DEPARTMENT OF STATE





# CASE STUDY

## SOME THOUGHTS CONCERNING INTERNATIONAL IMPLICATIONS OF SATELLITE SENSING OPERATIONS



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# SOME THOUGHTS CONCERNING INTERNATIONAL IMPLICATIONS OF SATELLITE SENSING OPERATIONS

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# TABLE OF CONTENTS

## SUMMARY

Remote sensing from satellites is a technology laden with promise -- and with potential problems. Although still termed experimental there is good cause to act in the belief that, in its impact on our environment and resource management, satellite sensing will in time effect societal changes even more extensive than those arising from communications satellites.

Remote sensing is young and its international context is still malleable. It is now time, however, to consider how the world can best organize itself to make optimum use of the new tool, and for planners to recognize the essentially political nature of that organizational problem.

# SOME THOUGHTS CONCERNING INTERNATIONAL IMPLICATIONS OF SATELLITE SENSOR OPERATIONS

## INTRODUCTION

For reasons not yet disclosed The Great Creator gave man and other animals only five senses [1], of which four are severely restricted in ambit. Taste is totally dependent, and touch almost so, on physical contact with the object "sensed" to detect and relay fact, or at least perceptions of external reality, to the intellect. Smell and hearing can operate at greater reaches because they need only indirect contact to perceive and report to the mind. None of the four, however, can operate across a vacuum [2]. Only our optical sensory equipment is able to leap the expanse of space (and therefore of time) regardless of vacuum or aether; the eye is man's only natural discriminating remote sensor.

Primitive man, or his ancestors, untroubled by such idle speculations, quickly learned that the limited technology then available could augment his senses. Perhaps first was cupping his ear to improve the quality of faint sounds from the jungle. A step away from primitivism was man's first into the night with a burning faggot to aid his optical sensors. Was one of his earliest policy decisions to stay downwind of the excellent olfactory equipment of unfriendly sabretooth tigers? Despite early innovation, however, progress seems to have ground to a prompt halt.

From Java Man to Galileo's telescopes, luminous minds, like those of Aristarchus, Ptolemy, Copernicus and Kepler, fed on logic and inspired intuition, not on any growing physical ability to penetrate and perceive the remote secrets of space. For hundreds of thousands of years man frolicked and reveled in his natural sensory equipment, quite unaware that he had been shortchanged in that department by The Great Creator.

From man's beginning we count a half million years until Newton lifted a corner of the veil, decomposing white light and putting it back together again with his prisms. More important, in some ways, than his orderly and unchanging procession of primary colors were the newly discovered invisible emanations at and beyond the edges of visible light. Beyond red they were invisible, but with amazing heating effect. Beyond violet, invisible but with great impact on photographic emulsions. Post-Renaissance man had to know what else was out there beyond the visible, undetected and unassessed. Two hundred years later, science had postulated the essential answers. By 1900 Maxwell, Herz and Marconi had pried open the universe of electromagnetic radiation and launched the new technologies of communications and remote sensing [3]

By detecting and sorting out from remote points the minute variations in the patterns of electromagnetic radiation emitted or reflected by everything on earth, remote sensing can selectively identify and report many essential characteristics of things at or near the earth's surface. The resulting information is germane and of value to every activity associated with management of man's dwindling resources and control of his environment. Remote sensing data already cuts across many disciplines, with proven applications in agriculture through zoology, in hydrology and arid-zones assessment, sea-state and snow pack measurements, cartography, geodesy, minerology, oceanology and on.

The future may hold more promise still. The major benefits of new technologies, as in the case of the laser, often lie in applications not intended, nor indeed even foreseen, in their early stages. "The true benefit of satellite sensing is likely to be in things we can't even imagine now."4/

There can be little question that remote sensing seems destined to have an important impact on the tenor and tenure of man's occupancy of this planet. Alva Myrdal holds that earth resource satellites are by definition international in character. "They will, willy-nilly, have agreat impact on all countries. They bear in themselves unparallelled possibilities to make that impact a positive and constructive one." It now seems time for statesmen and policy makers to take over center stage, to exercise their wisdom and expertise in determining how a politically partitioned world can best organize itself for optimum use of a global technology incapable of recognizing either political boundaries or political divisions.

## SOME TECHNICAL ASPECTS 5/

The components of a remote sensing system are most often classified as: platform and sensor design, data acquisition, data processing, data storage and distribution, interpretation (or analysis) and use of information. Not all of this needs discussion to get an idea of how the thing works.

