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REMOTE SENSING UTILIZATION OF DEVELOPING COUNTRIES:

AN APPROPRIATE TECHNOLOGY

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ABSTRACT

Studies sponsored by AID have verified that remote sensing technology can play a highly useful role in development. As a result, AID has committed itself to an expanded, multi-faceted program. This paper discusses AID's activities for establishing regional and national training and user assistance centers, conducting workshops and training seminars, conducting demonstration projects, carrying out research on applications, and granting financial and technical assistance to build or strengthen a country's capability.

I. INTRODUCTION

Two years before the launch of ERTS-1, AID recognized that remote sensing could have a substantial impact on development programs of developing countries. Accordingly, the office immediately initiated a program of analysis, cautious testing and experimentation designed to create an understanding of the role and impact of remote sensing in the developing process. This paper discusses the program that has evolved within AID from these early studies. For the purposes of this paper, AID's remote sensing activities have been grouped into the following six categories:

- Training and Workshops
- Research in Applications
- Grants
- Training and User Assistance Centers
- LANDSAT in Projects
- AIDSAT - High Level Awareness

It should be noted that these categories are not mutually exclusive. For example, people are trained in the process of working on projects, and grants are given to assist an investigator in carrying out research or project demonstrations.

Before discussing these elements of AID's remote sensing program, it may be well to say a few words about the appropriateness of remote sensing technology, and in particular LANDSAT, to development. LANDSAT is a product of a highly sophisticated technology, and the engineering required for its success is truly impressive. Consider for the moment just one parameter of the LANDSAT system —

repetitive coverage every 18 days. The linear velocity of a point on the equator due to the earth's rotation is 24,900 miles/day or 1,210 miles/hour or 20 miles/minute. If after 18 days or 252 orbits of the earth, the timing of the satellite crossing of the equator is off its nominal 0930 crossing by ± 1 minute, and the center point of two successive images of an area at the equator will be displaced from each other ± 20 miles. Yet the center point of LANDSAT images have remained within this displacement over several years of operation, a miracle in timing. Other parameters of the LANDSAT system have similar, high technology requirements.

Despite the fact that the LANDSAT system itself represents the cutting edge of technological development, extraction and use of information from LANDSAT data products can be done at almost any technological level. Useful information can be obtained from simple visual inspection with little or no training, e.g., black-and-white images can be used as a map substitute. With training and information extraction aids, such as a light table, color additive viewer, density slicer or zoom transfer scope, considerably more information can be extracted. For example, identification and mapping of surface features and land cover. With still higher technology such as computer processing, information from LANDSAT can be automatically extracted based on spectral signatures and changes occurring with time. Furthermore, the data can be presented as summary statistics or placed automatically in a geographic data base.

In large, underdeveloped areas where maps and resource information are inadequate for optimum project design, LANDSAT can provide various levels of information needed for assessing, monitoring, or extracting resources. As discussed in the preceding paragraph, the level of technology used to extract the information required by a country can be sized to its needs and/or abilities. It is AID's goal to assist developing countries to acquire the remote sensing capability appropriate to them. Figure 1 is a map of the world showing the developing countries which receive some form of economic assistance from AID.

II. TRAINING AND WORKSHOPS

The limiting factor in the transfer of technology is often the capability of the recipient country to absorb the technology. Capacity, in turn, is measured by the number of trained personnel available to receive and use the technology. Thus training is the common denominator in almost every project involving the transfer of technology undertaken by AID. Furthermore, training, because of its multiplier effects, is one of the best values for our AID dollars. Many foreign assistance programs only help the developing nations, but training helps them to be able to help themselves with far more lasting effects.

The importance of training in the transfer of remote sensing technology is no exception. Accordingly, training was one of the first activities undertaken when the Agency first became aware of the many important benefits of remote sensing technology for developing countries. In May 1973, AID sponsored its first international workshop in the Philippines. This workshop was of two weeks duration and covered the fundamentals of multispectral remote sensing from satellites. ERTS-1 imagery of the participants' own countries was used in lectures and laboratories and gave the workshop a sense of being directly applicable to development problems. Since that time, AID has sponsored similar workshops in Mali, Indonesia, Panama and Kenya and has participated with the U.S. Information Agency in regional remote sensing seminars. AID also sponsored the first two international training courses at the EROS Data Center. This course is now continuing on a twice yearly basis under U.S. Geological Survey sponsorship and has become the most widely attended international training course of its kind.

