports of their activities in the area.

This is a revision of an earlier report prepared by Valerie Hood with the research assistance of John McLean. In preparing the second edition of this report invaluable research assistance was provided by Mary E. Kimball. We all owe a special debt to Dorothea Bodison for the long hours spent typing endless drafts.

David A. Kay, *Director*,
International Organization Research Project
American Society of International Law

Washington
June, 1976

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A GLOBAL SATELLITE OBSERVATION SYSTEM FOR EARTH RESOURCES: PROBLEMS AND PROSPECTS

During the present decade, the rhetoric of world politics has shifted from an emphasis on "cold war" competition between the super powers to a stress on the possibilities of detente. Global problems that require multilateral cooperation for their solution are now receiving new attention. One of the most pressing problems facing the world today is that of diminishing non-renewable natural resources which, with growing populations, increased pressure on world food production, and the widening gap between the wealth of developed and developing nations, poses a grave threat to international stability. Mankind must accordingly look for ways to conserve non-renewable resources, and increase the production of renewable resources by the application of science and new technologies.

The relevance of space activities to these goals lies in the possible applications of space technology to produce tangible benefits for society. The United States has created an operational meteorological system which serves national needs and the needs of the international community under the auspices of the World Weather Watch (WWW) of the World Meteorological Organization (WMO). A broadcast satellite, Applications Technology Satellite (ATS), is being tested for educational and community purposes. The ATS–6 satellite was initially positioned to rebroadcast programs to the Appalachians, Rocky Mountains and Alaska. It was moved in August 1975 to a position over Lake Victoria in Africa, where it was used for one year as part of the Satellite Instructional Television Experiment (SITE) initiated by the Indian Space Research Organization (ISRO). This experiment broadcast programs for four hours every day to 2,700 remote villages. Using conventional television receivers augmented with a low-cost 10-foot diameter parabolic antenna, a frequency converter and a pre-amplifier, these villages were able to receive programs on family planning, agriculture and public health, as well as school and adult education programs.[1] In July, 1975, the ATS–6 satellite was also used to relay to the earth the televised rendezvous and docking of the Appollo-Soyuz mission.

Satellites are proving cheaper and more effective than submarine cables for telegraphic communications and for relaying television programs of global interest. International telecommunications satellites are operated by two international organizations—Intelsat and Intersputnik. Domestically operated satellite communications systems have been established in Canada, Japan, the Soviet Union and the United States, and Indonesia is in the process of establishing its own domestic communications satellite service. France and Germany have established a communications satellite service, "Symphonie", for European use.

In 1972, the National Aeronautics and Space Administration (NASA) launched the first experimental unmanned satellite designed to provide synoptic imagery of the earth's surface on a repetitive basis. The remote sensing satellite was named the Earth Resources Technology Satellite (ERTS–1) and represented another step in the search for ways in which outer space could be used to benefit mankind.

The performance of ERTS–1, even in its present experimental mode, has exceeded all expectations both in the length of its lifetime and in the amount of useable data acquired about the earth and its resources. Of all the satellite systems launched to date, ERTS may hold the greatest promise of widespread benefits to mankind. Nationally and internationally, increasing use is being made of the data to aid in the search for solutions to resource management problems. Ground stations are being established by nations at their own expense under bilateral arrangements with NASA in order to enable them to obtain instantaneous data from surveying as they pass over their territory.

1. UN Doc. A/AC.105/PV.158, from statement by Mr. Reis, US delegate to UNCOPUOS meeting held in New York, 22 June, 1976, p. 26.

In 1959 the Committee on the Peaceful Uses of Outer Space (COPUOS) was founded at the United Nations. Its mandate directs it to study, *inter alia,* the legal problems arising from the exploration and use of outer space. The committee and its two subcommittees, the Legal Subcommittee and the Scientific and Technical Subcommittee, consist of 37 member countries and work on a basis of consensus without resorting to actual votes on issues. The committee reports to the General Assembly of the United Nations through the First, or Political, Committee.