Remote sensors depend on the fact that everything6/ emits or reflects some kind of eletromagnetic radiation, such as visible light or infrared waves. Sensors are highly sensitive devices, including cameras, which by optical, electronic, mechanical and chemical means can detect and register electromagnetic radiation at desired wavelengths. By focussing a number of sensors on the same area at the same time, but registering different wave lengths on each, the system collects multiple images of the same scene, each bearing a message, sometimes highly nuanced, for the trained interpreter. By comparing images, by cross-reference and overlays, by combining them through projection of transparencies, a lode of information can be produced on every area "imaged".

Sensors other than cameras generally work on the principle of scanning, by optical/mechanical means, the affected area, and converting what they "see" into electrical impulses which are either temporarily stored or immediately transmitted to a processing facility for reconversion into imagery. Some sensors resemble TV cameras and transmitters in the way the function; others work on different principles.

Remote sensing on the earth's surface and by aircraft is not very new. Aerial photography was used in the Civil War. Radar grew up in WW-II. Airborne magnetometers and gravitometers are standard equipment in mineral searches. But now, in many quarters there is excitement and ferment in anticipation of a major new step: the upcoming launch by the United States of the first satellite devoted to civil applications of remote sensing of the earth.

The first Earth Resources Technology Satellite (ERTS, an acronym well below NASA's usual imaginative efforts) raises a whole new set of considerations. It has certain tremendous advantages in that its height will permit a synoptic view of earth and its orbit will permit the repetitive coverage at low cost, constant light angles, etc. which are most difficult to achieve by other sensing modes. For many purposes satellite sensing promises the highest cost benefits.

One major factor is data transmission. An immense amount of data will have to be radioed to earth by ERTS because each picture and digitized image of the earth's surface will cover an area 10,000 miles square [7] and because each part of the earth will be subject to sensing once every eighteen days. This vast data job is being handled by a computer-straining transmission rate of 15 million bits (tiny data elements) per <u>second</u>, by a specially developed on-board tape-recorder to store and disgorge over the United States data acquired outside the range of the three United States ground stations, and by automated ground processing facilities. The success of the ERTS system is as much dependent upon an effective data-handling component as it is on the sensors themselves.

Raw data is of little use until man or computer converts it into meaningful information. Depending on the nature of the problem, the volume of data involved, and the availability of information to verify and correlate the satellite data, the analytical process can range from relatively simple and inexpensive (a couple of photo-interpreters and a few thousand dollars for equipment) to complex and costly, involving highly trained personnel and exotic machines. To cover large areas, to establish trends, norms or departures from norms, or to go for polydisciplinary data on large areas, will tend to drive up the costs.

The occasional enthusiast tends to attribute to satellite sensing the same curative magic as miracle drugs, to see in it alone a panacea for the world's resource-related ills. It should be very clear, however, that satellite sensing is only a new tool, albeit an important one. Its achievements will be a function of how wisely man applies it, and how well he exploits the data which it produces. Until all aspects of satellite sensing have been refined, moreover, it will continue necessary to use satellite data in conjunction with collaborating information acquired on the ground or by airborne sensing. Usually, as is said of occupied territory and infantrymen, ultimately only the man on the ground can do the job. An optimal system will almost always use all three tiers.

THE EARTH RESOURCES TECHNOLOGY SATELLITE

Over the past few years the conviction has been growing in the United States that a satellite sensing system would be technically feasible and economically useful for domestic applications. Experience with airborne sensors and data from Gemini and Apollo photography "justify considerable confidence in the utility of resource data acquired from space.[8] A NASA-sponsored study, in 1967/68 by the National Academy of Sciences-National Research Council, concluded that the "potential economic benefits to our society from space systems are enormous."[9] A House Subcommittee found that "the unique observation and data collection capabilities of the earth orbiting satellites are such that it promises to become an instrument having a profound impact upon the discovery, management, utilization, and conservation of the world's natural resources within the next few years."[10] Needed was a system "for keeping satellite watch on the globe's natural resources with the aim of better managing nature's bounty ... to alleviate some of the world's paramount ailments by helping to produce more arable land, more water, food, clothing shelter and fuel to meet the needs of a population that is growing at an alarming rate."[11]

NASA responded to these aspirations with great deliberation [12], and its usual high technical competence. Developed over a number of years, ERTS is a substantial modification of the unmanned Nimbus (weather-watch) spacecraft. It is very much experimental, a fact which NASA and United States governmental spokesmen take pains to reiterate. Until ERTS "flies" and functions, the extent and nature of its successes and failures will not be known. However, even granting the experimental nature of ERTS, high hopes abound for it.