These training courses have not been one-way streets as far as the transfer of information is concerned. They have given AID valuable insights into the needs and capabilities of the countries they have served. Each course has been characterized by frank exchanges of views on the usefulness of this technology and its importance to application areas in the developing world. Each course has been concluded with a critique in which the views of the participants have been carefully analyzed and used in designing the next course.

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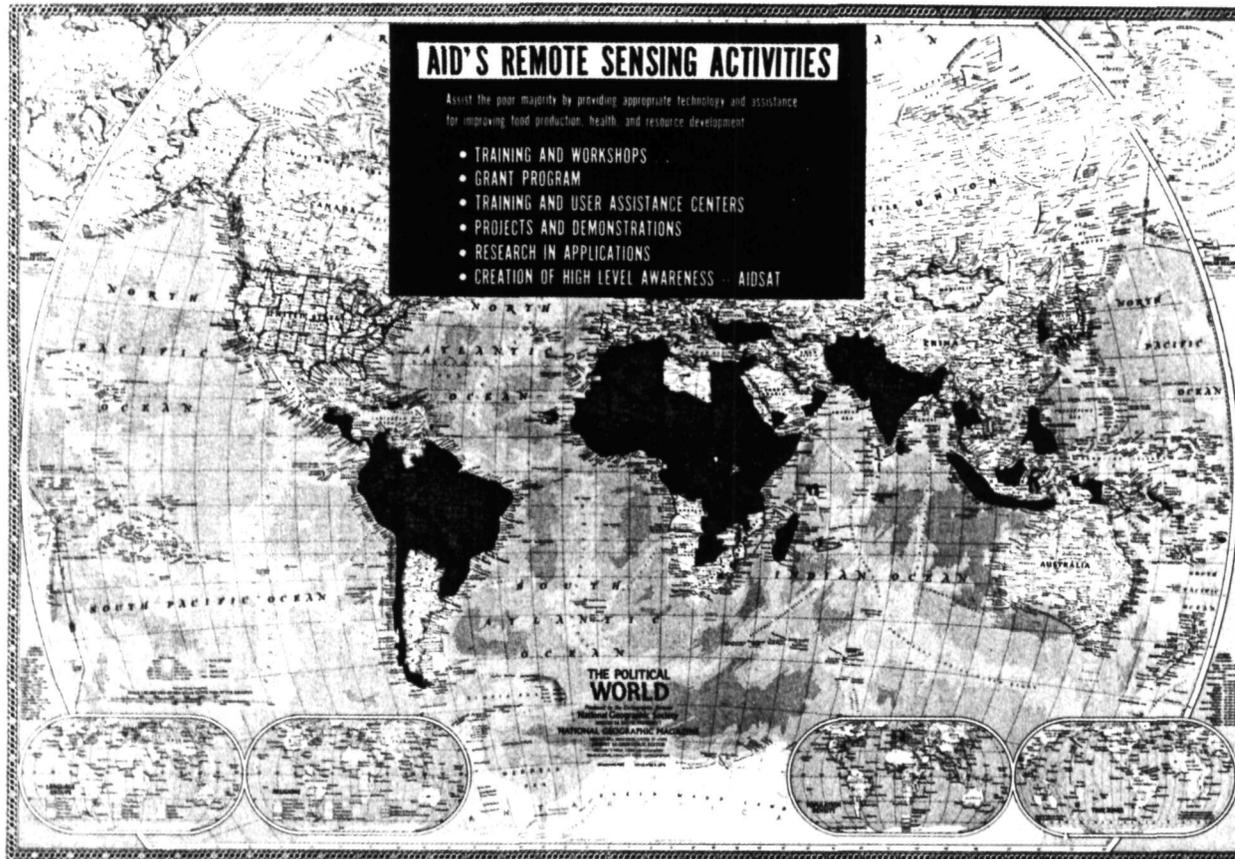


FIGURE 1. COUNTRIES WHICH RECEIVE ECONOMIC ASSISTANCE FROM AID

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Two of the most significant conclusions have been the need for more intensive training to develop a higher level of competence in interpreting LANDSAT imagery and the need to make the training even more relevant for the participants. In response, AID has now designed a course with these objectives in mind. This course is presently being initiated in Nepal with the Remote Sensing Institute of South Dakota State University as the contractor. The course will begin with a seminar designed to familiarize the host country participants with the latest applications of the technology. The seminar will also familiarize the contractor team with the data needs of the host country, resource projects presently underway, and the key persons involved in resource management. If appropriate, three or four resource managers from the host country will be selected for further training in the U.S. under the guidance of the contractor. This training will extend for a period of four to eight months and will include the processing and analysis of imagery of previously identified project areas in the host country. After the trainees return to their home country, they will continue to work on these projects under the periodic supervision of the contractor. With the assistance of the contractor, they will provide workshops and on-the-job training for their colleagues. The total period of contact with the contract team will be approximately eighteen months.

