Report C-56

EAST PAKISTAN

PROPOSED INVESTIGATION:

EARTH RESOURCE TECHNOLOGY SATELLITE (ERTS-A) SENSOR DATA FOR AGRICULTURE AND WATER RESOURCE DEVELOPMENT

Draft Proposal Prepared by

Mr. Earl S. Merritt, Consultant to the World Bank

for submission to

Office of International Affairs, Code I

NASA Headquarters

FOB 6

Washington, D. C. 20546

April 29, 1971

Public Disclosure Authorized

TECHNICAL

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SUMMARY PROPOSAL FORM

PRINCIPAL INVESTIGATOR (PI) Government of Pakistan/Government of East Pakistan/East Pakistan Water and Power Development Authority

ORGANIZATION/ADDRESS Dacca, East Pakistan

PHONE NUMBER

INVESTIGATION DISCIPLINE(S) (LIST ALL IN ORDER OF IMPORTANCE)
(e.g., AGRICULTURE, FORESTRY, GEOGRAPHY/DEMOGRAPHY/CARTOGRAPHY, GEOLOGY, METEOROLOGY, HYDROLOGY, OCEANOGRAPY, ENVIRONMENTAL QUALITY/ECOLOGY, INTERPRETATION TECHNIQUES DEVELOPMENT SENSOR TECHNOLOGY)

Agriculture

Hydrology

Interpretation Technique Development

PURPOSE OF INVESTIGATION (BRIEF DESCRIPTION) Evaluate the complementary applications of ERTS-A Data to East Pakistan Action Program.

GEOGRAPHICAL LOCATION East Pakistan

SPACECRAFT (ERTS/SKYLAB/BOTH) ERTS

FUNDS REQUIRED (YES/NO) NO

NASA FUNDS REQUIRED $

OTHER FUNDS REQUIRED $162,684 SOURCE(S) Government of Pakistan

AIRCRAFT DATA FLIGHTS REQUIRED (YES/NO) YES

SOURCE(S) (NASA, DOD, CONTRACTOR) East Pakistan Air Photo Project

GROUND TRUTH REQUIRED (YES/NO) YES

TEST SITE LOCATION East Pakistan

NEW INSTRUMENTATION REQUIRED (YES/NO) YES

NEW INSTRUMENTATION TO BE PROVIDED BY Government of Pakistan

IS REPETITIVE SATELLITE COVERAGE REQUIRED (YES/NO) YES

IS AUTOMATIC DATA PROCESSING EQUIPMENT (ADPE) REQUIED (YES/NO) YES

OTHER CAPITAL EQUIPMENT REQUIRED (YES/NO) YES

DURATION OF INVESTIGATION (MONTHS) 18 Months

FORMAT OF DATA Bulk Film (Black and White and Composites) Precision Film (Black and White) and Composites and MSS Computer Readable Tapes

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1. INTRODUCTION AND BACKGROUND

The Governments of Pakistan and of East Pakistan, assisted by the IBRD, are at present engaged in a major program in East Pakistan focused on the development of land and water resources. The objectives of this so-called "Action Program" are essentially as follows:

a. to intensify efforts to get projects going that would bring results in the short term;

b. to develop flood protection works that are hydrologically safe and assist in controlling annual floods;

c. to fill specific gaps in basic data required for the evaluation and execution of projects; and,

d. to develop a systematic and comprehensive approach to the identification of constraints and potentials and to establish investment criteria for the selection of projects.

The Action Program for East Pakistan presents a solid basis for the proposed ERTS-A 1/ investigation for the following social and economic reasons:

a. East Pakistan is located primarily on a deltaic floodplain of 33 million acres (approximately the size of Florida), with an estimated population of 75 million people. Located in the delta of the Ganges and Brahmaputra, it has, perhaps, the most complex water control problems in the world. Flooding and drainage are severe problems affecting between 40 and 70 percent of the Province during the monsoon season (May through September). Conversely much of the Province suffers from drought during the dry season (October through April).

b. Soils are fertile and two or three crops of rice can be grown annually with adequate water control and irrigation.

c. During the past decade, agricultural production has increased by only about two percent per year while the population has increased at three percent although new rice types (e.g. IRRI 20) are now increasing production significantly in local areas.

1/ The A refers to the first and experimental model of the satellite which is scheduled to be followed by ERTS operational satellites in future years.

d. Approximately 22.5 million acres of the total area of the Province are cultivated and there are only very limited possibilities for expanding the cultivated area.

e. Agricultural practices are complicated by population pressures as well as hydrological conditions. Average farm sizes are estimated at 2.4 acres.

f. Per capita income in East Pakistan is estimated at about $60 among the lowest in the world.

Data essential to the review and survey of the various projects in the East Pakistan Action Program have, in the past, been inaccurate or not available. New data gathering programs are being established as a part of the Action Program. The proposed investigation will evaluate the utilization of ERTS data to complement existing programs in the East Pakistan Action Program and perhaps to provide hitherto unavailable types of sequential survey data.

This request was prepared by Mr. E. Merritt, Consultant to the World Bank. The "Principal Investigator" of the proposed ERTS-A program in East Pakistan would be the East Pakistan Water and Power Development Authority, acting on behalf of the Governments of Pakistan and East Pakistan. The proposed program is subject to final approval by the Government of Pakistan.

II. OBJECTIVES

The overall objective of the proposed investigation is: "assessment of the complementary value of ERTS-derived information to that obtained for the complex resource management and development program as described in the East Pakistan Action Program."

In the context of this overall objective, the goals of the proposed investigation are intimately linked to the Action Program. Priority items in the Action Program include:

(a) Basic Data Studies: to gather, interpret and evaluate basic resource data on hydrology, soils, agriculture, topography, etc. The proposed investigation of ERTS data will have an objective to use ERTS data to complement the "Basic Data Studies" of the Action Program.

(b) Flood Control and Water Studies: to begin the major analytic work on flood and drainage problems as it pertains to the different regions of the Province and to lay the framework for longer range water control and agricultural developments. The proposed investigations of ERTS data will parallel these studies through emphasis on the mapping and evaluation of surface water, flooding (inundated area and depth estimation) and estuarine dynamics (including related sedimentation and erosional factors).

(c) Agricultural Studies: to evaluate the agricultural potential of the regions of the Province and to broadly relate agricultural development objectives to longer range planning of water development. The proposed ERTS study objectives include development of techniques for land use studies and, as feasible, estimating yield, estimating salinity of soils, defining irrigation seepage and examining the influence of water management practices on the distribution of observable water.

(d) Comprehensive Program Evaluation: to review, analyze and synthesize the different elements of the studies in (a), (b) and (c) into a comprehensive framework for long range development of the Province's agricultural and water resources management.

The proposed ERTS data evaluations emphasize the development of complementary information which can assist the evaluation studies.

In summary, the Short Term, i.e. one to two years, objective of the proposed program is:

(a) application of ERTS data to complement the inventory, analysis and management planning aspects of the East Pakistan Action Program with primary emphasis on:

i. Cartographic updating;
ii. Land use mapping
iii. hydrology

The Long Term, i.e. two to five years, program objectives are:

(a) confirmation of ERTS-type remotely sensed data which may prove useful as a continuing complement to data collection activities for the East Pakistan Action Program;

(b) establishment of an East Pakistan interpretation center which may permit maximum benefits to be derived from the ERTS and other types of remotely sensed data.

