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A collection of three papers and three case studies on the applications of remote sensing in developing countries. This report is intended to assist planners in developing countries to assess how their countries might participate more effectively in remote sensing activities. It includes a general discussion of how multispectral techniques can be used by countries with limited investment, manpower, and institutional capabilities. It then describes activities in three countries where advanced techniques are being practically applied. The first paper, "Prospects for Remote Sensing in International Development," by Glenn Schweitzer, was first presented at the CENTO seminar on this subject, held in Ankara in November, 1971. The second paper, "Practical Applications of Satellites in Earth Resource Surveys with Special Reference to African Countries," by John Fry, was first presented at the Third Regional Cartographic Conference for Africa, Addis Ababa, in November, 1972. It broadly describes the ERTS system and selected applications. The third paper, "Space for World Development," by John Fry, was presented at the 23rd International Astronautical Congress in Vienna in October, 1972. It discusses applications of satellite imagery to population census; agricultural development, and cartographic activities. The case studies discuss ERTS-1 and small-aircraft programs conducted in Mali, Lesotho, and Indonesia.

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REMOTE SENSING: A DEVELOPMENTAL FRAMEWORK AND CASE STUDIES

Office of Science and Technology
Agency for International Development
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REMOTE SENSING: A DEVELOPMENTAL FRAMEWORK AND CASE STUDIES

January 1973

Office of Science and Technology
Agency for International Development
Washington, D. C.

PREFACE

This report is intended to assist developing country planners and technical specialists assess how their countries might participate more effectively in remote sensing activities being supported by the United States and other developed countries. The report includes a general discussion of how multi-spectral techniques can be used by countries with limited investment, trained manpower, and institutional capabilities. Then it describes specific activities in three countries which are attempting to apply these advanced techniques to development problems in a very practical way. These specific experiences should be of interest to many other countries at about the same level of development with similar developmental concerns.

The first paper on "Prospects for Remote Sensing in International Development" was presented by Glenn Schweitzer, Director of the Office of Science and Technology, as the keynote address for the CENTO Seminar on the Application of Remote Sensing in the Determination of Natural Resources, held in Anakra, Turkey, November, 1971. It emphasizes the economic environment in developing countries into which aircraft and satellite remote sensing programs must fit if the transfer of this technology is to be successful.

The second paper entitled "Practical Applications of Satellites in Earth Resource Surveys with Special Reference to African Countries," was prepared by John Fry of the Office of Science and Technology for presentation at the Third Regional Cartographic Conference for Africa, Addis Ababa, Ethiopia, October 30 - November 10, 1972. The paper broadly describes the ERTS system and selected applications. It notes the opportunity for developing countries to obtain ERTS 1 imagery for experimental investigations and to formulate proposals, if desired, for consideration by NASA for ERTS B -- tentatively programmed for launch in November 1973.

The third paper, also prepared by Mr. Fry, was presented at the Twenty-Third International Astronautical Congress in Vienna, October 8-15, 1972, at the theme session: "Space for World Development." Specific applications of satellite multispectral imagery to population census and related agricultural statistics and cartographic activities are described.

The report concludes with three case studies. These include ERTS-1 experiments being carried out by the Governments of Mali and Lesotho and a small aircraft experimental program being conducted by the Government of Indonesia. The Agency for International Development is participating in each of these activities.

While the purpose of this report is to broaden understanding of the potential applications of the technology and opportunities for developing country participation in future programs, some of the material may raise questions which are not adequately answered in the text of the papers. Therefore, the Office of Science and Technology will welcome comments on any aspect of the report and endeavor to respond promptly to questions from developing country officials and specialists.

TABLE OF CONTENTS

	Page
Prospects for Remote Sensing in International Development.	1
The Economic Environment.	3
Aircraft Programs	5
What About Satellites?.	7
Current Status of the NASA Satellite Program	8
Low Cost Models	9
The Approach to Training.	10
An Opportunity for Science.	11
Practical Applications of Satellites in Earth Resource Surveys with Special Reference to African Countries	12
Characteristics and Status of ERTS-1. . .	12
Earth Resource Applications of ERTS-1 Data.	14
Experiments in Mali and Lesotho	16
Looking Ahead	20
Space for World Development Forum Session - Demography	21
ERTS-1 Experiment of the Government of Mali.	26
Background.	26
Objectives.	28

Page

Approach. 31

Results of the Investigation. 33

ERTS-1 Experiment of the Government of Lesotho 35

Background. 35

Objectives. 38

Approach. 41

Results of the Investigation. 44

Aircraft Remote Sensing Investigations of the Government of Indonesia 47

PROSPECTS FOR REMOTE SENSING IN INTERNATIONAL DEVELOPMENT

by

Glenn E. Schweitzer, Director

Office of Science and Technology

Agency for International Development

Washington, D.C.

Keynote Address

at

CENTO Seminar on the Application of Remote Sensing in the Determination of Natural Resources

Ankara, Turkey, November 10, 1971

"Science can only give us the tools in a box ... but of what use to us are miraculous tools until we have mastered the human, cultural use of them?" These words of Frank Lloyd Wright aptly describe the theme of this seminar --to transfer the potential of some of the most dramatic scientific achievements of recent years into practical benefits for all of us.

The CENTO region is indeed an appropriate site for this international effort to come to grips in concrete terms with the application of remote sensing technology to the practical problems of development. On the one hand, the scientific and technological communities of the CENTO region are now in a position to deal effectively with the complexities of modern technology -- technology which appears to offer an unprecedented opportunity to increase very rapidly our currently limited knowledge of the resource potential of the area. On the other hand, many investment decision-makers and development planners remain unconvinced that developing countries should invest scarce resources in high technology enterprises. Thus, it is the task of the "development technologist" -- your job and my job -- to determine under what conditions modern technology provides a faster and cheaper way to solve problems of priority development interest, and then to develop and articulate an approach that is persuasive to political and economic leaders.

Many papers have been written in recent years about the potential of remote sensing for development. Most of these have been cast in vague terms and rest largely on an intuitive, inner conviction that this new technology has many high pay-off applications. Hopefully, from this seminar will emerge a broadened framework for understanding the practicality and tangible benefits of such applications -- a framework based on sound economic consideration of direct and indirect costs and related advantages and disadvantages of using remote sensing techniques in this region. If we are successful, this seminar will not only clarify many of the issues of concern to decision-makers but can also serve as a model for replication in other areas of the world.

My recent experience in a number of countries has repeatedly demonstrated that there are few problems and few solutions, if any, that are not better perceived by your specialists than by ours. While developed country experts can acquaint their colleagues with the lessons they have learned through experience, I doubt that we can offer many new insights into the solution of development problems which are not already

obvious to you. However, collectively we may be able to present these insights in such a manner that the path to development becomes straighter, less precipitous, and better illuminated.

During the next several days, you will be discussing in great detail a wide variety of applications. Therefore, I shall not attempt to catalog recent technological advances nor describe the many disciplines which can benefit from this technology. Rather I will confine my remarks to a few broader considerations. In my view, investments in remote sensing activities should be assessed within a framework characterized by such considerations.

THE ECONOMIC ENVIRONMENT

The traditional starting point for considering the potential of any technology in a developing country is cost. But cost cannot be easily measured. It is likely that foreign exchange costs will be involved -- in training, equipment, supplies, or operations. Alternative uses of foreign exchange are manyfold, and judgments on use of such a visible political commodity as foreign exchange are not always rational. Indeed, this irrationality is likely to work in favor of remote sensing investments in view of the glamor attached to this field.

The type of skilled manpower that is needed for successful efforts in almost every high technology field is in short supply. Furthermore, the value of a technical specialist cannot be measured only by his salary. Frequently, a single specialist provides the buoyancy for an entire laboratory in a developing country, and his diversion to other activities can have many adverse secondary effects.

Will the diversion of limited technological resources to remote sensing contribute to stimulating the type of technological infrastructure that best serves the nation's overall development -- both in the immediate future and the longer term? Will the technological resources needed to support remote sensing activities complement or detract from comparable resources needed for agriculture, medical, and industrial advancement?

Another type of concern that is in the forefront of every meeting of international development experts today is the impact of technology on jobs, and employment is probably the most important development issue of the 1970's. Is development of highly automated data collection techniques -- which

are clearly not labor intensive -- consistent with employment concerns, or are there no other alternative means of essential data collection? Ground survey techniques considered totally unrealistic in developed countries often become more attractive in an environment where labor is available at very low costs, payable in local currency.

Now let's turn to the use of data, for if information is not used, why collect it? The data we are considering is being acquired within the context of overall technological, economic, and social systems that are often slow, sluggish, and very imperfect at best. There is little sense in having a high strength steel rung in a frayed rope ladder. In short, there needs to be a readiness, and capability, to translate data into meaningful economic activity -- activity that must extend all the way through the production or export phase.

The types of data that are useful to a developing, or developed, country are as varied as life itself. Let me identify several types of particular relevance to our discussion.

Developing countries invariably have five-year development plans which are usually updated annually. These plans are the principal documents that set forth national priorities and resource allocations. Clearly, the data base on which these plans rest is important. The extent and precision of planning data vary from country to country, but are usually not adequate.

"Discovery data" -- data which provides significant leads to mineral resources, agricultural blights, ground water patterns -- is of particular interest. However, our experience has shown that the lack of "discovery data" is often far less of a constraint to resource development than the lack of a capability to use "discovery data."