Outside of NASA a number of knowledgeable authorities believe that the remaining problem is only to determine the degree of ERTS success, and to bolster whatever relatively weak points may appear in the system. The United States, however, holds that receipt and definitive analysis of ERTS data must precede further deliberations on how to organize an operational system. This policy line is interpreted in some foreign circles as comparable to the modest pre-game disclaimers of a winning coach or, less charitably, as a device to forestall debate until the United States gets around to building a policy on satellite sensing.

ERTS is scheduled for launch this month or next. It[13] will weigh about 2,100 lbs. Its near-polar orbit will take it around the earth about 565 miles up, covering any segment of the earth's surface once every eighteen days. It will be "sun-synchronous" so that sensing will take place at a constant 9:30 a.m. local time of the area sensed. The sensors will be a TV-like Vidicon Camera to register in the Infra-red, Red and Green bands, plus a multispectral scanner to cover two near Infra-red bands, one Infra-red and one Green band. When sensing over the United States, ERTS will disgorge its data, simultaneously with acquisition, to three ground receiving sites in the United States. It will sense only over those areas which have been selected for experimentation, not the whole country.

Because only a near-polar orbit can give the desired coverage of the United States, the ERTS flight path will put the satellite over other countries during most of each orbit. The United States has opened the ERTS program to the world, offering to conduct experiments for foreign as well as United States experimenters. The invitation elicited the largest number of foreign-proposed experiments in NASA's history of international cooperation.[14]

Foreign experimenters apply and are approved under groundrules set up by NASA.[15] They must have the approval of an agency of their government (emphasis added) and, if their proposal would require access to a third country to obtain on-the-ground facts (termed "ground truth"), the consent of an agency of that government (emphasis added) must also be obtained by the would-be experimenter. It is left to a NASA-appointed committee to determine which experiments are accepted, under rather nebulous criteria, but foreign experiments are given the same competitive status as those proposed from the United States. NASA undertakes to use its best efforts to acquire the necessary data and to deliver it, without cost, to the foreign experimenter in the format desired (photography of particular sizes, certain kinds of imagery, or data on computer tape). The experimenter, in turn, agrees to analyze the data at no expense to the United States and to share the results with NASA. The experimenter also agrees beforehand that the information derived from the ERTS program is to be available on a totally open basis at "equitable" cost to all comers ("interested parties") requesting it.

Brazil and Canada have a special interest in ERTS. Both have advanced remote sensing capabilities including well-led and adequately funded space research entities. Each is setting up its own ground station and analytical center. Canada's facility is almost complete and ready for operation; Brazil has funded the project but actual construction of the receiving station has not begun.

Each country will be able to "read" the data stream directly from ERTS so long as the satellite is in line-of-sight with the ground station. With the sensors and transmitters left on over these countries, all sensed data could be sent directly to the ground station with very substantial benefits to each country. They could begin analysis of the data immediately, rather than having to await its receipt from NASA. By not being reliant on the limited capacity of the ERTS tape-recorder they can acquire more data than would ordinarily accrue to them, and would be able to acquire it even after the indefinite point in the future when the taperecorder -- believed to be the component most likely to malfunction first -- no longer works. This direct reading of the data stream from a sensing satellite which must ignore invisible political boundaries has political implications taken up later in this report (P. 9 ).

PROMISE AND --

> "Given the present outlook, only the faithful who believe in miracles from heaven, the optimist who anticipates superwonders from science, the parochial fortunate who think they can continue to exist on islands of affluence in a sea of world poverty, and the naive who anticipate nothing, (only they) can look to the future with equanimity." 16/

There is almost no currently perceived end to possible useful applications of ERTS-type data. A random selection will indicate the scope: Crop and forest surveys, crop production predictions, detection and assessment of diseases of vegetation, land use patterns, soil maps, hurricane damage assessment, minerology surveys, hydrological investigations, cartography, geodesy, location and tracking of major ocean currents, mapping of sea ice, detection of specific phenomena of limited area and varying locations such as fish schools, oil slicks, and red tides, desert-locust control, range management, flood prediction, urban development, identification of major geological features such as faults and folds, demographic studies, atmospheric and water pollution traces and tracks, and regional planning.

The promise of satellite sensing is very real. It is also very much colored in the eye of the beholder. The statesman may see it as a means of helping to bring countries or even regions together in fruitful relationships, irrespective of national boundaries. The development planner may envisage a quantum jump in the availability of information needed to form and underpin his judgements. The economic buccaneer may see the chance for quick loot. The scientist can see new horizons for exploration or perhaps new tools for old problems.

