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APPLICATION OF REMOTE SENSING TECHNOLOGIES TO NATURAL RESOURCE DEVELOPMENT AND MANAGEMENT IN THE PHILIPPINES

(Report on Visit by U.S. Advisory Team on Remote Sensing, October 11 - 22, 1971)

October, 1971

CONTENTS

I. Introduction 1

II. Status and Utility of Remote Sensor Techniques 6

III. Potential Application of Remote Sensors in Priority Philippine Resource Sectors 11

(1) Minerals and Energy 13

(2) Agriculture 18

(3) Forestry and Soils 21

(4) Land Use Survey and Classification 24

(5) Water Resources 26

(6) Oceanography 28

(7) Disaster Monitoring and Assessment 31

(8) Environmental Pollution 34

IV. Significant Aspects of Coordinated Satellite and Aircraft Sensor Applications 37

V. Analysis and Recommendations 45

APPENDIXES

(1) Itinerary of U.S. Advisory Team 56

(2) Philippine Institutions and Individuals Contacted 58

(3) Membership of the National Committee for Mineral Exploration and Survey Operations 62

(4) Program Recommendations for Remote Sensing Applications to Natural Resource Surveys in the Philippines 63

APPLICATION OF REMOTE SENSING TECHNOLOGIES TO NATURAL RESOURCES DEVELOPMENT AND MANAGEMENT IN THE PHILIPPINES

I. INTRODUCTION

This is the report of a four-man U.S. advisory team, sponsored by the Agency for International Development, which visited the Philippines from October 11 to 22, 1971, to investigate the potential application of remote sensing technologies to the development and management of Philippine natural resources. Members of the team were:

John A. Reinemund - Chief, Office of International Geology, U.S. Geological Survey.

Robert L. Thomson - Chief, Engineer Agency for Resources Inventories, U.S. Corps of Engineers.

William Crea, Jr. - Staff Agronomist, Earth Observations Division, Manned Spacecraft Center, NASA.

Bill L. Long - Environmental Affairs Specialist, Office of Science and Technology, Agency for International Development.

The visit was arranged in response to Government of the Philippines desire for U.S. assistance in identifying opportunities and methodologies for applying aerial and satellite remote sensing techniques to natural resource surveys, particularly for mineral and petroleum exploration. This interest was first communicated

to the U.S. Embassy and Mission in early Spring, 1971, by the Executive Office of the Philippines.

In July, NASA received a preliminary plan from the Philippine Government which outlined an earth resources survey program based in large measure on the use of imagery from the Earth Resources Technology Satellite (ERTS). Thereafter U.S. agencies assisted the Government in preparing a more comprehensive proposal, "To Use ERTS-A Imagery for Natural Reources Investigations in the Philippines". This second proposal, which has now been formally submitted by the GOP to NASA, stated that it constituted "part of a broader scheme using remote sensing techniques with other systems which allow acquisition of greater detail and of different types (of natural resource data)". It also recommended a "visit of U.S. experts to the Philippines to evaluate facilities and personnel in order to formulate a training program and the elements of a technical action plan".

Discussions on the feasibility and potential value of a team visit were subsequently held in Washington between representatives of the State Department, AID, NASA, the U.S. Geological Survey, and the Corps of Engineers. There was agreement that a U.S. advisory team could serve a useful purpose; that it should be limited in size and interagency in composition; and that the following objectives should be pursued:

(1) to acquaint Philippine officials and natural resource planners and managers, as well as Embassy and Mission personnel, with the capabilities of aerial and satellite-based remote sensing systems, with particular emphasis on the ERTS (Earth Resources Technology Satellite) and SKYLAB (Earth Resources Experiment Package) systems:

(2) to identify and describe potential applications of remote sensors to resource surveys in the Philippine context, based on an evaluation of Philippine interests, problems, and capabilities (manpower, financial, and institutional);

(3) to recommend specific initiatives the Philippine Government might wish to undertake in priority resource sectors that would match the most promising sensor systems with Philippine institutional capabilities to acquire, interpret, and use data from both aircraft and satellites.

It was further agreed that the team would focus its attention on the eight priority resource areas identified in the Philippines' preliminary ERTS proposal, namely:

- Minerals and energy (including petroleum and geothermal power)

- Agriculture
- Forestry and Soils
- Water Resources (including both surface and ground water)
- Land Use Survey and Classification
- Oceanography
- Disaster Monitoring and Assessment (volcanoes, earthquakes, typhoons)
- Environmental Pollution

The U.S. team arrived in Manila on October 11 and, during a two-week period, consulted with top Philippine officials from approximately twenty offices, bureaus and commissions with natural resource responsibilities, plus U.S. Embassy and USAID personnel. In addition, a field trip was arranged to the International Rice Research Institute and the College of Agriculture and Forestry at Los Banos; and an aerial reconnaissance made of several areas of major resource interest in central and northern Luzon. The itinerary and persons contacted are included as Appendixes 1 and 2.

The team is indebted to many individuals who took time from busy schedules to engage in long and frank discussions of agency programs, interests, and capabilities, and the potential contribution of remote sensors. Special appreciation for their encouragement, guidance, and hospitality is extended to the

Honorable Alejandro Melchor, Executive Secretary, Executive Office of the President; the Honorable Arturo Tanco, Jr., Secretary, Department of Agriculture and Natural Resources; Major Luis Mirasol, Office of the Executive Secretary; Mr. Fernando Busuego, Jr., Director, Bureau of Mines; and Messrs. Francisco Comsti and Carlos Teodoro of the Bureau of Mines staff. Gratitude is also expressed to Mr. Thomas Niblock and Mr. William Larson, USAID, for their sound advice and administrative support. The team operated under arrangements made through the interagency National Committee for Mineral Exploration and Survey Operations (NACOMESCO) of which the Secretary, Department of Agriculture and Natural Resources, is Chairman and the Director, Bureau of Mines, is Vice Chairman. Agencies represented on this Committee are listed in Appendix 3.

II. STATUS AND UTILITY OF REMOTE SENSOR TECHNIQUES

The first objective of the U.S. team was to provide an overview of the status and utility of remote sensors, and to place in their proper perspective the current, planned, and potential roles of aircraft and satellite-based resource survey systems. Thus, the initial point of departure during all discussions in the Philippines was presentation of a briefing by the team to acquaint host country planners, managers, and technical personnel with the current and projected state-of-the-art for conducting natural resource surveys. It was noted that the Philippine participants in the discussions invariably chose to focus on satellites to the exclusion of some of the less exotic but proven aircraft-based sensor systems. To provide a proper framework for a description of various remote sensor systems, the team attempted to emphasize the following general considerations:

(1) Remote sensing has a significant potential for helping to rapidly upgrade county capabilities to survey and manage their natural resources. It has special advantages for reconnaissance and mapping in regions such as the Philippines where conditions of persistent cloud cover, thick vegetation, and difficult accessibility make traditional ground and aerial-based surveys

extremely difficult, if not impossible;

(2) Aircraft and satellites serve basically as vehicles for carrying the photographic equipment and imaging sensors; the proper focus of attention should therefore be on the sensors. Serious thought and attention should also be given to the acquisition, operation, and maintenance of the airframe which is to house the sensors. Although satellites offer advantages for some purposes (e.g., when repetitive, orthographic, or synoptic coverage over large areas, is desired), aircraft-based sensor systems will continue to provide the broadest range of applications for the foreseeable future. Optimal use of remote sensing techniques in the future will generally involve a mix of aerial, satellite and ground-based observations. Consequently, country planning in this field should aim at the development of a working knowledge and capability across the spectrum of remote sensors and sensor systems, as well as the continued improvement of ground surveys.

(3) The rapid evolution of the state-of-the-art, coupled with the large capital investment associated with acquiring remote sensing capabilities, require the continuing availability of trained personnel capable of assisting country resource planners assess opportunities for, and constraints on, applications of

natural resource development. Countries will face increasingly difficult investment decisions as the choice of equipment, techniques, and combinations thereof widens. Enlightened decision-making is particularly crucial for developing countries faced with limited capital and trained manpower -- and will ultimately hinge on an ability to carefully and accurately assess the cost-effectiveness of alternative approaches (e.g., aircraft, satellite or ground-based survey).

(4) The forthcoming Earth Resources Technology Satellite (ERTS) and the Earth Resource Experiment Package (SKYLAB) are experimental systems. The usefulness of data to be obtained cannot be predicted at this time. One must therefore guard against excessive optimism with respect to ERTS-A and SKYLAB contributions to resource management. Rather, they should be viewed as the first step toward an operational resource satellite system which will evolve with the development of improved sensors, and data handling and interpretation techniques;

(5) While remote sensing provides powerful new tools for acquiring resource data, the efficient utilization of this data for developmental purposes is highly dependent on the presence of a viable institutional

base within the country. This includes a program planning and coordinating mechanism; sufficient manpower trained in data interpretation; a photo and data storage and dissemination capability; and healthy technical agencies which can provide the requisite "ground truth" and administrative/logistical support for the remote sensing systems.

It was within this framework that the team presented an initial illustrated briefing on October 12 for agency representatives of the National Committee for Mineral Exploration and Survey Operations on the general range and characteristics of various remote sensors, and possible applications to resource surveys both from satellite and aircraft. With regard to the satellite systems, the team discussed the characteristics and specifications of the return-vidicon and multispectral systems on ERTS-A and pointed out that the applications most likely to be successful in the Philippines are: (1) improving the tectonic map of the Philippines through better identification of regional structures; (2) improving existing base maps through updating cultural and erosional or depositional features; (3) preparing photo-maps for small-scale land-use studies; (4) mapping and classifying land-use; and (5) monitoring changes in hydrologic and coastal phenomena. These potential applications were illustrated with photographs acquired

by spacecraft and high-altitude aircraft, and the various agency representatives were encouraged to analyze their own programs to identify possible applications.

