LANDSAT PROJECT
STATE OF HAWAII

A PRELIMINARY REPORT

DEPARTMENT OF PLANNING AND ECONOMIC DEVELOPMENT

LANDSAT PROJECT
STATE OF HAWAII

A Preliminary Report

Prepared By The

Ad Hoc Committee on Remote Sensing*

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* The Ad Hoc Committee on Remote Sensing is an inter-agency task force comprised of representatives from the State of Hawaii Departments of Agriculture, Land and Natural Resources, and Planning and Economic Development, The Governor's Office of Environmental Quality Control, and the County of Hawaii Planning Department

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF FIGURES (Cont.)

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FOREWORD

Sound planning and management of Hawaii's valuable resources must be supported by relevant and valid information. New technologies have provided increased opportunities for effective information gathering, analysis, and dissemination.

We are now on the frontier of exploring the satellite remote sensing technology as a possible means for meeting growing land use and environment-related information needs. Together with the National Aeronautics and Space Administration, we are looking at the possibilities of establishing in Hawaii an operational system for processing and analyzing satellite acquired information. In order to determine the viability of such a system, its technical, economic, and organizational requirements must be carefully reviewed and studied.

This preliminary report indicates some of the dramatic capabilities and potentials offered by this new and exciting technology. While much work is still required, our initial investigative efforts give reason to believe that the technology can be effectively applied toward important planning and management concerns.

Hideto Kono, Director

INTRODUCTION

Emerging public policies and programs, as exemplified by the Hawaii State Plan and the Hawaii Coastal Zone Management (HCZM) Program, have been very much concerned with the need to better manage Hawaii's physical environment. As recognized by the HCZM Program, government planning and management of valuable physical resources in today's complex society require the best possible data base. This requirement includes the need to improve agencies' technical analysis capabilities along with the creation of an effective and efficient data collection and processing system.

The remote sensing approach to land use and environmental data acquisition and analysis has emerged as a particularly viable tool for meeting a large part of the informational requirements of State and local agencies. There has been a relatively sudden nationwide proliferation of satellite remote sensing applications to planning and resource management. This technical achievement represents a potentially valuable means for resolving environment-related issues and problems.

Satellite remote sensing has received considerable attention in Hawaii, which is well known for its planning pioneering. This new report is intended to:

1. Apprise decision-makers and government agency personnel of the potentialities of satellite remote sensing.
2. Describe the State of Hawaii's current effort to evaluate the utility of data acquisition and analysis via satellite remote sensing.
3. Report on the State's initial satellite remote sensing demonstration application.
4. Examine the future of satellite remote sensing technology in Hawaii.

BACKGROUND

An Overview of Remote Sensing

Remote sensing is defined as the ability to record information about an object or area without coming into direct contact with it. It is the process of extracting useful information by viewing an object or area from a distance. For the purposes of this report, remote sensing involves the use of reflected and emitted energy from objects on the ground as the basis for detecting and identifying features on the earth's surface. The human eye and cameras are fundamental examples of remote sensing data collection devices.

The term remote sensing is employed to encompass the total observational process. Conventional photographic techniques were the most widely utilized form of remote sensing during its evolutionary phases. Recent technological advances, however, have added options for earth observation. Today, aerial photographs from high altitude aircrafts, such as the U-2, and space imagery from satellite platforms are rapidly expanding data acquisition capabilities.

The LANDSAT Remote Sensor

One of the most frequently used satellite platforms for remote sensing is LANDSAT, formerly referred to as the Earth Resources Technology Satellite (ERTS). LANDSAT is a polar earth-orbiting satellite which obtains and transmits information about the earth's surface to receiving stations on the ground. LANDSAT is the generic designation of a series of unmanned satellites which gather data for a variety of practical applications relating to earth resources.

The first LANDSAT was launched in July, 1972 and operated through January, 1978. Functional satellites now include LANDSAT 2 and LANDSAT 3 launched in January, 1975 and March, 1978 respectively. The launching of yet another satellite, LANDSAT D, is scheduled for 1981.

LANDSAT moves in an orbit around the earth 14 times per day at an altitude of nearly 570 miles and returns to the same position at the same time of day every 18 days. LANDSAT 2 and 3 have been synchronized in a manner providing for repetitive coverage of the earth's surface every nine days.

The two principal imaging systems on LANDSAT are the return beam vidicon (RBV) and the multispectral scanner (MSS). The RBV is fundamentally a television camera system, while the MSS detects differences in light reflectance from features on the earth's surface. The MSS data does not transmit images per se; an electronic numerical format is employed. This is referred to as a digital format and requires computer processing before any image can be derived. The MSS is presently the primary data gathering system utilized.

The sensors on the LANDSAT transmit data to earth-receiving stations. They are then stored on computer tapes from which the data can be converted from a digital to photographic format. A number of computer-assisted techniques can be used to process LANDSAT data.

LANDSAT Applications in State and Local Government

The LANDSAT data acquisition and analysis capabilities offer support for data needs associated with numerous planning and resource management applications. The LANDSAT data acquisition and processing system has been and is being used to inventory existing land uses and covers; identify patterns of change and trends; identify water resources; classify agricultural crops, forest covers, and soils; and monitor coastal resources (see Table 1).

Table 1

Summary of Operational LANDSAT Applications*

Management Concern	Applications
Water Resources Management	Surface water inventory (7) Flood control mapping and damage assessment (7) Snow cover mapping (3) Water resources planning and management (2) Irrigation demand estimation (2) Determination of runoff from cropland (2) Watershed or basin studies Water circulation Land eutrophication survey Irrigation/saline soil Geothermal potential analysis Ground water location Offshore ice studies
Forestry and Rangeland Management	Forest inventory (6) Forest productivity assessment (3) Clear cut assessment (2) Forest habitat assessment (2) Wildlife range assessment (2) Fire fuel potential Fire damage assessment and recovery
Fish and Wildlife Management	Wildlife habitat inventory (9) Wetlands location and analysis (3) Vegetation classification Snow pack mapping Salt exposure
Land Resources Management	Land cover inventory (18) Comprehensive planning (4) Corridor analysis (2) Facility siting (2) Flood plain delineation Solid waste management Lake shore management

(Continued on Page 7)

Management Concern	Applications
Environmental Management	Water quality assessment and planning (16) Environmental analysis or impact assessment (4) Coastal zone management (3) Surface mine inventory and monitoring (2) Wetlands mapping Lake water quality Shoreline delineation Oil and gas lease sales Resource inventory Dredge and fill permits Marsh salinization
Agriculture	Crop inventory (7) Irrigated crop inventory (5) Noxious weeds assessment Crop yield prediction Grove surveys Assessment of flood damage Disease monitoring
Geological Mapping	Lineament mapping (9) Geological mapping (6) Mineral surveys (4) Power plant siting Radioactive waste storage

* The number in ( ) indicates the number of states for each application, where greater than 1.

Source: Intergovernmental Science, Engineering and Technology Advisory Panel, <u>State and Local Government Perspectives on a LANDSAT Information System</u>, June, 1978.

The potential of the LANDSAT information system has been recognized by State and local governments as a practical means of gathering and analyzing land and water resources data. The Presidential Intergovernmental Science, Engineering, and Technology Advisory Panel (ISETAP), for example, has found that at least 217 feasibility demonstration projects have been conducted in 48 States. In addition, at least seven States possess operational LANDSAT analysis and application capabilities.

Nationally, considerable funding and manpower have been invested in the LANDSAT technology. Furthermore, present trends indicate an increasing rate of State interest and participation in LANDSAT technology applications. This trend is reinforced with the knowledge that NASA is intensifying its support for the LANDSAT program.

THE INITIAL DEVELOPMENT OF HAWAII'S REMOTE SENSING PROGRAM

In recognition of the potentials offered by LANDSAT and other remote sensing systems, the State of Hawaii Department of Planning and Economic Development (DPED), through its HCZM Program, began discussing with NASA possible access to remote sensing data for the State of Hawaii. The initial result of these discussions was the establishment, in 1974, of an aerial photography data facility at the DPED. Aerial photographs covering most of the eight major Islands are available. The DPED facility has been used as a physical resource data source by numerous public and private agencies and organizations.

The HCZM Program, as part of its resource inventorying methodology, continued its investigation into the applications of remote sensing to coastal zone management. Consultants set out to develop an efficient methodology for data collection, analysis, and dissemination based on remote sensing in order to satisfy the information requirements of the

HCZM Program. The effectiveness of the methodology was tested by performing inventories of selected resources in test areas.

Based on its investigations, the consultants recommended the establishment of a HCZM information clearinghouse or data facility, in part to serve as a mechanism for identifying information requirements and also for assisting in the implementation of HCZM policies and guidelines. Furthermore, in reviewing the applications and potentials of LANDSAT-derived data, the consultants recommended that the DPED:

1. Determine the future availability and quality of LANDSAT data for the State.
2. Establish a process by which repetitive classification of land use and cover could be accomplished over time.
3. Determine the cost-effectiveness of LANDSAT-derived data.
4. Structure a data collection framework to include LANDSAT data, high and low altitude aerial photography, and ground truth data to meet information needs.