The United States Government will have to view satellite sensing at many levels. It is a technology with many domestic applications and implications. Abroad it may permit better targetting of our AID projects. For the practitioner of foreign affairs, it could provide a windfall, or a pratfall. If used wisely it could support a broad range of foreign policy objectives. If misunderstood by foreign affairs officials it could take on the appearance of a unilateral program designed to preserve American freedom of action and domination of civil applications in space.

There is no good way to estimate the value of earth resource sensing by satellite. One benchmark, however, is the belief of the Department of Agriculture that satellite sensing could "ultimately save a billion or more dollars a year in farming costs to the United States alone, one-quarter of the current annual cost of the whole space program." 17/

One of the earliest demonstrable triumphs of satellite sensing could be in conquering the biblical pest, the desert locust. With adequate ground truth, a few key indicators such as ground temperatures and moisture content, and the state of vegetation growth, could give the tipoff to locust breeding grounds and as to when they might swarm. The vast trouble area, 30 million square kilometers of northern African and southwest Asia, is highly suited to the synoptic repetitive coverage from satellites. "The gross value of the agricultural output which is subject to annual depredations amounts to $15 or $20 million. The main victims of this natural calamity are the developing nations which already suffer on account of ever-increasing food shortages from several other causes." 18/

The current Stockholm Conference is focussing on a different potential for calamity, this one man-made, arising from mismanagement of his resources and his atmosphere. The chorus from developed and developing countries of concern for our ecology, our air and water, emphasizes the need to apply the best of technology to these problems, and promptly. Satellite sensing seems almost tailor-made for a major role in improving the quality of life if it is organized and applied wisely.

## -- AND PROBLEMS

The international aspects of the United States program for remote sensing of earth resources has gone well. There is unprecedented foreign interest in participation. Expressed national concerns about national sovereignty, economic exploitation, and the like, have generated a notable lack of international support. It is, nevertheless, open to question whether the United States can expect this happy state to continue, especially as the time of transition from experiment to full operation draws closer.

A combination of factors not necessarily applicable to an operational system could explain the smooth progress of the experimental ERTS. First is the fact that it is experimental. States often can accept temporary procedures and situations they would not readily adopt for the longer run. It is clear that many developing states have as yet little or no interest in and knowledge of this new technology. They are not now prepared to identify or assess or debate those relevant problems which may later seem important to them. Of course, too, there are a number of states which fully accept the American position which, in essence, says let's talk about the substantive side some time later.

There is much merit in American policy for handling ERTS, even if one were to think of it as a possible framework for an operational system. This organizational arrangement leaves full operational responsibility with a central expert authority. It is the cheapest possible system for foreign participants and other interested parties. It opens up vast realms of useful information to the world on a non-discriminatory basis. It is admittedly somewhat unilateral in its opt-in or stay-out feature, but that feature largely accommodates the ticklish issue of national sovereign rights. It, in effect, creates full disclosure policy. It avoids difficult, time-consuming and probably fruitless negotiations in a multilateral forum, perhaps ending up with an operational system providing lower cost effectiveness or lessened product quality.

The argumentation has appeal. It also has some probably fatal flaws.

There is now in evidence no persuasive reason for the United States Government not to start reformulating its satellite sensing policy, and there are several reasons to think that it should. Technology has a way of outstripping the expectations, and managerial/planning capabilities, of its presumed masters. Perhaps technicians and scientists are more competent than diplomats and politicians, or perhaps their subject matter is less nebulous. It will take some months, presumably, for the interested United States agencies to come to agreement on all components of an operational system, including its international aspects. That process should be begun to permit substantive international talks as soon as possible, before time and technology overtake us and necessitate resort to some jerry-built interim system.

United States policymakers should go back to Square One for a penetrating, broad and dispassionate examination of United States national interests, opportunities and problems in putting satellite sensing at the world's disposal. We should carefully assess the expressed (and unexpressed) interests of other states. We must sort out and weigh the considerations which lead states as diverse as the USSR and Brazil, Mexico and Sweden, Canada and Italy, to raise publically the urgent need to consult together on the substantive considerations important to the establishment of a successful international operating system.

There are many ways to classify the non-technical problems. One is to categorize them as: General Malaise, Economic Advantage, Security, Unilateral Reliance, and Political.

General Malaise refers to the vague allusions to "national sovereignty" which might be affronted by satellite sensing in some cases, to unfocussed statements referring to invasions of national privacy and the like, and to general pronouncements about looking into the relevant "legal aspects". Such phrases are probably in themselves of little significance; they seem to mask more specific concerns.