In 1972, COPUOS created a working group to deal with questions relating to remote sensing of the earth by satellites. The topic of earth resource surveying satellites has become a major item on the agendas of both subcommittees and COPUOS is the major forum for debate between countries concerned about the future of remote sensing both in international law and in an operational system. COPUOS has drafted several treaties, the most significant of which is the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (the Outer Space Treaty) of 1967. COPUOS[2] has recently drafted several new principles and common elements dealing with remote sensing. These will be discussed in the section dealing with LANDSAT satellites and international law.

All this activity would appear to be dependent on a continuous earth surveying satellite program, but the United States Government has made no commitment so far to such a program on a national basis. The present experimental system has been continued with the authorization of a third satellite in the ERTS series, but the question is, what happens after that? Will the United States Government establish an operational earth surveying satellite program nationally or agree to some form of international system? What does a remote sensing satellite actually do? Are the benefits proving promising enough for an operational system to be considered? What would the political and legal

2. UN Doc. A/AC.105/171, Annex III, 28 May, 1976, pp. 1–5.

implications of such a system be? This report briefly outlines the developments of remote sensing techniques, describes the satellite, highlights some of its myriad applications, looks at the political-legal situation, and suggests possible organizational frameworks, national and international, which could be considered for an operational earth surveying satellite system.

HISTORICAL OUTLINE OF THE DEVELOPMENT OF REMOTE SENSING

For centuries the almost universal desire to discover more about the earth has driven people to explore and record their findings. Much of the exploration began primarily for military purposes, the civilian applications coming later. Man's predilection for mountains was at least in part attributable to the fact that the higher he climbed, the farther he could see; consequently, he was less likely to suffer a surprise attack.

With the invention of manned balloons, more of the surrounding surface of the earth became visible. The invention of the camera opened new avenues and aerial photography became a possibility. The earliest documented cases of aerial photography from balloons were for military reconnaissance during the Austrian-Italian War of 1859, the American Civil War of 1861–65, and the Franco-Prussian War of 1870–71. By the time of the First World War, aircraft had taken the place of balloons, and automatic cameras, which provided more sophisticated aerial photography, were developed by the onset of World War II. Higher flying airplanes coupled with advanced cameras were able to photograph larger areas of the earth in greater detail, creating a need for photointerpreters. Training programs were established and corps of photointerpreters formed. One of the famous uses of aerial photography during World War II was "Operation Crossbow," mounted in 1944 by Duncan Sandys in conjunction with the Royal Air Force. Germany was extensively photographed in an endeavor to find the launching pads for V–1 and V–2 rockets so that they could be destroyed.

Since World War II, the technology of highflying aircraft has rapidly advanced. Airplanes such as the U–2 and the SR–71 can cruise at heights of above 60,000 feet. Today aircraft carry sensors that operate in the radio frequency, infrared, ultraviolet, and even x-ray and gamma ray regions of the electromagnetic spectrum. The application of aerial photography to earth resources management became widespread after World War II. In 1948, Australia was mapped using a combination of aerial photography and traditional cartography. Remote sensing became an indispensible aid to mineral exploration, forestry management, pollution control and land use. Countries that lacked the means or the personnel to undertake surveys often entered into cooperative agreements with other, more technologically advanced countries. For example—Argentina and the United Kingdom conducted earth surveying experiments using Skylark rockets.

Although the potential of artificial satellites for military reconnaissance was recognized immediately after World War II, the first satellite, Sputnik, was launched in 1957 by the Soviet Union under the auspices of the International Geophysical Year. The exciting possibilities for space research that satellites offered led to a rapid development of both manned and unmanned non-military satellites initially by the Soviet Union and the United States, but now by many other countries. The results of the early programs stimulated worldwide interest in the possibilities that satellites might afford, not only for space research, but also as an aid in the solution of terrestrial problems, through the addition of a new perspective. This rapid evolution of satellite technology—from a science fiction concept a mere twenty years ago, to its present routine worldwide application in the fields of telecommunications, space research, and meteorology—is due in no small part to the approach of the National Aeronautics and Space Administration (NASA).