The HCZM Program's investigations and recommendations thus set the stage for State of Hawaii-NASA discussions regarding a LANDSAT demonstration application program. A series of meetings of State and County agencies and NASA was held in 1977, culminating in a two-week NASA-sponsored remote sensing applications session for seven State and County agency employees at the University of California, Berkeley, and NASA's Ames Research Center. The session provided valuable data acquisition and analysis experience for the State by giving participants from the DPED, Department of Land and Natural Resources, Department of Agriculture, Office of Environmental Quality Control, and the County of Hawaii the opportunity to review and manipulate data derived from LANDSAT and other remote sensing devices.

Hawaii's LANDSAT Technology Assessment Program

To continue the State's assessment of the utility of LANDSAT technology, the seven participants organized, in December 1977, an Ad Hoc Committee on Remote Sensing under the administrative auspices of the DPED.

The primary function of the seven-member Committee is to conduct, in consultation with NASA, the required technical and economic analysis for assessing LANDSAT application potentials.

NASA, through its Western Regional Applications Program, is currently funding all technical assistance services necessary for the satisfactory completion of the LANDSAT analysis and evaluation tasks.

An overall program for studying LANDSAT feasibility was formulated by the Ad Hoc Committee in order to facilitate its investigative effort. The objectives of the program are to:

1. Assess the utility of LANDSAT and related remote sensing techniques with respect to current and future coastal and related land and water use management problems and needs in Hawaii.
2. Evaluate existing systems and processes for the manipulation of LANDSAT and other remotely sensed data.
3. Investigate the possibilities of establishing a Hawaii State remote sensing data collecting, processing and storage facility.

In line with these objectives, a demonstration project approach to assessing LANDSAT capabilities is being undertaken. Each demonstration project identifies resource-oriented problems or needs which can potentially be resolved by LANDSAT-derived data. The evaluation framework for the LANDSAT technology, therefore, is based on actual applications of LANDSAT data in Hawaii.

REGIONAL LAND AND WATER USE CLASSIFICATION PROJECT

The initial LANDSAT demonstration project formulated involves the assessment of land use/cover and water classification capabilities of the LANDSAT technology. The project was designed in concert with informational needs identified by each agency represented on the Ad Hoc Committee.

In line with the overall program objectives, the following demonstration project objectives were established.

1. Evaluate the utility of LANDSAT land use/cover and water classification schemes with respect to selected agency information requirements.
2. Document technical LANDSAT analysis procedures.
3. Evaluate alternative LANDSAT classification techniques and systems.
4. Provide State and County personnel experience in analyzing LANDSAT-derived data.

In order to develop a LANDSAT-derived land use/cover and water classification able to meet the wide range of needs falling under State and County planning and management programs, a regional urban classification scheme and a regional non-urban/rural classification scheme were generated. Two test sites were selected for this purpose: The Honolulu-Pearl City urban region on the Island of Oahu, and the Hamakua, North Kohala, and South Kohala non-urban/rural region on the Island of Hawaii (see Figures 1 and 2).

Desired land use/cover and water classes were selected, based on an identification and evaluation of user agency (i.e., DPED, DOA, DLNR, OEQC, and County of Hawaii Planning Department) needs. General classes desired for the LANDSAT classification included the following:

1. Urban classification - commercial, industrial, residential,

figure I.

URBAN TEST SITE

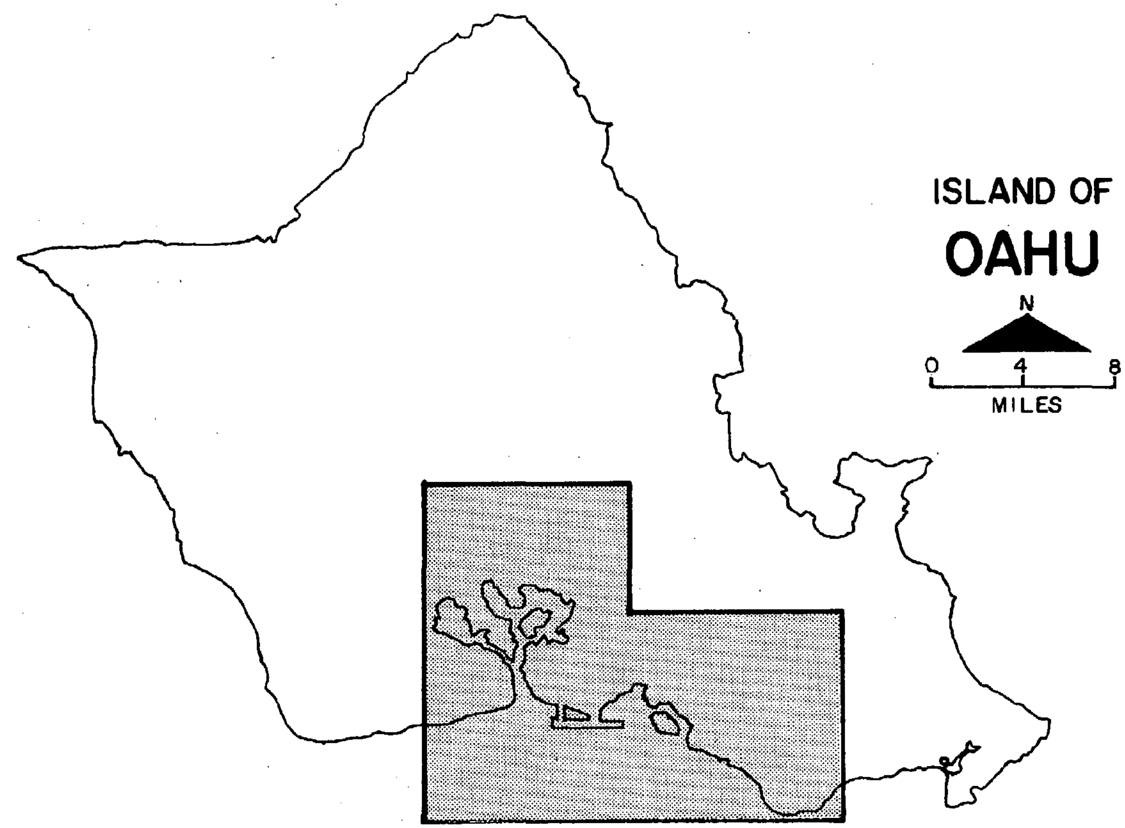
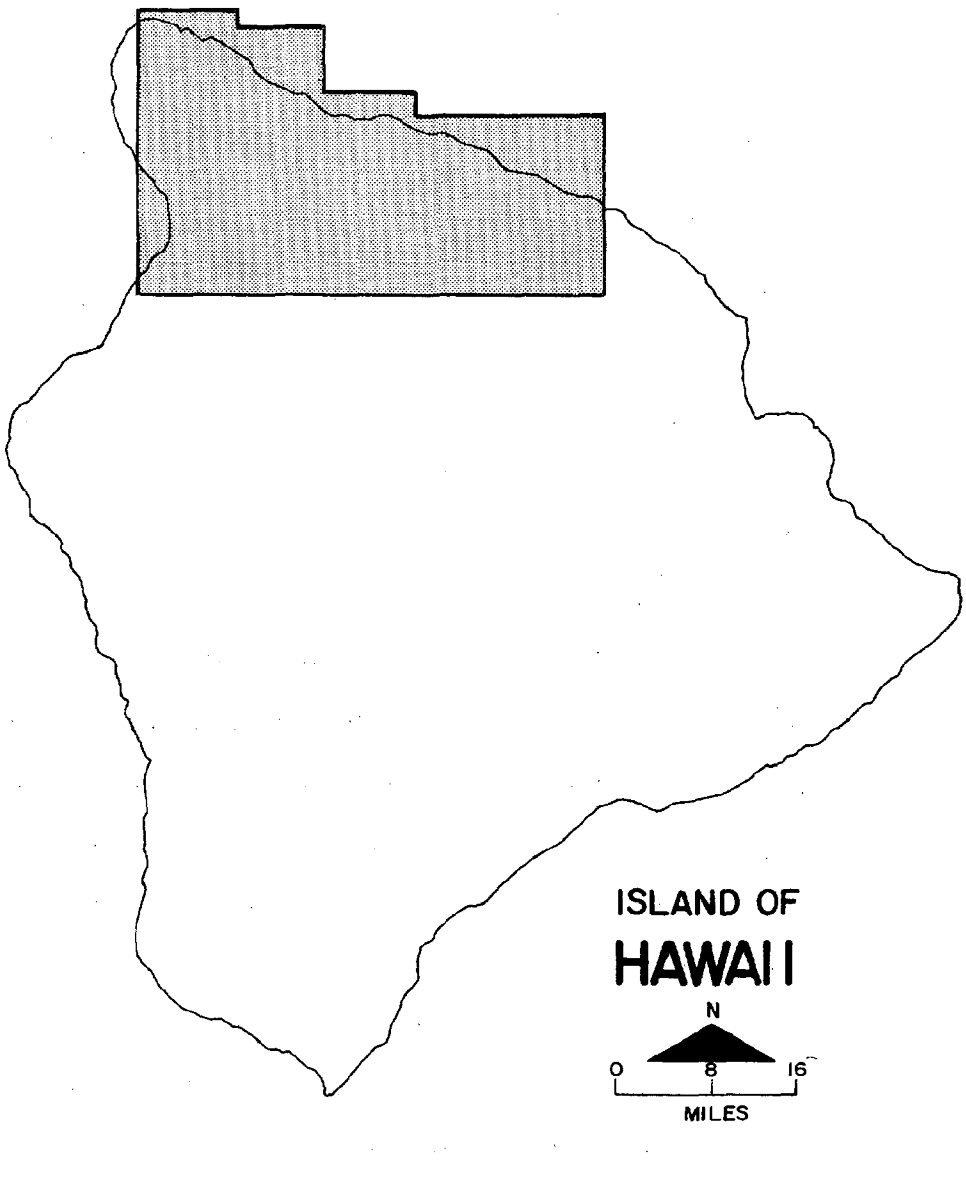


figure 2.