The question of Economic Advantage is complex. Some countries are guilty of not having done their homework, or of letting economic chauvinism inform their judgements. Yet there are important issues here, for underdeveloped and developed countries. A few cases will illustrate, but not catalogue, the problems.

Developing Country A is reluctant to participate, partly because it believes that its inadequate capability for data analysis will either miss important information or will ferret it out too late, allowing foreign exploiters -- who will also have access to the data and fast accurate analytical capabilities -- to slip in and take economic advantage.

Developing Country B is loath to have its mineral assets laid bare to the world at this point since it does not have the money or manpower to exploit them, and does not wish to call in neo-imperialists to help.

Country C is wary of participation since it finds that its constitutional and statutory system would not provide the legal tools necessary to stop or inhibit "ransacking" of discovered assets by foreign economic interests. Included in this category would be developed countries with extant heavy foreign investment operating through domestic firms. For example, some United States corporations, with wholly owned subsidiaries legally operating in Canada, might be particularly well situated to exploit any major resource finds there.

International commodity trading will be a terribly sensitive point. Consider the advantage to derive to he who first reliably learns of, say, a windfall crop of cocoa, or of a devastating blight in the Latin American coffee plantations. The Chicago Board of Trade might disappear without trace or tears after one or two successful manipulations made possible by advance information of that sort. What system of information dissemination, under any organizational arrangements, can handle this problem with guaranteeed equity and security?

A last case, an important one needing comprehensive consideration, concerns exploitation of international areas. Illustration: the American fishing fleet is in distress apparently because the fish are not where they used to be and because of an outmoded technology. Could our fleet not be restored to health if the United States were to reserve to itself the oceanographic data from relevant areas, data which could prove effective in indicating where to look for big fish finds? American policy now calls for sharing this, and all other acquired data, with the world. To what extent will Senators and Congressmen from fishing states feel some proprietary and political interest in the subject? How many, if any, can fail to wave the bloody shirt of the taxpayer dollar? Extending the concept somewhat, need we not give some thought to the relationship between satellite sensing and Law of the Sea issues?

The Security aspect has two major parts, military and civil. The ability of ERTS to perceive objects on the earth's surface will be limited. It will rarely be able to single out anything smaller than roughly 300 feet long. Three hundred feet would catch only something the size of a battleship, hardly of security concern when the fact is understood. The limit stems from the intentional "low resolution" or power of definition of the sensing equipment. Higher resolution would take in less territory during each sweep, necessitating more passes to cover the earth, and lengthening the cycle for full earth coverage. The lower resolution is desired for ERTS so as to permit the more frequent repetitive coverage of some areas. Though that low resolution may provide some sense of protection from an eye, or spy, in the sky, the trend is inevitably going to be toward the substitution, in later satellites, of greater resolving power.

Statements already abound, from official Americans and others, indicating that thinking is going on about resolutions down to a few meters or feet. Perhaps by the time the scientists are ready to propose higher resolution, ERTS will have shown that satellite sensing is so cost beneficial that residual doubts and concerns will have been swept away. Or, perhaps not.

On the non-military side, information of an economic nature often has security significance. Consider, for example, the degree of interest the USSR might have in receiving early comprehensive information on a failing Chinese rice crop. How anxious is Morocco to unveil the possible oil-bearing structures on its eastern frontier to the scrutiny of Algiers?

Unilateral reliance refers to the reluctance of other countries to put too many chips on United States' goodwill. The United States, more specifically NASA, has built up a reputation for honesty, reliability and cooperativeness despite some alleged authoritarian quirks. Still, serious planners of an operational system know that an indispensable element will be constancy, or reliability. Planners need to know that the data required, particularly repetitive data, will be forthcoming, on time, and irrespective of possible differences between governments. A question therefore arises as to the reliability of a system wherein the United States or any single country has total operational control. The United States may have the best of intentions, the argument runs, but would it honor an ERTS-type commitment to, say, the UAR for important hydrology data in a limited war situation with Israel? 19/ Other factors presaging a truly international operation over the long term are a desire to participate in design of systems, including sensors; a thrust toward a system which will carry a greater chance of technology transfer; and a system which would offer other countries more opportunities to supply hardware and software. This interest should be factored into the longer-term aspects of a revamped US policy.

VS I.O.

Satellite sensing developments in the United States to date have been largely of technical character. What lies ahead looks to be essentially political. The economic and security questions (above) have political bases. Bringing a full scale global operational system into being is a political problem. The Contiguous Country problem (below) is political.