Adequate data relevant to new engineering projects -- dams, roads, irrigation systems -- is of continuing interest. Engineering organizations need and use such data, particularly information concerning the physical conditions of the immediate locale of the project. However, they are often poorly equipped to acquire or analyze data related to the project's broad ecological ramifications which extend over larger geographical areas.

Resource management data can be many faceted. This term frequently means the basis for leasing agreements. It often concerns land demarcation for tax purposes. There are also many other aspects of resource management data. Unfortunately,

the term seldom refers to regional resource management in a comprehensive sense -- an approach that is of growing concern throughout the world.

Before turning away from these general economic considerations, I would like to re-emphasize several points. As discussed above the approach to costs and benefits must be tailored to the social and economic conditions of the particular country and may vary significantly at different levels of development. While data -- of some quality and quantity -- is the lifeblood of every expanding economy, the shortage of adequate data is only one of many constraints to economic progress, and often it is not at the top of the list of constraints.

AIRCRAFT PROGRAMS

I am pleased to report to you a number of success stories in the use of remote sensing from aircraft in recent years. I am sure you can add to the list from your experiences in the CENTO region. While I would like to report this information in dollar and cents terms, remote sensing data is always used together with other information, and determination of its exact contribution is difficult. Nevertheless, we need to define its value more precisely.

-- In the Dominican Republic aerial photography played an important role in an integrated resource survey that served as the basis for preinvestment and feasibility studies of (a) development of the Yuna River Delta, (b) modernization of farming practices in the Azua Plain, (c) drainage of the Atlantic Coastal Plain, (d) citrus fruit production, and (e) several irrigation projects.

-- In Ecuador, aerial photographs were a significant part of the resource surveys which provided the basis for a $192 million plan for development of the Guayas River Basin.

-- In the Philippines, infrared measurements and aerial photographs contributed to warnings of volcanic eruptions and subsequent evacuation of people and property from danger areas.

-- In Jordan, aerial photography was a key factor in locating ground water drilling sites, developing phosphate deposits, classifying soils, and planning highway, rail, and water routes.

-- In Honduras, recent aerial surveys of timber resources provided the basis for contract negotiations designed to develop paper, pulp, and plywood industries in two areas.

-- In the Sudan, crude aerial photography of Khartoum provided the basis for determining the least disruptive building condemnation schemes necessary for expanded city traffic patterns.

-- In Tanzania, aircraft surveys are being used in delineating local jurisdictions and determining tax patterns and have also assisted in studies of mosquito breeding habitats.

-- In Venezuela, Colombia, and Panama radar surveys are significantly enhancing the quality of maps available in areas currently being opened for settlement and exploitation.

You may have noted that black and white photography played a prominent role in these success stories. This obviously reflects the current and near-term state of the art in most developing areas.

However, we have also had some setbacks in the aircraft field. The most serious problem is the under utilization of the data that has been collected. There are thousands of aerial photographs of Latin American and Africa that have never even been seriously examined, let alone utilized in an economically productive fashion. The principal constraints have usually been lack of local governmental interest in the projects that have led to the photographs, over-zealous photographers, and the lack of manpower to interpret the photographs.

This brings me to a related point on past aircraft programs -- and particularly programs supported by foreign assistance agencies -- namely, over-reliance on the "turn key" approach. The objectives of assistance projects should not be to collect data -- which is straight forward and relatively simple -- but the harder task of assisting in the establishment of a local capability to collect and use the data.

In summation, aircraft programs have proved their worth when two conditions have existed: recognition of a clearly definable problem of narrow scope and of economic significance, and a readiness and capability of the concerned government agency or private investor to incorporate the data into an action program.

Local capabilities and resources to carry out aircraft surveys for operational purposes are growing, and sensitivities to the value of such activities are spreading. These are healthy trends.

WHAT ABOUT SATELLITES?

From Apollo photography we have already seen the value of some of the unique aspects of satellite imagery -- such as synoptic coverage of large areas, constant sun angle, and concentration of broad scale data on a single photograph. Such imagery is of clear interest to topographic mapping agencies in need of improved base maps and to educational institutions concerned with subjects such as oceanography, geology, and hydrology. At this seminar we will emphasize its potential for natural resource agencies.

The uses of satellite imagery are clearly linked to the quality of the imagery -- and specifically the ground resolution. To be sufficiently interesting to attract investment funds which are in short supply, the imagery will have to represent a major advance over the quality of currently available data. Most countries will await delivery of the imagery and then make judgments concerning commitment of resources in country-specific situations. This seems to be a prudent approach. At the same time, however, the question is not whether high quality imagery will be a reality, but rather when this imagery will be available. There is no doubt that the technology is at hand, but there is always uncertainty as to the time scale for this type of research and development program.

It is likely that in the years ahead satellite imagery will be particularly interesting to regional economic planners since they are ideal consumers of broad scale reconnaissance data. To formulate sensible development plans they need an understanding of the resource potential related to the geography of their nations, and satellite data should help considerably in targeting detailed exploration activities.

Much has been written as to how resource managers will use satellite data. However, keeping in mind that developmental problems which are susceptible to solution are usually confined to quite limited geographical areas, the economically competitive applications in developing countries remain to be demonstrated in hard, cost terms. Hopefully, imagery of adequate quality, frequency, and reliability will be available at an attractive cost, and then past rhetoric can be translated into operational reality.

Two additional areas of application which are worth considering relate to the settlement of new territories -- and particularly shortly after the decisions have been made to open the areas -- and redevelopment of large areas struck by typhoons, floods, or earthquakes. In both cases the local government and perhaps international agencies are presumably prepared to invest substantial resources in development of sizeable geographic regions. Well-interpreted satellite imagery might contribute substantially to insuring that these resources are invested wisely.

CURRENT STATUS OF THE NASA SATELLITE PROGRAM

On October 20 NASA announced selection of the initial group of experimenters from 28 states and 22 foreign countries for the Earth Resources Technology Satellite (ERTS-A) and the manned Skylab which will carry an Earth Resources Experiment Package (EREP). The objective of both ERTS-A and the EREP aboard Skylab is to obtain multi-spectral images of the surface of the Earth with remote sensors and to process and distribute the imagery to users in a wide variety of disciplines. Selection of additional experimenters will be made in the next several months.

ERTS-A will be launched next spring into a 920 kilometer near-polar orbit. This will permit observation of the same spot on the Earth once every 18 days. The altitude allows the narrow-angle sensors to obtain virtually undistorted images. Each image will cover an area about 185 kilometers by 185 kilometers. The sensors include a high resolution return-beam vidicon system to record images in three spectral bands. The system provides the basis for the preparation of thematic maps over large surface areas where ground resolutions are expected to fall in the range of 92 to 185 meters. A four-channel scanner with ground resolution of about 160 meters extends spectral coverage to important longer wavelengths and permits analysis at the level of each resolution element. ERTS-A should provide photo images particularly useful in the analysis of regional geology, land use, land-water interfaces, and vegetation changes. It is anticipated that more than 9,000 different photographs and digital images will be produced each week -- many in multiple copies -- with the bulk of the data processed and made available directly to experimenters within 10 days. Other interested persons will be able to obtain the imagery on a cost-of-duplication basis.

Skylab is scheduled to be launched in the spring of 1973 into a 435 kilometer orbit. The first three-man crew will rendezvous with Skylab within several days of the unmanned launch and will spend 28 days in orbit. A second and third crew will spend 56 days each in orbit. EREP sensors include six bore-sighted cameras, a multi-spectral scanner, two radiometers, and a scatterometer. These sensors will provide images ranging from 75 to 150 kilometer squares. The photography should be an improvement over the excellent Apollo 9 results. All film and tape for these sensors will be carried to and from Skylab by the crew. In addition, one high resolution camera -- identical to the Apollo 15 moon camera -- will provide very limited photography with a ground resolution of about 10 meters. EREP data will be made available in the same manner as ERTS data.

A word of caution concerning these flights is in order. They are experiments, and while we are optimistic that exciting results will be obtained, there are many uncertainties. On the technical side, we know that the ERTS tape recorder is pushing the state of the art, and its lifetime may be limited. Also, Skylab photographic missions will be severely limited by the 50 pound allowable weight for film return.

As a final point regarding the United States program, I should like to mention that NASA is prepared to consider additional foreign government proposals for participation in the ERTS/Skylab experimental program.

LOW COST MODELS

Even the poorest countries can participate in satellite programs. It is not true that computers, air conditioned rooms, and elaborate equipment are essential components of a program to derive useful data from satellite imagery. When properly designed, experiments can be carried out on a low cost budget, and I am optimistic that future operational satellite programs will similarly provide for participation by countries which are short on investment resources. A well trained hydrologist, geologist, or agriculturist with minimal photo interpretation experience should be able to derive some useful information from satellite imagery using only a light table and manual plotting equipment. Indeed one of the advantages of satellite imagery is the concentration of large quantities of data on a single photograph, thus easing the correlation and scanning aspects of data reduction and interpretation problems. In short, I am not suggesting that expensive interpretation equipment is an unnecessary luxury. Rather,

there are alternative approaches -- well known to you -- which can be effectively employed with a little imagination, perserverance, and determination. Relatively primitive data interpretation techniques can be particularly useful when existing information is in extremely short supply.