NON-URBAN/RURALTEST SITE



improved open space, unimproved urban land, coastal and related water bodies.

2. Non-urban/rural-forest types, agricultural crops, wetlands, grasslands, and coastal waters.

In addition, administrative and environmental boundaries such as the CZM Special Management Area Boundaries and the State Land Use District Boundaries were selected as possible classification overlays for enhancing the utility of the final output products. The evaluation of these overlays will be completed during the next phase of the program.

Demonstration Project Technical Analysis

The technical analysis phase of the demonstration LANDSAT classification was conducted at NASA's Ames Research Center by five Ad Hoc Committee members during the weeks of July 16 and 24, 1978. Field checks were conducted prior to the Ames analysis session.

The analysis process can be generalized as follows:

1. Scene Selection

   A satellite scene or image for analysis is selected. Selection is dictated by a number of factors including image quality and the degree of cloud cover. The project area and test site locations for the Regional Land and Water Use Classification Project were selected from available 1973 imagery.

2. Geometric Control Establishment

   Once the desired image is selected, a skew correction is performed to geographically orient it in the proper North-South and East-West directions. This step is necessary to accurately reference the image to an appropriate base map.

3. Training Site Selection

Small training sites or areas that reflect the range of known land and water categories are then selected from the scene.

4. Guided Clustering

The training sites are subsequently used to determine the various cover classifications that can be depicted in the scene. The computer is used to make the groupings on the basis of variations in light reflectance characteristics for each cover type. This process requires much testing and refinement. The skill and knowledge of the analysis is a key to obtaining meaningful and realistic results.

5. Data Classification

Once the cover classifications are determined within each test site, the results are extrapolated by the computer to encompass the total area selected for study.

6. Output of Results

The classification of the entire study area can be developed in a variety of formats. Both visual results, such as color-coded digital images and line-printer maps, and tabular data can be generated.

Due to the limited time available to perform the analysis, the classification for only the Big Island's non-urban/rural test site was completed by the Ad Hoc Committee. However, the urban test site was analyzed and classified by the NASA and USGS staffs in consultation with the Ad Hoc Committee.

Demonstration Project Results

LANDSAT derived land use/cover and water classifications were developed for each test site. In addition, acreage summaries for each use and cover type were computed as part of the classification process.

Figures 3 and 4 display the classification in a color-coded digital image format. Acreage summaries for the respective use and cover categories are shown in Tables 2 and 3.

Other display formats for the LANDSAT-derived data are described in the following section.

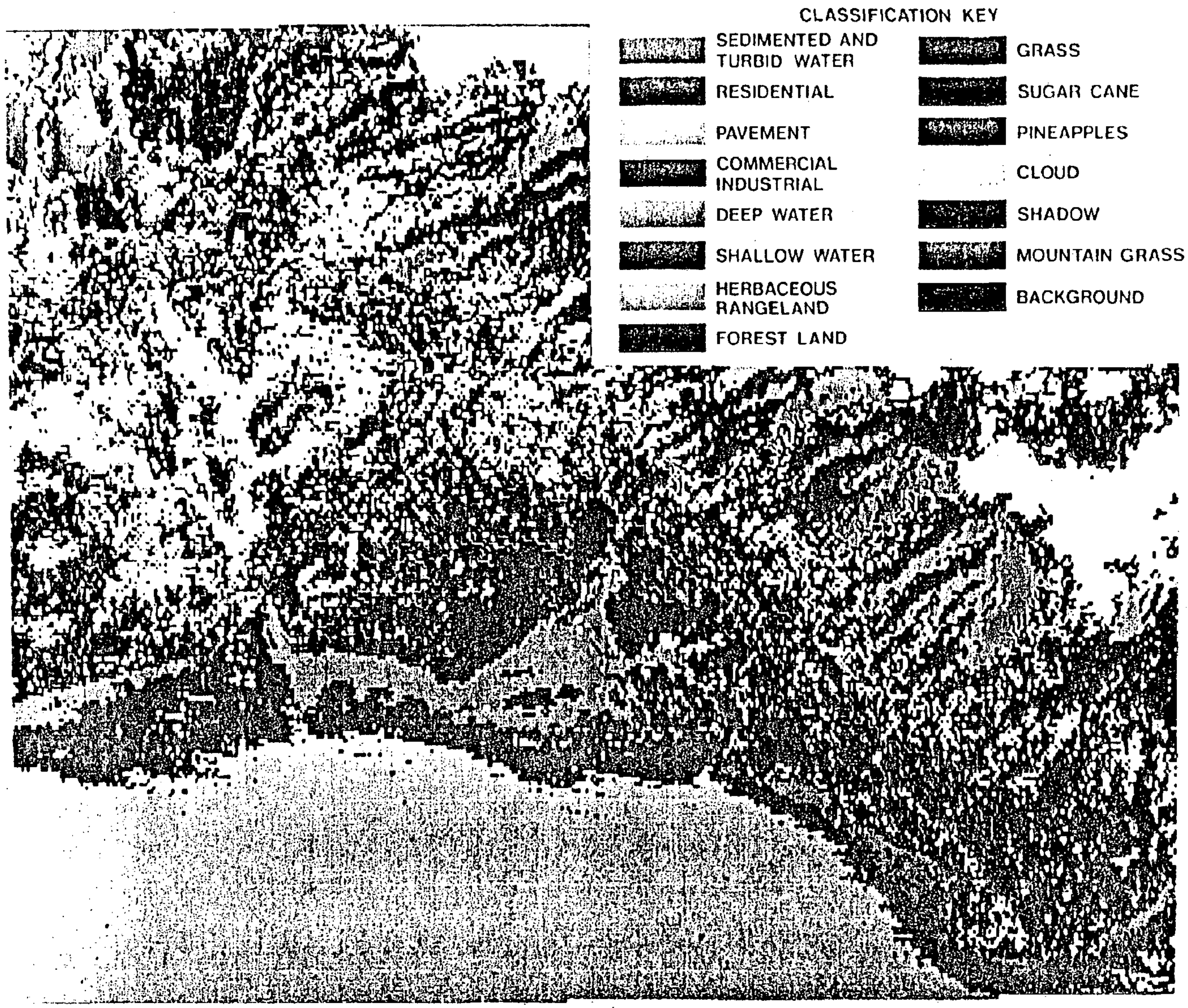
FIGURE 3

ISLAND OF OAHU

URBAN TEST SITE - 137,060 ACRES — LANDSAT 1 - OCTOBER 1973

SUPERVISED, STRATIFIED COMPUTER CLASSIFICATION ON EDITOR-TENEX

14 LAND USE/COVER TYPES — 46 CLASSES



NOTE: This is a black and white illustration of the computer classified map. Original map is displayed in a color-coded format.