NASA was established in 1958 [3] with a broad mandate to learn how to operate and explore in space, and make avail-

3. PL 85–568 enacted July 29, 1958, at 72 Stat. 426: 42 USC 2451.

able any new technology for the "peaceful uses of mankind." In 1961, President John F. Kennedy set the tenor of U. S. space activities for the 1960's by establishing a national goal of a manned lunar landing before the end of the decade. This led the United States to allocate $25 billion to the Apollo program. During the 1960's, NASA concentrated mainly on the concept of manned space flights but at the same time developed and operated a wide variety of research and applications missions, including telecommunications and meteorological satellites. The first remote measurements of the earth by satellite for civilian purposes were made by the meteorological satellite, Television Infrared Observation Satellite (TIROS–1), which was launched by NASA on April 1, 1960. Since then the earth has been viewed continuously in various ranges of the electromagnetic spectrum. The data obtained from the Appollo and Gemini programs demonstrated that there was a possibility that a satellite system could be used to monitor the earth's resources, and NASA focused attention on the concept of manned earth resources surveys.

In 1966, the Department of the Interior asked NASA whether it would be feasible to launch an unmanned polar orbiting satellite to survey the earth in order to discover if such a satellite could aid in exploration for heavy minerals and in management of public lands in the United States. In 1970, after four years of research and consultation with other potentially interested agencies including the Departments of Agriculture and Commerce, NASA formulated specifications for two Earth Resources Technology Satellites, ERTS–A and ERTS–B. ERTS–A had a planned lifetime of one year. ERTS–B was built as a backup satellite or for subsequent launch. The satellite mission "was to demonstrate the feasibility of repetitive multispectral remote sensing from space for use in practical earth resources management applications." [4]

4. John H. Boekel, NASA, Goddard Space Flight Center, "ERTS–1 System Performance Overview," *3rd ERTS–1 Symposium*, Vol. 1, Sec. A, p. 1.

In addition to developing ERTS, NASA included an earth resources experimental package on its Skylab experimental mission which returned very clear non-repetitive photography of the earth's surface.

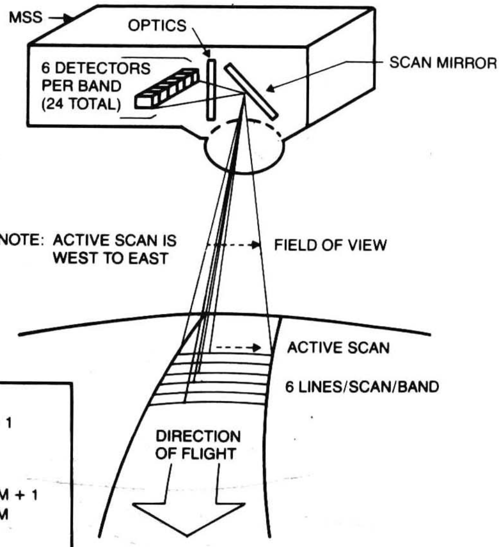
EARTH RESOURCES SATELLITES—TECHNICAL DESCRIPTION AND BASIC OPERATING COSTS

ERTS–1 was launched on July 23, 1972, and is still in operation although its sensors are now gradually failing. ERTS–2 was launched on January 22, 1975. ERTS–2 was initially intended to carry a heat measuring sensor in addition to the sensors carried by ERTS–1, but development difficulties led to a duplication of the ERTS–1 satellite. In January 1974, NASA renamed the Earth Surveying Satellites LANDSAT–1 and LANDSAT–2 in order to bring the names of the earth surveying satellites in line with other space applications missions and to clarify the intent of the experiments, which was to sense the land for beneficial purposes, not just to survey resources.