With regard to low cost aircraft programs, clearly the expense of acquiring and operating the aircraft is an essential investment that is far from insignificant. Perhaps the greatest hope in reducing this expense is that military agencies throughout the developing world are gradually becoming interested in using their planes for development as well as security purposes. Under these circumstances civil agencies may be able to obtain aircraft services at acceptable costs. The problem then is outfitting the aircraft and carrying out well planned programs designed to provide useful data. Mounting cameras in a pressurized or unpressurized hull of a plane or in a wing pod, installing the camera triggering and control devices, and adapting appropriate navigation equipment to correlate aircraft location with photographic targets are important, but the techniques are well known and should not be expensive -- at least in terms of foreign currency requirements. More critical are the selection of the camera and the approach to data interpretation which will provide information of genuine interest to the user organization. There are clearly cost tradeoffs between the type of camera employed, the altitude of the aircraft, the ground resolution desired, and the quantity and form of the data to be analyzed. Thus, in designing low cost aircraft programs, the alternatives of all elements of the entire system from data acquisition to final usage should be carefully considered.

THE APPROACH TO TRAINING

If there is one word that is sacred in development circles, it is "training," for who can deny that training is a number one priority for developing countries? However, the wrong kind of training, particularly abroad, may be worse than no training. The "brain drain" and academic isolation from practical problems are tiresome cliches to many people, but unfortunately they are still very real by-products of poorly conceived training activities.

What kind of training makes sense, given the limitations on funds? We would welcome your views on this subject since we do not have the answers. The trend among development

agencies is to encourage training to the fullest extent possible in the developing countries themselves on the grounds that there are now institutions capable of providing training and such training will be more relevant to real needs. Also, emphasis is on training the future trainers to achieve a multiplier effect. At the same time there is clearly great value in awareness of advanced techniques and technologies available in developed countries. Thus, it would seem that training efforts in remote sensing should be directed to encouraging appropriate courses of high quality local institutions and coupling this training with short-term familiarization visits to facilities in the developed countries.

What should be the substance of training programs? Here the proposed approach diverges somewhat from the approach of some universities in the United States which consider remote sensing as another academic subject. Experience has shown that the most effective and lasting training experiences are those directed to real problems -- in this case problems related to specific resource investigations or utilization of interest to the student's country. In the near term this means using available aircraft photography as the basis for training programs; in the future, satellite imagery hopefully will be available. In short, training will probably have the most lasting impact if it stresses the learning of interpretation techniques through problem oriented studies of imagery of direct current and future interest to the student.

AN OPPORTUNITY FOR SCIENCE

Science was at the heart of the Green Revolution. Not only did science uncover new ways to increase the yield of individual rice and wheat crops, but perhaps more importantly research was the catalyst that brought together the other essential elements of the system -- credit, extension, fertilizers, marketing -- into a coherent and viable economic unit which is essential for increased harvests.

Similarly, remote sensing can be the driving force that stimulates collaborative efforts of bankers, economists, technicians, and conservationists to use natural resources more effectively. Next year the satellite will capture the eyes of all -- politicians and technicians alike. Now is the time to prepare to capitalize on this interest in fostering the accelerated, and at the same time, wiser use of our resources.

ECONOMIC COMMISSION FOR AFRICA

Third Regional Cartographic Conference for Africa

Addis Ababa (Ethiopia) 30 October - 10 November 1972
Provisional agenda item 7(b)

PRACTICAL APPLICATIONS OF SATELLITES IN EARTH RESOURCE SURVEYS WITH SPECIAL REFERENCE TO AFRICAN COUNTRIES*

Submitted by the Government of the United States of America

INTRODUCTION

The launching of the first earth resources technology satellite - known as ERTS-1 - by the National Aeronautics and Space Administration (NASA) earlier this year is part of a continuing effort by the United States to translate the potential of space technology to practical economic and social benefits. While remote sensing technology has advanced rapidly in recent years for both aircraft and spacecraft programs, the launching of ERTS-1 represents probably the most significant advance in technological capability for exploring the earth's resources and providing more complete information for their effective management and development. This paper concentrates on the ERTS-1 program, in which experimental investigations are currently underway in 38 countries, including a number of African countries, concerning the usefulness of satellite multispectral imagery in practical applications in such fields as agriculture, geology, hydrology, cartography, geography, demography, and oceanography. Beyond ERTS-1, which has a designed lifetime of one year, a second earth resources satellite may be launched by NASA late in 1973, thus broadening the opportunity for participation by African countries in this experimental program.

CHARACTERISTICS AND STATUS OF ERTS-1

ERTS-1 was launched July 23, from California into a near-polar, sun-synchronous orbit 900 kilometers above the earth. The spacecraft, equipped with return-beam vidicon

*By John C. Fry, Office of Science and Technology, Agency for International Development.

(RBV) and multispectral scanner (MSS) systems, circles the earth every 103 minutes, returning to the same spot every 18 days. Three sensors of the RBV and four sensors of the MSS, each covering discrete bands in the visible and near-infrared spectrum, simultaneously view an area of roughly 34,000 square kilometers of the earth's surface.* Following a period of initial testing by NASA of all system components, it is planned that the sensors will be activated 78 minutes each day over cloudless regions, 18 minutes over the United States and 60 minutes over other countries which are participating with NASA in the ERTS-1 experiment.

Sensor data will be transmitted from the satellite to three ground stations in the United States and then relayed to the Goddard Space Flight Center in Maryland, where the data will be processed into useful form and forwarded to principal investigators in all countries participating in the experiment. Data products will be produced at two scales: 1:3,369,000 and 1:1,000,000. Products at the former scale include 70 millimeter, black and white, positive and negative transparencies. Products at 1:1,000,000 scale include 9-1/2 inch, black and white positive and negative transparencies and paper prints and color positive transparencies and prints. Computer-compatible magnetic tapes are also available.

Information concerning the ground resolution of data products and their positional mapping and registration accuracies may also be of interest to this conference. Ground resolution is a function of individual sensors and systems, the radiance and reflectance of ground features, and the tonal contrast of features with their background. Considering system specifications, it was expected that ground resolutions would be between about 100 and 200 meters. Evidence from initial performance of the system indicates that resolutions better than this are being achieved.

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* 3 Camera Return Beam Vidicon Multispectral TV System (RBV)
Spectral Bands (micrometers)
Channel 1. 0.475 - 0.575 (green)
Channel 2. 0.585 - 0.680 (red)
Channel 3. 0.690 - 0.830 (infrared)
Multispectral Scanner System
Spectral Bands (micrometers)
Band 1. 0.5 - 0.6 (green)
Band 2. 0.6 - 0.7 (red)
Band 3. 0.7 - 0.8 (infrared)
Band 4. 0.8 - 1.1 (infrared)

The positional mapping accuracy for bulk processed products in terms of expected errors measured in distance on the ground for the RBV and MSS systems is expected to be about 760 meters. The registration accuracies for the two systems - that is, the ability to superimpose the same point on two spectral images of the same ground scene viewed at the same time - are about 336 and 159 meters, respectively.

The positional mapping accuracy for precision processed products for the two systems varies between 92 and 246 meters, with registration accuracies between 118 and 154 meters. Between 5 and 10 percent of the bulk-processed imagery can be precision processed in the framework of the Universal Transverse Mercator projection and grid through special arrangements with NASA, provided ground control points such as river junctions, topographic features, or prominent cultural landmarks can be identified in the bulk imagery and related to controlled maps of 1:250,000 scale or larger. Thus, either the bulk or precision processed imagery could be used in preparing photomaps, which might contribute to updating or supplementing available chartographic information in many African countries.

In regard to the current status of ERTS-1, at the time of this writing, the four MSS sensors and one of two magnetic tape recorders are operating extremely well, with the MSS providing excellent spatial and spectral resolution; at the same time a technical problem has arisen in the power supply for the RBV system and the second tape recorder which NASA is attempting to correct. In view of the highly successful MSS operation, NASA is planning to switch soon from a testing to an operational mode so that data products for numerous experiments could begin to become available by mid-September. Additional information on this will be available at the time of the Conference.

EARTH RESOURCE APPLICATIONS OF ERTS-1 DATA

The broad array of possible applications of ERTS-1 data in earth resource fields is evidenced by the scope of the proposals approved by NASA for this experimental program. Apart from over 200 investigations in the United, there will be a number of foreign studies, including:

- investigations of the geological structure of the Kalahari Basin by the Geological Survey of Botswana;

- assessment of soil conditions, land use, and surface water by the Interamerican Center for Photointerpretation of Colombia;

- survey of agriculture, forestry, and hydrology by the National Planning Council of Ecuador;

- upgrading land use and resource data by the National Geographical Institute of Guatemala;

- inventory of earth resources by the Indian Space Research Organization;

- assessment of agricultural, geological and hydrological resources by the Department of Mines and Geology and other agencies of Mali;

- use of ERTS data for resource planning and management by the National Research Council of Thailand; and

- use of ERTS imagery for natural resources research by the Department of Mines and Geology and other agencies of Lesotho.