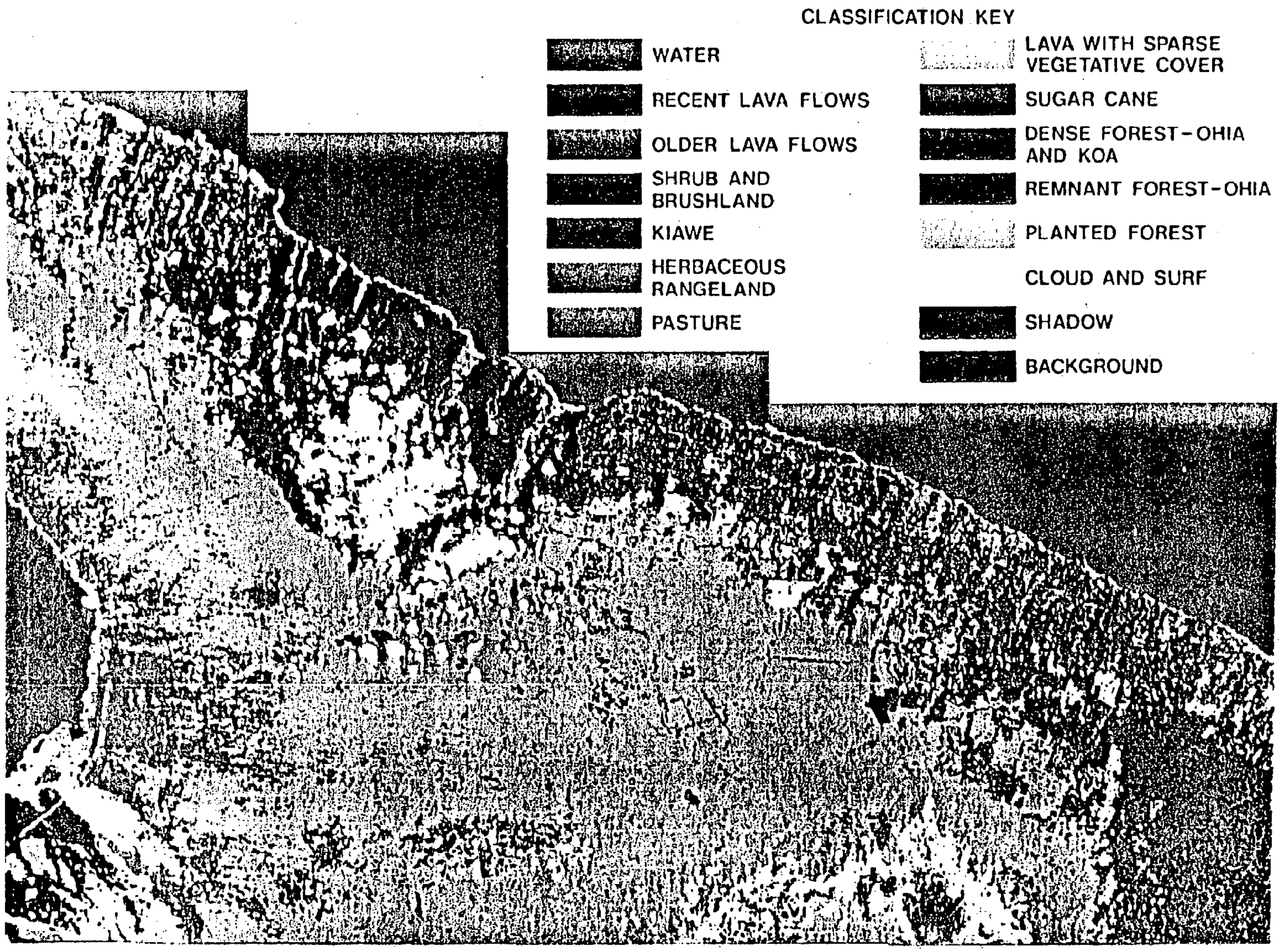
FIGURE 4

ISLAND OF HAWAII

RURAL TEST SITE-703,041 ACRES — LANDSAT 1-FEBRUARY 1973

SUPERVISED, STRATIFIED COMPUTER CLASSIFICATION ON EDITOR-TENEX

16 LAND USE/COVER TYPES — 64 CLASSES



NOTE: This is a black and white illustration of the computer classified map. Original map is displayed in a color-coded format.

Table 2

Land Use/Cover and Water Acreage Summary, Big Island Test Site

Category	Use/Cover	Acres
1	Water	92,749
2	Black Lava	7,982
3	Lava with Vegetation	12,242
4	Brush	41,634
5	Dry Brush	44,498
6	Range	104,453
7	Pasture	110,200
8	Medium Grey Lava	11,415
9	Cane	43,443
10	Dense Forest - Ohia and Koa	24,105
11	Remnant Forest - Ohia	27,876
12	Planted Forest	4,383
13	Cloud	11,561
14	Shadow	8,522

Table 3

Land Use/Cover and Water Acreage Summary, Oahu Test Site

Category	Use/Cover	Acres
1	Water	582
2	Residential	2,249
3	Residential	4,554
4	Residential	4,854
5	Residential	4,224
6	Residential	3,921
7	Pavement	1,620
8	Commercial/Industrial	1,448
9	Commercial/Industrial	2,454
10	Commercial/Industrial	1,473
11	Commercial/Industrial	1,362
12	Commercial/Industrial	1,469
13	Commercial/Industrial	897
14	Commercial/Industrial	503
15	Commercial/Industrial	305
16	Water	28,468
17	Water	10,098
18	Water	3,786
19	Commercial/Industrial	486
20	Range	687
21	Range	1,179
22	Range	3,881

Table 3 (Cont.)

Category	Use/Cover	Acres
23	Residential	3,891
24	Forest	5,544
25	Forest	2,287
26	Forest	5,340
27	Forest	2,537
28	Forest	2,084
29	Forest	1,982
30	Grass	1,394
31	Grass	1,172
32	Forest	4,064
33	Cane	1,584
34	Cane	784
35	Cane	1,065
36	Pineapple	336
37	Range	192
38	Range	290
39	Pineapple	930
40	Range	246
41	Pineapple	147
42	Cloud	4,876
43	Cloud	6,806
44	Shadow	1,508
46	Mountain Grasses	7,538

Preliminary Review of Results

In order to discern the practical advantages of LANDSAT-derived data, the results were reviewed in terms of its output format, resolution, temporal detection capabilities, manipulation ease, and accuracy.

1. Output Format

Depending on user needs, a variety of output formats can be used to display and analyze LANDSAT data. The data, for example, can be displayed on cathode ray tubes as photographic images, computer line-printer maps, color-coded "hard-copy" maps, overlay line maps, or tabular acreage summaries. The primary output products used in analyzing data from the Oahu and Big Island classifications are line-printer maps and tabular summaries of acreages of land use/cover and water categories. Line-printer maps (Figure 5) were displayed at a scale of 1:24,000 to provide direct overlay capabilities with USGS quad maps, State Land Use Boundaries, CZM Special Management Area Boundaries, and other reference bases on the 1:24,000 scale.

In addition, as discussed in the previous section, tabular acreage summaries for each land use/cover and water categories were generated.

The various data display formats discussed above, therefore, offer great flexibility for interpreting and applying land use information.

2. Resolution

The LANDSAT's resolution capability or ability to distinguish features on the earth's surface is approximately

Figure 5
Example of Line Printer Display - Pearl City Region, Oahu

1.1 acres*. As such, each alpha-numeric symbol in Figure 5 represents a 1.1-acre picture element or pixel. Output products, both graphic and tabular, are commonly rendered at the 1.1-acre minimum resolution. The 1.1-acre resolution can meet a large part of the data requirements of the various planning and resource management programs and activities undertaken by State and County agencies.

3. Temporal Factors

Temporal factors--those happenings that occur with the passage of time--can also be accounted for by LANDSAT technology. Examples of temporal conditions which often are cyclic in nature include agricultural crops in varying stages of maturity, the location and extent of turbid waters and general seasonal changes.

LANDSAT data can be acquired to take advantage of certain temporal occurrences. For instance, drought and water pollution conditions may be more easily evaluated if LANDSAT data can be obtained from a time when such occurrences are clearly displayed.

Temporal factors can also reflect change. Urban development, plant disease, and the use patterns of agriculture may be clearly documented through a series of images acquired over time.

The next phase of Hawaii's evaluation of LANDSAT data will include a Change Detection Demonstration Project to determine

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* LANDSAT-D, scheduled for launch in 1981, will have a resolution capability of approximately 0.2 acre.

the feasibility of using LANDSAT-derived data in monitoring changes in land and water conditions.

4. Manipulative Ease

A series of manipulative functions were performed to the LANDSAT-derived data in order to facilitate the data evaluation process. For example, a cathode ray tube which displays the LANDSAT images enables the enlargement, color-highlighting, and identification of land features of special interest.

In order to facilitate the review of the data's accuracy, individual cover categories were delineated on separate line printer maps. Figure 5, for example, illustrates the line-printer map containing urban use/cover types only. Similar maps were produced for the agriculture, range, and water categories.

The utility of the mapped output products can be further enhanced by digitizing or inputing environmental or administrative boundary data, thereby establishing computer overlay capability. In order to evaluate this capability, CZM Special Management Area Boundaries, State Land Use District Boundaries, and major land ownership boundaries were digitized. This additional capability provides a potentially effective means of analyzing land and water uses/cover within special areas of concern.

5. Accuracy

Accuracy refers to the validity of the product. Accuracy should describe how truthfully the product reflects the "real world." While no quantitative studies have yet been done, comparative examinations of the output have been made, comparing it with known conditions. This is illustrated by the following examples:

Example 1 - Water Classification:

The water classification shown in Figure 6 depicts the Middle and East Loch of Pearl Harbor. Symbols G and H represent deep and shallow clear water, respectively. Symbols I and 1 represent areas of water overlying mud and coral. Pearl City Peninsula and Ford Island, including a blank space for the Arizona Memorial, can be easily discerned.

Example 2 - Forest Classification:

Figure 7 shows the Nienie section of the Hamakua Forest Reserve on the Island of Hawaii. Symbols #, $, %, and * represent the planted forests within the reserve. The plantations are clearly displayed, being symbolically unique from their surroundings. The Committee's overlay comparison of this section with existing forest plantation maps indicates a high degree of concurrence.

Example 3 - Urban Classification:

An examination of the LANDSAT urban classification indicates consistency with areas developed and undeveloped in 1973. Residential, commercial-industrial land uses, as well as paved areas such as runways and large parking areas in the Pearl

Harbor region are readily identifiable in Figure 8. The symbols #, $, and I, represent these categories, respectively.