With regard to aircraft sensors, the team reviewed and illustrated typical uses that have been made of airborne magnetic and radiometric techniques; thermal IR scanners and radiometers; multispectral and color infra-red photography; and side-look radar. The team pointed out that all these techniques are fully operational, and would be useful for specific purposes in Philippine resource surveys whenever they appear to offer a favorable cost-benefit ratio. Philippine agencies were encouraged to consider the importance of the airborne magnetic and radiometric surveys for mineral and petroleum exploration; the infra-red scanner for geothermal, volcanologic, pollution, and hydrologic studies; the use of multispectral and color-IR photography in studies of crops, soils, plant stress, and selective land-use mapping; and the use of side-look radar for penetration of soil and vegetation to bring out geologic and topographic details.

In subsequent visits to the various technical agencies, potential applications were again reviewed, this time with specific reference to on-going agency programs and specific resource problems of each user. The nature and results of these discussions are included in the following chapter.

III. POTENTIAL APPLICATION OF REMOTE SENSORS IN PRIORITY PHILIPPINE RESOURCE SECTORS

The major portion of the advisory team's effort was devoted to discussions at Government bureaus and offices to identify and evaluate their interests, program responsibilities, and capabilities with respect to participation in natural resource surveys utilizing remote sensors. A schedule of meetings (Appendix 1) was arranged through the NACOMESO and reflected the team's wish to address remote sensing applications within the context of the eight Philippine natural resource priorities: (1) minerals and energy; (2) agriculture; (3) forestry and soils; (4) water resources; (5) land use surveys and classification; (6) oceanography; (7) natural disaster monitoring and assessment; and (8) environmental pollution. Offices and institutions visited included:

- Office of the Executive Secretary, Executive Office
- National Science Development Board
- Infrastructure Operations Center
- National Food and Agriculture Council
- National Computer Center
- Board of Technical Surveys and Maps
- National Water and Air Pollution Control Commission
- Commission on Fisheries
- Commission on Volcanology

- Bureau of Mines
- Bureau of Forestry
- Bureau of Coast and Geodetic Survey
- Bureau of Soils
- Bureau of Plant Industry
- Bureau of Lands
- Bureau of Public Works
- College of Agriculture and Forestry
- International Rice Research Institute

Information obtained during these consultations was supplemented as the result of sessions with the Honorable Arturo Tanco, Jr., Secretary of Agriculture and Natural Resources, and Chairman, National Committee on Mineral Exploration and Survey Operations; Vicente Arancillo, Manager, Development Bank of the Philippines; the full NACOMESO Committee in plen ary session; and staff of the U.S. Embassy and USAID (Note: see Appendix 2 for additional detail).

1. Minerals and energy - The Philippine Government has given high priority to accelerated exploration and development of mineral and petroleum resources, both to increase the export income of the country and to provide raw materials for industry and agriculture. The hope that remote sensors might be useful for locating minerals and petroleum has been responsible for much of the Philippine interest in a remote sensor program, and there is good reason to believe that some of the sensor techniques can be of great help in identifying exploration targets.

Production and use of mineral raw materials are of rapidly-growing importance in the Philippine economy. The total value of Philippine mineral production rose from about 0.27 to about 1.72 billion pesos in the decade from 1960 to 1970 and has grown more than 40% each year in the past two years. Mineral raw materials (chiefly copper, iron, chromite, gold, silver, and mercury) now account for more than 20% of the total value of Philippine exports. Nevertheless, mineral production still is far below the potential that seems indicated by the geological environment.

A major impediment to accelerated discovery and development of mineral resources has been the lack of geologic maps and information needed to identify exploration targets and guide

mineral development. Less than 5% of the country has been geologically mapped in sufficient detail to adequately appraise resources and plan exploration. Accelerated surveying and mapping is essential as a basis for rapid resource exploration and appraisal, but will likely have only limited success if restricted to ground observational methods. Rocks, structures, and mineralization are not widely exposed because of soil, vegetation, and cultivation, and in most places cannot be mapped accurately by visual means or interpreted through standard black-and-white aerial photographs. Geochemical and ground geophysical methods can be effective once mineral target areas have been identified but may be difficult, slow, and costly to apply in the regional studies designed to isolate the localized targets. Remote sensing techniques may be especially helpful in accelerating regional geologic mapping and mineral exploration.

Petroleum and natural gas have not yet been found in significant quantity in the Philippines and the Government is interested in expediting exploration activities since the importation of petroleum and petroleum products cost over 600 million pesos annually. Although the geologic conditions are not as favorable as for minerals, a number of sedimentary basins both on-shore and off-shore seem attractive for oil and gas exploration -- particularly along the west side of the Philippine arc. Possibilities have yet to be tested, however. Geologic conditions affecting petroleum accumulation in the Philippine region are complex, and considerable investigation will be required to assess the potential.

In the absence of known oil and gas resources, geothermal energy possibilities are being studied intensively. One geothermal area in southern Luzon is believed to have economically-important geothermal resources, based on studies by the Commission on Volcanology and Bureau of Mines. It is now being developed under contract with the Union Oil Co. Many other areas of geothermal potential exist in the Philippines, and exploration targets should be identified and tested. A map prepared for the team by the Commission on Volcanology shows 14 areas of primary interest for geothermal exploration, and the most promising targets should be identified and tested.

Geologic mapping, exploration, appraisal, and regulation of mineral and petroleum resources are the responsibility of the Philippine Bureau of Mines in the Department of Agriculture and Natural Resources. Geothermal investigations are conducted by the Commission on Volcanology in the National Research Council, in cooperation with the Bureau of Mines. Both agencies have a good basic understanding of, and capability in, their assigned functions, and both would provide a sound institutional base for the introduction and application of remote sensor techniques appropriate to their respective missions. However, both are seriously deficient in trained scientific personnel and at present have only enough manpower to carry on minimal operational functions. At the time of this evaluation the Bureau of Mines had 62 of its 115 professional positions vacant and the Commission on Volcanology had five vacancies in its authorized level of 23 professional

positions. Filling these vacancies should be given high priority not only to provide a capacity for the efficient introduction of remote sensors, but also to enable them to carry on with traditional surveys, without which the sensors will have limited usefulness.

The introduction of airborne and satellite remote sensing systems offers an opportunity to circumvent many of the non-institutional impediments to surveys and mapping which are currently retarding the development of Philippine mineral and energy resources.

The most important sensor techniques for petroleum and mineral exploration in the Philippines are airborne magnetic and radiometric surveys. These have not been used as widely as they should be, although petroleum and mining companies have carried out surveys in some areas. Systematic aerial magnetic and radiometric surveys should be planned and conducted in favorable on-shore and off-shore areas, incorporating geophysical data obtained by private companies. Such surveys should be supplemented, of course, by geologic mapping and the use of aerial photography and satellite imagery when available. In some areas these surveys might reveal geophysical anomalies indicating buried ore deposits, but more likely would show structures and properties of rocks that can be interpreted in terms of mineral and petroleum exploration targets.

For geothermal exploration, the most attractive new technique is the thermal infra-red scanner which has already been used successfully to a limited extent in monitoring Taal volcano. A systematic thermal survey of favorable regions by an airborne scanner should prove to be great value in rapidly identifying exploration targets.

Color IR and multispectral aerial photography, and possibly reconstituted color IR imagery from the ERTS satellite may also be helpful in mineral exploration. Research in the U.S. has shown that certain trees over porphyry copper-molybdenum deposits pick up metals from the soil and thus acquire measurable differences in reflectance detectable with color-infrared photography. Experimentation with trees over similar deposits in tropical areas may be undertaken during the coming year by the U.S. Geological Survey with A.I.D. support. The Philippine Bureau of Mines has expressed interest in the research which, if partially targeted in the Philippines, would provide excellent experience and training in the remote sensing field for participating Filipinos.

Side-look radar, another tool that can be applied in the search for petroleum and minerals, has been used extensively in other countries for mapping purposes, especially where heavy cloud and forest cover interfere with normal aerial photography. Radar commonly gives sharp definition to some topographic features that might not readily show up on photography, and to structures in

the bedrock . Because it helps define geologic structures, radar can be especially effective in studying regional tectonic features that may be related to petroleum and minerals. It could thus be of great help in the Philippines, although its priority is somewhat less than that which should be accorded other sensors at present.

Other techniques such as gamma ray spectrometry, multi-spectral photography, and radiometry may be useful in the search for mineral deposits in the Philippines and thus should be tested when possible.

2. Agriculture - The Philippines is heavily dependent on agricultural products both for domestic consumption as well as for foreign exchange derived by the export of primary and secondary agricultural commodities. One-third of this island nation's land is currently used for agricultural production, and two-thirds of the population resides in rural agricultural areas. Philippine agencie and institutions have been progressive in testing and using new agronomic techniques (genetic improvement of varieties, soil fertility testing, and use of fertilizers, herbicides and pesticides) The results of research on improved crop varieties and agronomic practices carried out by the Bureau of Plant Industry and the Phil. University's College of Agriculture and Forestry are disseminated by experiment stations and also by the National Food and Agriculture Council. The latter,through the use of credit control and supervision of farmers receiving credit, insures that improvements in

traditional approaches or new breakthroughs are put to use. As a result, the growth rate of the agricultural sector was a healthy 5.5% in 1970.