While the scope of applications suggests substantial benefits from participating in this experimental program, other considerations should also be weighed. Recognizing that the potential usefulness of large field of view, repetitive satellite imagery for earth resource studies might stimulate broad international interest in the ERTS program, the United States has endeavored in announcements concerning foreign participation not to create false expectations from it, particularly in developing countries. There are several reasons for this:

- ERTS-1 is an experimental satellite incorporating advanced technology leading the state-of-the-art and its performance, whether for a month or a year, cannot be assured;

- participation in the experiment requires a concurrent investment in basic photointerpretation equipment and ground and possibly aerial surveys to facilitate image analysis; and

- the successful interpretation of the satellite imagery requires the efforts of scientists and engineers who might be diverted from priority development programs for this purpose without assurance at this time that the value of new information generated from the imagery would more than offset investments and costs to other programs.

Nonetheless, eighteen developing countries being assisted by the United States Agency for International Development, including Mali, Kenya, Botswana, and Lesotho in Africa, have submitted proposals which NASA has accepted for the ERTS-1 program. When so little is known about the nature and extent of earth resources in many developing countries and tight budgets sharply limit national capabilities for acquiring resource information by conventional means, satellite imagery may be extremely useful - perhaps more so than in developed nations where comparatively more resource information is available, having been developed and maintained through mapping, surveying, and statistical programs over many years. In developed countries the information generated from satellite imagery mainly will add incrementally to considerable existing knowledge of earth resources, whereas in developing countries the information may have much greater value by providing entirely new insights related to resource endowments and development planning.

EXPERIMENTS IN MALI AND LESOTHO

The ERTS-1 experiments in Mali and Lesotho are representative of the kinds of investigations that are being undertaken by many developing countries, including other African nations, and because they may be of considerable interest to the conference, they are elaborated here in greater detail.

The Republic of Mali - a large country situated in the heartland of West Africa with its great Niger and Senegal river systems - extends from the harsh Sahara desert of the North, to wooded highlands of the South, with desert steppe and savannah lying between them. The investigations in this country will give emphasis to studies in agriculture, hydrology, and geology related to priority development programs in these fields. With limited scientific and technical resources, Mali is only

slowly acquiring the different kinds of information and understanding recognized as being needed for progressive development planning. To accelerate this understanding, the investigations have these specific objectives:

In regard to agriculture and livestock:

- surveying the grassland resources of Mali as a basis for improved range management for livestock. Mali has extensive areas which may be suitable for more intensive livestock production, including ranching, in the Bamako and Segou regions;

- assessing the seasonal changes and geographical distribution of soil moisture with regard to the productivity of grasslands and other crops, including sorghum, millet, wheat, and cotton; and

- delineating dune sand, soil, and plant relationships in the southern Sahara desert steppe and savannah regions to facilitate assessments of desert encroachment and desertification below latitude 17°N.

In regard to hydrology:

- beginning to clarify relationships between surface waters of the Niger and Senegal river systems and underground water resources;

- advancing knowledge of the geographical distribution of potential underground water resources for human settlements and rural development; and

- defining temporal and spatial changes in the propagation of the Niger river flood crest and zone of inundation throughout an annual cycle over the course of the Niger river in Mali, including its inland delta.

In regard to geology:

- clarifying the spatial distribution and structure of the Birrimian rocks in southern Mali, to identify possibly promising areas for mineral exploration;

- identifying the bounding faults of the Gao graben to facilitate subsurface water exploration and discovery; and

- delineating the structural geology and stratigraphy of various regions to aid in hydrological, mineralogical, and petroleum exploration.

The Government of Mali recognizes that not all of these objectives necessarily need be met in the experiment for it to be considered a success. On the other hand, the inventory and assessment of resources in the form of thematic maps made possible by the ERTS experiment could not be achieved in any other way, short of enormously large investments in conventional resource surveys. The approach the Government is taking in this program appears to be most effective, namely (1) the mobilization of a small team of specialists - two agriculturalists, one hydrologist, and one geologist - under the leadership of a geologist with training and experience in photointerpretation; (2) provision of office facilities for the team and basic photointerpretation equipment, including a light table with 4 power magnification for tracing features of interest and drafting and photographic equipment and supplies; and (3) logistics and staff for limited field surveys to correlate ground conditions with spectral response in the imagery for selected test sites. The approach recognizes ERTS-1 is an experimental program and effectively limits initial investments in utilizing the technology until evidence is at hand demonstrating its usefulness in producing new information of value in national development programs. As confidence is gained in the benefit of these investigations, then further investments might be considered related to additional manpower and training, more sophisticated image interpretation equipment, and intensified ground and possibly multispectral aerial surveys, should the earth resources satellite program continue from its experimental into an operational phase.

In regard to the Kingdom of Lesotho, somewhat different development problems are encountered which are reflected in the nature of the ERTS investigations proposed by the Government. Lesotho is a small mountainous country of 32,000 square kilometers entirely surrounded by the Republic of South Africa. Rainfall is erratic, temperatures drop sharply in wintertime, particularly in the high mountains and mountain valleys; and - like Mali - agriculture is the major source of local income for over 1,000,000 people.

The investigations proposed by the Government for participation in the ERTS-1 program are designed to contribute information and understanding which would assist in meeting several national needs, including:

- formulation of a land use plan for the whole of Lesotho, so that each unit of land can be developed to its optimal potential under conditions of increasing population pressure;

- intensification of grain production, including maize, sorghum, and wheat to eliminate food imports;

- efficient control of commercial grazing, to increase livestock production for export and to reduce the effects of overstocking on the mountain rangeland;

- control of ruinous gully erosion in the lowlands where, owing to population pressure, unsuitable duplex soils must be cultivated;

- acceleration of diamond exploration and discovery for export development; and

- identification of target areas for petroleum and ground water exploration and development.

As in Mali, the Government of Lesotho is not planning to make large commitments to manpower, facilities, or equipment for this program until confidence is gained that the information derived will strongly benefit the development programs the investigations are designed to support. Initially, a small, multidisciplinary team will be provided offices, co-located with the UNDP diamond exploration project, at the Department of Mines and Geology in Maseru, basic photointerpretation and related equipment for image analysis, and staff and logistical support for ground truth surveys at three agricultural and one geological test site. The principal investigators in Mali and Lesotho periodically will report to NASA the substantive results of the investigations, including maps and survey reports, and their views on the usefulness of the imagery in various earth resource studies and development programs.

LOOKING AHEAD

NASA is tentatively planning to launch a second earth resources satellite - identical to ERTS-1 - in November, 1973, and has called for proposals for participation in the ERTS-B program to be submitted by January 31, 1973. Once proposals are received by NASA, they will be thoroughly reviewed by expert panels and compared for quality in a competitive selection process which would approve only the strongest proposals. Those considering the submission of proposals for ERTS-B might benefit from the study of available ERTS-1 imagery from countries with terrain similar to their own. The imagery can be obtained at nominal cost from the EROS Data Center, 10th and Dakota Avenue, Sioux Falls, South Dakota 57198.

The Agency for International Development has assisted the Governments of Mali and Lesotho in preparation of the proposals submitted to and subsequently approved by NASA for ERTS-1 and is continuing to provide advice to developing countries concerning the ERTS-1 and B programms. The Agency, through its Office of Science and Technology, is also broadening its support for training in multispectral image interpretation and related earth resource applications through regional workshops and a one-month training course to be conducted at the EROS Data Center in South Dakota in June, 1973. With governmental co-operation, one of the regional workshops will be convened for two weeks in Mali in April, 1973. Beyond such training, which should assist current and future participants in the ERTS program in practical aspects of image interpretation, the Agency will be studying the results of ERTS-1 investigations in selected developing countries to infer from the experimental evidence the contribution a continuing earth resource satellite program could make toward international development.

TWENTY-THIRD INTERNATIONAL ASTRONAUTICAL CONGRESS
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SPACE FOR WORLD DEVELOPMENT
FORUM SESSION - DEMOGRAPHY

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First, let me express my gratitude for having been invited to participate in the proceedings of this very important meeting as a guest panelist, to highlight promising space applications in the field of demography. I welcome this opportunity to acknowledge the benefit of earlier discussions with Dr. Mendonca -- one of our chairmen and organizers -- in stimulating our interest in space studies in this field and in giving impetus to some exciting investigations which we believe may foster a variety of practical uses of space data in demographic studies in the future.

The term "demography" was first used in French academic circles over a century ago to describe statistics concerning the life conditions of people, especially those concerning health and mortality. In modern usage it is sometimes restricted to more formal aspects of population studies, such as quantitative analysis of population structures and trends. But demography is less interested in the fate of individuals than in the size and shift of population -- statistics which generally are based upon systematic field studies, such as a population census, demographic survey, or sample survey.

Before proceeding to discuss implications for remote sensing, let me elaborate the nature of these various field studies, whose methodologies and limitations have become so important to demographers. The population census is a country-wide enumeration providing not only a portrait of the population at a given time -- including such data as the size of the population by sex, age, marital status, and citizenship -- but also a history of

the population, for example, data on family statistics and internal migration. Also, generally it provides supplementary information related to educational achievement, occupations, dwellings and residential structures, industries, businesses and so forth.

Demographic surveys usually involve the collection of data on a small scale, based on individual questionnaires, to explore the micro-structure of demographic phenomena, such as migratory movements or the demographic history of families. A third kind of study, the sample survey, endeavors to obtain information valid for an entire population on the basis of data obtained from only a fraction of the larger population. The samples may be selected by quotas or at random, but in either case, in such a way as to infer from sample analysis, findings valid for a much larger population.