III. TECHNICAL APPROACH

The proposed investigation is multidisciplinary, with the complex requirements for ground truth, aircraft observations, system modeling, etc. largely met by the programs already planned under the GOEP Action Program. The following section will discuss the approaches necessary for supplementing the ground truth measurements, processing the ERTS imagery and correlated data analysis and display.

3.1 Data Collection

3.1.1 Data Collection - Ground

The GOEP Action Program has, as a priority effort, the gathering interpreting and evaluation of basic natural resources data on topography, surface water, ground water hydrology, soils, agriculture, etc. These data should be partially available by the time ERTS-A is launched in the spring of 1972.1/ Supplementary measurements will be necessary to efficiently implement the proposed ERTS investigation. These supplementary measurements include the following:

(a) spectral reflectances from .400 to 1.350 micrometers over various surfaces, e.g. paddy rice, floating rice, soils and soil moisture contents, tree canopy on the test sites to be selected in the field;

(b) wind speed, temperature, sky cover, relative humidity, etc. at the test site (if not normally collected); and

(c) survey of area and land uses in the test site, emphasizing the area of farms included in the site. Crop calendars will be developed.

These data (except (c)) should be collected within one hour of the overpass of the ERTS. Training programs will be planned for EPWAPDA or other East Pakistan government agency personnel during a period approximately four months prior to the launch of ERTS.

The proposed ground truth site areas are presented on Figure 1. The primary ground truth area is centered in the circle near the confluence of the Ganges and Brahmaputra. Secondary sites will be selected within the irregular outlined area and along selected parts of the south coast.

1/ Data collection activities depend on the scheduled execution of projects which may have to be revised in view of current political situations.

3.1.2 Data Collection - Aircraft

The EPWAPDA aerial photography project is scheduled for initiation in the near future. The General Consultants to EPWAPDA, (Acres International Ltd. of Canada) jointly financed by the UNDP and the World Bank, consider that the aircraft photographs are essential to the effective progress of the various projects proposed in the Action Program.

The overall program envisions utilizing a special aircraft and cameras and establishing photographic processing facilities and a photographic interpretation training center in East Pakistan. The current photographic survey plan envisions uniform, 1:30,000 scale, photography for one season. This "Basic Year" photography would serve as a datum from which to evaluate change.

A part of the planned aerial photography program envisions a multi-spectral 1/ survey mission over the confluence area of the Ganges and Brahmaputra (see Figure 1). It has been proposed that this area be designated a primary ERTS ground truth site (area in circle on Figure 1). Aircraft missions may be run concurrently with the ERTS pass and subsequent correlations between the aircraft data and ERTS data could be established thereby calibrating the ERTS imagery.

Coordination of the proposed ERTS program and the EPWAPDA aircraft program should be readily achievable through the office of the Chairman EPWAPDA assisted by the General Consultants.

3.1.3 Data Collection - ERTS

The proposed project analysis and training activities will be initially centered in facilities of EPWAPDA with the technical assistance of its General Consultants. ERTS data taken over East Pakistan should normally be acquired by Fairbanks, Alaska. Present plans call for mail delivery of the ERTS sensory data tapes to the NASA Data Processing Facility (NDPF) at Goddard Space Flight Center (GSFC) for forwarding to East Pakistan. The bulk display of the imagery will begin immediately upon arrival. First copies of the bulk data should be available for viewing approximately three to five days after they are acquired by the satellite. The ground truth observations should also be available at the GOEP analysis facility in about the same period of time.

1/ It is planned to select the spectral band passes to coincide with those carried on ERTS. The area circled is that included in the GOEP project proposal.

Because of the cloud cover limitation in summer, it is proposed that sensory data be acquired on all passes over East Pakistan. Cloud cover will significantly reduce the possibilities for seeing the surface from May through September, e.g. the estimation probability of less than 50 percent cloud cover over a 30 mile diameter circle in June to August is approximately 10 percent. It might be noted, however, that the mornings, particularly at 9:30 a.m. when the ERTS data is scheduled to be collected, are the most cloud free times of the day.1/

The following types of ERTS data will be requested from NASA (quantities, area coverages, special requirements, etc. are stated in a future section):

(a) bulk 9-1/2 inch color composites from Multispectral Scanner (MSS) and Return Beam Vidicon (RBV) and black and white 70 mm. positives of each band. (Color balance approaching Kodak false color infrared to provide maximum separation between vegetation, soils and water.);

(b) selected precision processed RBV color composites for selected test areas, e.g. over the confluence area of Ganges and Brahmaputra;

(c) computer readable Bulk MSS Imagery Tapes for four channels. (Frame sizes will be selected on the basis of cloud cover emphasizing areas with 50 percent or less cloud cover.)

3.2 Data Analysis Program

The data analysis program will be accomplished in four phases:

(a) Phase A - Initial Preparation;
(b) Phase B - Launch to Four Months After (Experimental - Quick Look)
(c) Four Months to Eight Months After Launch (Operational Experiment)
(d) Eight Months to One year After Launch (Operational Application of Some Types of ERTS Data).

3.2.1 Phase B

In the initial analysis phase, the proposed primary test site areas will receive maximum emphasis. Some difficulty is anticipated in data acquisition if the ERTS launch is delayed until June or July when the heavy cloudiness of the monsoon season is present. Assuming that the scheduled March 31, 1972 launch data can be achieved, two months of satisfactory coverage can be anticipated, i.e. three or four passes over the