Potential Product Application

Based on a preliminary review of user needs for each agency represented on the Ad Hoc Committee, a list of possible applications utilizing the classification capabilities of the LANDSAT technology was derived (see Table 2). In meeting the information needs indicated in Table 2, LANDSAT-derived data provide information which currently does not exist and/or provide a new data source for supplementing or updating old or unreliable data.

While it is important to recognize that LANDSAT technology is not intended to meet all agency data requirements, it is encouraging that several useful applications having resolution and accuracy requirements compatible with LANDSAT-derived data have been identified. The LANDSAT technology, therefore, should be regarded as a new opportunity for agencies to assume greater planning and resource management responsibilities in line with growing public and legislative demands.

Figure 6
Water Classified Categories, Pearl Harbor Region, Oahu
G - Deep Water; H - Shallow Clear Water; I, 1 - Water Overlying Mud and Coral

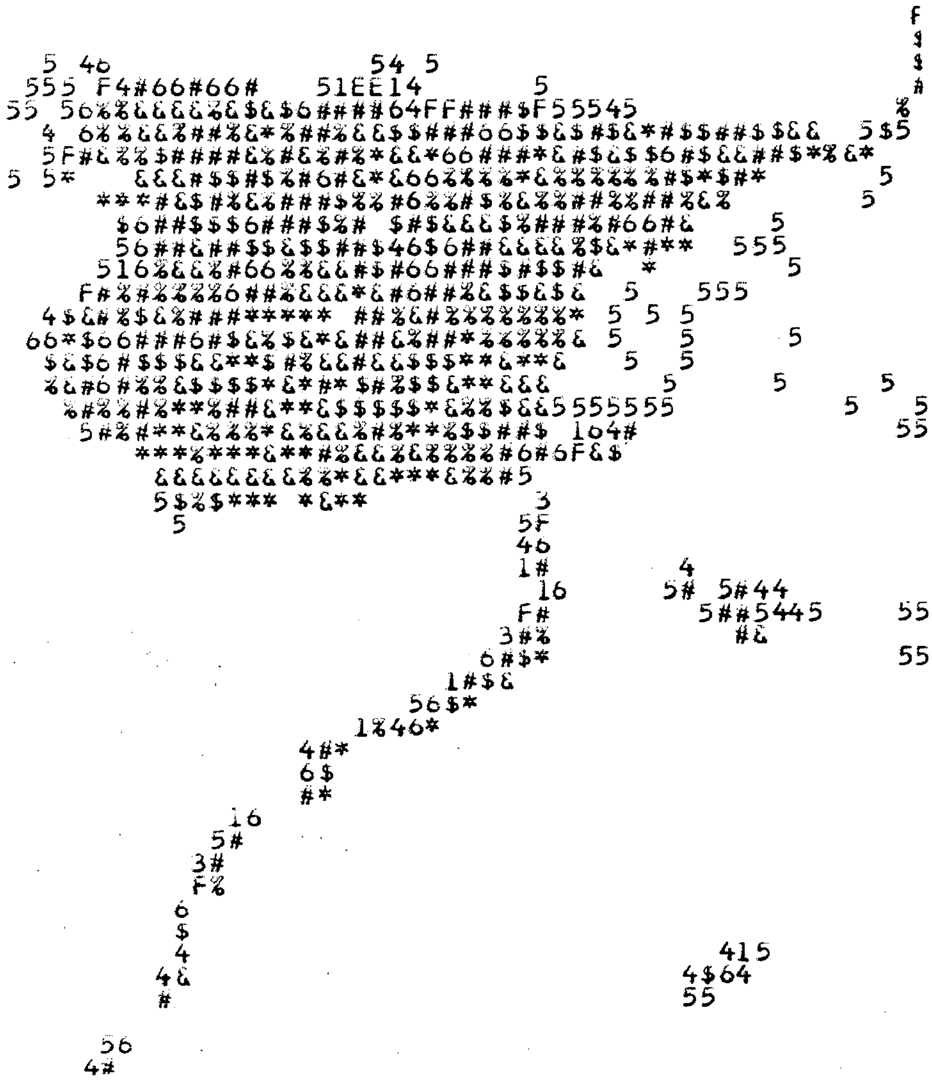


Figure 7
Forest Classified Categories, Nienie Section, Hamakua Forest Reserve, Hawaii. #, $, %, &, * - Planted Forest; 1, 4, 5, 6 - Remnant Ohia Forest; F - Dense Ohia and Koa Forest

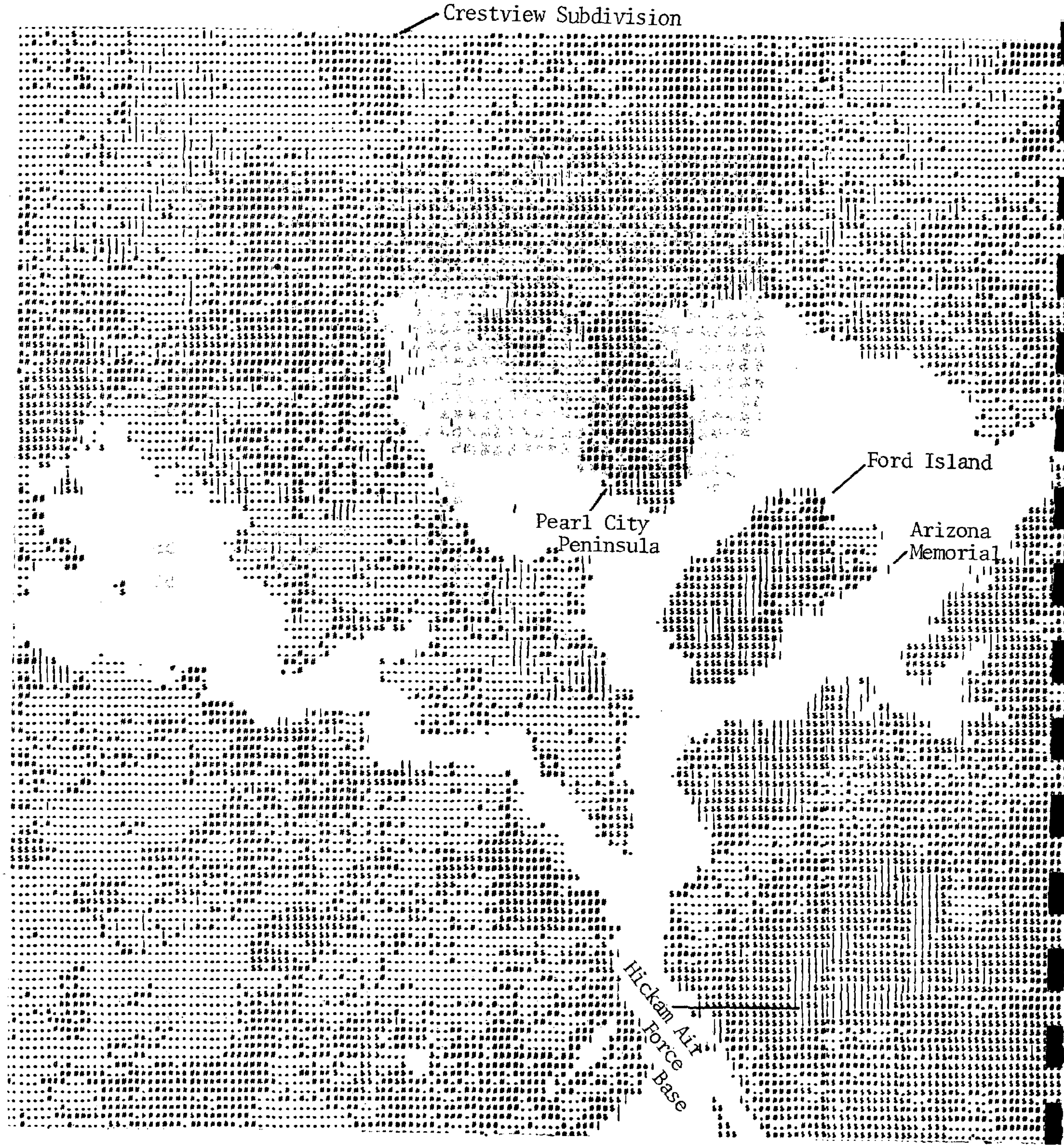


Figure 8
Urban Classified Categories, Pearl City Region, Oahu
- Residential; $ - Commercial-Industrial; | - Pavement;
. - All Other Non-Urban Categories

Developing an "In-State" Analysis

LANDSAT data analysis

Ames Research Center where state-

ties are available. If an opera

system is to be established, how

computer-capabilities to handle

accomplish this, it will be adva

during the current investigative

for accessing the Ames Research

Specifically, this would involve

Hawaii to NASA's computer facili-

systematically plan for installi

facility in Hawaii.

One possibility for im

of the communications relay capa

Satellite (ATS). The ATS would

with NASA computers. A cooperat

been proposed which will enable

utilizing the satellite communic

LANDSAT data analysis. This exp

will be a key determinant in est

operational State LANDSAT inform

Economic Evaluation

A justifiable LANDSAT

establish its economic value by

resources information in a more

data gathering techniques such a

Alternate Methodology

Certain comparisons and generalizations of the LANDSAT output can be made with output from other data sources. For instance, the satellite classification for the Island of Hawaii discussed in this report required approximately two weeks to complete. The result is land use and cover-type displays to the nearest acre. Acreage information is also available. While admitting possibilities of refinement, a similar project, that of creating land use and vegetative maps for the State, took over one man-year on the aerial photo-interpretation alone. Subsequent mapping and acreage determinations added another two man-years of effort. Ultimate results were to the nearest 40 acres.