Apart from the theme of demographic studies and mechanisms for data acquisition, one should understand the cost involved in these activities, even if more than compensated by benefits derived from them,is large. For example, the decennial census in the United States taken in 1970 cost roughly $220 million. In a smaller country, with a population of, say, 10 million people, approximately 20,000 enumerators, 4,000 field officers, and 400 supervisors would be needed to conduct a population and housing census.

Moreover, even larger investments in demographic activities may be required both in developed and developing countries in years immediately ahead. Canada conducted its first mid-decade census in 1956; consideration is being given to implementing such censuses in the United States. Hearings on this matter highlighted the importance of mid-decade census figures for many types of decision making. The forces of economic and social change experienced by the United States, particularly over the past decade, have made a national census conducted every ten years grossly inadequate to meet the immediate and future needs of business, labor, research and planning organizations, and government at all levels.

If the need for more comprehensive and frequent demographic data is great in developed countries, it is equally great in many developing countries, to assess the impact of increasing internal migration from rural to

urban areas on national, regional, and local planning, and to foster economic systems responsive to national needs. While many developing countries are according demographic activities higher priority, much remains to be done. Fourteen of the relatively less developed countries have never had a population census; six of these countries have never had a demographic survey and the size of their populations is based on unreliable estimates. Ethiopia and Afghanistan -- two of the largest of these countries -- are turning their attention to new initiatives in this field.

At the same time there is growing evidence that advanced remote sensing techniques may be of significant value in strengthening census efforts by providing useful data at lower cost than the data could be obtained through conventional methods. A recent study by Professor Hsu of the State University of New York, for example, emphasizes the urgent need for the development of appropriate techniques by which intercensus population can be estimated with a high degree of accuracy and low cost and describes one such technique employing U.S. Geological Survey topographic maps at a scale 1:24,000, aerial photographs, and census data to identify the population change in rural, suburban, and urban sectors of the Atlanta, Georgia area from 1952 to 1968. The study succeeded in mapping population change in the area for regional and urban planning and development.

While few would doubt that large scale aerial photographs might be useful in various demographic studies, would space imagery be useful as well? An analysis by Anderson and Place of Apollo 9 photography, related to regional land use mapping in the Phoenix, Arizona area, concluded that land use maps and accompanying statistical information of reasonable accuracy and quality can be compiled at a scale of 1:250,000 from orbital imagery.

More recently, James Wray of the U.S. Geological Survey is utilizing both high altitude multispectral photography and satellite imagery in the Census Cities Project designed to detect change in the boundaries of urbanized areas and patterns of internal land use. The project has demonstrated the contribution remote sensing can make to projecting future population densities and estimating changes in population distribution between censuses. Of related interest, the study is also assisting

in calibrating a traffic flow model and estimating day time distribution of population; estimating water use requirements; assessing environmental hazards for land previously urbanized and in the path of urbanization; identifying appropriate land use patterns; and assessing the quality of the environment and impact of the urbanization process.

Apart from various technical aspects of this project, one of its most important conclusions thus far is that the expanding limits of urban areas can be monitored with satellite imagery, such as will be available from ERTS satellites, and that intercensal population estimates can be derived for urban areas with models relating the area of human settlements to the magnitude of their population.

Recognizing the accelerating need for demographic studies and related governmental interest in several developing countries and the opportunity presented by the earth resources satellite program to respond to these needs, at least in part, consideration was given to how, realistically, satellite imagery might be used in national census and related statistical programs. Three possibilities were singled out for experimental investigation using the combined strength of Brazil's remote sensing and census achievements, namely:

- providing improved frames for census-taking through image mapping;
- developing models for estimating rural population and detecting population change by assessing land use - population relationships; and
- developing models for estimating urban population and detecting population change by monitoring urban boundaries and assessing land use-population relationships.

Let me say a little more about each of these. One of the very real constraints in census-taking in many countries is the lack of adequate frames for enumeration, such as areas delineated on maps or lists of villages or tribes. The frame serves two statistical purposes. In a census it identifies the administrative subdivisions for which separate data are to be presented and is used to define work assignments for data collectors, so that the

country can be covered completely and without duplication. In a sample survey it facilitates sample selection and will be useful for many non-statistical purposes related to administrative and economic planning and other governmental and non-governmental activities. In preparing for a population census, up-to-date frames for its implementation can be delineated directly on photomaps prepared from satellite imagery.

Concerning the magnitude and change of population in rural areas, one should understand that satellite imagery cannot be used to count people or single houses or even small villages, whose size is smaller than the threshold of image resolution. But the imagery can be most readily applied to identifying land use in conjunction with ground truth surveys, particularly agricultural land use. The prevalance of subsistence agricultural patterns in remote areas of many developing countries along with only gradual technological change should allow reasonably accurate inferences of population change in such areas from verified agricultural land use-population models. We believe such models can be developed and tested for operational implementation for some regions within five years.

Similarly, we believe satellite imagery offers tremendous potential for delineating the boundaries of urbanized areas and monitoring changes in the boundaries and shifting patterns of land use. While our understanding of what Kaysen calls the "demographic transition" is far from complete, clearly rural to urban migration is accelerating in many regions, cities are growing more rapidly in population than rural areas, cities require a greater share of government services than other demographic units, and more frequent urban census will be required. New technological readiness may make these activities economically feasible.

Our efforts in undertaking these experimental studies of space applications in demography will be greatly enhanced by professional collaboration with scientists and engineers in developing countries which may be interested in matching the potential of space to unmet census and related statistical needs. Satellite data will certainly not meet all of these needs. But we believe that satellite systems will be powerful additional tools for use in obtaining more timely estimates of population change than might otherwise be possible with scarce investment resources. If this is found to be true, it will magnify the benefits of space for all countries.

ERTS-1 EXPERIMENT OF THE GOVERNMENT OF MALI

BACKGROUND

a) Agriculture

The Republic of Mali, situated in the heartland of West Africa with its great Niger and Senegal river systems, has identified agricultural and livestock development as a high priority effort. Of particular concern is the expansion of:

- grain production, including rice, sorghum, millet, and wheat to feed a growing population and to aid livestock development;
- livestock production for domestic consumption and export; and
- cotton and peanut production, primarily for industrial use and export.

There are four vegetative regions: the desert of the North, the wooded highlands of the South, the desert steppe and the savannah lying between them. While the soils of the southern areas are primarily lateritic, thus intensifying problems in soil management, the extensive water resources of the Niger and Senegal river systems can be developed further to aid agricultural and livestock productivity.

To foster agricultural and livestock development a better understanding is needed of:

- the annual plant growth cycle in the grasslands of southern Mali, in terms of available feed for livestock;
- the nature of land use and grassland changes in the Bamako and Segou regions, to intensify cattle production;
- the problem of desert encroachment and local dune formation over grazing lands in the North; and

- the distribution of water resources available for present and future crop and livestock production.

With limited scientific and technical resources, Mali is only slowly acquiring the different kinds of information recognized as being needed for development planning. ERTS imagery should contribute to our better understanding of these problems for all of Mali and thus support more effective national planning for further development of agriculture and livestock production.

b) Hydrology

The hydrological regime of the Republic of Mali is not well described and even less well understood in relation to its principal feature, the great Niger river system of West Africa. With only limited hydrological observations available for research, great difficulty is experienced in correlating hydrological and related information and developing a more complete understanding of the Niger and Senegal river networks and underground water resources within Mali.

The great hydrological problem facing Mali is the unequal distribution of water in time and space. During the three or four months of the rainy season each year, water is relatively plentiful in many areas of the country; but during the remainder of the year the rains stop and water is scarce. With regard to the spatial distribution of water, there are, of course, the great Niger river and its tributaries. But in the large desert area of the north, there is virtually no water at all.

If economic development of the Republic of Mali is to advance satisfactorily, enhancing the general welfare of the Malian people, efforts should be intensified to rationalize the development and management of surface and sub-surface water resources. Of particular importance in this regard are the development of ground water resources for livestock production and domestic usage in selected areas of the country and the management of surface water to accelerate grain production.

Republic of Mali hydrologic resources are derived from precipitation occuring mainly in the highlands in the south of the country and in Guinea, Ivory Coast, and

Upper Volta. These sources feed the three major rivers. However, the major portion of the precipitation within Mali occurs during four months from May to August. The remainder of the year is cloudless and dry. The evaporation rate is about two and one half meters per year.

Stream flow in the rivers occurs as a great but slow moving pulse of water. The flood crest reaches Bamako in mid-September, Mopti in mid-October, moves into the broad inland delta, north to Tombouctou by January, and passes Gao around mid-February. The flood is the most important annual hydrologic phenomenon in Mali, and indeed in central West Africa.

Our request for space imagery from ERTS-1 is based on our desire to obtain synoptic coverage of Mali during several periods of the year to support detailed analyses of the flood, the water budget of the rivers and inland delta, and the ground water resources of the country.

c) Geology

Over an area of 1,200,000 square kilometers, different geological formations of varied structure, ranging in age from Precambrian (Precambrian I) to Quaternary, constitute the geological and tectonic substructure of the Republic of Mali.