It is hoped that this longer period of contact will be sufficient to establish the technology in the host country as a lasting institution. It is also hoped that permanent linkages will be developed between the host country managers and the U.S. scientists. Finally, it is expected that during this period, the trainees will have achieved a level of competence and confidence to enable them to continue on their own.

III. REMOTE SENSING GRANTS

A competitive grant program was instituted by AID in late 1974 to provide incentive to developing countries to achieve broader use of information available from LANDSAT and other types of remote sensing data. This program which is being administered by the Environmental Research Institute of Michigan is designed to strengthen the capability of in-country institutions, while they apply remote sensing technology to projects of high priority to the grantee's country. Each grant carries a financial award (nominally \$20,000) plus technical assistance in the form of training, acquisition of materials and supplies, and occasionally data processing at the request of the grantee. These grants are intended to support "seed projects" concerned with specific applications of remote sensing data. Each grantee designs and administers his own project and is responsible for its execution. Successful grant projects promote an increasing awareness of the value of remote sensing to economic development and a self-perpetuating and expanding use for remote sensing data within developing countries.

To date, ten grants have been awarded to investigators in ten different countries. Table I lists these grants by country and gives a brief description of the projects. Each investigator identified a project oriented towards a particular application area and national need. Each project had a specific set of data requirements and goals and was designed to take about one-year to accomplish, although unforeseen delays resulted in some projects lasting for longer periods. In selecting projects for support, emphasis was placed on the identification of a specific information need which could be met by use of remote sensing data, and which was important for development planning purposes.

The need for data from the U.S. earth observational satellites to perform the projects resulted in choosing investigators from countries that had NASA-approved LANDSAT experiments. In some cases, the AID grantee for a country was the same as the NASA principal investigator, in other cases, a different investigator was selected. In no case, however, was the AID grant project the same as the NASA-approved experiment. In some cases, the AID grant provided data and facilities complimentary to the NASA experiment, but each project was intended to be a separate and distinct effort. Three of the ten grantees are in South America, two are in Africa, and five are in South and Southeast Asia. These countries have a combined population of 318.8 million people and cover a total of approximately 2.84 million square miles.

TABLE I. AID GRANT PROJECTS

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<u>COUNTRY</u>	<u>GRANTEE</u>	<u>PROJECT</u>
South America:		
Bolivia	Dr. Carlos Brockman Servicio Geologico de Bolivia (GEOBOL), La Paz	Detect and identify iron ore deposits of economic significance in eastern Bolivia.
Chile	Messrs. German Errazuriz & Arnoldo Ortiz-Riveros Instituto de Investigacion de Recursos Naturales (CORFO), Santiago	Inventory the natural resources of Tarapaca and Antofagasta Provinces.
Peru	Mr. Walter Danjoy Arias Oficina Nacional de Evaluacion de Recursos Naturales (ONERN)	Identify and map the extent of the economically important Aguaji Palm in the eastern jungle.
Africa:		
Lesotho	Messrs. Anthony Jackson & Edwin M. Seithleko National University of Lesotho, Roma	Investigate snowfall, drainage patterns, and vegetation in relation to soil conservation requirements.
Zaire	Dr. Sendwe Ilunga, Director, ERTS-Zaire Bureau de President Kinshasa	Develop annotated LANDSAT images as cartographic substitutes by Institute Geographique du Zaire.
South Asia:		
Bangladesh	Prof. M. I. Chowdhury, Chairman, Department of Geography, Jahangirnagar University, Savar	Provide agricultural and land-use information for further develop- ment of the Haor areas in north- east Bangladesh
Pakistan	Dr. M. Shafi Ahmad, Director, SPARCENT - Pakistan Space & Upper Atmosphere Research Committee (SUPARCO) Karachi	Provide geomorphological information concerning vegetation and littoral conditions for construction of a new industrial port for the City of Karachi
Sri Lanka	Mr. Chris Nanayakkara, Survey Department, Ministry of Agriculture & Lands, Colombo	Develop digital analysis techniques for obtaining agricultural crop information.
Southeast Asia:		
Philippines	Mr. J. C. Fernandez, Director, Bur. of Mines, Department of Natural Resources, Manila	Provide natural resource information for integrated economic development of Island of Mindoro.
Thailand	Dr. Somnuk Striplung, Dept. of Agricultural Economics, Ministry of Agriculture & Crops Bangkok	Provide acreage statistics to annual crop surveys of corn, rice, and sugar cane.