Remote sensing, both from spacecraft and aircraft, could provide needed information applicable to various agricultural resources in the Philippines. If cloud cover is absent when ERTS passes over the country during different seasons of the year, the imagery could be used to discriminate among forest lands, cultivated areas, and water-covered locales. If repetitive coverage is available, preparation of a "crop calendar" may allow differentiation between rice-sugar cane-corn areas and coconut-mango-banana areas. Under optimum climatic conditions, and with skilled photo interpreters, the quality of the acquired imagery may allow the various individual crops within a particular area to be identified. This would, however, also require the availability of interpretation tools such as zoom stereoscopes, photo enlargers, and color reconstitutors for use in analyzing combinations of multi-spectral images.

The geographical extent of crop damage due to floods and typhoons can be determined quite easily with low and high altitude aerial photography. If large areas are affected, use of repetitive ERTS coverage would allow mapping the extent of damage.

Obviously, there are agricultural objectives which cannot be met with ERTS data and may be difficult if not impossible to

accomplish even with aircraft data. Estimating yield, for example, requires crop area information obtained from aircraft to be used in association with corollary data obtained by other means (i.e. weather information, disease and insect incidence, fertility of land, etc.). This allows a "yield" factor to be multiplied by the crop area. Also, determination of the location and size of areas affected by diseases and insects is quite difficult, even using relatively large scale imagery, unless affected areas within the fields are quite large and there is considerable contrast between healthy and damaged crops in one or more of the sensor channels. However, considerable research in this area is underway in the U.S. at the present time. A case in point is the identification and survey of the Southern Corn Leaf blight which took place in the midwestern U.S. this past growing season -- a program which was more experimental than operational.

Determining levels of pesticide residues is an objective which no known spacecraft or aircraft sensor is capable of accomplishing. Remote sensing ground instruments offer the greatest potential for automatic monitoring.

Use of thermal infrared scanners has been somewhat successful in detecting disease and insect infestations. However, experimental work should be done to improve the use of this sensor prior to the receipt of data from ERTS-B (follow-on satellite to ERTS-A). ERTS-B will provide thermal data not available with ERTS-A.

3. Forestry and Soils - The extent and rate of depletion of its valuable forest land constitutes one of the priority interests of the Philippine Government in the natural resources sector. The use of ERTS data and medium or small-scale aircraft imagery for assessing the type, extent, and depletion of forest resources is both feasible and practical. It would allow rapid classification of an area (e.g.,analysis of forest cover by major types; identification of range lands; and location and extent of recently cleared areas). Determination of individual tree species within a mixed stand would require an image scale beyond the point of economic feasibility until, and unless, an image interpretation key is developed to accommodate small and intermediate scale interpretation. Special circumstances may, however, dictate acceptance of high costs for detailed analyses of small selected areas. A demonstration project using imagery and ground inventory of species would provide valuable experience for photo-interpreters in the forestry field.

The major application of ERTS and small-scale aerial photography would be to map areas of forest degradation and deforestation due to agriculture encroachment and "slash and burn" practices. Repetitive coverage by ERTS and later resource satellites should allow a determination to be made of both the extent and intensity of such pressures on forest lands.

The Bureau of Forestry, which has an extensive network of field offices throughout the country which can be employed in conjunction with the ERTS program, might profitable employ ERTS imagery and high altitude black and white and IR photography to upda the existing forest inventory. Forest area classification, conservation of forest lands, timber cutting controls, and estimates of timber production are all amenable to interpretation by remote sensing supplemented by random field observations. Evergreen forests, mixed deciduous, dry dipterocarp, pine forests and recently cleared areas can be identified from small-scale, hi-resolution sensing. A new forest inventory based on advances in the state-of-the-art in remote sensing would: (1) refine the original classification of forested areas and tree species; (2) determine the extent of deforestation that has occurred since the last inventory; (3) identify major sources and types of forest pressures; and (4) identify priority sites for reforestation and other protective measures.

Additionally, low-altitude IR sensing could be carried out in conjunction with field checks of individual forest species in order to develop an aerial interpretation key for use by forestry and land affairs personnel.

Soil surveys might be expedited and enhanced through data acquisition by remote sensing techniques. Identification of soils from aerial imagery is based upon an evaluation of, among others, land forms, vegetation, gully shapes, drainage systems, and color

tone. Depending upon the sensor (i.e., color photography, color infrared photography, thermal infrared scanner, or airborne magnetometer) detection of various edaphic properties is possible. Aerial infrared data, for example, permits discrimination between sandy and nonsandy soils based on silica content. Moreover, locating lateritic soils unsuited for irrigated agriculture has been demonstrated with scanners. Generally when applying remote sensing techniques to soil surveys, inference and associative parameters weigh heavily in arriving at an overall analysis. Traditional methods of field inspection and sampling must still be utilized for detailed analysis. The Bureau of Soils might effectively:

(1) update soil maps on a country-wide basis at the reconnaissance scale of 1:250,000;

(2) identify priority areas for early map publication at 1:50,000 and schedule publication of the required 900 sheets over a 6-year period;

(3) select several ground locations which contain dominant agricultural soils as well as a variety of soil types and attempt to develop an identification key using color and IR photography from low-flying aircraft.

4. Land Use Survey and Classification - A basic problem affecting all aspects of economic, social and technological development in the Philippines is land use. Newly-evolving technology now allows the broad subject of "land use administration" to be approached for the first time in a comprehensive, integrated, and rapid manner. The result should be an increase in both technical and administrative efficiency within existing manpower limitations. By utilizing the full range of remote sensing and automated data processing at various scales, a comprehensive program of land survey, classification, utilization, and administration can result. Most important, it can be done on a scale which is large enough to make a very real and profound impact on public policy.

A basic and historic impediment to planning and managing the optional use of land has been the difficulty of acquiring and analyzing basic data on existing uses of land for agriculture, forestry, water resource development, and human settlements. By means of satellite imagery used in association with standard survey techniques, it may be possible to rapidly update land use mapping of the entire country with each sheet delineating,

at the minimum, forest areas, paddy land, upland crops, horticulture, pasture and rangeland, marshes and other wetlands, and urban areas.

The administration of land affairs constitutes a complex and varied field that involves many different offices and bureaus of government at central, provincial and municipal levels. Infrastructure operation and development should be greatly enhanced by an upgrading of capabilities to rapidly carry out both large and small scale land use analysis and classification since transportation nets, electric power grids, municipal and industrial demands and outputs all impact on, and incur impact from, the agricultural, forest, water and mineral resource sectors. When photogrammetric and automated data processing techniques are applied to the survey of land, the preparation of land registers, and the issuance of titles, the labor return benefit is on the order of 100 to 1 compared with traditional approaches.

Of particular importance in the use of satellite imagery for land classification purposes will be the potential for using the orthographic (scale constant) characteristics of the images to make photomaps showing current land use and culture entirely by photographic processes. Moreover, repetitive coverage by the satellite will provide a means of quickly updating the maps to reflect infrastructure project activities, urban growth, seasonal flooding, limits of cultivated and forested land, and many other

situations which change as a function of time.

Another tool of great potential for land use mapping and analysis is multi-spectral black-and-white aerial photography. The multi-spectral photographs are analogous to multi-spectral synoptic imagery that will be available from the ERTS system. Multi-spectral images from satellite and aircraft can be studied individually or in combination to enhance certain classes of land data such as vegetation, cultivation, water and various man-made features. The potential for these applications is sufficiently promising to justify efforts to introduce some of them into programs of agencies having responsibilities for mapping related to land utilization, classification, and development (e.g. Bureau of Lands, Bureau of Coast and Geodetic Survey, and Bureau of Mines).

5. Water Resources - Water resources planning, development, and management is another area in which emerging remote sensing technologies can play an important role. The Philippine Government is especially concerned with the assessment of the distribution and quality its surface waters and with the location of ground water for irrigation, especially in central Luzon.

Thermal infra-red scanning has proved to be of great value in assessing surface water distribution, locating sources and extent of thermal pollution, outlining the distribution of industrial

effluents, mapping currents and water masses, and identifying areas of near-surface ground water. Thermal springs can also be located with this technique. The thermal scanner was tested several years ago along the Luzon coast where it revealed a number of fresh water inflows from the land into coastal waters.

Multi-spectral imagery both from the ERTS satellite and from aircraft could also be of considerable help in mapping surface water and perhaps identifying areas favorable for ground water. In particular, satellite imagery and aircraft photography in the infra-red part of the spectrum can be used to rapidly and accurately map the distribution of surface water. Comparative imagery in other spectral bands may be helpful in identifying water characteristics.

The Philippines has a special problem in identifying the distribution of wetlands and changes in their seasonal extent. ERTS imagery repeated at appropriate intervals can be especially useful in monitoring these changes, assuming reasonably cloud-free images can be obtained. The combination of satellite and aircraft remote sensing may be of great assistance in planning and managing irrigation and hydroelectric projects, particularly with respect to integrating the development projects with regional land use planning and watershed characteristics.

Responsibility for water resources investigations and development is shared by several agencies. The Bureau of Mines is the principal agency concerned with ground water investigations; the Bureau of Public Works with studies related to surface water distribution and drainage; the National Irrigation Admin. with surface water use including irrigation and dam projects; the Coast and Geodetic Survey with mapping of coastal and offshore areas; the Commission on Water and Air Pollution with water pollution; and the Bureau of Fisheries with ecological conditions in lakes and streams. All have a need for aerial photography and data in the conduct of their special missions, and a coordinated program involving remote sensor applications could have great collective importance in water management.