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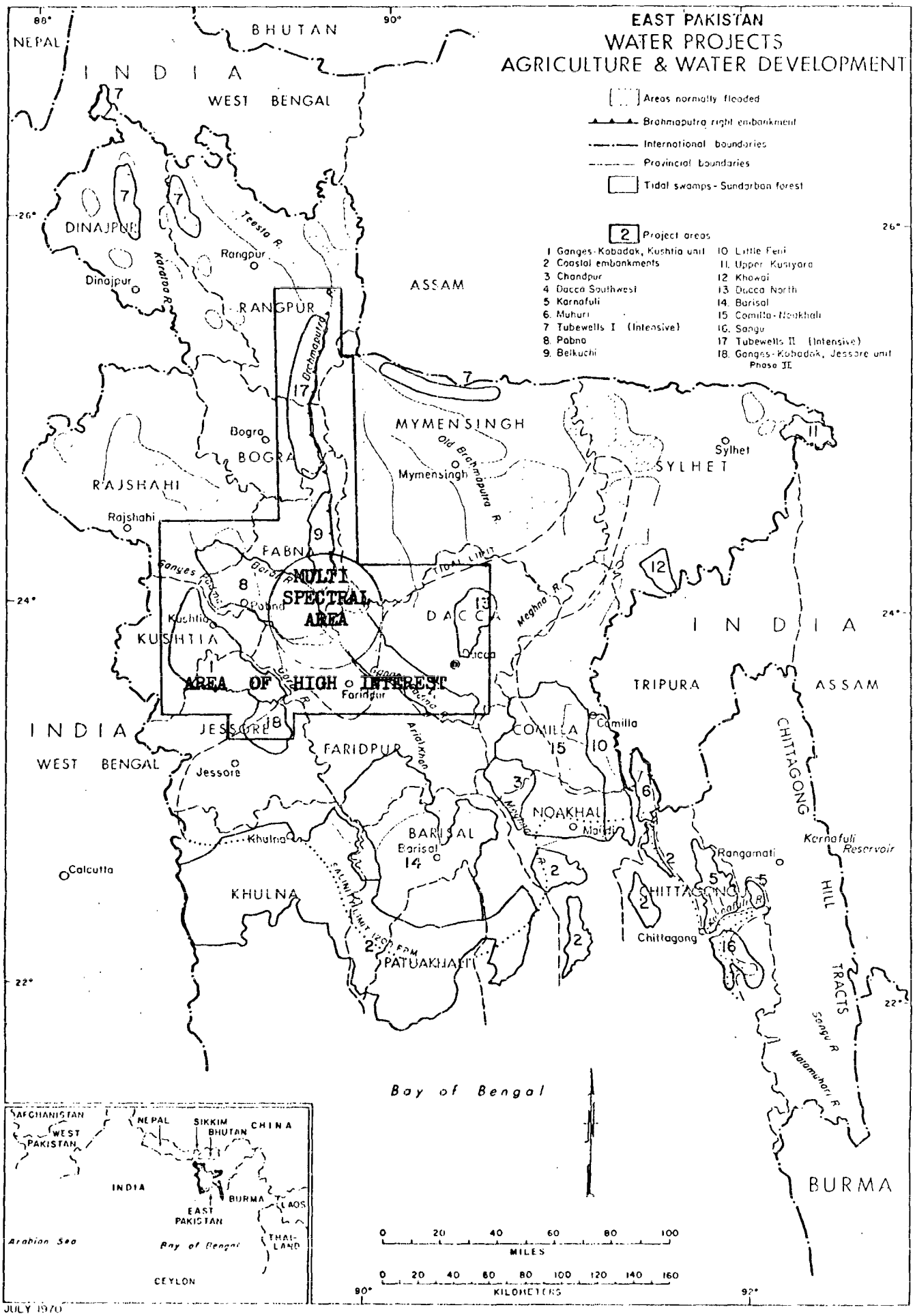
1/ The Air Photo Project plans Side Looking Radar or below cloud flights with super wide cameras to offset the cloud problem.


EAST PAKISTAN
WATER PROJECTS
AGRICULTURE & WATER DEVELOPMENT
Areas normally flooded
Brahmaputra right embankment
International boundaries
Provincial boundaries
Tidal swamps - Sundarban forest
2 Project areas
1 Ganges-Kobadak, Kushtia unit
2 Coastal embankments
3 Chandpur
4 Dacca Southwest
5 Karnafuli
6. Muhuri
7 Tubewells I (Intensive)
8 Pabna
9. Belkuchi
10 Little Feni
11. Upper Kustyara
12 Khowai
13 Dacca North
14. Barisal
15 Comilla-Noakhali
16. Sangu
17 Tubewells II (Intensive)
18. Ganges-Kobadak, Jessore unit Phase II
NEPAL
BHUTAN
INDIA
WEST BENGAL
ASSAM
DINAJPUR
Dinajpur
Rangpur
RANGPUR
Teesta R.
Karatoa R.
Brahmaputra
Bogra
BOGRA
RAJSHAHI
Rajshahi
MYMENSINGH
Mymensingh
Old Brahmaputra R.
SYLHET
Sylhet
PABNA
Pabna
Ganges R.
Baral R.
MULTI SPECTRAL AREA
TIDAL LIMIT
DACCA
Dacca
Meghna R.
KUSHTIA
Kushtia
AREA OF HIGH INTEREST
Faridpur
TRIPURA
JESSORE
Jessore
FARIDPUR
Arial Khan
COMILLA
Comilla
CHITTAGONG
NOAKHALI
Noakhali
Meghna
BARISAL
Barisal
Khulna
KHULNA
Calcutta
SALINITY LIMIT 1200 PPM
PATUAKHALI
Rangamati
Karnafuli Reservoir
CHITTAGONG
Chittagong
HILL TRACTS
Sangu R.
Matamuhari R.
Bay of Bengal
BURMA
0 20 40 60 80 100
MILES
0 20 40 60 80 100 120 140 160
KILOMETERS
AFGHANISTAN
WEST PAKISTAN
NEPAL
SIKKIM
BHUTAN
CHINA
INDIA
BURMA
LAOS
EAST PAKISTAN
THAILAND
Arabian Sea
Bay of Bengal
CEYLON

JULY 1970

imary test area, resulting in three or four image data sets. (Our request r data will be collected and carefully reviewed in Phase B but the primary alyses will be conducted on the images containing the ground truth sites.) e proposed analysis steps are:

(a) manual transfer of identified patterns and tones in the ERTS image to a large scale map of the test area;

(b) preparation of densitometric sections on each of the ERTS and aircraft spectral separations over the ground sites which are acquiring spectro-radiometer data;

(c) perform comparisons between the crop types or land uses derived from ground truth and the initial spectral reflectance distributions to delineate some initial spectral signatures. (On the basis of the difference between the ground/aircraft spectra and the ERTS spectra, estimates can be calculated to define the influence of the atmosphere on the measurements.)

(d) perform comparisons among existing surface water/drainage maps, aircraft image interpretations of the surface water/drainage distributions and ERTS imagery interpretations. The number of sample areas in the Ganges/Brahmaputra test area should yield results that can be subject to statistical significance tests even though the total ERTS sample size will be small;

(e) on the basis of the initial investigations of spectral signatures and the geometric accuracy of imagery, a preliminary land use map will be manually prepared for the Ganges/Brahmaputra site and distributed to GOEP agencies for review and evaluation;

(f) at the same time as the manually prepared land use map is in preparation, action will be initiated to apply the Laboratory for Agricultural Sensing (LARS), Purdue University, programs to produce an equivalent but machine produced land use map. This map will also be made available for the GOEP to review and evaluate; and

(g) special investigations will be directed toward "targets of opportunity" that may appear during the early ERTS period. For example, if significant flooding occurs, analysis would be initiated to map the extent and depth (if possible, one foot and four foot depths). Also the influence of the low-lift pump and tubewell irrigation can be examined in selected areas. These types of investigation will necessarily be poorly defined prior to the actual arrival of ERTS data.

3.2.1.1 Transfer of Tonal and Spatial Patterns

Past studies have shown that multispectral imagery can readily be used to identify crop species providing that interpretation "keys" are available. In the proposed tonal and pattern transfer activity, the emphasis will be directed to:

(a) using the "keys" developed by other investigators to differentiate among water, vegetated surfaces and bare soils;

(b) defining a coding scheme to permit transfer and depiction of the tonal signature/crop or land surface identity on moderately large scale, e.g. 1:125,000, maps of the test area.