This comparison indicates that LANDSAT data processing and analysis can be a timely, responsive, and cost-effective planning and management tool.

FUTURE ACTIVITIES

Change Detection Demonstration Project

As a follow-up to the land use/cover and water classification demonstration project, the monitoring or change detection capabilities of the LANDSAT technology will be evaluated by analyzing repetitive satellite coverage. As indicated earlier, LANDSAT 2 and 3 pass over the same position over the earth's surface every nine days. This repetitive data acquisition capability enables users to monitor changes in land use/cover and water characteristics over time.

A demonstration project plan will be formulated for the analysis of multidate LANDSAT data for the State of Hawaii. An identification of user requirements for specific monitoring applications will be used in evaluating the potential utility of LANDSAT's monitoring capability.

Developing an "In-State" Analysis Capability

LANDSAT data analysis to date have been conducted at NASA's Ames Research Center where state-of-the-art data analysis computer facilities are available. If an operational State LANDSAT processing and analysis system is to be established, however, State agencies will need to develop computer-capabilities to handle LANDSAT data locally. In order to accomplish this, it will be advantageous to the State to implement, during the current investigative phase, an effective and efficient program for accessing the Ames Research Center's computer facilities from Hawaii. Specifically, this would involve linking a remote computer terminal in Hawaii to NASA's computer facilities. This will allow the State to systematically plan for installing an operational LANDSAT computer analysis facility in Hawaii.

One possibility for implementing this concept is through the use of the communications relay capabilities of the Applications Technology Satellite (ATS). The ATS would enable the State to "communicate" directly with NASA computers. A cooperative State-NASA experiment has, therefore, been proposed which will enable the State to evaluate the feasibility of utilizing the satellite communications approach to conducting "in-State" LANDSAT data analysis. This experiment, scheduled to begin in early 1979 will be a key determinant in establishing the economic feasibility of an operational State LANDSAT information system.

Economic Evaluation

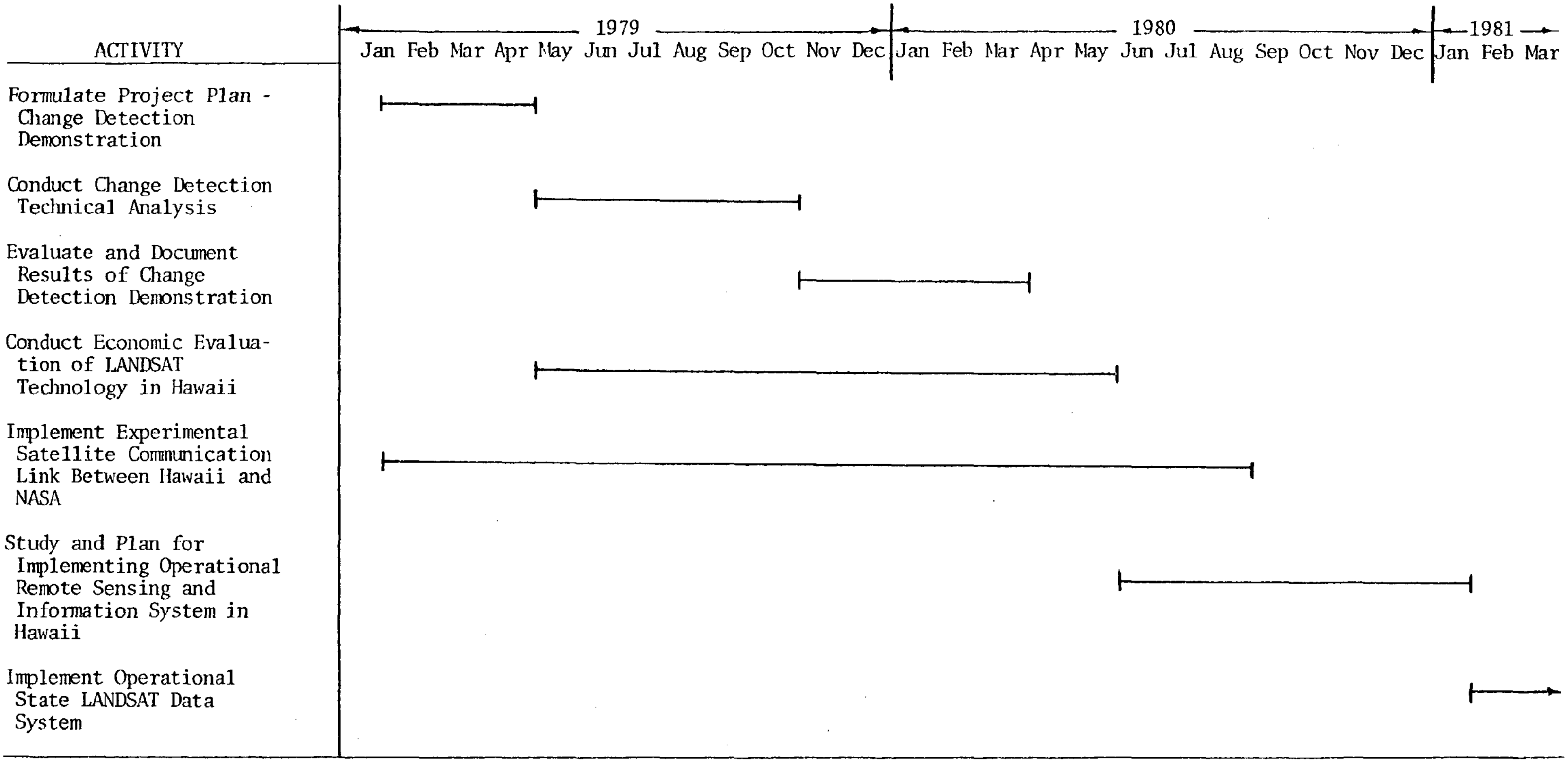
A justifiable LANDSAT data processing and analysis system should establish its economic value by demonstrating its ability to provide earth resources information in a more cost-effective manner than conventional data gathering techniques such as "windshield" surveys.

As such, the Ad Hoc Committee will be assisted and guided by the NASA staff in conducting a cost-effectiveness analysis of a State LANDSAT data collection and processing system. This analysis will include a comparison of costs between LANDSAT and conventional resource data acquisition methods.

It is recognized, of course, that LANDSAT cost-effectiveness will vary for each type of LANDSAT application (e.g., monitoring, inventory, mapping). It is anticipated, therefore, that an overall cost-effectiveness assessment of a Hawaii LANDSAT system will require an economic analysis for a number of demonstration applications.

A summary of the forthcoming program tasks is shown in Figure 9.

Figure 9
Future Activities Time Chart



SUMMARY

Assessment of the LANDSAT technology to date indicates substantial promise for applying this tool towards State and County planning and resource management activities. The speed with which data can be processed, as well as the accuracies that can be achieved, has established the LANDSAT methodology as a valuable management tool. The change detection or monitoring capabilities of the LANDSAT system further enhance the value of this technology.

The future of satellite remote sensing appears promising. NASA has made major commitments in this direction with the planned launching of another satellite in 1981. The new satellite will allow areas as small as one-fifth of an acre to be separately examined. This represents a substantial technical improvement over the 1.1-acre capability currently available.

The State of Hawaii's participation in satellite remote sensing investigations and projects appears timely in view of the increasing number of State and local government LANDSAT applications being undertaken. While further studies of the LANDSAT technology will need to be conducted, there is optimism that this technical achievement can be employed to meet today's challenging land use and environmental issues and problems.

Table 2

Land Use/Cover and Water Acreage Summary, Big Island Test Site

Category	Use/Cover	Acres
1	Water	92,749
2	Black Lava	7,982
3	Lava with Vegetation	12,242
4	Brush	41,634
5	Dry Brush	44,498
6	Range	104,453
7	Pasture	110,200
8	Medium Grey Lava	11,415
9	Cane	43,443
10	Dense Forest - Ohia and Koa	24,105
11	Remnant Forest - Ohia	27,876
12	Planted Forest	4,383
13	Cloud	11,561
14	Shadow	8,522

Table 3

Land Use/Cover and Water Acreage Summary, Oahu Test Site

Category	Use/Cover	Acres
1	Water	582
2	Residential	2,249
3	Residential	4,554
4	Residential	4,854
5	Residential	4,224
6	Residential	3,921
7	Pavement	1,620
8	Commercial/Industrial	1,448
9	Commercial/Industrial	2,454
10	Commercial/Industrial	1,473
11	Commercial/Industrial	1,362
12	Commercial/Industrial	1,469
13	Commercial/Industrial	897
14	Commercial/Industrial	503
15	Commercial/Industrial	305
16	Water	28,468
17	Water	10,098
18	Water	3,786
19	Commercial/Industrial	486
20	Range	687
21	Range	1,179
22	Range	3,881

Table 3 (Cont.)