6. Oceanography - Being a nation of islands, the Philippines has a vital stake in the identification, utilization, and conservation of marine resources. The ocean serves the Philippines as a medium for trade and transport, a source of animal protein through fish farming and traditional harvesting, and a receptacle for wastes, The sea also serves to separate the nation, to spawn devastating storms, and to submerge the mineral wealth of the continental shelf areas. Consequently, the quality of the nation's capability to understand oceanic processes and systems, and to inventory the resources within and below the water column, can

serve either as a valuable asset for promoting economic growth or -- in the absence of a strong capability -- as a major constraint on country development.

Remote sensing systems can greatly enhance and expand conventional oceanographic survey capabilities. By providing rapid and multi-purpose detection and reconnaissance, they can rapidly add to the store of knowledge of current patterns, sea state, coastal topography and erosion, sedimentation, freshwater discharges, hydrography and marine geology, pollution sources and dispersion patterns, and biological productivity.

Black and white aerial photography has long been employed in many parts of the world to survey and map coastal margins; airborne magnetics has yielded information of economic utility on the character and structure of the ocean floor. Now, new remote sensing techniques and systems, operational or under development, will supplement these older, proven tools. Thermal infrared imagery has already been applied successfully to identify inflections of fresh water into the ocean from both surficial runoff and submarine springs. The same method has contributed new knowledge on currents and water mass movements in oceanic areas. Data obtained by the infrared radiometer of the Nimbus satellite has enabled the course of the Gulf Stream to be traced more precisely than ever before.

Applications of remote sensing to marine pollution studies are becoming the focus of international attention, and will be discussed at next June's U.N. Conference on the Human Environment. A fuller account of this topic is contained in the "Environmental Pollution" section of this chapter.

Another potentially valuable application of remote sensing to oceanography is the use of color or infrared photography to measure the abundance and distribution of kelp and phytoplankton. The former can be harvested commercially, and the presence of phytoplankton can often be correlated with the presence of fish stocks. Infrared radiometer studies from aircraft were used successfully off Iceland to assist fisherman relocate fish that had disappeared due to a shift in a cold water-warm water boundary.

Successful studies have been carried out on the use of radar for measuring wave heights and sea state. Since radar can penetrate clouds, a system can be envisioned that would monitor sea state and, indirectly, wind velocity via aircraft or satellite in the open ocean under the worst of weather conditions. Maritime transport would benefit immensely.

A number of Philippine technical offices are presently engaged in missions which could be assisted and facilitated by the availability of data on oceanic phenomena derived from remote sensing. This includes the Coast and Geodetic Survey, Commission on Fisheries, Commission on Water and Air Pollution, Bureau of

Public Works, Bureau of Mines, and the military agencies. In addition to the possible applications already enumerated, standard black-and-white photography and color composites* from satellites can provide small-scale orthographic maps of vast areas which could be invaluable for delineating coastline topography and erosional processes; classes and distribution of land use in coastal areas; reefs and shoals; and gross water circulation and current patterns. ERTS photography, for example, might make a major contribution to a joint hydrographic survey of the South China Sea being planned by a 6-nation committee under ECAFE currently chaired by the Philippines. It would therefore be useful for the Bureau of Coast and Geodetic Survey, the Philippine action agency for the hydrographic survey, to examine ERTS-A imagery from this point of view, and explore the feasibility of an ECAFE proposal for ERTS-B and SKYLAB photography specifically designed to assist the South China Sea Hydrographic Survey.

7. Disaster Monitoring and Assessment - The Philippines is seriously affected by typhoons and volcanic eruptions, and less seriously by earthquakes and landslides. Remote sensors on satellites and aircraft can be helpful in monitoring these phenomena and in assessing damage.

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*Color composite data are photographic products containing more than one spectral band registered and combined into a single picture by producing each band in the picture with a different color dye.

Weather satellites are already tracking typhoons and thus helping to predict where typhoon damage can be anticipated. The ERTS satellites may be useful in assessing damage from typhoon winds and floods, including destruction of crops and structures. Changes in drainage, erosion and deposition, and landslides caused by the rains may also be observed. However, since the ERTS satellite will pass over a given area only every 18 days, and since there will be a time lag of two weeks or more before the imagery from a flight is received in the Philippines, it will not be possible to assess changes on a day-to-day basis, or even to get an overview of a particular region until some time after a particular phenomenon occurs.

Volcanic activity can be monitored by ERTS-A satellite either through images of the volcanic eruption or of the effects of the eruption on the landscape and vegetation. The ERTS-B satellite, tentatively scheduled for launch in 1973, will probably carry a radiometer for obtaining thermal data, which may assist in studying gross thermal activity in volcanic areas. To some extent it may be helpful in detecting increasing heat flow prior to volcanic eruptions. Also of potential value for the Philippines is a telemetering relay system linking ground radiometer and seismic stations via satellite to a central monitoring station; such a system is already monitoring thermal activity at Mount Rainier in the State of Washington.

Of proven value for volcano monitoring is the aircraft-borne thermal infrared scanner. Such a scanner was flown over Taal Volcano at intervals after the eruption of 1965, and demonstrated its value by revealing the renewed thermal activity that preceded the 1966 eruption. There is little doubt that systematic overflights with the thermal scanner would be highly effective in helping predict volcanic eruptions. A capability for systematic overflights of an IR scanner to monitor active and dangerous volcanos in the Philippines should be established as soon as feasible. A map prepared for the team shows six active volcanos near populated areas.

Although earthquakes have not been as destructive as volcanos and typhoons in the Philippines, they are a serious threat especially along the easternmost islands. Satellites may be very useful in identifying areas of potential earthquake activity, and the probability of damage, by facilitating improved mapping of the major rift systems along which the earthquakes occur, and in detecting surficial effects of fault movements. Also, the telemetering of seismic data from ground instruments throughout the islands to an earthquake monitoring center in Manila will be feasible via satellite in the future. Whether or not satellites are used as relay stations, the installation of a seismic monitoring network to develop a better understanding of earthquake activity and its relation to volcanism along the Philippine arc should be given a high priority.

Aircraft surveys along the major fault zones with thermal infrared scanners may be useful in detecting surface expressions of heating related to fault movements, as well as thermal springs and igneous emanations. It is possible also that high altitude aircraft surveys using color-infrared photography would be useful in refining the mapping of active fault systems by showing changes in vegetation caused by thermal and hydrologic conditions along the faults.

8. Environmental Pollution - As in most countries of the world, population growth coupled with increased agricultural and industrial production are placing stresses on the environment which are collectively resulting in serious pollution problems. The National Water and Air Pollution Control Commission (NWAPCC) is the Government regulatory agency empowered to identify, measure, control and abate pollution of the water and air. It has recently been directed, through the National Science Development Board, to prepare a national anti-pollution program. A Cabinet-level interagency committee has been established to supervise the preparation, coordination, and implementation of this program. Other agencies with major responsibilities and interests in pollution monitoring and control include the Department of Health, the Philippine Fisheries Commission, and the Coast Guard.

Commissioner Lesaca of the NWAPCC has been actively involved in preparatory planning for the U.N. Conference on the Human Environment, scheduled for next June in Stockholm, particularly with respect to developing conference documentation on the nature of a global pollution-monitoring network. Because such a network would include both satellite and aircraft detection and surveillance components, the Philippines -- through their continued participation in the U.N. Conference -- will have a mechanism for keeping abreast of the state-of-the-art in this area.

Remote sensing, both by thermal scanner and infrared films, has great immediate potential with respect to pollution studies. By recording temperature variations, thermal IR sensors can detect and monitor waste effluents discharged into rivers, lakes, bays, and the open ocean. Several Government offices called attention to the fact that it would be useful to monitor powerplant effluents now being introduced into Laguna de Bay. Philippine sewerage engineers are interested in locating fresh water discharges in Manila Bay which could serve to dilute sewage to be piped out to sea for disposal. Airborne IR photography has already been employed successful in locating freshwater springs off Florida, Hawaii, Greece, and a number of other countries. Thermal IR flown from aircraft, and possibly from satellite altitudes in the future, could assist in detecting the deliberate, unlawful discharge of

thermal wastes into the air or water under the cover of darkness -- a situation which is now occurring in the Philippines.

Color and color IR photography may be useful in tracing the migration of pollutants in water bodies. Application of these techniques could be the basis for "pollution-warning" advisories for commercial fishermen, particularly for accidental spills or leakages of toxic materials. Decision-making on the siting of industrial plants could be enhanced through color photography of the movement of dyes into potential waste receiving waters at various alternative plant sites.

None of the Philippine offices contacted have ongoing or planned projects which utilize remote sensing to detect or monitor pollution (including standard aerial photography). Both those with specific missions in the environmental pollution field, as well as those whose programs suffer from the impact of pollution (e.g. fisheries), expressed interest in possible applications of remote sensors, but acknowledged that they do not have the in-house capabilities required to interpret the photography once acquired.

IV. SIGNIFICANT ASPECTS OF COORDINATED SATELLITE AND AIRCRAFT SENSOR APPLICATIONS

Assuming that the U.S. National Aeronautics and Space Administration accepts the Philippine proposal for inclusion in the ERTS-A experiment, space imagery should be available within one year for large, if not all, areas of the country, including offshore margins. Although the usefulness will depend to a large extent on the cloud and haze conditions encountered over the country (exclusive of the proper functioning of spacecraft systems), plans should be formulated by the various potential user agencies of the Philippines for the handling, interpretation, and application of the imagery, both in photo and digitized formats.