For example, healthy wheat will present a dark tone (high density) on the Band 2 (red) of the ERTS RBV or MSS and a light tone on the Band 3 (photographic infrared) of either the MSS or RBV. This difference may be enhanced in the ERTS imagery since the atmosphere will normally transmit infrared reflected radiation more readily than green or red. Healthy rice fields should have a similar tonal signature.

The probable reason for the healthy green vegetation reflectance tone signature lies in; (a) the presence of chlorophyll which absorbs red light and (b) the presence of a healthy spongy mesophyll which is highly reflective in the photographic infrared.

Water (non-turbid) will be identified by low reflectances in all bands but particularly for very low infrared reflectance (Band 3 RBV or MSS). Bare soils, while possessing a variety of signature, normally present a signature with moderately high reflectance in the red (Band 2 RBV or MSS) and low reflectance in the photographic infrared (Band 3 RBV or MSS).

In the initial analysis, the tonal signatures will be evaluated by densitometric measurements to establish tonal categories for vegetated land, bare soil and water. Later iterations will emphasize analysis of those signature characteristics that may permit discrimination among the various types of the vegetated surfaces that may be present.

The coding scheme to be derived will probably use letters or symbols to identify the surfaces. If standard map nomenclature is in use in East Pakistan, this approach will be examined and used if practical.

3.2.1.2 Preparation of Densitometric Sections

Densitometer readings will be taken over test site areas which are contained in both the aircraft images and the ERTS images. These readings will be initially plotted on an arbitrary scale to provide relative spectral differences over various crop types, land surface types and water.

Calibrated and quantitative measurements from the RBV and MSS could be derived from the digatal tapes and used, but the aircraft images are not well calibrated so efforts beyond the use of relative values do not seem justifiable.

3.2.1.3 Comparisons and Atmospheric Consideration

The density measurements will be compared, in a relative sense, with the ground measurements obtained with the proposed ISCO Spectroradiometer. Statistical correlations of relative differences between pairs of each of the three sets of readings will provide an estimate of signature calibration for the ERTS sensors. The effect of the atmosphere on the differences between the aircraft or ground measurements and ERTS can be examined through model atmospheric calculations.

The atmospheric calculations can only be approximated using several different types of Rayleigh and combinations of Rayleigh and turbid atmospheres. Some of these model calculations have been accomplished using estimated RBV and MSS filter characteristics. These calculations indicate a 50 percent reduction in radiance sensed at the satellite for a turbid atmosphere as compared to a Rayleigh (non-turbid) atmosphere for a surface reflecting at 100 percent (no absorption).

The atmosphere over East Pakistan is assumed to be a highly turbid atmosphere throughout much of the year; hence, all measurements at the satellite will be significantly attenuated. Spectral signatures which demonstrate high infrared reflectance, however, may be enhanced for certain kinds of surfaces, e.g. rice, trees, etc., with Rayleigh atmosphere because the atmosphere transmits the IR more readily than green or red. Seasonal changes in the atmosphere will also modify the satellite-sensed tonal signatures, thus, seasonal signature evaluation is important to future operational applications.

3.2.1.4 Water Surface/Drainage Comparison

The tonal signature for water is generally unique, i.e. little or no change in tone with wavelength; hence, the mapping of surface water and related drainage will be straightforward. In the proposed task, the area of water in a given image area will be calculated using normal planimetry approaches, i.e. either using dot counts or a polar planimeter.

The comparison of drainage "patterns" is more complex. One possible approach might be through comparison of maps of the drainage derived from the aircraft and from ERTS, noting the area of difference between the two through overlays.

3.2.1.5 Manual Land Use Map

The tasks described in the previous sections are all prerequisites to the preparation of a land use map. A 1:125,000 scale land use map is planned. Other scales could be used to assure compatibility with the standard map systems of East Pakistan. A 1:125,000 scale map of the Ganges/Brahmaputra test site area is approximately two and one-half feet square.

The approach to mapping will, therefore, be:

(a) a review of the spectral signatures developed for each test area in the region;

(b) identify all of the areas in the region that have an ERTS tonal signature similar to those developed over the test areas (a densitometer will be used to measure the "unknown" area);

(c) use a coding scheme (the symbols or letters could be expressed as color values) to illustrate the ERTS-derived crop type, land surface and water distributions over the area.

3.2.1.6 Automated Land Use Map

Purdue University's Laboratory for Agricultural Remote Sensing (LARS) has developed a computerized system for mapping land use from remotely sensed data. The LARS system uses "signatures" derived from multispectral remote sensing. The LARS concept is simple although implementation is complex.

A brief explanation of the LARS system may be useful. In the case example, three bands of imagery in three narrow spectral intervals from green through infrared have been acquired. At the same time as these imagery were acquired, field measurements were taken over various crops or surfaces in some area. The known "ground truth" signatures are used in the system to teach the recognition scheme to separate different classes of surface features. The discrimination computation depends on assigning a probability density, in vector space, for each class of surface to be discriminated. The assignment procedure requires an assumption of the shape of the statistical surface representing the signature; LARS has used a Gaussian assumption. Following this, the surface feature class is assigned a sample vector. A thresholded maximum likelihood ratio strategy is then used to separate signature classes.

The use of this approach for land use mapping in East Pakistan will be facilitated by the proposed ground truth program to measure sample spectral data. The small number of different object surface classes over a given area should also ease the computations.

NASA has modified the LARS program to operate efficiently on the UNIVAC 1108 computer at Houston. If the modified LARS program were available at the NDPF at GSFC, some test work might be performed on sample areas. In any event, a 360/44 system appears at present to be the smallest practical operating system on which to operate with the LARS program. The 360/30 at EPWAPDA will probably not be suitable for the LARS program although some consideration will be given to the problem of modifying the LARS operating system to operate on smaller systems.

3.2.2 Phases C and D

In the Phase B analyses, primary emphasis is directed to a few (one or two) selected test site areas. In the Phase C and D analyses, the analysis area will be expanded to include the parts of the entire Province of East Pakistan with special emphasis on developing data which are complementary to the data program and requirements of the various projects in the GOEP Action Program. Test sites will be established on a data priority basis, e.g. if additional data are necessary to confirm a particular spectral signature, the ground truth measurements will be taken at the location or locations which best illustrate the particular crop, land surface, etc. Project priority could also be a reason for establishing and/or moving a ground truth site, e.g. flood damage surveys may often take top priority and ground truth sites may need to be established. Specific investigations and/or applications to be conducted during Phases C and D would include:

(a) development of improved interpretation "keys" and/or spectral signatures through analyses of a statistically significant sample. The techniques of analysis to be employed would parallel those of Phase B outlined in Section 3.2.1.2, e.g. densitometry over sections of the ERTS and, if possible, concurrent aircraft imagery. The scanned spectral reflectances will then be correlated with the spectroradiometric data and atmospheric influences on the spectra will be computed;

(b) preparation of land use/thematic maps using both manual and automated techniques for other project areas and other periods over the same areas in the GOEP Action Program. Sections 3.2.1.5 and 3.2.1.6 define the mapping procedures;