The LANDSAT–1 and LANDSAT–2 satellites weigh about 950 kilograms. They follow a sun-synchronous polar orbit wtih an inclination of 99.1 degrees crossing the Equator in a North-South direction at about 9:42 local time. This particular time was chosen because, while regions of interest may be cloud-covered for much of a day, statistical analysis indicates that they are generally clear in the early part of the day. Consistency in both the time of coverage and the illumination from the sun minimizes the chances of data misinterpretation. Morning shadows are also an important analytical tool in the interpretation of remotely sensed data. Successive orbits are separated by about 2,870 kilometers at the Equator. The satellite's orbit results in repetition of the same ground track every eighteen days. With two LANDSATs in orbit the same area is covered by one of the satellites every nine days. In order to maintain the orbital pattern and achieve global coverage from 80° N–80° S, the spacecraft includes an orbital-adjust propulsion system.

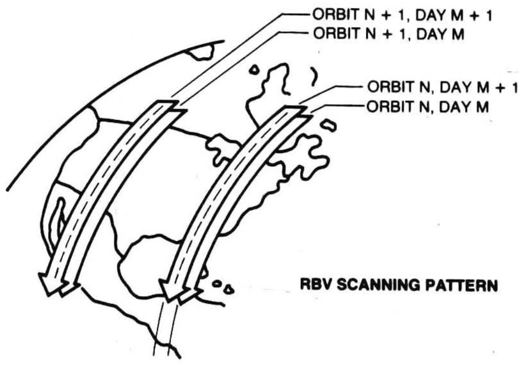
CHART I The Orbit Parameters of LANDSAT 1 and 2 and Sensors' Scanning Patterns

MSS GROUND SCAN PATTERN



/ERALL ERTS SYSTEM

Orbit Parameter	Nominal Orbit
Semi-major axis	7294.69 km
Inclination	99.092 deg
Period	103.267 min
Eccentricity	0
Time at descending node (equatorial crossing)	9:30 a.m.
Coverage cycle duration	18 days (251 revs)
Distance between adjacent ground tracks	159.38 km



RBV SCANNING PATTERN

Source: Enrico P. Mercanti, "ERTS–1 Teaching us a New Way to See", Astronautics and Aeronautics, September, 1973, p. 38–39.

[B6725]

Chart I shows the orbital parameters of LANDSATs–1 and 2 and the sensors' scanning patterns.

The payload consists of:

(1) A multispectral scanner (MSS) which gathers data by scanning the surface of the earth in four spectral bands simultaneously through the same optical system. Table I shows the four spectral bands for LANDSAT–1 and 2, their scanning width, color spectrum, and major uses.

TABLE I

Band	Scanning Width (micrometers)	Color	Spectrum	Use	
4	0.5 – 0.6	green	visible	water quality	Land Use Patterns
5	0.6 – 0.7	red	visible	vegetation, water quality	
6	0.7 – 0.8	near infrared	invisible	vegetation	
7	0.8 – 1.1	infrared	invisible	surface water, vegetation	

The MSS scans horizontal swathes 185 kilometers wide (100 nautical miles) imaging six scan lines across in each of the spectral bands. The instantaneous field of view of each detector subtends an earth area of 79 meters square on a side from the nominal orbital altitude. This distance is called the "resolution" of a processed image. In order to produce "map-like" images the data obtained by the MSS must be translated and corrections must be made for earth rotation, altitude variation, altitude rates and non-linearity of mirror velocity. These corrections are made in the NASA Data Processing Facility (NDPF) before the imagery is released.

(2) A Return Beam Vidicon Camera (RBV) which views the same 185 kilometers square area in three spectral bands; green, red, and near infrared. On LANDSAT–1 this was deactivated shortly after launch because of a switching malfunction. Although it could have been reactivated the MSS proved so successful that it was considered inadvisable to put the satellite at risk by reactivating the RBV. On LANDSAT–2 the RBV has rarely been used, primarily be-