Category	Use/Cover	Acres
23	Residential	3,891
24	Forest	5,544
25	Forest	2,287
26	Forest	5,340
27	Forest	2,537
28	Forest	2,084
29	Forest	1,982
30	Grass	1,394
31	Grass	1,172
32	Forest	4,064
33	Cane	1,584
34	Cane	784
35	Cane	1,065
36	Pineapple	336
37	Range	192
38	Range	290
39	Pineapple	930
40	Range	246
41	Pineapple	147
42	Cloud	4,876
43	Cloud	6,806
44	Shadow	1,508
46	Mountain Grasses	7,538

Preliminary Review of Results

In order to discern the practical advantages of LANDSAT-derived data, the results were reviewed in terms of its output format, resolution, temporal detection capabilities, manipulation ease, and accuracy.

1. Output Format

Depending on user needs, a variety of output formats can be used to display and analyze LANDSAT data. The data, for example, can be displayed on cathode ray tubes as photographic images, computer line-printer maps, color-coded "hard-copy" maps, overlay line maps, or tabular acreage summaries. The primary output products used in analyzing data from the Oahu and Big Island classifications are line-printer maps and tabular summaries of acreages of land use/cover and water categories. Line-printer maps (Figure 5) were displayed at a scale of 1:24,000 to provide direct overlay capabilities with USGS quad maps, State Land Use Boundaries, CZM Special Management Area Boundaries, and other reference bases on the 1:24,000 scale.

In addition, as discussed in the previous section, tabular acreage summaries for each land use/cover and water categories were generated.

The various data display formats discussed above, therefore, offer great flexibility for interpreting and applying land use information.

2. Resolution

The LANDSAT's resolution capability or ability to distinguish features on the earth's surface is approximately

Figure 5
Example of Line Printer Display - Pearl City Region, Oahu

1.1 acres*. As such, each alpha-numeric symbol in Figure 5 represents a 1.1-acre picture element or pixel. Output products, both graphic and tabular, are commonly rendered at the 1.1-acre minimum resolution. The 1.1-acre resolution can meet a large part of the data requirements of the various planning and resource management programs and activities undertaken by State and County agencies.

3. Temporal Factors

Temporal factors--those happenings that occur with the passage of time--can also be accounted for by LANDSAT technology. Examples of temporal conditions which often are cyclic in nature include agricultural crops in varying stages of maturity, the location and extent of turbid waters and general seasonal changes.

LANDSAT data can be acquired to take advantage of certain temporal occurrences. For instance, drought and water pollution conditions may be more easily evaluated if LANDSAT data can be obtained from a time when such occurrences are clearly displayed.

Temporal factors can also reflect change. Urban development, plant disease, and the use patterns of agriculture may be clearly documented through a series of images acquired over time.

The next phase of Hawaii's evaluation of LANDSAT data will include a Change Detection Demonstration Project to determine

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* LANDSAT-D, scheduled for launch in 1981, will have a resolution capability of approximately 0.2 acre.

the feasibility of using LANDSAT-derived data in monitoring changes in land and water conditions.

4. Manipulative Ease

A series of manipulative functions were performed to the LANDSAT-derived data in order to facilitate the data evaluation process. For example, a cathode ray tube which displays the LANDSAT images enables the enlargement, color-highlighting, and identification of land features of special interest.

In order to facilitate the review of the data's accuracy, individual cover categories were delineated on separate line printer maps. Figure 5, for example, illustrates the line-printer map containing urban use/cover types only. Similar maps were produced for the agriculture, range, and water categories.

The utility of the mapped output products can be further enhanced by digitizing or inputing environmental or administrative boundary data, thereby establishing computer overlay capability. In order to evaluate this capability, CZM Special Management Area Boundaries, State Land Use District Boundaries, and major land ownership boundaries were digitized. This additional capability provides a potentially effective means of analyzing land and water uses/cover within special areas of concern.

5. Accuracy

Accuracy refers to the validity of the product. Accuracy should describe how truthfully the product reflects the "real world." While no quantitative studies have yet been done, comparative examinations of the output have been made, comparing it with known conditions. This is illustrated by the following examples:

Example 1 - Water Classification:

The water classification shown in Figure 6 depicts the Middle and East Loch of Pearl Harbor. Symbols G and H represent deep and shallow clear water, respectively. Symbols I and 1 represent areas of water overlying mud and coral. Pearl City Peninsula and Ford Island, including a blank space for the Arizona Memorial, can be easily discerned.

Example 2 - Forest Classification:

Figure 7 shows the Nienie section of the Hamakua Forest Reserve on the Island of Hawaii. Symbols #, $, %, and * represent the planted forests within the reserve. The plantations are clearly displayed, being symbolically unique from their surroundings. The Committee's overlay comparison of this section with existing forest plantation maps indicates a high degree of concurrence.

Example 3 - Urban Classification:

An examination of the LANDSAT urban classification indicates consistency with areas developed and undeveloped in 1973. Residential, commercial-industrial land uses, as well as paved areas such as runways and large parking areas in the Pearl

Harbor region are readily identifiable in Figure 8. The symbols #, $, and I, represent these categories, respectively.

Potential Product Application

Based on a preliminary review of user needs for each agency represented on the Ad Hoc Committee, a list of possible applications utilizing the classification capabilities of the LANDSAT technology was derived (see Table 2). In meeting the information needs indicated in Table 2, LANDSAT-derived data provide information which currently does not exist and/or provide a new data source for supplementing or updating old or unreliable data.

While it is important to recognize that LANDSAT technology is not intended to meet all agency data requirements, it is encouraging that several useful applications having resolution and accuracy requirements compatible with LANDSAT-derived data have been identified. The LANDSAT technology, therefore, should be regarded as a new opportunity for agencies to assume greater planning and resource management responsibilities in line with growing public and legislative demands.

Figure 6
Water Classified Categories, Pearl Harbor Region, Oahu
G - Deep Water; H - Shallow Clear Water; I, 1 - Water Overlying Mud and Coral

Figure 7
Forest Classified Categories, Nienie Section, Hamakua Forest Reserve, Hawaii. #, $, %, &, * - Planted Forest; 1, 4, 5, 6 - Remnant Ohia Forest; F - Dense Ohia and Koa Forest

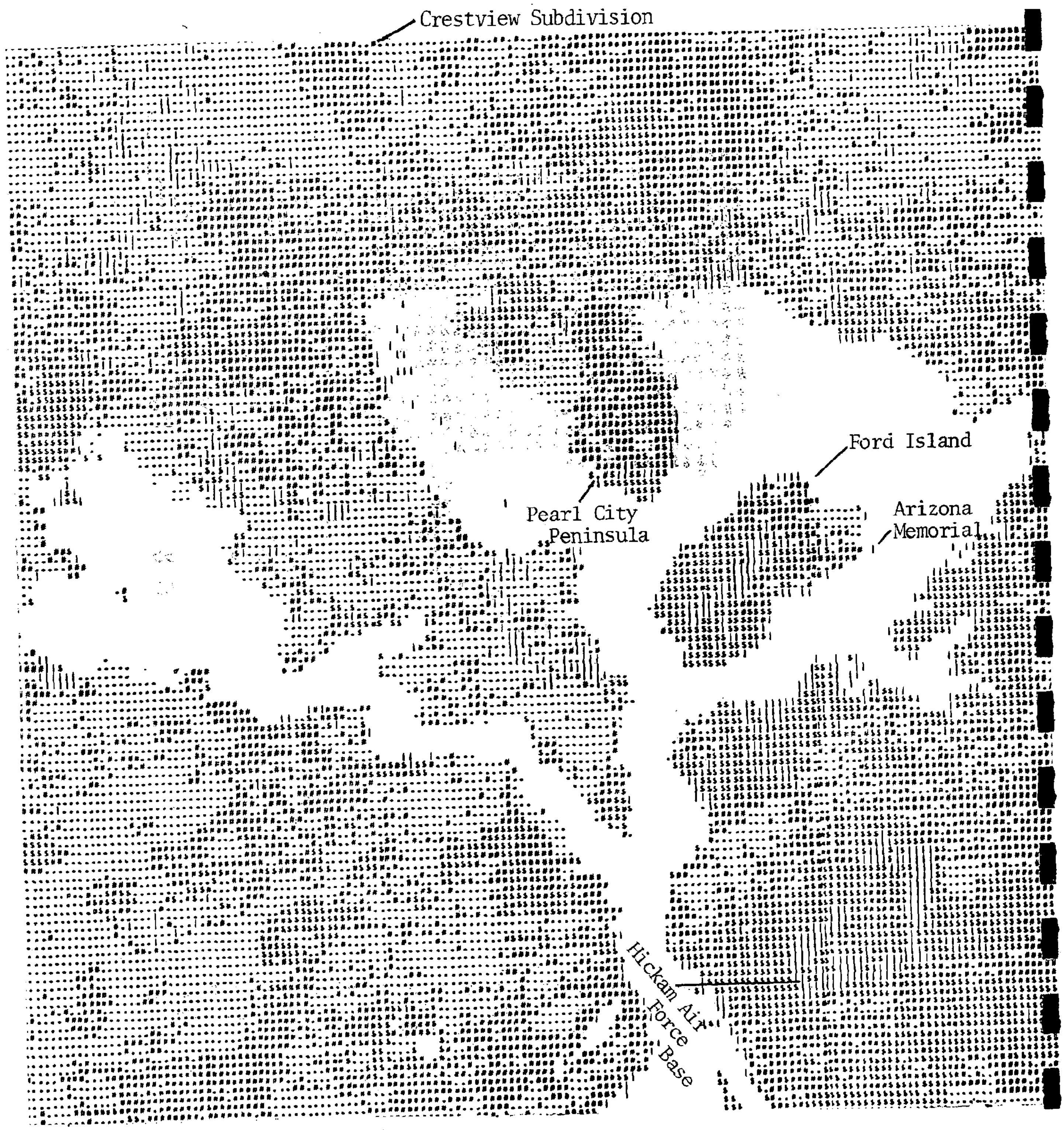


Figure 8
Urban Classified Categories, Pearl City Region, Oahu
- Residential; $ - Commercial-Industrial; ⁞ - Pavement;
. - All Other Non-Urban Categories