Several applications of small-scale imagery of vast areas of the Philippines should be considered, as mentioned above in the discussions of resource sector programs. In particular, photomaps prepared directly from the orthographic imagery could have wide application for classifying and mapping land use patterns; identifying and tracing major geologic linaments and structures possibly associated with mineralization or petroleum; and updating earlier maps in terms of urban growth, irrigation patterns, coastline configuration, and road networks.

Use of the space imagery will provide Philippine specialists an opportunity to become acquainted with techniques for handling

and interpreting the photos and digitized data. This type of training experience, it should be remembered, is a principal objective of the ERTS program. Moreover, used in conjunction with aerial photography already available to the Philippine Government, plus other high and low level aircraft imagery which may be acquired, the emerging satellite technology should stimulate institutional and operational changes within both Government and non-governmental resource agencies as well as foster improved interagency program coordination.

Since data acquired from space will potentially contribute to the missions of many Philippine resource agencies, mechanisms must be developed to disseminate the photography and data to user agencies in a timely and efficient manner. Because subsequent interpretation by one agency will undoubtedly contribute to the work of others, a capability must be developed within the country to effectively disseminate not only the raw photos and data, but also the results of the photo and data interpretation.

An extremely important aspect of Philippine participation in the ERTS experiments, and subsequent satellite-based resource survey programs, is the manner and extent of the integration of imagery acquired by spacecraft and that obtained by aircraft sensors. As previously mentioned, the satellite will serve only as a platform for sensors with certain advantages in terms of repetitive coverage of large geographical areas. However, the value of

satellite imagery can be maximized only through its use in association with lower-level, aircraft-based sensing, as well as with ground-truth studies. This means that any program developed for handling and using ERTS data should not be compartmentalized; rather a way must be found to facilitate the acquisition and flow of standard aerial photographs and other natural resources data to enable the user to integrate all relevant information on a particular area. In summary, satellite data should not be accorded preferential treatment in the establishment of a resource survey capability.

This point is stressed because the team was concerned about apparent difficulties resource agencies presently have in gaining access to aerial photography already on the shelf. The problem seems to be caused partly by the plethora of agencies within and outside Government which acquire and interpret aircraft photography; partly by the absence of effective communication between the many agencies with respect to what is available; and partly by the lack of a centralized location for the storage, reproduction, and distribution of photographs and maps.

An index of available photography and its location would be important first step in upgrading Philippine capability both to take better advantage of existing photos, and to monitor the dissemination of forthcoming satellite imagery. The National Computer Center might be looked to for the development of an index

continually updated and periodically printed out
for general distribution. Security classification
acknowledged, but these too will have to be
the GOP if maximum benefits from spacecraft and
tography for country economic development are to be

in the art of acquiring and interpreting photography
data both from spacecraft and by new aerial remote
is understandably of critical importance. The
extent of training requirements are different from
country but, at a minimum, an indigenous capability
veloped which will permit knowledgeable management
whether and how much to invest in remote sensor
. This means that personnel in the technical agencies
pped to monitor the state-of-the-art in their special
know the advantages and disadvantages of alternative
techniques, and make enlightened recommendations to
nners on applications which promise to maximize cost-
ns.

the Philippines, this means that, initially, at least
with advanced technical knowledge and high status
agency should be trained to move knowledgeably in the
ing field. The training itself should provide an
overview of the field

and its evolution, as opposed to a detailed, technical insight. The latter type of training would follow. In recognition of this, it is suggested that an individual be designated by each of a number (approximately 8) of selected Philippine technical agencies with responsibilities in the natural resource field. These designees would then be brought to the U.S. for a 2 - 3 week period to visit several institutions engaged in remote sensing data and photo storage, retrieval, interpretation, and dissemination, Special emphasis would be placed on techniques and equipment for utilizing ERTS imagery. Upon return, it is envisioned that these individuals would serve as coordinators and points of contact within the agencies for remote sensing projects and applications (both spacecraft and aircraft).

The National Committee for Mineral Exploration and Survey Operations might take the lead in coordinating Philippine participation in such a training program. In addition, this Committee would be a valuable mechanism of sorting out, on a high priority basis, agency responsibilities within an integrated satellite/aircraft resource surveys program -- and, most important, the means to coordinate their individual activities including data interpretation, map preparation and reproduction, and photo and map storage.

Aerial photography and other airborne sensors will be important to any future resources program, and especially significant in interpreting the ERTS imagery. Aerial data acquired by sensors (multi-spectral cameras) sensitive in the same wavelengths of light as the ERTS sensors -- and collected over areas covered by ERTS-A -- would serve as sub-sampling tools to bridge the gap between very small scale ERTS data and ground zero. Consequently, the team felt that the Philippines should seriously consider the establishment of an in-country capability to collect multi-sensor aerial data in support of priority natural resources survey objectives. A multispectral camera array (e.g., three or four Hassalblad or Vinten-type 70 mm cameras) mounted in the Philippine Air Force aircraft which is already instrumented with an excellent mapping camera (RC-8) will provide a local capability to study a wide variety of significant problems in a number of disciplines. Flights over areas of special interest to various agencies (E.G., Laguna de Bay, Taal Volcano) would provide excellent indigenous training aids which would assist with the interpretation of ERTS data and the reconstitution of ERTS images into a color infrared image.

Another important aerial reconnanisance instrument for coordinated use in a Philippine aircraft is the single

or dual-band thermal scanner. This instrument could be of use to a number of resource agencies in a range of applications, including the detection of sources of water pollution either during the day or at night due to differences in water temperatures; location of temperature boundaries between warm and cool ocean water where fish usually congregate; mapping geothermal areas; monitoring volcanic activity; and the identification of crops and detection of stressed vegetation.

Several other aircraft remote sensors could be of great value to resource development in the Philippines, even though their high costs and limited application suggest acquisition under contract rather than through development of an indigenous capability in the near term. The Side-Looking Airborne Radar (SLAR) is an important instrument for use in mapping of geologic structures and formations. It is particularly valuable in areas of persistent if not constant cloud cover since the radar energy penetrates the clouds and, to varying degrees, the vegetation. For the location of mineral and petroleum deposits, the airborne magnetometer and scintillometer provide important geophysical data which can be used by oil and mining interests as "treasure maps" which will guide them to the areas most likely to contain oil or other minerals. A recent airborne geophysical survey in Liberia under private contract, for example, located offshore

structures favorable for petroleum occurrences, and subsequent leases by the Government brought in revenues which more than paid for the contract survey.

The team felt that the urgent Philippine requirement for accelerated mineral and petroleum explortation might provide an excellent opportunity for the coordinated application of aerial magnetic, radiometric, and photographic surveys, ERTS imagery, and ground studies. Areas already designated by NACOMESO would be appropriate for such a coordinated survey, assuming the aerial magnetic and radiometric data can be obtained. Side-look radar would be of great use in such surveys, but in view of the high cost involved it was felt that this technique should be deferred until the other techniques have been used and the results have been studied.

V. ANALYSIS AND RECOMMENDATIONS

The islands of the Philippines possess a rich and diversified natural resources potential which remains largely unexplored and underdeveloped due to several factors, not the least of which is lack of an adequate resource survey capability. Special conditions of persistent clouds, thick vegetative and soil covers, and rugged terrain render traditional survey techniques inadequate to meet rapidly expanding requirements for intensified resource development and improved resource management. As the country's population growth outpaces the ability to rationally develop and manage the natural resource base, mounting foreign exchange deficits in the natural resources sector plus increasing degradation of the quality of the air, land, and water retard or offset developmental gains in other areas.

New and emerging remote sensing systems carried by aircraft and satellite collectively offer a rapid resource reconnaissance and mapping capability which may enable the Philippines to make a quantu jump in the development of indigenous natural resources. Investment decisions in this rapidly evolving and complex field are difficult however, and there is a relatively high cost associated with acquiring the necessary capabilities, either under contract or via outright purchase. It is therefore important that older

but proven remote survey techniques (e.g., black-and-white aerial photography; airborne geophysics) are not overlooked in the quest to develop capabilities in newer, more sophisticated areas. Maximum advantage must be taken of the present state-of-the-art in both image interpretation and engineering with imagery, with emphasis on modern photogrammetry.

The U.S. team was impressed by the widespread interest in potential applications of remote sensors to resource development displayed at all levels during discussions with Philippine Government officials, program managers, and technical personnel. While the prospect of satellite imagery was of particular concern (due in large measure to knowledge of the Philippine proposal for participation in the ERTS-A experiment), the discussions revealed both a desire on the part of the Filipinos to become acquainted with the spectrum of remote sensors, and -- most important -- a realism attached to the prospects for finding easy solutions to complex resource problems by direct transfer of a new technology.

Executive Secretary Alejandro Melchor described the Philippine perspective as a recognition that remote sensing could offer an opportunity to make an urgently needed breakthrough in natural resource development. Further, that based on Philippine experience with other scientific programs such as Project Stormfury

(typhoon suppression), the Philippine Government is prepared to be patient, realizing that the technical and economical feasibility of many of the promising new techniques have yet to be demonstrated. However, the Government is convinced of the potential contribution remote sensing can make to country development, and it therefore wishes to be actively involved and share in the evolution of the state-of-the-art.

The extent of this commitment is reflected in a number of actions taken during the past year by the Philippines which have included submission of a proposal for participation in the ERTS experiment; representation at the International Workshop on Earth Resources Survey systems; creation of a national committee (NACOMESO) to coordinate activities in the remote sensing field; consideration of a radar mapping program to be financed under a loan agreement; visitation by GOP computer experts at Purdue University's Remote Sensing Program Office, and preparation of plans to co-locate an Earth Resources Survey Office at the National Computer Center. On the basis of the need to expedite resource development, coupled with the widespread interest in the potential of remote sensing, the team concluded that establishment of a Philippine capability in this field is both a justified and realistic goal.