The United States argues that acquisition of data by satellite, and unrestricted dissemination of it, is sanctioned by international law. This view extends even to the incidental or accidental sensing of countries not parties to agreements with NASA. The only relevant provision in the NASA guidelines pertains to situations wherein access to other countries is needed to get ground truth. Here prior consent of that country is required, not for the sensing, but for access.

Regardless of legal interpretation, this has the mark of bad policy. It is laden with potential trouble for the other two countries, one party to the agreement with NASA and one not, particularly if they are already on less than friendly terms. And it has a built-in peril for the United States: the tacit assertion that in cases where access to continguous Country C for ground truth is not required, the United States and Country B can agree to a program of sensing which would entail acquisition, formatting and general dissemination of data concerning Contiguous Country C without prior consent from, or

eg NK.

even consultation with that Country.[20] Note further that the NASA guidelines refer not to governmental approval of experiments, or governmental approval of access for ground truth, but to agency approval. This is an understandable objective from an agency point of view, since it tends to hold decisions below policy level within the operational agencies involved, reducing time lost among obtuse bureaucrats in peripheral agencies. But, for some years to come, the essence of the problem will lie in issues that are quite political, occasionally quite sensitive, and which should involve the consent of foreign policy authorities, political leaders in many instances, and not agency heads or their lieutenants.

There is another political trap which the United States must avoid. Suppose one or more major breakthroughs with remote sensing via satellite, such as might happen with control of desert-locusts, with evident economic benefit at minimal cost to the countries affected. The general indifference which until now has characterized the attitudes of most developing countries towards remote sensing could quickly be transformed. In these circumstances the United States Government might well find itself overwhelmed by requests for projects to go aboard successors to ERTS, to the extent, say, of having to decline five, fifteen or fifty times more experiments than can possibly be programmed for foreign investigators. Aside from the disappointment or frustration engendered in individuals, or academic or corporate entities turned down, sooner or later we are likely to refuse experiments considered by sponsoring governments to be important to their national interests.

Lincoln reputedly said he hated to appoint a postmaster because with each appointment he created one ingrate and eleven disappointed ex-friends. Surely the United States does not want to be caught in the middle, picking and choosing, setting priorities as among friendly states. There is no way beyond the short term to win this kind of contest.

Not last among the political perturbations which will be associated with satellite sensing technology could be suspicion of restrictive collaboration between the United States and the USSR. While the world welcomes the new cooperation in space matters, there are already faint signs that at least some authorities anticipate a superpower effort to minimize real participation by other powers in the exploration and use of space. A genuinely cooperative international program, giving other interested states a maximum opportunity to be active in a satellite system of sensing, could be of value in allaying suspicions that the American/Russian detente will act to the disfavor of other states.

## ERGO?

Because the concept, the fact and the products of remote sensing from satellites are so relatively new and unfamiliar, the situation is still malleable. Accordingly, a lay observer might be able to suggest the elements of an international arrangement which could meet the essential needs of the United States and of other participant states.

It is difficult to envisage a single operational system which could accommodate all the interests of the United States and other governments wanting to share in and make use of the technology. A galaxy of national interests, complex questions of funding, ownership and control, differing views on participation in systems design and priority of proposed experiments, and the like, would make a successful negotiation for a single all-encompassing system a dubious prospect at best.

A more promising approach, one which appears to accommodate most of the important problems without creating insuperable ones in their wake, would be to establish two classes of remote sensing satellites.

The first category, call it Class A if you will, would be an international satellite in every possible sense, perhaps moving into its international aspects by a phased plan less and less reliant on the U.S. for technical support. Assume a program organized under United Nations aegis, with membership composed of those states willing and able to accept the groundrules and to pay their own way, even if assisted by international economic aid funds. A governing body would set policy and a professional staff would provide backup. The costs of design, manufacture, launch and operation of the satellite would be borne by the participants. NASA, at least for the forseeable future, would serve as contractual agent in this matter, providing technical services, and would be responsible for launch and operation of the satellite, all on a cost for service rendered basis. NASA, however, would not be responsible for failures in the satellite proper deriving from design or manufacturing deficiencies. The governing body would decide, and instruct NASA accordingly, as to which experiments would be performed. Readout and processing facilities would originally be under contract with NASA but rules on data dissemination would be established by the governing body. The United States Government would make available maximum possible data on sensor technology and manufacturing processes, with due regard to patents and proprietary rights. Production of component soft-and-hardware would be carried out under rules set by the United Nations governing body but could not preclude bidding by United States firms, even if it should be decided to divide the job on some arbitrary basis of geography or "equity".

Under such an arrangement the political, economic, security and related problems which might attach to the United States would be shifted to an international forum, costs would be put on a multilateral basis, and an opportunity to participate in every part of the system would be open to states willing to pay their own way. At the same time developing states, less able to pay, would have access to remote sensing experimentation and operational uses through Class B satellites.