The geological history (structural, sedimentary, magmatic) of the Republic is known only in a general way, owing to the lack of basic studies both theoretical and practical. This is due to the unfavorable geographical position of a continental country without access to the sea and to the fact more than one third of the country is situated in one of the climatic zones unfavorable to conventional methods of geological research and mining.

OBJECTIVES

a) Agriculture

Objectives of the proposed experiment for agriculture and livestock are to:

1. Obtain an initial survey of the grassland resources of Mali as a basis for improved

management planning. Mali has extensive areas which may be suitable for more intensive livestock production, including ranching, in the Bamako and Segou regions.

2. Assess the seasonal changes and geographical distribution of soil moisture with regard to the grasslands and other crops, including sorghum, millet, wheat, cotton, etc.

3. Delineate dune sand, soil, and plant relationships in the southern Sahara desert steppe and savannah regions as a baseline for assessing desertification in Mali below 17°N. We have observed a change in plant communities and surface sands that indicate to us that desertification is occurring in southern Mali. It is of great importance that this process be understood, arrested, and if possible, reversed.

b) Hydrology

Objectives of the proposed experiment for hydrology are to:

advance understanding of the geographical distribution of potential underground water resources;

begin to clarify relationships between surface waters of the Niger and Senegal river systems and underground water resources; and

delineate temporal and spatial changes in the propagation of the Niger river flood crest and zone of inundation throughout an annual cycle over the course of the Niger river in Mali, including its inland delta between Tombouctou and Segou.

We intend to pursue these objectives, respectively, by:

delineating surface structural geological characteristics, including fault zones, to identify formations favorable for underground water exploration, particularly in regions west and east of Gao and north of Tombouctou;

- correlating ERTS imagery with gauging measurements already being obtained and possibly other related measurements with the viewpoint of understanding more clearly the water budget of the lakes region of the Niger; and

- measuring spatial changes in the flood and contraction of the Niger river over an annual cycle in ERTS imagery, to aid water resource and land use management related to dams, reservoirs and agricultural areas, particularly in the Segou and Mopti regions.

c) Geology

In relation to the structural and stratigraphic units, our objectives in interpreting the ERTS imagery are to:

- clarify understanding of the spatial distribution and structure of the Birrimian rocks in southern Mali, to identify possibly promising areas for mineral exploration;

- delineate the structural geology of the Infracambrian system of Gourma to aid in mineralogical and hydrological exploration;

- delineate the structural geology and stratigraphy of the Taoudenni basin to aid in hydrological and petroleum exploration;

- attempt to identify the bounding faults of the Gao graben to facilitate subsurface water exploration and discovery; and

- develop new knowledge of the crystalline shield of Adrar des Iforas to guide exploration for possible metalliferous deposits.

These objectives are based on the following premises:

- Birrimian rocks elsewhere have proved very productive economically;

- Infracambrian rocks have some economic potential and significance in hydrological development;

- marine Paleozoic rocks have potential both for subsurface water and petroleum discovery;

- the structure of the Gao basin indicates the possible presence of subsurface water resources; and

- the crystalline shield of Adrar des Iforas, a virtually unexplored region of difficult access, may have potential for the economic recovery of metalliferous deposits.

APPROACH

a) Agriculture

Positive transparencies of the requested imagery will be studied directly with a light table to endeavor to associate changes in image density with plant growth; changes in soil conditions, such as moisture and surface texture; and the distribution of plant communities. The infrared imagery will contain the most important data relating to changes in soil moisture, surface texture (related to desertification), and grassland plant community distributions. The grazing of the very extensive rangeland in Mali follows a seasonal pattern of cattle movement to the North from the Dougou region to Mopti, thence across the Inland Delta as the rainy season advances. The herds are moved slowly to the South as the rains diminish. Dry-land pasturage is not widely practiced, owing to the lack of waterholes for the animals. Changes in seasonal grassland patterns occur on such an extensive scale they will be readily delineated.

Objective 1. Recognizing that the appearance of plant communities in space imagery will change seasonally, the imagery will be studied to associate such changes with the spatial distribution of plant communities. For example, at the end of the rainy season grasslands will become brighter in the infrared imagery, while wetland communities will become darker owing to increasing wetness associated with the flood of the Inland Delta. Such changes will be used to delineate and inventory plant communities.

Objective 2. The decrease in reflectivity at infrared wave-lengths will be measured and related to soil moisture and surface water distribution.

Objective 3. Because sands reflect very brightly in the near infrared wave-lengths and plant leaves much less so, the observation of large scale dune development (greater than 200 meters in extent) within major plant communities can be studied directly in ERTS imagery. Early studies will be directed toward areas of known dune and sand development to confirm initial analyses of the space imagery. While the ERTS-1 program is too brief to observe shifts in plant communities, the presence of plant indicators of dry environments observed in moist areas may assist in assessing the extent of desertification in areas where sand dunes have not developed.

Owing to limited technical staff and resources, only selected ground studies will be conducted. However, agricultural research efforts will be directed, as may be necessary, to confirm preliminary hypotheses derived from ERTS data.

b) Hydrology

In identifying our approach for pursuing objectives of the project, it is important to realize that we have fewer scientists and engineers and technical resources than perhaps most countries planning to participate in the ERTS experiment. For this reason we wish to adopt a direct but simple approach to interpretation and use of ERTS imagery to generate new knowledge about our country. Using the positive transparencies that we are requesting, with a light table, we will endeavor to delineate the geological features relevant to ground water hydrology, changes in spatial boundaries of the Niger river system over time, and other distinguishable features of hydrological application.

c) Geology

Considering that many geological formations and structures yield distinctive topographic and vegetative patterns and considering further that major structural and stratigraphic features control the movement of ground water, with consequent effect on vegetation, repetitive synoptic ERTS imagery over an annual climatic cycle will greatly facilitate structural and lithologic analyses. These

analyses will be performed using ERTS positive transparencies, both composite and single RBV and MSS bands, and a light table to delineate significant features. Other methods of analysis may also be used. Base maps at a scale of 1:250,000 of the southern half of the country are available for assembling the data.

RESULTS OF THE INVESTIGATION

a) Agriculture

Maps delineating vegetative types and soil moisture and their seasonal distribution will be most valuable in planning the further development of Malian agriculture. For example, the Mali rangeland is one of the country's most valuable resources now and its improved utilization is of great economic importance. Maps of Malian ecological zones of agricultural production will provide much more detail than is currently available for development planning. New knowledge of the agricultural aspects of water resources in Mali and the encroachment of the desert into agricultural regions of southern Mali should result from the interpretation of ERTS data.

b) Hydrology

In connection with generating beneficial results from our proposed investigation, it should be realized very little is known about the hydrological regime of the Republic of Mali. We are hopeful the kinds of maps and related information described in the preceding section will assist in clarifying alternative solutions to our most important hydrological problems. Where so little is known now, even a small increment of additional knowledge may have a substantial impact on accelerating the development of our country.

c) Geology

1. A tectonic map, scale 1/250,000, of the Birrimian zone with identification of the strike of the faults and dikes.

2. A photogeological map of the granites that contain spodumene-bearing pegmatites (Bougouni-Sikasso region).

3. A map of the tectonic relations of the manganiferous mineralization and a structural study of the Gourma region from the viewpoint of localizing mineral and subsurface water resources.

4. Structural study and maps of the Taoudenni basin, particularly of the pre-Devonian unconformity. Further, a stratigraphic-structural study of the central basin for the discovery of structures of possible significance in petroleum research and exploration and in hydrogeology.

5. Structural study of the Gao graben. Owing to the limited outcrops and the restricted area of this zone, it is most difficult to study using conventional methods. The ERTS data will provide a basis for elaboration of a second phase geophysical research program.

6. A general study from the viewpoint of localizing mineral resources of the crystalline shield of Adrar des Iforas. A further target is the identification of larger masses of ultramafic rock than the few now known, as well as identifying other carbonatites, one of which has been reported.

ERTS-1 EXPERIMENT OF THE GOVERNMENT OF LESOTHO

BACKGROUND

a) Geology

The geology of Lesotho, which lies at the center of the Karroo basin, is a simple stratification of shales and sandstones, forming a western lowland strip. These are overlain by up to a mile thick sequence of basaltic lava in the eastern highlands, rising to a height of 11,000 feet. The structure is essentially horizontal; however recent mapping of the lowlands has indicated the presence of numerous gentle basins and domes of about 10 miles width. In addition, there are a series of dolerite dykes of late Karroo age (Triassic/Jurassic) which cut the sediments and lavas. These are traversed by well-marked joint directions, one of the most conspicuous being the WNW-ESE trend that typifies the later kimberlite instrusions of cretaceous age.

Apart from a superficial understanding, the geology of Lesotho is not well known; only some 20 scientific geological reports related to field work in various parts of the country have been prepared since 1905. These studies indicate, however, that the only commercially exploitable mineral resources of the country are diamonds, which in 1970 constituted 11 percent of export earnings, and possibly petroleum, although exploration for the latter has not begun.

Thus far the diamonds have been found by Basotho diggers in several parts of the country, but two prominent kimberlite pipes, those of Letsong-la-Terai and Kuo, are now being evaluated by the Rio Tinto and Newmont mining companies to determine their commercial potential. Recognizing the potential of diamond exploration and development to the economic advancement of Lesotho, the United Nations Development Programme, through its Special Fund, is assisting in a diamond exploration effort in a northern area of 1,800 square miles. The project involves acquiring multispectral aerial photography of 1,000 square miles of this area, 4 field teams for ground surveys, and

participation by other geological and photogeological personnel. The multispectral photography was obtained in 1971 under contract by North American Rockwell; a report on this survey was submitted February 15, 1972.