It is apparent, however, that parallel with building new remote sensing capabilities must come a strengthening of the basic infrastructure and services required to sustain and optimize even standard resource survey programs. The team was concerned that present understaffing and vacancies in several of the technical agencies will constrain their ability to provide the necessary backup "ground truth" and data interpretation support for the aerial and satellite surveys. In addition, there currently exist problems associated with the storage, reproduction, and dissemination of photos and maps which must be addressed. For example, to insure that usable imagery is obtained from black-and-white, color, color IR, and various multi-spectral bands, special attention must be paid to providing improved quality control during the developing, printing, and reproducing processes. Solutions to all these problems must not necessarily be sought in the establishment of new institutions or the procurement of new technologies, but rather in the removal of administrative requirements that unnecessarily retard the flow of information, and in the improved coordination and use of existing institutions and equipment.

Regardless of whether the Philippines invests additional resources in the remote sensing field, solution of the aforementioned institutional problems should signficantly

strengthen the ability of the resource agencies to carry out their missions. The team was convinced, however, that involving the civilian and military technical bureaus in a coordinated (albeit modest) remote sensing program promises to introduce a new fervor and vitality into their operations which could have benefits extending even to the area of personnel recruitment. Since data acquired by remote sensors invariably have multiple applications, greater interaction on the part of participating technical agencies and Government planners will undoubtedly result. If properly nurtured, major payoffs could accrue in terms of more efficient program development and implementation.

One of the principal objectives of the team visit was to make recommendations on the extent and nature of possible Philippine involvement and investment in the remote sensing field in the near term. In formulating the following recommendations, the team was guided by the necessity to bring into proper balance: (a) the limitations on financial resources and manpower available to apply to this area; (b) the need to select possible initiatives on the basis of their relevance and potential short-term contribution to programs of national priority; and (c) the desire of the Philippine Government to become involved in the full range of the most promising new remote sensing technologies.

Recommendation #1 - that consideration be given by the Philippin Government to the initiation of a broadly-based natural resources survey program involving the application of a range of selected remote sensors both for operational and demonstration purposes. To implement such a program, an initial plan consisting of three interrelated initiatives which address priority resource sectors, institutional problems, and training needs is recommended (see Appendix 4 for details). The possibility of financing and undertaking the project package as a cooperative Philippine-U.S. activity should be explored.

Recommendation #2 - that full use be made of existing technical agencies in the development and conduct of an intensified Philippine resource program based on remote sensing techniques. However, to ensure that full value is derived from investments made by the GOP in this field, Philippine technical agencies should be strengthened as rapidly as possible, and full utilization of their present capabilities should be sought. The following specific actions are recommended:

a. A concerted effort should be made to fill existing vacancies and develop a better supply of technical manpower. The causes of manpower shortages in each resource agency should be investigated and appropriate steps taken to recruit and train the necessary personnel as rapidly as possible.

b. Studies of operating procedures in technical agencies should be carried out to make certain that standard survey, analytical, data-handling, and reproduction techniques are adequate to justify and support the use of remote sensors.

c. A sharper definition of agency responsibilities for the conduct of resource surveys and interpretation of data should be achieved before the initiation of an expanded resources program using ERTS imagery. This is essential to eliminate possible confusion and duplication of effort. Particular attention should be given to the storage of aerial photographs and the preparation, reproduction and distribution of maps.

Recommendation #3 - that centralization of supporting services for resource surveys should be carried out through the establishment of new facilities or the reorganization of present agency responsibilities. The objectives should be:

a. An integrated facility for receiving, storing, reproducing, and distributing to user agencies aerial photography, aircraft and satellite imagery, and base maps. At present the responsibility for such functions is scattered and no adequately equipped facility exists.

A study of the problem is under way by a specialist from the United Nations (FAO) and his recommendations should be given immediate and serious attention. The NACOMESO has already begun to address this problem. A central computer facility for receiving, storing, and processing digital information from sensors, as well as other resources data. The National Computer Center appears to be a well-organized facility and has adequate potential capacity for this purpose. A computer center is also being organized in the Department of Agriculture and Natural Resources. The respective functions of these and possibly other computer centers in the natural resources field should be clearly defined to avoid further scatteration of resource data which has maximum value only if available on demand by the user from a minimum number of sources. The appropriate function of a central computer facility would be to provide computer-support services to user agencies on the processing, programming, and display of computerized information. However, it should resist the impulse to develop its own staff of technical specialists in the earth sciences in competition with the user agencies. Consideration

should be given to developing an automated national bibliographic and reference center for natural resources information. Specifically, a centralized computer facility could maintain a continually updated index of maps and photos (type, location, scale, etc.) for periodic printout and general distribution. A special study of computer requirements and procedures in user agencies, in relation to soft ware, computer programs, processing requirements, and computer staffing needs, would be desirable, preferably by computer specialists who have worked with such data. A central facility for publication of maps and reports to standards adequate for the types of surveys made possible by the new remote sensor technology. Such a facility does not presently exist. Several agencies have some capability for publication, but none are adequate for national resources programs, especially in view of the need for high-volume production of negatives and maps that an intensified resource program would create. This facility and the aerial photography-imagery facility mentioned in paragraph 3-a above could be combined, or at least be located in contiguous space.

Recommendation #4 - that a local capability for conducting airborne remote sensor surveys of limited areas be developed for studies of local resource problems. Such a capability might be vested in the Philippine Air Force, which already has the capacity to fly and maintain an aircraft. It is recommended that a multi-spectral camera assemblage (probably 70mm. focal length) and a thermal infrared scanner be mounted in a two-engine aircraft such as a C-47 and operated as required for user agencies in monitoring pollution, volcanic activity and other transitory phenomena, as well as for studies of crops, soils, water resources, and other uses over limited areas as defined in part 3 of Appendix 4

Recommendation #5 - that an advisory subcommittee be established by NACOMESO to provide guidance on remote sensor programs and applications; maintain contact with remote sensor development and applications in the U.S. and elsewhere; and help guide and train other Philippine specialists in the use of remote sensors. The subcommittee should be composed of one senior employee selected by each user agency so as to cover all categories of resources for which major remote sensor applications are anticipated. Each employee should have the best scientific or technical background available and be of such stature as to command attention within his agency. We recommend that these agency representatives comprise a team to visit the U.S. for a few weeks before the

ERTS-A satellite is launched in 1972, inspect remote sensor equipment and applications in U.S. agencies, and help organize remote sensor applications after returning to the Philippines.

Recommendation #6 - that the membership of the NACOMESO be expanded to include representatives from all agencies and institutions which play, or will play, a prominent role in natural resource programs involving remote sensing. We suggest in particular that representation from the University of the Philippines, the Board on Technical Surveys and Maps, the Bureau of Soils, and the Bureau of Lands be considered.

APPENDIX 1

ITINERARY OF U.S. ADVISORY TEAM

October 11			Arrival of Team
October 12	A.M.	-	USAID (discussions with staff)
		-	Bureau of Mines (meeting with Director, staff, and Maj. Mirasol, Exec. Office)
	P.M.	-	National Science Development Board
October 13	A.M.	-	National Committee on Mineral Exploration and Survey Operations (illustrated briefing by U.S. Team for representatives of Phil. natural resource agencies).
	P.M.	-	Commission on Volcanology
		-	Commission on Water and Air Pollution
October 14	A.M.	-	USAID (briefing for Mission Staff and Col. Patterson, U.S. Embassy).
		-	National Computer Center
		-	Infrastructure Operations Center
	P.M.	-	Bureau of Mines (Reinemund and Long)
		-	Bureau of Forestry (Thomson and Crea)
October 15	A.M.	-	Executive Secretary Melchor, Executive Office
		-	Bureau of Coast & Geodetic Survey (Reinemund and Long)
		-	Bureau of Soils (Thomson and Crea)
	P.M.	-	Commission on Fisheries (Reinemund and Long)
		-	Bureau of Plant Industry (Thomson and Crea)

APPENDIX 1 (Continued)

October 16	A.M.-P.M.	-	Airplane reconnaissance - northern Luzon area
October 18	A.M.	-	National Food and Agriculture Council
	P.M.	-	Bureau of Public Works (Reinemund and Long)
		-	Bureau of Lands (Thomson and Crea)
		-	Secretary Tanco, Dept. of Agriculture and Natural Resources, and Director Busuego, Bureau of Mines
October 19	A.M.	-	USAID and Embassy staff (status report)
	P.M.	-	Board of Technical Surveys and Maps
October 20	A.M.-P.M.	-	Los Banos College of Agriculture and Forestry; and International Rice Research Institute
October 21	A.M.-P.M.	-	National Committee on Mineral Exploration and Survey Operations (report by team on recommendations)
October 22	A.M.	-	Conference with Director, Bureau of Mines, Maj. Mirasol, and Mr. Macabuhay on Phil. training program
	P.M.	-	Departure of team.