Class B satellites would operate along lines essentially similar to the ERTS system. Foreign participation, however, would be on an altered basis. Experiments from developing countries would be given some priority and projects involving regional groupings of developing countries might be given greater priority. If demand outstrips the capacity of Class B sensing satellites, it might be necessary to have foreign project priorities established by a multilateral entity, such as the United Nations body governing Class A operations.

In all cases, projects for Class B which would or could entail sensing of adjacent countries would have to have the prior written approval of that country's government, not just an agency. Formatted imagery would continue to be provided by the United States without cost. Collateral programs for developing countries would be augmented, with training of technical personnel, such as for data interpretation. Some stimulus might be applied selectively by devoting some USAID funds to training, equipping modest analytical centers, or even to help develop new found resources.



More important than any particular operating structure is the extent to which the United States evolves a system which, while complementing our domestic needs for an optimum system, will assure maximum useful product for other countries and maximum returns -- political, economic and other -- for the United States.

ANNEX

There is nothing known [6] which does not radiate some electromagentic energy by emission, reflection or both. Emitted energy derives from molecular movement in the object; reflected energy normally originates with the sun but may be from an artificial energy source such as a radar or a flashlight. Any kind of radiated energy has two principal characteristics: length of each wave and frequency of wave occurence. The difference between any waves (radio, visible light, heat, ultraviolet, X-rays, cosmic rays, etc.) lies only in their differing wave lengths and frequencies.

The range of wave lengths and frequencies are mind-bending: from thousands of meters down to, and beyond, the nearest fraction of a billionth of an inch, and from a few thousand cycles per second to tens of billions.

While not fully germane to this paper, it is interesting to think about the likely physical and mental configuration which might be required of a human endowed with sensors covering any substantial segment or segments of the electromagnetic spectrum. The mind boggles, for example, at the cranial capacity which might be needed for comprehension and selective storage of information received via his, say, TV and microwave channels. And would the necessary sensing equipment involve him in rod-like head antennae in the classic science-fiction tradition?

The electromagnetic spectrum is obviously vast. But not all of it is useful for remote sensing. Wavelengths shorter than visible light (ultraviolet, X-rays, gamma and cosmic waves) are quickly absorbed in the atmosphere. In the longer microwave and radio wavelengths there are frequencies which penetrate the atmosphere only with great difficulty adjacent to others which penetrate with ease. The infrared, just outside of our natural capacity to perceive visible light, is important. It penetrates readily; it is a spectral "window" with the adjoining wavelengths (on both side of about 10 microns) quite opaque. Moreover, the maximum radiant power emitted by both land and ocean surfaces occurs in this region of the infrared. Since infrared is essentially emission of heat it does not require light and can operate as well in darkness as in the light. Other sensors, in the visible light range, depend largely on the reflected natural radiation of the sun for illumination. But it is possible to illuminate a specified area with artificial radiant energy in the visible and invisible ranges, electric light, radar and lasers, for example.

Remote sensors are devices, including cameras, which from a point removed from the object sensed, detect and register specified portions of the electromagnetic spectrum as reflected or emitted by that object. By bringing a number of sensors to bear on the same target at the same time, simultaneously recording a range of preselected wavelengths, a wealth of information can be produced. Depending upon the target, range, atmospherics, sensors used, etc. characteristics can be identified such as size and shape, texture, temperature, moisture content, color and color gradients, vegetation type and distribtuion, plant vigor, etc. with applications across a broad range of human activity.

With cameras, selective use of filters and film emulsions gives data in the visible and near-visible bands, with color permutations which yield up data not available under white light. Other kinds of sensors, e.g. the "multispectral scanner", operate on different principles. They involve, essentially, scrutinizing the target area by electric, optical and mechanical means, converting what is "seen" into electrical impulses divided according to bands of wavelength, and storing or reproducing the impulses either on computer tape or as "images" comparable to nature but not in content to photographs.

FOOTNOTES

1/ Even among proponents of a human "sixth sense" the common terminology is "extra-sensory perception" (emphasis added). As to other possible senses beyond five, there is a species of Brazilian cockroach which apparently is able to "see" X-rays with his unaided natural equipment.

2/ However humans and other animals can "feel" across the void of space, i.e., solar warmth.

3/ The very title, "Remote Sensing", may be the heaviest burden the technology must bear. The Spanish "Percepcion Remota" has more meaning. But a good descriptive English-language title and some apt verbs are badly needed.