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The specific objectives and results to date of the ten grants vary considerably. Four of the grant projects were primarily concerned with applications of remote sensing to agriculture (Bangladesh, Lesotho, Sri Lanka and Thailand), although the approaches were different for each. Two projects were concerned with multidisciplinary resources information needed for planning integrated development of underutilized regions (Chile and the Philippines), and one country each was concerned with cartography (Zaire), forestry (Peru), geology (Bolivia), and coastal zone development (Pakistan). This range of resource applications reflects the multidisciplinary nature of remote sensor-derived data and different information needs of different developing countries.

The grant financial awards were designated to be used for acquisition of data, supplies, equipment, training, travel and in several cases, some advanced data processing in support of the project. Funds were not to be used for salary or expenses incurred in connection with the investigator's normal duties. The time of the investigators and their colleagues were donated by their respective institutions, and facilities existing within the grant countries were expected to be made available as required.

In eight of the projects, the investigators were national government employees; in the two other cases, they were university faculty. Major emphasis was placed on supporting projects which seemed to have good linkages with decision-making institutions and involved a number of the agency or institution personnel at both the technical and administrative level. The capability of investigators to interact with various in-country institutions was a key consideration in selecting projects for funding. While the results of the grant projects are still being developed and documented, a preliminary evaluation indicates the occurrence of both successful and unsuccessful projects, with most projects being somewhere between these two extremes. Because of the low level of activity, several of the grants were judged as having limited success to date, but further progress may occur in time. As anticipated, the key ingredients leading to successful grant programs are (1) an energetic and enthusiastic principal investigator, (2) high level government interest and concern for the programs, and (3) involvement in an operational program of concern to the country.

IV. RESEARCH IN APPLICATIONS

In addition to training, technical assistance, and grant support for institutional development, AID supports research designed to explore those application areas which are of particular importance to developing countries. While much research has been undertaken in connection with the LANDSAT program, there are still many potential research areas that have been underexploited largely because they are of interest only to developing countries.

A typical example is in demographic applications. For the past three years, AID has sponsored demographic studies in Kenya and Bolivia. These projects are designed to determine whether census tracts of uniform population density can be identified on LANDSAT imagery based on observed land use. If so, reasonably accurate population estimates could be determined with relatively small samples. So far, the results of these projects have been very encouraging. This is an example of an application which would be of little interest in most developed countries because these countries already have the means to acquire much more accurate demographic data by conventional methods.

Another area where research is needed is in tropical agriculture. The LACIE program and other agricultural research has focused on temperate latitudes where large homogenous fields and regular seasons make the job of crop forecasting relatively easier. Some of these techniques may be applicable in the rice growing areas of Southeast Asia but much tropical agriculture takes place on small family size plots where a variety of crops is grown year around. To forecast crops and otherwise aid agricultural planners in these areas, we need to know more about what kinds of agricultural data are needed by the planners and how they can be collected. Such items as sensor types, resolution requirements and frequency of coverage need to be more clearly defined for use in tropical settings.

Desertification is another area where a great deal of research is needed. There is still insufficient evidence to state with authority the relative impact of human activity and weather changes in areas, such as the Sahel in West Africa, where desert encroachment is said to be taking place. One also needs to know more about rainfall characteristics and recurrent weather patterns in arid regions for more efficient land management. World-wide attention will be focused on these problems during the forthcoming United Nations Desertification Conference. AID is expected to join with other nations of the world at that time in seeking solutions to the problems of desertification.

Cartography is an application area where additional research could pay large dividends. Most developing countries are not only poorly mapped but they have inadequate geodetic control on which to base additional mapping. LANDSAT imagery has provided many of these countries with useful map substitutes. The next step is to determine the extent to which this imagery can be utilized in the production of medium and small scale photo-image maps with adequate geometric fidelity.

AID's development assistance program in remote sensing will, therefore, include a certain amount of pioneering in addition to the more routine training and technical assistance. The space program is still in its infancy, and as it grows, there will be even more opportunities for research in applications that directly benefit the developing countries. AID will continue to be watchful for these opportunities.