APPENDIX 2

PHILIPPINE INSTITUTIONS AND INDIVIDUALS VISITED

A. OFFICE OF THE PRESIDENT

(1) Office of the Executive Secretary
Hon. Alejandro Melchor, Jr. - Executive Secretary
Major Luis Mirasol, Jr.
Mr. Ramon Macabuhay

(2). National Science Development Board
Pedro Laudencia - Chief, Agriculture and Natural Resources

(3) Infrastructure Operations Center
Carlos C. Leano, Jr. - Ex. Director

(4) National Computer Center
Col. Juan Sanchez EDP Director
Maj. Fermin Javier - Systems and Program Manager
Eduardo Advincula Systems Analyst

(5) Office of Technical Surveys and Maps
Marcelino Tabin - V. Chairman/Ex. Director

(6) National Food and Agriculture Council
Doming Panganiban - Dep. Ex. Director
Virgilio Caringal - Nat. Coordinator/Feed Grains

(7) Development Bank of the Philippines
Vicente P. Arancillo - Manager, Baguio Branch

(8) National Commission on Water and Air Pollution
Hon. Reynaldo M. Lesaca - Commissioner
P.P. Viray

(9) University of the Philippines (Los Banos College of Agriculture and Forestry)

T. A. Bernardo - Director of Graduate Studies
S. N. Tilo - Asst. Prof. of Soils
Senen M. Miranda - Asst. Prof. of Ag. Engr.
Juanito D. Lamanilau - Asst. Prof. of Forest Mgmt.
Warren R. Philipson - Visiting Instructor; Univ. of Phil-Corn
Raymond E. Borton - Visiting Prof. - Dept. Ag. Econ.

(10) Commission on Volcanology

Arturo Alcaraz - Chief Volcanologist
Gregorio A. Andal

APPENDIX 2 (Continued)

(11) National Committee on Mineral Exploration and Survey Operations

Hon. Arturo Tanco, Jr. - Chairman
Fernando S. Busuego, Jr. - Vice Chairman
(Bureau representatives listed under home offices)

B. DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES

(1) Office of the Secretary

Hon. Arturo Tanco, Jr. - Secretary

(2) Bureau of Mines

Fernando S. Busuego, Jr. - Director
Francisco Comsti - Deputy Director
Oscar Crispin
Carlos F. Teodoro
Victor C. de los Santos
Telesforo Ejercito
Sesinando Samaniego
Carlos Balon
Regino Relova

(3) Bureau of Forestry

Juan L. Utleg - Assistant Director
Martin R. Reyes - Chief, Forest Management Division
Eliseo T. Capili - Chief, Domain Use Division
Artemio A. Caleda - Forestry Supervisor II
Cirilo B. Serna - Supervising Forest Economist
Napoleon B. Dalangia - Senior Forester, Forest Management

(4) Philippine Fisheries Commission

Hon. Andres H. Mane - Commissioner
Inocencio A. Ronquillo - Chief Fishery Biologist
Priscilla Cares Borja - Chief, Biological Research Section
Jose A. Ordonez - Chief, Exploration and Survey Sect
Manuel L. Llorca - Sup. Fishery Biologist

APPENDIX 2 (Continued)

(5) Bureau of Soils

Juan A. Mariano	- Director
Fernando Bernardo	- Acting Assistant Director
Godofredo N. Alcasid, Jr.	- Soil Project Coordinator
Francisco G. Salazar	- Chief, Soil Survey Division
Ignacio R. Ang	- Chief, Soil Conservation Division
Feliciano M. Lapid	- Chief, Soil Research Division
Isaac N. Nuestro	- Chief, Soil Fertility Division
Felipe T. Agdeppa	- Chief, Laboratory Services
John F. Derting	- FAO Land Classification Expert
Heindrick Engeler	- FAO Map Preparation Consultant

(6) Bureau of Lands

Atty. Vicente A. Valdellon - Director
Galicano I. Taduran

(7) Bureau of Plant Industry

Glicerio M. Garcia	- Assistant Director for Research
Teodoro T. Gonzalez	- Plant Research Coordinator
Alfredo V. Palo	- Vegetable Program Coordinator
Alfredo Hernaez	- Chief, Production Division
Felicio Rivera	- Production Division
Hipolito A. Custodio	- Senior Entomologist
B. R. Gonzalo	- Agricultural Engineering Division
Jose L. Morales	- Chief, Pest and Disease Control Division

(8) Philippine Tabacco Administration

Demetro P. Tabije - Asst. General Manager

C. DEPARTMENT OF PUBLIC WORKS AND COMMUNICATIONS

(1) Bureau of Public Works

Carlos Castillo	- Assistant Director
Leopoldo Kagahastian	- Chief, Water Resources Division
Ricardo Dantes	- Chief, Ports and Harbors
Antonio Cefado	- Ports and Harbors
Enrique Madamba, Jr.	- Flood Control
Candelario Patenio	- Flood Control
Antonio Agtarap	- Water Resources
Eliseo Tayao	- Water Resources
Pedro Razon	- Water Resources

APPENDIX 2 (Continued)

D. DEPARTMENT OF NATIONAL DEFENSE

(1) Bureau of Coast and Geodetic Survey

Capt Jayme V. Presbitero - Assistant Director
Mario C. Manansala - Chief Geophysicist
Cmdr. Amador V. Lucero - Staff Officer
Lt. Renato Feir - Photogrammetrist

(2) Philippine Air Force

Arnie Acedera - Off. Ex. Secretary
Antonio G. Villanueva

U. S. Agencies

1. U. S. EMBASSY

Terrell Arnold - Counselor for Economic Affairs
Col. Alfred Patterson - Defense and Air Attache

2. USAID

Thomas C. Niblock - Director
William C. Larson - Manager, Office of Industrial Development
Raymond Cohen - Regional Program Officer
Frank W. Sheppard - Manager, Office of Rural Development
James Brady - Deputy Manager, Office of Rural Development
Thomas Rose - Chief, Prov. and Local Development Division
Cleo F. Shook - Director, Office of Korea and Philippine Affairs, AID/W

APPENDIX 3

MEMBERSHIP OF THE NATIONAL COMMITTEE FOR MINERAL EXPLORATIONS AND SURVEY OPERATIONS

The Secretary of Agriculture and Natural Resources ------ Chairman

Director, Bureau of Mines ---------- Vice-Chairman

Representatives of the:

Office of the Executive Secretary ---------- Member
Presidential Economic Staff ---------- Member
Bureau of Mines ---------- Member
Department of Commerce and Industry ---------- Member
National Science Development Board ---------- Member
Development Bank of the Philippines ---------- Member
Budget Commission ---------- Member
Philippine National Bank ---------- Member
Philippine Air Force ---------- Member
Philippine Navy ---------- Member
Bureau of Coast and Geodetic Survey ---------- Member
Philippine Fisheries Commission ---------- Member
Base Metals Association of the Philippines ---------- Member
Petroleum Institute of the Philippines ---------- Member
Central Bank of the Philippines ---------- Member

APPENDIX 4

RECOMMENDATIONS FOR REMOTE SENSOR APPLICATIONS TO NATURAL RESOURCE SURVEYS IN THE PHILIPPINES

INTRODUCTION

At the request of the Philippine Government, possibilities for United States assistance in the application of remote sensors to natural resource surveys have been examined by a U.S. advisory team during two weeks of consultations with Philippines program planners and managers. Based on a review of agency programs, interests, and capabilities, the following three-part program is recommended:

(1) Magnetic and radiometric surveys in combination with aircraft and satellite imagery, to identify targets for mineral and petroleum exploration;

(2) Coordinated use of satellite imagery and new aircraft data acquisition techniques for land classification, land titling, and cadastral surveys; and

(3) Multi-sensor surveys (thermal, color infra-red, and multi-spectral) to demonstrate potential applications to a wide range of studies including geothermal energy, volcanic activity, mineral resources, water resources, pollution, soils, crop distribution, and plant diseases.

The principal thrust of the program is to build Philippine capabilities to apply information from selected remote sensor systems to natural resource surveys.

The systems recommended for inclusion in this program are those which offer the greatest potential for contributing to the achievement of Philippine development goals in the near term. The program seeks to achieve a proper balance between immediate operational application of established sensor techniques not now being utilized in the country, and demonstration of the applicability of the most promising new sensor systems in the Philippine setting. It also is responsive to the necessity for careful and balanced integration of satellite and aircraft applications. Specific objectives are: (1) to demonstrate the applicability of the various sensing techniques to resources surveys and problems in the Philippines; (2) to develop a capability for applying these techniques within the Philippine resources agencies; and (3) concurrently to provide these agencies with a substantial amount of imagery, maps, and data on resources, areas, and potentials of high priority for economic development.

Each part of the program would utilize imagery from the Earth Resources Technology (ERTS) satellites to be launched in 1972 and 1973, as well as sensor data or photography from aircraft, supplemented by ground studies and verification. The work would be carried out by appropriate Philippine resource agencies, with guidance and help from U.S. consultants, using contractual aircraft surveys.

The program would be coordinated through the National Committee for Mineral Exploration and Survey Operations (NACOMESO).

SUBPROJECT # 1 -- Magnetic and Radiometric Surveys

This part of the program would involve the application of magnetic and radiometric data from aircraft, together with the study of satellite and aircraft imagery, in four areas regarded as favorable for petroleum and mineral exploration. The work would be undertaken by the Philippine Bureau of Mines, with the help and guidance of U.S. technical consultants, using air-borne geophysical data obtained under contract. Specific objectives would be:

1) To compile and publish a set of geological and geophysical maps and interpretive reports of the survey areas to guide and stimulate petroleum and mineral exploration.
2) To demonstrate methods of applying and interpreting the data from aircraft and spacecraft.
3) To train at least two Philippine geologists and two geophysicists in methods of planning and conducting a regional geophysical program and interpreting the results.

As a result of this activity the Philippine Bureau of Mines should have the capability to conduct and interpret similar surveys in other parts of the country, to make more effective use of geophysical data resulting from oil and mineral exploration, and to develop an understanding of the possible uses of satellite imagery as a supplement for ground and aircraft survyes. Moreover, the results of the program would be immediately useful for exploration and development within the survey areas.