(c) preparation of pseudo-orthophoto maps and photomosaics which should permit the updating of existing maps of cultural and physical features. Modified orthophoto mapping technology will be applied as appropriate and on the basis that money may be available within the GOEP Action Program. No funding estimates are provided for this work in the proposed investigation;

(d) preparation of maps to show changes in physical features defining major erosional and depositional processes. These maps will generally be prepared manually for large areas. Tests will be conducted to examine the use of automated change detection approaches over small geographic areas;

(e) studies will be conducted using the maps and automated imagery prepared in (b), (c) and (d) to establish the potential for ERTS mapping of flood area and depth (Section 3.2.1.4 outlines techniques for flood water mapping), flood water sources (in those cases where the causes are not well understood), to identify population patterns, to distinguish irrigation from low-lift pumps and tubewells from other irrigation systems, to map broad forest types and distributions, etc.;

(f) ERTS data formats and displays will be examined in the light of the data requirements of the various simulation models being developed by regional consultants (i.e. the Southwest and the Northeast Regional Studies) and those under the Harvard University Program. For example, the Flood Simulation Model may be complemented by ERTS-derived information on the existing state of a given river channel and thereby permit more realistic prediction of future effects of empoldering or double embanking. Similarly, the Ground Water/Surface Water Interaction Model may find ERTS-derived information on tubewell irrigation patterns and concurrent river levels useful in their implementation phases.

The possible capability of the satellite to provide sequential data over relatively large areas should prove invaluable to the practical implementation of agricultural management models.

In summary, the Phases C and D analyses will be directed toward application of ERTS data to complement the GOEP Action Program data gathering programs. Straightforward remote sensor applications, such as surface water mapping, will probably provide a useful data complement early in the investigation. On the other hand, the techniques for identification of rice types may not be as readily implemented and would only be available at later stages of project analysis.

IV. ANTICIPATED RESULTS

The proposed investigation of ERTS data of East Pakistan is anticipated to yield the following specific results. If satisfactorily achieved, these results could provide a significant complement to data being collected for the East Pakistan Action Program. Anticipated results of the project discussed in the previous sections may be summarized as they pertain to the following sectors:

4.1 Cartographic Sector

(a) Cultural feature mapping and updating;
(b) physical feature mapping and updating;
(c) extension of geographic grid coordinant base utilizing the Universal Traverse Mercator (UTM) system, already employed for photo interpretation in the southern coastal regions, to the remainder of the Province; and
(d) the data presented above may well assist in eventual declassification and removal of security restrictions presently affecting development operations.

4.2 Hydrologic Sector

(a) Snow melt (Himalayas) influence evaluation;
(b) sequential flood monitoring;
(c) recording the extent and depth of flooding (one foot and four foot depth estimates desired);
(d) identifying flood water sources (fluvial, rainfall);
(e) mapping distributions or anomalies of high soil moisture content;
(f) mapping of erosion and deposition; and
(f) estimating the location of the interface between salt and fresh water, i.e. defining the 1,200 ppm line.

4.3 Agricultural Sector

(a) Mapping existing land use patterns;
(b) mapping the seasonal variations in crop distributions;
(c) differentiating rice lands from other crops in the monsoon period;
(d) delineating the areas of different types of rice, e.g. Aman transplant from Aman broadcast and IRRI 20 varieties;
(e) differentiating rice areas from other crops in the dry season;
(f) delineating significant crop stress areas and estimating potential yield; and
(g) delineating of major forest types of various parts of the Province.

4.4 Miscellaneous

(a) Defining population patterns and correlating them to densities;
(b) delineating areas influenced by storm surges and cyclonic storms;
(c) redefinition of road and river embankment sites as they relate to observable erosion and deposition;
(d) identification of possible sources of construction materials by geologic structure (rocks, sand); and
(e) distinguishing low-lift pump and tubewells irrigation areas from other irrigation systems in the dry season.

V. DATA HANDLING PLANS

The ERTS imagery collected over East Pakistan will be received by EPWAPDA and its General Consultants from the NASA Data Processing Facility (NDPF) at GSFC. Once the data have been received they will be subjected to various handling or processing procedures. In general, the procedures can be divided into approximately three activities:

(a) Logging and Acceptance;
(b) Preprocessing and Preparation; and
(c) Analysis

In the proposed East Pakistan investigation, film products and computer readable tapes have been requested. The film products will require different processing and analysis techniques than the tapes.

5.1 Film Products

5.1.1 Logging and Acceptance

Film products will be viewed immediately upon receipt in the analysis area and principal points plotted on outline coverage maps of East Pakistan. The principal points for each series of photographs, i.e. for each four-day coverage period will be identified on a single map. This map will be the primary coverage file reference on firm data received. Listings, provided by NASA, of the frame times, location, etc. will be cross referenced to the coverage maps.

Data quality and cloud cover will be evaluated and logged. Cloud cover will be assessed as percentage cover over the entire scene and in each quarter of the scene.

5.1.2 Preprocessing and Preparation

In the proposed investigation, the film products provided by the NDPF should be satisfactory for analysis and little preprocessing will be required. However, in order to assure consistency in the anslyses, measurements of the density over various tonal areas and on the stepwedge 1/ will be accomplished using a densitometer. These density measurements will be recorded as a function of time. In this way significant difficulties due to photographic processing or sensor response may be minimized. Variations in the quality of the film products can thus be monitored and reruns requested if the standards are not met.

1/ Stepwedge - a gray scale placed on the film during processing in NDPF.

5.1.3 Analysis

The analysis of the film products can be achieved in any number of ways. The simplest involve manual transfer of data from the image to a larger scale map. This transfer is easily accomplished through a common grid mesh. Other approaches include projection concepts whereby the image can be projected onto a transfer map. Digital scan techniques are also possible but expensive. Utilizing a combination of manual transfer and projection to prepare land use/thematic maps is planned. Digital techniques will be reserved for the processing of the computer readable tapes.

Some experimental color composites may be evaluated if equipment is available at NASA. Current evaluations suggest that the Infrared Ektachrome color balance should be satisfactory.

5.2 Computer Readable Tapes

Computer readable tapes would be ordered on the basis of frame areas with 50 percent or less cloud cover. Ideally, this order would be submitted after the film products have been received and evaluated. Otherwise, the NDPF will have to make the selection.

5.2.1 Logging and Acceptance

The tape receipt procedure would require only that the related date, orbit, frame number and frame size, i.e. whole, quarter, be logged and filed. Acceptance testing will need to wait until the analysis phase.

5.2.2 Preprocessing and Preparation

It is assumed that the tapes received from the NDPF will be reasonably "clean", i.e. the identifiable Gaussian noise will have been removed. If this is not true and significant noise is present, then the tapes may need processing through a filtering routine prior to operation with the LARS program.

5.2.3 Analysis

The digital analysis proposed has been largely limited to automated land use/thematic mapping through the use of LARS-type programs. Some use may be made of digital printer displays of small sections of individual frames to provide a full resolution view in order to evaluate the utility of these type displays in an operational interpretation scheme.

5.3 Photo Reproduction

It is anticipated that the NDPF photographic products will be satisfactory for the proposed investigation. Duplication may be required but this should not influence the studies.