V. REMOTE SENSING CENTERS

The acceptance and use of remote sensing techniques can be facilitated by concentrating facilities and expertise into groups. For example, one can find user assistance centers in the United States which serve national, regional, or state needs rather than individual needs. For developing countries, which have limited human and financial resources, it is visualized that user assistance and training centers should be organized initially on regional and/or national levels. Such centers would provide data interpretation facilities, training and consultation on a readily available basis.

A center has a number of advantages for transferring remote sensing technology. For example, in the absence of a center, personnel are sent outside their country for training and too often find:

- (1) the training exercises address problems foreign to them,
- (2) their newly acquired enthusiasm is not shared or appreciated by their management,
- (3) they have no data or interpretation facilities,
- (4) their "foreign" training qualifies them for promotion to a different, non-remote sensing job.

The center concept not only provides data, facilities and consultation on a readily accessible basis, but its staff can conduct demonstration projects as well as an organized campaign to create awareness of remote sensing potential among high level government officials. Indeed, the existence of the center itself will be a stimulus for remote sensing activity.

Plans for establishing Regional Remote Sensing Training and User Assistance Centers at Ouagadougou, Upper Volta and Nairobi, Kenya have been approved. These centers are expected to be operational by the end of 1977. The Ouagadougou Center will service West Africa (the Sahel and bordering countries), and the Nairobi Center will service East Africa. It is anticipated that AID will establish additional regional centers in Asia and Latin America.

Each center will be staffed by four or five specialists representing different disciplines plus local technicians. Each center will also contain analytical equipment, imagery files, image reproduction facilities, a technical library and ground truth equipment. In addition to being able to provide workshops and other training, each center will have a strong outreach or extension

capability. The staff will be encouraged to acquire familiarity with the needs of the countries of the region in order to provide the kind of assistance that will directly satisfy those needs.

The regional centers will also be focal points for the development of networks and linkages. They will be important contact points between local resource managers and experts in the U.S. and elsewhere. The personnel of the centers will work closely with national universities in the introduction of remote sensing into their curricula. Remote sensing is seen as a tool in resource management just as mathematics is a tool in science or engineering, and AID's objective is to see remote sensing taught in the same way, that is, as an integral part of any resource oriented curriculum.

Care will be taken to select staff for the centers who are knowledgeable about developing country problems and who will not oversell the technology or stimulate expectations that cannot be fulfilled. In fact, the stated goal of AID's assistance program in remote sensing is "to assist developing countries in improving their capabilities for assessing and managing resources through the use of remote sensing and other appropriate technologies." As much of the training and technical assistance as possible will be undertaken in the recipient countries working with ongoing projects of high national priority. Skilled resource specialists are in short supply in most developing countries and cannot be diverted for long periods of training away from home or on projects that are merely designed to demonstrate new techniques. AID will, therefore, seek opportunities to work directly with resource managers on existing projects and demonstrate how various remote sensing techniques can improve the efficiency of resource data collection.

It is expected that nations will want to have their own centers as their remote sensing requirements expand. One should not look upon national centers as competitors of the regional centers. Rather, they compliment one another. In general, regional centers will be a larger and more sophisticated operation than the national centers as the former serves a larger clientele and can draw upon a larger body of technical expertise for its staffing. Thus, the regional center could provide more sophisticated analysis or processing than would be possible at the country level.

Recognizing the importance of a well directed national remote sensing program, AID is also sponsoring the development and strengthening of national remote sensing centers. A program of this nature has already been approved for Zaire. This program is focused on building and strengthening ties between the ERTS-Zaire program office and user organizations.

VI. AIDSAT — CREATION OF HIGH-LEVEL AWARENESS

Since remote sensing is a tool to service multiple users, development of the technology requires at least multiple agency cooperation, if not, organized multiple-agency support. These requirements impose a need for high level management awareness and support for remote sensing. Taking advantage of the fact that NASA was moving the ATS-6 geostationary communication satellite and the U.S. bicentennial celebration, AID contracted NASA to conduct a demonstration to make heads of states and their staff aware of how the space age technologies of communication and remote sensing can help developing countries. This program reached 27 countries in the fall of 1976. It created high-level government awareness of remote sensing applications and more importantly committed AID to the development of a program of sharing these technologies with the poorer countries of the world. This commitment had earlier been voiced by the Secretary of State who said at the United Nations Conference on Trade and Development in Nairobi, "Satellite technology offers enormous promise as an instrument for development. Remote sensing satellites can be applied to survey resources, forecast crops and monitor land use. AID is prepared to cooperate with developing countries in establishing centers, training personnel, and where possible, adapting our civilian satellite program to their needs."