The Philippine Government has given high priority to intensifying the exploration for petroleum and minerals. The most effective tools for such exploration, to augment geologic mapping, are aerial magnetic and radiometric surveys. Most of the known Philippine mineral resources are associated with rocks that are magnetic or have distinctive magnetic characteristics detectable from airborne surveys. The combination of magnetic and radiometric patterns from these surveys would provide guides to underlying rock structure, and geologic information that would help identify petroleum and mineral exploration targets. The magnetic and radiometric data would be compared with geologic information from ground surveys, from existing aerial photography, from aircraft surveys carried out under parts 2 and 3 of this program, and from satellite imagery, in preparing a series of maps and interpretive reports of the project areas.

The National Committee for Mineral Exploration and Survey Operations (NACOMESO) has given top priority to geophysical surveys in three areas (northern Luzon, eastern Mindanao, and the Sulu-Zamboanga arch) based on apparent resource potential. It is proposed to carry out the airborne geophysical surveys, and geological interpretations, in those areas, including contiguous offshore shelves, and also in a fourth area, probably along the Mindoro-Palawan arch. These four areas would provide a full range of geological environments and interpretation possibilities, and the survey results in these areas would be a significant contribution to the knowledge of Philippine

Specifications for contractual flying and data acquisition in the survey areas should be prepared by consultants, and interpretations made by U.S. resource agencies with guidance and help from consultants. Existing geological and physical information in the selected areas will be studied both in planning the work -- to avoid duplication of surveys -- and in the interpretation of results. Final maps will be compiled and issued probably at a scale of 1:250,000.

Dollar fund requirements for this activity would be approximately as follows:

Aerial survey contract services	$1,800,000
Technical consultants	550,000
Equipment, materials, and support services	100,000
Training activities	50,000
Total	$2,500,000

Consultants would be required at the rate of about 2 to 3 man years each year during the 5-year period of the program. At least 4 or 5 Philippine personnel would be given opportunity to study advanced geophysical techniques and applications in the U.S.

Philippine support would be required in the form of services of at least two full-time geophysicists, three full-time geologists, and about eight supporting field and laboratory personnel. Local currency funds would also be required for office, laboratory, and field expenses.

SUBPROJECT # 2 -- Land Classification, Land Titling and Cadastral Surveys

Land resource classification to identify and delineate areas of forest, agriculture, pasturage and inland fishing, and the subsequent reclassification to effect maximum efficiency of land use, constitutes a high priority ne as identified by the Government of the Philippines.

Closely associated with the need to classify land according to its most desirable and productive use, is the requirement to delineate and describe the existing status of land occupancy, both from the standpoint of identifying land ownership for purposes of taxation and for providing to the owner a valid title of ownership which protects his rights in the land and serves as a legal document for purposed of inheritance, transfer, sale or security.

The most effective tools that could be supplied to land classification, titling and cadastral mapping in the Philippines are a combination of small-scale and large-scale remote imagery, primarily photography. These should be used with photogrammetric instruments and automatic data processing techniques.

The objective of this part of the program would be to expedite and accelerate the current efforts of the Government and people of the Philippines in the associated fields of: land classification, tax mapping, and cadastral mapping.

The rational for this part of the program is that the rapidly evolving new technology allows the broad subject of land affairs to be approached in a comprehensive and integrated

manner with a manyfold increase in both administrative and technical efficiency but within existing limitations on total numbers of personnel.

It is envisioned that small-scale imagery from the ERTS-A satellite will be utilized as the controlled base for the purpose of land use classification. It will be supplemented by intermediate scale sensing from winged aircraft at altitudes above 20,000 feet; from low altitude coverage where available; and from ground observation and sampling. The primary effort will be directed to Mindanao in order to refine and strengthen previous land classifications taking advantages of recent progress in the state-of-the-art. Forests would be classified as least to the level of evergreen, mixed deciduous, dry dipterocarp, pine and recently cleared forest area. Other land use would include paddy land, upland rice, horticulture, pasture and range, urban and village areas, wetlands, and those that are intermittently flooded. The standard scale of coverage would be 1:250,000 and 1:50,000.

Closely associated with land classification are the corollary actions of tax and cadastral mapping. The island of Mindanao would be divided into areas of priority for purposes of tax mapping; a grid system developed based on economies of scale between 1:12,500 and 1:2,000; a tentative production schedule adopted and implemented for supplying controlled imagery of the grid system for field utilization in the identification of owners and occupants; and field assistance

At the same time, an area would be selected by mutual agreement in Mindanao to demonstrate the advantage which occurs to the residents of the area when photogrammetric cadastral surveys are substituted for traditional ground procedures.

Project dollar costs over the period of five years would average $440,000 a year for a total of $2,200,00. Local costs to be borne by the Government of the Philippines would be primarily those of office space, per diem, in-country travel and international travel of Philippine nationals who would work in the U.S. from time to time in support of this project.

Of the above figure, consultant salaries would average $250,000 per year, an 8-10 man year effort divided between production activities abroad and personnel permanently stationed in the Philippines. Funding also provides for up to 18 man years of on-the-job production by Philippine nationals in the United States. $250,000 is programmed for the effort with the GOP providing normal salary and benefits during the period of service in the U.S.

Contract services, supplies and equipment are programmed at a level of $700,000. Approximately $100,000 of this amount would be utilized for high altitude, high resolution reconnaissance photography should ERTS imagery require enhancement. The remaining $600,000 will be utilized to purchase photogrammetric instrument support, photographic supplies and equipment, reproduction supplies and services. Consideration should be given

to utilizing a portion of these funds for the establishment and equipping of supplemental photographic and reproduction capabilities in Manila.

SUBPROJECT # 3 -- Multisensor Demonstration Surveys

The use of color, color-infrared, and other types of aerial photography, together with thermal infrared and other sensors from aircraft and multispectral imagery from spacecraft, offers an opportunity for remote sensor applications in a wide range of resource survey problems. This part of the program would involve the acquisition and use of such photography and imagery from aircraft over selected areas of limited extent, mainly in Luzon, where a wide range of agricultural, hydrological, environmental, and geological programs are under way. The aircraft imagery, supplemented by satellite imagery, would be applied to help the various resources agencies study the resources and environmental problems with which they are concerned, obtain a better understanding of the potential uses of sensors within their own programs, and develop a capability for applying sensors elsewhere in the Philippiness.

Objectives of this part of the program would be to:

1) Introduce the use of a number of aircraft sensing techniques (specifically thermal infrared scanning; color and multispectral photography; and photomapping) and demonstrate their applicability to specific resource surveys and problems;

2) Help Philippine resource agencies develop experience and capability in applying these techniques; and

3) Help develop an indigenous aircraft survey capability for operating these sensors.

Consultations with Philippine agencies have shown that a wide range of resources programs, environmental problems, and information requirements exist in Luzon, the study of which could be helped by applications of remote sensors. For example, thermal infrared imagery could be helpful to the Commission on Volcanology in the study of geothermal resources and volcanological problems, to the Bureau of Mines and Bureau of Public Works in water resources investigations, to the Commission on Air and Water Pollution in thermal pollution, and to the Bureau of Fisheries in studies of marine ecology. Color, color infrared, multispectral photography could be helpful to programs of the Bureau of Plant Industry, Bureau of Soils, Bureau of Forestry, and Bureau of Mines. Photo mapping techniques from both aircraft and spacecraft could be especially helpful to the Bureau of Coast and Geodetic Survey and various mapping programs coordinated through the Board of Technical Surveys and Maps.

Under this part of the program,consultants for the various sensing techniques would help the Philippine agencies: define specific projects using (1) thermal infrared scanning, (2) multispectral, color, or color-infrared photography, or (3) photomapping; arrange for acquisition of imagery; and interpret the results. Initial projects using the thermal scanner might involve studies of geothermal energy, water resources, and thermal pollution in specified areas. Initial projects using

multispectral and color photography might involve crop and soil conditions, forest distribution, and offshore sedimentation. Photomaps would be prepared for selected areas of importance for cultural and land-use studies, from both aerial photography and satellite imagery.

Concurrently, the consultants would help develop a local capability, perhaps in cooperation with the Philippine Air Force, for aircraft surveys using these sensors, including procurement and operation of essential sensing and interpretation equipment. The intent would be to establish a capability for making surveys of limited areas and transitory phenomena using the simplest and least expensive techniques available - not to duplicate the capacity for systematic regional or national aircraft surveys that already exists among aerial survey contractors. Aircraft flights to acquire imagery for demonstration projects would be contracted until the indigenous capability for such acquisition was established.

Dollar costs for this part of the project are expected to be approximately as follows:

Contract services	$ 300,000
Consultant services	700,000
Equipment and supplies	250,000
Training	50,000
	$1,300,000

Consultants would be required, mostly on short-term tours of duty, at the rate of 3 to 4 man years each year for the 5 years of the program. At least 4 or 5 Philippine scientists

would be given an opportunity to study remote sensor applications and methods in the U.S. The amount required for contractual flying might be reduced if the indigenous capability for aircraft surveys can be developed rapidly.

Philippine support would be required in the form of at least one or two professional employees from each agency involved in the program, plus supporting field and laboratory personnel and operating expenses needed to carry out the projects. An aircraft would be required for the installation and operation of remote sensor instruments, together with operational and maintenance crews and expenses.

This sensor demonstration project would be significantly enhanced and augmented if the U.S. Geological Survey research project (on the identification of mineral deposits in heavily vegetated areas) now under consideration by AID could be targeted partially in the Philippines. The research project has been discussed with Philippine officials who have expressed interest in participating.