5.4 Data Products

The anticipated products to be derived from the investigation have been listed in Section 3. The primary items of interest will be summarized here for proposal uniformity and clarity.

5.4.1 Phase B - End of Four Months

(a) Spectral distribution of light reflecting from various types of East Pakistan rice, bare soils, water, etc. from ground measurements aircraft imagery and ERTS imagery. Atmospheric attenuation factors will be calculated for each experiment day;

(b) initial evaluation of ERTS potential will be made for surface water and drainage pattern determination. Maps will be presented if possible for selected areas showing surface water as derived from aircraft and from ERTS;

(c) two land use maps for the Ganges/Brahmaputra test area will be prepared by manual methods and by the LARS-type automated system;

(d) annotated images and maps showing coverage and cloud cover will also be prepared.

5.4.2 Phase C and D - From Four Months to End of Program

(a) Detailed seasonal spectral signature specifications for various crops, soils and water surfaces together with atmospheric attenuation corrections will be applied to ERTS signatures;

(b) land use/thematic maps will be made for selected areas of East Pakistan;

(c) land use/thematic change maps will be made for selected areas of East Pakistan to illustrate seasonal patterns;

(d) erosional/depositional maps of selected major river and coastal area changes, such as the increase of char areas, will be depicted;

(e) studies and maps should illustrate the extent and depth of flooding over specific Action Program project areas;

(f) studies and maps distinguishing low-lift pump and tubewells irrigation from other areas of irrigation in East Pakistan will be attempted;

(g) studies and maps showing the location of potential construction materials will be undertaken in this phase;

(h) annotated images and maps showing detailed cloud cover as defined from the ERTS cloud evaluation will be analyzed.

VI. DATA REQUIREMENTS

The proposed investigation of ERTS sensory data application in the Action Program for East Pakistan will utilize sensory data from the RBV and MSS sensors over various areas of East Pakistan. Basically, the entire Province may be considered as the test area. Study emphasis will be on practical applications of ERTS data to proposed development projects. Figure 1 presents the area of prime remote sensor focus within a larger area of high interest within East Pakistan.

6.1 Test Area Cloud Characteristics

East Pakistan is largely cloud covered in the months of May through September. The estimated unconditional probability of equal to or less than 50 percent cloud coverage over a 30-mile diameter area at 0930 Local Time is approximately 15 percent. From October through April the average rises to about 60 percent. January has the least cloudiness with a 71 percent probability. It is important to note, however, that these statistics do not allow for cloud distribution over areas smaller than 30 miles nor do they include cloud type. It is anticipated that substantial areas of ground may be visible through the clear spaces between the predominant cumulus clouds. Therefore, and whereas the proposed investigation has considerable importance to the GOEP Action Program, it is requested that sensory data be taken on each available pass over East Pakistan. The area completely covered by clouds will be screened on the basis of initial bulk film review. Color composites and computer readable tapes would be ordered after review of the initial bulk data. A listing of the types of data and estimated amounts is presented in the following section.

6.2 ERTS Product Requirements

6.2.1 Bulk Film Products

(a) Nine and one-half inch black and white positive and negative transparencies from RBV and MSS. The estimated amounts required during the three to four day period of East Pakistan coverage are 84 positives and 84 negatives.

(b) Nine and one-half inch color composites, positive and negative transparencies prepared with Infrared Ektachrome color balance from the RBV will also be used. The MSS should be composited to provide information from Bands 2, 3 and 4. The estimated combined amounts of the negative and positive RBV and MSS color composites (assuming 50 percent cloud cover or less for any four day period) are:

January	- 48*	July	- 8
February	- 48	August	- 8
March	- 40	September	- 8
April	- 32	October	- 8
May	- 12	November	- 12
June	- 8	December	- 40

* Number in one four-day coverage period.

6.2.2 Bulk Computer Readable Tapes

Only the MSS data in computer readable tape format will be used. The estimated number of tapes, all four channels, per three to four day coverage period is (assuming 50 percent or less cloud cover over some quadrant of the frame):

January	- 48*	July	- 8
February	- 48	August	- 8
March	- 40	September	- 8
April	- 32	October	- 8
May	- 12	November	- 12
June	- 8	December	- 40

* These numbers are the same as the color composites because there are four reels required for each frame. The color composites include two sensors and both negative and positive formats.

6.2.3 Precision Film Products

Precision color composites for a small percentage of the total scenes will be requested (an estimated five to ten percent will be used).

6.3 Summary of Requirements on Annual Basis

(a)	Nine and one-half inch Bulk Black and White (negative and positive transparencies)	2,184
(b)	Nine and one-half inch Bulk Color Composites	624
(c)	Nine track Computer Readable Tapes	624
(d)	Precision Color Composites (positive transparencies)	62

EXHIBIT 1, APPENDIX B

ERTS-A IMAGE DATA REQUIREMENT

PRINCIPAL INVESTIGATOR (PI) Government of East Pakistan: East Pakistan Water and Power Development Authority[1]

AFFILIATION

TEST SITE: East Pakistan INSTRUMENT: RBV

PERIODS (IN MONTHS) DURING WHICH DATA IS REQUIRED

from - to from - to from - to from - to from - to from - to

Launch to end of mission

REMARKS: Data to be evaluated over all seasons.

PERCENT CLOUD COVER PERMITTED 50 percent on color composites. All passes over East Pakistan should take data.

SINGLE-BAND PRODUCTS

PRODUCT	PRECISION BANDS 1X	2X	3X	4	BULK BANDS 1X	2X	3X	4
Neg. Xparency		31			260	260	260	
Pos. Xparency		31			260	260	260	
Pos. Print								
Dig. Tape								

COLOR COMPOSITE PRODUCTS

PRODUCTS	PRECISION BANDS 1X	2X	3X	4	Quan.	BULK BANDS 1X	2X	3X	4	Quan.
Pos. Xparency		31					156			
Print										

1/ The GOEP/EPWAPDA will be assisted in the project by their General Consultants (Acres International Ltd.) and the Special Projects Department, East Pakistan Division of the World Bank. (1818 H Street N.W. Washington, D.C. Tel: 477-5088)

EXHIBIT 1, APPENDIX B

PRINCIPAL INVESTIGATOR (PI) Government of East Pakistan: East Pakistan Water and Power Development Authority 1/

AFFILIATION

TEST SITE: East Pakistan INSTRUMENT: MSS

PERIODS (IN MONTHS) DURING WHICH DATA IS REQUIRED

from - to from - to from - to from - to from - to from - to

Launch to end of mission.

REMARKS:
Data to be evaluated over all seasons.

PERCENT CLOUD COVER PERMITTED 50 percent on color composites/Tapes.

All passes over East Pakistan should take data.