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The AIDSAT program warrants discussion far beyond the scope of this paper. For the reader unfamiliar with AIDSAT, a brief description follows. The ATS-6 is an experimental, high-powered, geostationary communication satellite. Broad-band video data can be transmitted and received with antennas only 10 feet in diameter. The parking station for the geostationary satellite was being moved from over the Indian Ocean to the Pacific Ocean. As the satellite made its three-month westward journey, live color television programs were beamed between the U.S. and each of 27 countries in Asia, Africa, and South America. One portable receive and transmit terminal was set-up in the capital city of the developing country and up to three receive-only terminals were set-up in outlying cities. The audiences in the capital cities consisted of about 150 high-level government officials and often included the chief-of-state. The U.S. beamed a filmed greeting from President Ford and three excellent color films, one of which described LANDSAT and its applications. This was followed by a live, two-way panel discussion between officials of the host country and a panel of experts in the U.S. The panel moderator was an astronaut who selected the U.S. respondee to questions or comments posed by the host country panel. These questions were stimulated by the films being shown. Much of the time and interest of the live, one-half hour panel discussion was directed toward how LANDSAT could assist the host country in working out specific problems associated with their development.

VII. LANDSAT APPLICATIONS IN AID PROJECTS

Despite the fact that the LANDSAT program continues to carry the experimental label, the imagery produced has many useful applications in operational projects. This is especially true in developing countries where LANDSAT imagery is often the most up-to-date and reliable source of data. Accordingly, AID has begun using LANDSAT imagery routinely in resource investigations.

One of AID's first experiences in using LANDSAT imagery as an operational tool was in a range study in Tanzania recently completed by the Earth Satellite Corporation. In this project, covering the Masai region in northern Tanzania, LANDSAT imagery, supported by aerial and ground observations, was used as the basis for determining the possibilities and limits in land use for agricultural cropping and range and water resource development. LANDSAT imagery was used to help identify vegetation cover, land use, soil associations, and fracture zones that might be indicators of ground water.

In West Africa, LANDSAT imagery has been used in a similar manner in Mali to provide the basic data source for a comprehensive resource inventory. Here again, LANDSAT imagery is being used to map vegetation, soils, land use, and other elements needed to provide planners with a source of information for decision making.

Through the use of this technology, AID hopes to assist development planners to avoid some of the mistakes in land utilization that have led to overgrazing, deforestation, and soil erosion. AID, in cooperation with the African Development Bank, is planning to support a major land suitability study and resettlement plan for a large area in West Africa that is being freed from the threat on onchocerciasis or river blindness. Recent control measures have been effective in freeing areas in Ghana, Benin, and Upper Volta from this disease but the countries correctly want to develop orderly, rather than random, plans before permitting resettlement of these areas. The techniques employed here could also be used in other resettlement schemes, such as the tsetse fly infested areas of East and Central Africa when those areas are made inhabitable.

VIII. SUMMARY OF AID'S REMOTE SENSING PROGRAM

Since the launch of ERTS-1 in July 1972, AID has been involved in fostering the use of satellite data for developing purposes. This involvement began with cautious experimentation and training in the fundamentals of image analysis. The studies conducted by ERIM [1] and the National Academy of Sciences [2] have given the Agency additional assurance of the usefulness of this technology and guidance on future assistance efforts. This has led to the distribution of grants to support local initiatives and institutional development and the use

of the imagery in an operational mode on various resource inventory projects. With positive feedback from these activities, the Agency publicly committed itself to a greatly expanded level of assistance in remote sensing for developing countries during the AIDSAT demonstration. As a result of these commitments, requests have been received from numerous countries throughout the world. Examples are requests for assistance in the development of national laboratories in Zaire, Tunisia, and Thailand; training programs in Nepal, Tanzania and Sudan, and several Central American countries; resource inventories in the Central African Empire, Cameroon and others; and various miscellaneous projects, such as monitoring deforestation and soil erosion. The response to these requests will include further development of institutional capability in the form of regional centers to give the developing country resource managers more direct access to sources of assistance.

As long as AID remains committed to such humanitarian goals as alleviating hunger throughout the developing world, the Agency will seek to utilize new and appropriate technologies, such as remote sensing, which promise to help overcome the slow evolutionary pace of development.

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