4/ Strome, Dr. W. M., Department of Energy, Mines and Resources, Ottawa, Canada.

5/ The Annex amplifies some of the technical points covered in this section.

6/ An object at absolute zero, wherein all molecular movement had ceased, would not emit radiation. So far absolute zero has been a theoretical concept only. There is also apparently some question as to whether the black stars either emit or reflect energy.

7/ 185 x 185 km, or 100 x 100 miles. Maryland has 10,577 square miles, Belgium a little less than 12,000 square miles.

8/ Hanessian, Dr. John, Jr., "International Aspects of Earth Resources Survey Satellite Programs", Journal of the British Interplanetary Society, Vol. 23, P. 535, 1970.

9/ Hanessian, Ibid., P. 535.

10/ Hanessian, Ibid, P. 535.

11/ Congress of the United States, Committee on Science and Astronautics, 92nd Congress, First Session, "For the Benefit of All Mankind", P. 33.

12/ A number of observers, among them some Congressmen, have criticized NASA's dilatory pace in setting up ERTS. It is thought that NASA saw in earth sensing an added raison d'etre for the manned space program, and was therefore loath to split it off as an unmanned application.

13/ The ERTS program in fact comprises two satellites, ERTS-A and ERTS-B. The first is now scheduled for launch late this month or in July. The second is intended for launch about one year later with about the same kind of sensing equipment. Between A and B will intervene a set of earth sensing projects known as the Earth Resources Experiment Program (EREP), to be carried on board the manned SKYLAB project to be launched later this year. This paper for brevity does not address itself specifically to ERTS-B and EREP since they do not affect its fundamental considerations, conclusions or recommendations.

It is noted, however, that the equipment in EREP will, in lay terms, be different, bigger and probably better than that on ERTS-A and B.

EREP will produce a relatively small volume of data since most of the time its platform, SKYLAB, will be "looking" to outer space, not to earth.

14/ At the end of March NASA had received 115 proposals for such "Data Use Investigations" from 36 countries, the United Nations Food and Agriculture Organization, and the Mekong Committee of ECAFE. Of these, 37 had been approved from 21 countries and more were in process for approval.

15/ "Policy Relating to ERTS and EREP Experiments, January 31, 1972.

16/ Hauser, Philip M., Director, Population Research and Training Center, Professor of Sociology, University of Chicago.

17/ Congress of the United States, House of Representatives, Committee on Science and Astronautics, "For the Benefit of All Mankind", December, 1971, P. 61.

18/ Fischnich, Dr. O.E., Assistant Director, Agriculture Department, Food and Agriculture Organization of the United Nations, in "FAO's Interest in the Application of Remote Sensing Techniques", P. 35, as presented at the XIX Rassegna Internazionale Elettronica Nucleare ed Aerospaziale, Rome, March, 1972.

19/ The converse question is no less interesting. In case of war with Israel, would the UAR want important information, such as on its hydrology, if that information would automatically become available to Israel?

20/ As an example of the degree of potential overlap, of reading data being sensed over another country, the United States/Canadian agreement on remote sensing cooperation is germane. Without use of the onboard taperecorder (which is normally used to record data in connection with experiments run while the satellite is out of sight of United States ground receiving stations, and to play out that data when it is over the United States) Canada and the US will have an almost total capability of reading the other country. From its three ground receiving sites, the United States will be able to cover all of Canada except for a small wedge in the central part of the extreme north, should it wish to do so. Canada, reading from its centrally located receiver in Saskatchewan, will be able to read all of the United States except for our extreme Southeast and a thin strip along the New England seacoast. Moreover, there is no way for one country to know, independently, whether the other is reading. Between two good neighbors with a history of amicable relations, this kind of arrangement is feasible. However, putting this kind of reading capability over traditionally troubled areas could make big trouble.

NOTE

For a basic bibliography on satellite sensing, see Hanessian's article cited at Footnote 8/, supplemented by the subsequent work of the House Committee on Science and Astronautics and of NASA.

This study is based on extensive reading from these sources and from various publications obtained through the United Nations, the FAO, and from individuals and government agencies in the seven countries visited: Mexico, Brazil, Senegal, Nigeria, Italy, Sweden and the United Kingdom.

The author's judgements, however, are perhaps more based upon consultations in the United States and abroad than on published material. Foreign government officials, speaking without attribution, tend to be more frank than in the written word in assessing some of the problems of adequate international organizational arrangements for satellite sensing systems.

Consultations were: foreign government officials - 37, foreign private individuals - 4; United States Government (Executive and Congressional Branches) officials - 20, United States private individuals - 5.