In regard to petroleum discovery, the location of Lesotho in the heart of the Karroo and Ecca sedimentary basin, together with favorable geological structures, has attracted the interest of several oil companies. Ponder Oils of Canada is currently negotiating with the Government to obtain a concession for exploration over most of the country.

The availability of ERTS imagery for all of Lesotho would thus enable us to extend research on multispectral techniques for kimberlite exploration, particularly in regard to identifying dyke swarms for extension of the UNDP project to other areas of the country, and to obtain knowledge of the large-scale structural features of the country which can be obtained in no other way at this time. Repetitive multispectral imagery should be particularly useful in relating vegetative cover to kimberlite intrusions through geobotanical ground surveys in the geological test area. It should be noted that advanced techniques such as these for kimberlite discovery may be used by De Beers Corporation or the Soviet Union, but information on these activities is not generally available.

b) Agriculture

The importance of agriculture to Lesotho's development was identified in the First Five-Year Development Plan: 1970 - 75, in which the principle of increasing prosperity for the bulk of the population of one million people through improved farming practices was firmly established. Lesotho consists of two main agroecological zones. Lowlands and foothills, at an altitude of 5,000 to 7,000 feet, occupy one third of the area and contain the majority of the cultivated land, estimated at 1,000,000 acres. The Maluti mountains make up the remaining two-thirds, rising from 7,000 to 11,000 feet. They are utilized for communal grazing, with seasonal movement of cattle, sheep, and goats from the lowlands to the mountains in early summer; the high mountains above 8,500 feet with an alpine environment are restricted to sheep grazing. Some cultivation is carried out in the mountain valleys up to 7,500 feet.

The two general problems which most hamper agricultural development in Lesotho are poor communications due to the mountainous terrain, and the erratic rainfall, both between and within years, which leads to widely varying crop yields and range conditions. Repetitive coverage with satellite imagery would facilitate information acquisition, where it is not feasible at present, particularly in regard to continuously updating data on plant growth.

Of particular concern to the Government is:

- the formulation of a land use plan for the whole of Lesotho, so that each unit of land can be developed to its optimum potential under conditions of increasing population pressure;

- the intensification of grain production, including maize, sorghum, and wheat to eliminate food imports;

- the efficient control of communal grazing, to increase livestock production for export, and to reduce the effects of overstocking on the mountain rangeland; and

- the control of gully erosion in the lowlands where, owing to population pressure, unsuitable duplex soils must be cultivated.

The Government has ongoing programes in each of these activities, and several additional agricultural development projects are in progress or being planned, including:

UNDP: Integrated Dryland Farming Project, Leribe 1971
UNDP: Senqu River Project, Quthing and Mohale's Hoek 1972
World Bank and USAID: Thaba Bosiu Project, Maseru 1972

With limited scientific and technical resources, Lesotho is only slowly acquiring the different kinds of information recognized as being needed for development planning. If successful, ERTS imagery should contribute

to present development programs, and also support more effective national planning for the future development of agriculture.

OBJECTIVES

a) Geology

Objectives of the geological investigations using ERTS imagery are immediate and intermediate, both to be accomplished in 18 months. Immediate objectives are to:

-- delineate kimberlite dyke swarms, such as those being studied in northern Lesotho, as targets for concentrated ground survey; and

-- identify the spectral response in repetitive ERTS imagery of the vegetative cover of known kimberlite deposits in the geological test area as a possible means for kimberlite discovery in other areas.

Intermediate objectives are to:

-- map large scale structural features in the Karroo basalt sequence, including target areas for petroleum and ground-water exploration;

-- chronicle the geomorphological history of Lesotho, using as datum horizons, the several well developed erosion surfaces, and identify former river systems, river capture, and the distribution of alluvial deposits, some possibly diamond-bearing.

b) Agriculture

Due to the compact size of Lesotho, it is proposed to take the whole country as the unit of investigation. ERTS imagery will be used to explore two types of applications: first, to provide 1972 baseline data in several disciplines; second, to trace temporal changes in vegetation. In both cases, the information obtained will be immediately utilized by the staff of the Ministry of Agriculture for on-going planning and extension/field work.

Objectives of the proposed investigation for agriculture are:

(1) Land use

A baseline survey and land use inventory will be obtained for the whole of Lesotho. Also, ERTS imagery will be studied to assess its potential in delineating areas suitable for establishing new land use patterns, such as forestry, which is presently limited.

(2) Crop production

It is important to evaluate ERTS imagery under conditions of small field size, as is often found in developing countries such as Lesotho. In this country these fields are close to each other, and while different crops may be grown in adjacent fields, blocks of the same crop are often present; grass buffer strips separate fields. In this category objectives are to:

-- produce a crop inventory, showing the areas of the major crops and their distribution, together with the area of fallow land. This will aid extension work during the growth of the crops, marketing at harvest time, and planning for the following season;

-- identify when crops are planted and harvested to aid the planning of rotations for optimum use of the land; and

-- detect and monitor attacks on crops by pests and diseases.

(3) Range management

For the success of the ongoing grazing control program, accurate estimates of the relative carrying capacity of lowland, and low and high mountain grasslands is required.

The degree to which ERTS imagery can meet the following needs will determine its usefulness in range management in Lesotho:

-- accurate mapping of different vegetation classes, taking account of seasonal changes in species composition;

-- recording the length of the growing season for different vegetation classes and altitudinal zones (e.g. the lowland range grows for eight months in the year compared to three months for the alpine communities);

-- surveying plant cover and related standing herbage;

-- evaluating the effectiveness of the range management program; the mountain range is divided into 15,000 ha. blocks, of which one third are rested each year.

(4) Soils and soil conservation

Severe gulley erosion is experienced in the lowlands, while overgrazing has lead to increasing sheet erosion in the mountains. Lesotho therefore presents a good site to test the efficiency of ERTS imagery in the field of soil conservation, in the following ways:

-- using the synoptic view to establish new baselines for erosion, and mapping eroded areas;

-- comparing new data with an aerial photo-survey of 1960, and estimating rates of erosion during the twelve year period;

-- preparing a more accurate soil survey than that currently available;

-- mapping basal plant cover, and water courses; and

using maps of soil type, basal plant cover, and water courses, to predict likely areas of future erosion and planning appropriate control measures.

APPROACH

a) Geology

The interpretation and analysis of the ERTS imagery requested for the experiment will be effected through use of the low altitude multispectral imagery acquired in 1971 in the 1,000 square mile geological test area, a Hilger and Watts light table with 4 power magnification, and ground truth surveys in the test area. Lesotho is fortunate in having recently obtained color and multispectral false color photographs, and thermal IR imagery of the geological test area to serve as intermediate ground truth. A Mini-Addcol viewer was used in the initial interpretation of the photographs obtained with an I^2S camera. A photogeologist assigned to the UNDP project in Lesotho is currently continuing the interpretation, in conjunction with the activities of 4 ground survey teams.

Our analysis of the ERTS imagery will endeavor to provide coherence to the low altitude photography, which is not mosaiced, particularly in regard to priorities in interpretation and follow-up ground survey. Even more importantly, it should be possible to relate kimberlite dyke characteristics in the low altitude photography to the ERTS imagery, and extrapolate this relationship to identify dyke swarms in the ERTS imagery outside the geological test area. Also, the ERTS imagery along with field surveys in the test area should make it possible for the first time to use geobotanical techniques to localize large scale kimberlite deposits throughout Lesotho.

Analyses of the imagery will be performed initially using ERTS bulk processed positive transparencies, both black and white single RBV and MSS bands and color composites, with the light table and magnification mentioned above to delineate significant features. As confidence is gained in the usefulness of the imagery in various geological projects, more advanced interpretation equipment may

be obtained to enhance the analysis. Results of light table interpretation will be transferred to 1:250,000 or larger scale topographic maps for field correlation and exploration. Also, ERTS image enlargements to 1:250,000 scale will be compared with and used to refine existing 1:250,000 scale base maps.

These investigations along with mapping of tectonic and hydrogeological features will be conducted by existing staff of the Department of Mines and Geology and the UNDP diamond exploration project. The geomorphological aspects of the project will be conducted using the same equipment by the Professor of Geography (Science Faculty), University of Botswana, Lesotho and Swaziland located at Roma, Lesotho, near Maseru.

b) Agriculture

(1.A) 1960 aerial photography, 1:15,000, complete coverage of Lesotho

(1.B) 1971 aerial photography, 1:15,000, selected coverage of Lesotho

(2) 1966 Land Resources Survey

(3) 1970 Census data

(4) 1950-present. Related land resource studies.

These data will be collated and an index established for land use, crop, range management, and conservation sections. They will provide one basis for the correlation of ERTS imagery.

Analysis

Conventional photo-interpretation techniques will be used initially to evaluate the ERTS imagery. Positive transparencies of the requested images will be studied on a light table at contact scale and using facilities for 4 power magnification. Details will be drawn onto existing 1:250,000 base maps. At a later stage, more sophisticated techniques, including use of a densitometer and mini-addcol viewer, may be applied to interpretation.