SINGLE-BAND PRODUCTS

PRODUCT	PRECISION BANDS 1	2	3	4	BULK BANDS 1X	2X	3X	4
Neg. Xparency					260	260	260	
Pos. Xparency					260	260	260	
Pos. Print								
Dig. Tape						624		

COLOR COMPOSITE PRODUCTS

PRODUCTS	PRECISION BANDS 1	2	3	4	Quan.	BULK BANDS 1	2X	3X	4X	Quan.
Pos. Xparency							156			
Print							156			

1/ The GOEP/EPWAPDA will be assisted in the project by their General Consultants (Acres International Ltd.) and the Special Projects Department, East Pakistan Division of the World Bank, (1818 H Street N.W. Washington, D.C. Tel: 477-5083)

MANAGEMENT

EAST PAKISTAN

PROPOSED INVESTIGATION:

EARTH RESOURCE TECHNOLOGY SATELLITE (ERTS-A) SENSOR DATA FOR AGRICULTURE AND WATER RESOURCE DEVELOPMENT

Draft Proposal Prepared by

Mr. EArl S. Merritt, Consultant to the World Bank

for submission to

Office of International Affairs, Code I

NASA Headquarters

FOB 6

Washington, D. C. 20546

April 29, 1971

TABLE OF CONTENTS

I. INTRODUCTION

The proposed investigation of ERTS-A application to the East Pakistan Action Program will be initiated in East Pakistan by the Water and Power Development Authority (EPWAPDA) with assistance of its General Consultants (Acres International Ltd.) and the World Bank (Special Projects Department, East Pakistan Division) in Washington, D. C. The logistics of ERTS data handling will be facilitated through a receiving and evaluation office in the Washington area to be operated on behalf of EPWAPDA. In this way, the data quality can be checked prior to shipment to East Pakistan and ordering of color composites and computer readable tapes accelerated. This approach should reduce the possibility of lengthy delays due to shipping errors, errors in processing, etc. An EPWAPDA Engineer working closely with the General Consultants will be assigned to exercise overall management of all aspects of this program.

II. FACILITIES

The photographic Interpretation laboratory of EPWAPDA is basically equipped to handle most aspects of photo interpretation and analysis and may be utilized for the project. All standard interpretation and mapping equipment, e.g. stereo viewers, light tables, etc. are available.

III. EQUIPMENT

3.1 Specialized Ground Truth

Much of the equipment needed for the proposed study is readily available. However, instrumentation for ground measurements of special reflectance characteristics of various surfaces, e.g. crops, soils, water, etc., is not available. Since these data are essential for the evaluation of spectral signatures developed for use in the LARS-type of processing system, the purchase of one Spectroradiometer will be needed. Some slight modification may be required to reduce the field of view to five degrees from the normal 180 degree field.

It is anticipated that the major part of the meteorological measurements required by the experimental program will be available from other data collection programs in the area.

3.2 Government Furnished Equipment (GFE)

There is no requirement for GFE in the proposed investigation.

3.3 Automatic Data Processing Equipment

An IBM 360/30 processor is available in East Pakistan to accomplish the LARS-type processing. Extensive program adjustments are required, the LARS programs were developed for a 360/44. This is assumed, of course, that NASA can make the LARS-type program decks and documentation available at no cost.

IV. PHASE SCHEDULING AND PERSONNEL

4.1 Phase Schedules

A four-phase program as presented in Table 1 is planned.

Phase A, beginning six months prior to launch, will emphasize planning, training and equipment review.

Phase B, beginning two months prior to launch, will see the implementation of the investigation program, personnel hiring and initial analysis of the ERTS data. Program reviews are scheduled at one and four months after launch. Program cut-off could be initiated at either of these reviews depending on the satellite sensor status.

Phase C, beginning at four months after launch and continuing until eight months after, is planned as a period of critical analysis. A program review is scheduled at the end of this Phase. Success during Phase C might increase study efforts in Phase D.

Phase D is a five month phase of intensive data analysis and correlation. Maximum data rates are expected to occur during this period.

4.2 Personnel

The anticipated personnel required for the proposed analysis are presented by skill category in Table 2. The number of personnel are closely related to the phase. EPWAPDA personnel will be supplemented by the staff of the General Consultants and other technicians as may be required.

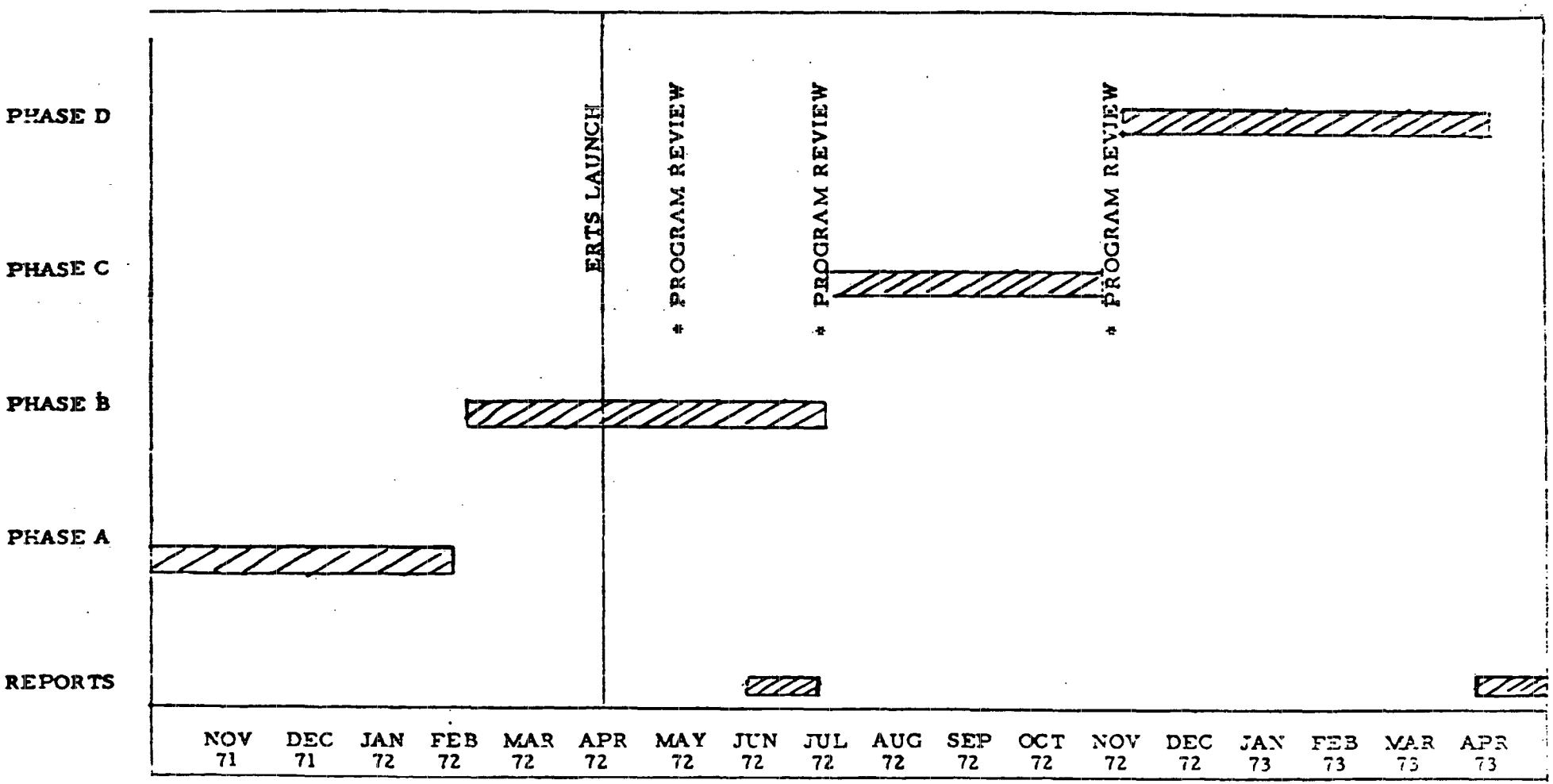


TABLE 1: PHASE SCHEDULES

V. FUNDING

Funds for the proposed investigation will be provided or secured by the Government of East Pakistan (GOEP). No requirements for NASA funding is envisioned. The GOEP funding will cover both the local and foreign exchange components. Estimates of the total funds required are:

a. Local Component $ 48,000

b. Foreign Exchange Component $115,000

This estimated distribution may change as EPWAPDA personnel become more familiar with the ERTS data. Estimated costs are tabulated in Table 3.