TABLE 4

POTENTIAL LANDSAT PRODUCT APPLICATIONS

Agency	LANDSAT Classification Application Potential
Department of Agriculture	a. Delineate areas and determine acres of crop types such as sugar, pineapple and diversified agricultural crops. b. Identify and determine acreage and assess conditions of pasture lands. c. Identify fallow lands within State Land Use Agricultural District.
County of Hawaii, Planning Department	a. Delineate existing land use patterns. b. Delineate areas and determine acreages of existing land uses and cover.
Department of Land and Natural Resources	a. Delineate areas and determine acreages of Forest types including ohia, koa, eucalyptus. b. Locate and determine acreages of stressed or diseased forests. c. Identify and determine acreage and assess conditions of wildlife habitat areas.
Office of Environmental Quality Control	a. Identify areas of potential non-point sources of pollution. b. Delineate areas and determine acreage of existing land use and cover.
Department of Planning and Economic Development: Land Use Division	a. All of the above. b. Identify and determine acreages of usable vacant or underutilized lands within State Land Use Urban Districts.
DPED, Planning Division	a. All of the above.

Alternate Methodology

Certain comparisons and generalizations of the LANDSAT output can be made with output from other data sources. For instance, the satellite classification for the Island of Hawaii discussed in this report required approximately two weeks to complete. The result is land use and cover-type displays to the nearest acre. Acreage information is also available. While admitting possibilities of refinement, a similar project, that of creating land use and vegetative maps for the State, took over one man-year on the aerial photo-interpretation alone. Subsequent mapping and acreage determinations added another two man-years of effort. Ultimate results were to the nearest 40 acres.

This comparison indicates that LANDSAT data processing and analysis can be a timely, responsive, and cost-effective planning and management tool.

FUTURE ACTIVITIES

Change Detection Demonstration Project

As a follow-up to the land use/cover and water classification demonstration project, the monitoring or change detection capabilities of the LANDSAT technology will be evaluated by analyzing repetitive satellite coverage. As indicated earlier, LANDSAT 2 and 3 pass over the same position over the earth's surface every nine days. This repetitive data acquisition capability enables users to monitor changes in land use/cover and water characteristics over time.

A demonstration project plan will be formulated for the analysis of multidate LANDSAT data for the State of Hawaii. An identification of user requirements for specific monitoring applications will be used in evaluating the potential utility of LANDSAT's monitoring capability.

Developing an "In-State" Analysis Capability

LANDSAT data analysis to date have been conducted at NASA's Ames Research Center where state-of-the-art data analysis computer facilities are available. If an operational State LANDSAT processing and analysis system is to be established, however, State agencies will need to develop computer-capabilities to handle LANDSAT data locally. In order to accomplish this, it will be advantageous to the State to implement, during the current investigative phase, an effective and efficient program for accessing the Ames Research Center's computer facilities from Hawaii. Specifically, this would involve linking a remote computer terminal in Hawaii to NASA's computer facilities. This will allow the State to systematically plan for installing an operational LANDSAT computer analysis facility in Hawaii.

One possibility for implementing this concept is through the use of the communications relay capabilities of the Applications Technology Satellite (ATS). The ATS would enable the State to "communicate" directly with NASA computers. A cooperative State-NASA experiment has, therefore, been proposed which will enable the State to evaluate the feasibility of utilizing the satellite communications approach to conducting "in-State" LANDSAT data analysis. This experiment, scheduled to begin in early 1979 will be a key determinant in establishing the economic feasibility of an operational State LANDSAT information system.

Economic Evaluation

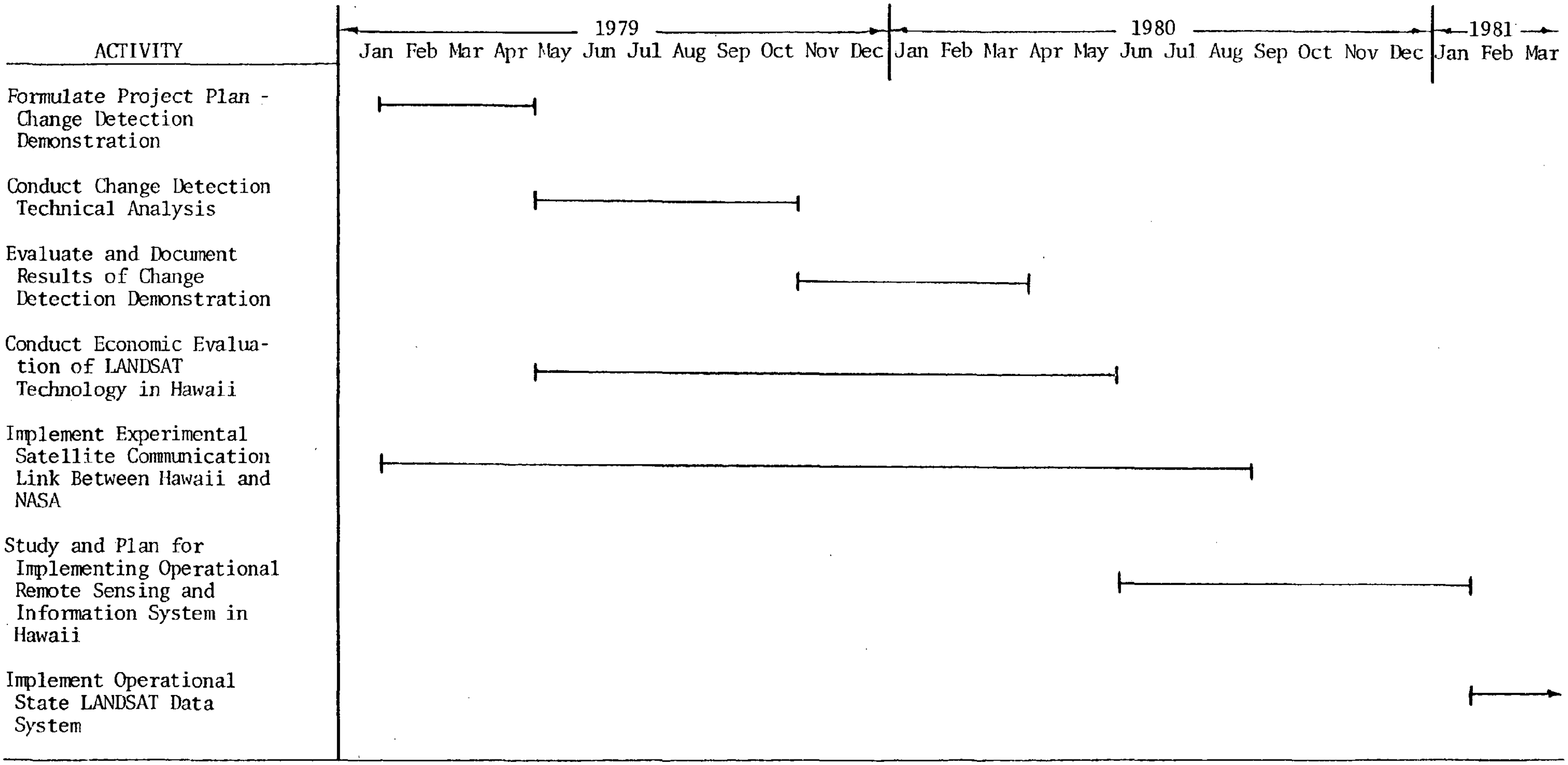
A justifiable LANDSAT data processing and analysis system should establish its economic value by demonstrating its ability to provide earth resources information in a more cost-effective manner than conventional data gathering techniques such as "windshield" surveys.

As such, the Ad Hoc Committee will be assisted and guided by the NASA staff in conducting a cost-effectiveness analysis of a State LANDSAT data collection and processing system. This analysis will include a comparison of costs between LANDSAT and conventional resource data acquisition methods.

It is recognized, of course, that LANDSAT cost-effectiveness will vary for each type of LANDSAT application (e.g., monitoring, inventory, mapping). It is anticipated, therefore, that an overall cost-effectiveness assessment of a Hawaii LANDSAT system will require an economic analysis for a number of demonstration applications.

A summary of the forthcoming program tasks is shown in Figure 9.

Figure 9
Future Activities Time Chart



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