The space images will be compared directly with available aerial photography and results of field surveys at the agricultural test sites, to facilitate the interpretation of the ERTS imagery and to assess its usefulness. Also, ERTS image enlargements to 1:250,000 scale will be compared with and used to refine existing 1:250,000 scale base maps.

The approach for each objective is as follows:

(1) Land use

Major land use classifications will be delineated from color composites.

(2) Crops

Ground information will be provided from the accurate record of crops grown at the site of the UNDP Leribe Project; there are large field units which should be recognizable in the space images. Crop calendars will be compiled for each district to aid interpretation.

Multiband and multidate imagery will be used to obtain unique spectral signatures for particular crops. Also pest and disease attacks will be identified in ground surveys and correlated with color IR imagery, for extrapolation of interpretation to other areas.

(3) Range Management

Ground truth will be obtained from two mountain grazing trials in areas of 1,000 and 2,000 acres. A calendar will be kept for the overall grazing control program. Multiband and multidate imagery will be used to obtain unique spectral signatures for particular vegetation classes. False color imagery should show the relative vigor of rangelands, and reveal when active growth begins and ceases. Color composites will be used to estimate relative plant cover.

(4) Soils and soil conservation

Multiband and color composites will be used to obtain unique spectral signatures for different soil types. The soil survey will be completed during the seasons when much of the cropland soil is exposed. (Additional ground truth is available from recent detailed soil surveys in selected areas). RBV band 3 and MSS bands 3 and 4 will be used for mapping drainage lines, during the wet season.

RESULTS OF THE INVESTIGATION

a) Geology

The participation of Lesotho in the ERTS experimental program will provide an unique opportunity to contribute to the scientific knowledge of the natural resources of this country -- particularly knowledge and understanding relevant to applied research directed toward the country's most urgent development needs. As information is generated during the course of the experiment it will be directed promptly for use in national development projects and planning. In addition, the following specific results will be incorporated in a final report to NASA as a tangible outcome of the investigation:

-- a photogeological map at 1:250,000 scale showing anomalous features representing targets for kimberlite search;

-- identification of the imagery characteristics of kimberlites in Lesotho. (We understand the Government of Botswana has submitted a proposal for participation in the ERTS experiment, but we have not seen it. Should their proposal include investigations of kimberlite intrusions in Botswana, the Lesotho and Botswana investigations would be complementary and aid in establishing continuity across the national boundary);

-- a structural map at 1:250,000 scale showing gentle, large-scale warping in the Karroo sediments and overlying basalts, together

with the principal lineaments, delineating target areas for petroleum and groundwater exploration and a series of geomorphological maps at 1:250,000 scale designed to give impetus to morphoconservation and hydro-conservation research at the University of Botswana, Lesotho and Swaziland.

b) Agriculture

The results of this investigation will provide an indication of the usefulness of ERTS data in various applications related to national planning and management of agricultural development in a developing country. If the experiment is successful, the preparation of various 1:250,000 scale maps as outlined below will be possible, while information regarding crop and range production will be continuously supplied to the Ministry of Agriculture and related Development Projects, for on-going management decisions. Insofar as possible the following information will be integrated in interim and final reports to NASA.

(1) Land use

-- map of land use;

-- inventory of land use, classifications by districts; and

-- report on areas suitable for new land use patterns.

(2) Crop production

-- map of major crops;

-- inventory of areas of major crops and fallow land, by districts;

-- forecasts of crop yields at bi-monthly intervals for market intelligence;

-- list of planting and harvesting times (means and variances) of major crops, by districts; and

immediate publication of pest and disease attacks on crops, followed by monitoring of the progress of such attacks.

(3) Range management

-- map of different vegetation classes;

-- map of duration of growth for range vegetation, giving extreme dates;

-- bi-monthly maps of total plant cover and standing herbage;

-- related inventories for the above maps by range management blocks; and

-- bi-monthly reports on the state of the grazing control program.

(4) Soils and soil conservation

-- map of eroded areas and soil types;

-- map of basal plant cover;

-- report on rate of erosion during past twelve years; and

-- report elucidating factors causing serious erosion in Lesotho, and delineating susceptible areas which should be safeguarded in future conservation programs.

AIRCRAFT REMOTE SENSING INVESTIGATIONS OF THE GOVERNMENT OF INDONESIA

1. Project Purpose and Objectives

The purpose of this joint project is to conduct in Indonesia a demonstration of relatively low-cost remote sensing techniques from conventional aircraft for natural resources inventory and assessment. The conduct of this demonstration is intended to: (a) establish an initial institutional capability in Indonesia to plan, execute and interpret multispectral photographic surveys, (b) introduce the potential benefits of such techniques in providing data for priority natural resource development programs to GOI departments and agencies concerned, and (c) through publication of demonstration results, provide other interested developing countries which are short on trained manpower, facilities, and investment capital an appreciation of the usefulness, costs, and requirements of such techniques.

It is expected that this project will complement the approved 1972/73 ERTS-1 experiment designed by the GOI for the island of Bali by providing intermediate (aircraft altitude) ground truth for the spacecraft imagery, thus facilitating interpretation of that imagery and generation of new earth resource information for Indonesia. Data from this remote sensing project is also expected to contribute in the future to a comprehensive integrated survey of Bali being planned by the GOI with UNESCO assistance.

II. Project Description

In outline, this experimental 18-month project consists of:

A. Joint identification and selection by Indonesian and U.S. specialists of those remote sensing applications with highest potential developmental payoff for Indonesia in the near term, such as agriculture, forestry, geology, hydrology, fisheries, or others.

B. Joint selection of one or more test areas of appropriate size for specific studies related to earth resource applications selected above.

C. Outfitting and testing of multispectral camera equipment on an Indonesian aircraft.

D. Flights over the test area(s) by Indonesian aircraft and conduct of related ground truth surveys as necessary for particular applications.

E. Interpretation and analysis of the photography by Indonesian specialists.

F. Publication and dissemination of the results of the demonstration by the GOI.

The detailed Work Plan developed for this Project provides an estimated schedule for the above operations and technical detail for one test site on Bali, including Bali Strait. Applications selected for this site include forestry, agriculture, soils, geology, marine biology and fisheries, and geography, including land use. Additional test sites and applications may be jointly selected during project implementation if additional GOI budgetary resources are made available. In addition to the multispectral camera, Kodak 2424 aerographic infrared film and color additive viewing equipment will be used in the experiment.

WORK PLAN

I. TIME PHASING

Phase 1 (Month 1 - 2)

A. Designation in writing of BAKOSURTANAL Project Manager and principal investigators from participating GOI agencies.

B. Formulation of joint BAKOSURTANAL/USGS training plan and schedule with designation of approximately 20 trainees for in-country training.

C. Arrangements for purchase of camera and viewing systems made through the USGS.

D. Remote sensing specialists engaged to provide training in techniques for specific disciplines and to assist in experiment design.

E. USGS to provide specifications for modification of aircraft for camera and mount.

Phase 2 (Month 3 - 5)

A. Training of Indonesian scientists in theory and applications of multispectral aerial photography and other remote sensing techniques of value for their specific disciplines.

B. After sufficient training, the investigators proceed to design experiments with the assistance of instructors.

C. Modification of GOI aircraft to be used in the survey flight to accommodate camera.

D. USGS to order film for survey flights and duplication for diapositives, and to arrange for processing.

Phase 3 (Month 6 - 8)

A. Acquisition, installation and in-flight testing of multispectral camera with assistance of instrumentation specialist provided by USGS.

B. Collection and preparation of equipment for ground control studies by GOI.

Phase 4 (Month 8 - 11)

A. Testing of ground control methods and equipment by GOI.

Phase 5 (Month 12 - 13)

A. Remote sensing mission flights over Bali area for acquisition of multispectral photography.

B. Coincident collection of ground control data.

C. Film and ground control data processing and reduction.

Phase 6 (Month 14 - 16)

Interpretation of data with the assistance of remote sensing specialists provided by USGS.

Phase 7 (Month 17)

A. Wet season flights over Bali area.

B. Coincident collection of ground control data.

C. Film and ground control data processing and reduction.

Phase 8 (Month 18)

Completion of final reports by GOI and USGS participants.

II. DESCRIPTION OF BALI TEST SITES

The Bali test sites consist of three areas which cover about 20 percent of the island. One area on the eastern side of the island is 2050 square kilometers and includes Gunung Agung volcano whose slopes were recently devastated by an eruption and by post-eruption mud flows. The volcano has provided fresh volcanic flows and ash deposits for geologic study. Limestone terrain is available for study on the southern peninsula of the island, as are reefs and terraces along the southeastern coast. This site also includes a large agricultural area on the south, providing a hydrological and pedological comparison of the wet southern slope with the rain shadow area of the northern slope. Demographic data are available throughout the area of coverage.

A second area of 2800 square kilometers includes the western end of the island, Bali Strait, and the southeasternmost tip of Java. Western Bali offers heavy vegetation for forestry studies and older volcanic rocks for the geologist. The adjoining strait with its rich biota and fishing is of interest to marine biologists and fisheries scientists.

A third area of about 200 square kilometers consists of a portion of the bay between southernmost Bali and eastern Java. It will be used to study a marine fisheries problem existing in the area.