VI. AIRCRAFT FLIGHTS

No requirements for NASA or other U.S. Government aircraft flights are anticipated in the proposed investigation. All aircraft surveys will be performed with aircraft from the East Pakistan Aerial Photography Project proposed to be undertaken by EPWAPDA.

VII. WORK STATEMENT

The Investigator shall provide all materials, personnel, services and facilities necessary to perform prelaunch preparation and post launch analysis of data from the Earth Resources Technology Satellite, Mission A. The effort shall be performed in general accordance with our proposal entitled: East Pakistan Proposed Investigation: Earth Resources Technology Satellite (ERTS-A) Sensor Data For Agriculture and Water Resources Development.

The analysis of the ERTS-A data will include analysis of ground truth data and aircraft data collected over various test sites in East Pakistan.

The specific items and services to be performed under this project are as follows:

Item 1: Phase A - Prelaunch preparation. During Phase A, training in ground truth acquisition will be given to EPWAPDA personnel. Familiarity lectures will be presented to project personnel to provide a background to the ERTS data. Computer programs for the LARS-type analysis will be obtained and tested on appropriate computer facilities.

	PHASE A	PHASE B	PHASE C	PHASE D/FINAL REPORT	TOTALS
PROGRAM	320*	960	640	960	2880
COMPUTER SCIENTIST	280	300	240	500	1320
PHOTO INTERPRETATION SCIENTIST		600	600	800	2000
PHOTO INTERPRETATION TECHNICIAN (TRAINEE)		300	300	300	900
INSTRUMENT SPECIALIST	40	120	160	160	480
AGRICULTURAL REMOTE SENSING EXPERT		80	80	80	240
HYDROLOGY REMOTE SENSING EXPERT		80	80	80	240
CLERICAL	20	300	300	300	920

NOV 71	DEC 71	JAN 72	FEB 72	MAR 72	APR 72	MAY 72	JUN 72	JUL 72	AUG 72	SEP 72	OCT 72	NOV 72	DEC 72	JAN 73	FEB 73	MAR 73	APR 73

* Manhours per phase.

TABLE 2: PERSONNEL REQUIREMENTS

TABLE 3

ESTIMATED COST

(in dollars)

Personnel (Program Management EPWAPDA)	Man Days	Rate/Day	Foreign	Local	Total
1(X) Project Coordinator (Senior Specialist in Remote Sensing Applications	360	165	59,400	-	59,400
2(X) Computer Scientist (Specialist in Digital Image Processing)	165	165	27,225	-	27,225
3(E) Photo Interpretation Scientist (Specialist in Agriculture/Hydrology)	250	82	-	20,500	20,500
4(E) Photo Interpretation Technician Trainee (Specialist in Agriculture/Hydrology)	112	82	-	9,184	9,184
5(E) Instrument Specialist (Ground Truth)	60	48	-	2,880	2,880
6(X) Agricultural Remote Sensing Expert	30	160	4,800	-	4,800
7(X) Hydrology Remote Sensing Expert	30	160	4,800	-	4,800
8(E) Clerical (Publications)	115	50	-	5,750	5,750
Travel - 3 round trips to Dacca			3,882	-	3,882
2 round trips to NASA			2,588	-	2,588
Per diems	390	25	9,750	-	9,750
Computer Time Rental (25 hrs @ $200/hr) IBM 360/44 or equivalent				5,000	5,000
Equipment - one Spectrometer			2,390	-	2,390
Shippment/Spec.Packing			75	-	75
Contingency				4,460	4,460
			114,910	47,774	162,684

(X) = Expatriate
(E) = East Pakistan: EPWAPDA Technician

Item 2: Phase B - "First Look" Data Analysis shall emphasize the following items:

a. Collection of ground truth data, ground spectra, aircraft imagery, etc.

b. Initial analysis of ERTS data in test area at confluence of Ganges and Brahmaputra.

c. Prepare a manual land use map for test area and concurrently prepare a similar land use map using the LARS-type automatic processing program.

d. Evaluate data analysis procedures based on the cloud cover affecting the proposed investigation area.

e. Prepare a Data Analysis Plan which summarizes the initial data analysis evaluation and establishes a base line for estimating probable success of the proposed investigation.

f. Prepare a summary Data Analysis Report describing the progress and results of the initial investigation.

Item 3: Phases C and D - Continuing Data Analysis phase, to be performed after discussion with NASA. The efforts planned for Phases C and D include:

a. Detailed specification of spectral signatures for various crops, land surfaces, etc. for various seasons.

b. Prepare land use maps showing patterns of land use as a function of season of the year.

c. Prepare other thematic maps and analyses as may be useful to the East Pakistan Action Program and the proposed investigation.

d. Prepare periodic reports and a Final Report.

Item 4: Reports and Documentation

a. Six (6) copies of the Data Analysis.

b. Six (6) copies of the Preliminary Data Analysis Report.

c. Six (6) copies of Published Reports, Scientific Papers.

d. Six (6) copies of Monthly Reports per standard NASA reporting requirements.

e. Twenty-five (25) copies of the Final Data Analysis Report.

f. Other reports as required by the negotiated agreement between NASA and the Government of East Pakistan.

VIII. DELIVERY

Item 1: Phase A/B - Prelaunch Preparation Report prior to end of six months.

Item 2: Phase B - "First Look" Analysis Report, four months after launch.

Item 3: Phase C/D - Continuing Data Analysis reports to be submitted per NASA reporting schedule.

Item 4: Reports to be delivered as required by NASA.

IX. SHIPMENT

Shipment of the reports called for shall be F.O.B. destination and shall be shipped "all transportation cost prepaid" to NASA/GSFC as follows:

Items 4a, b, c, d, e, f -	1 copy	- ERTS Negotiator Code 245 Goddard Space Flight Center Greenbelt, Maryland 20771
	Remainder	- ERTS User Coordinator Code 430 Goddard Space Flight Center Greenbelt, Maryland 20771
Item 4f (as negotiated) -	2 copies	- Technology Utilization Officer Code 206 Goddard Space Flight Center Greenbelt, Maryland 20771