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THE TEN-ECOSYSTEM STUDY INVESTIGATION PLAN

Job Order 75-315

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Prepared By

Lockheed Electronics Company, Inc.
Aerospace Systems Division
Houston, Texas

Contract NAS 9-12200

For

EARTH OBSERVATIONS DIVISION

SCIENCE AND APPLICATIONS DIRECTORATE

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

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13. ABSTRACT

With the continental United States divided into ten forest and grassland ecosystems, the Ten Ecosystem Study (TES) is designed to investigate the feasibility and applicability of state-of-the-art automatic data processing remote sensing technology to inventory forest, grassland, and water resources by using Land Satellite data. The similarities and anomalies among the ten ecosystems will be studied; and from this study, technical analysis problems will be identified and solutions recommended. The study will serve as a prelude to a possible future nationwide remote sensing application to inventory forest and rangeland renewable resources. This plan describes project design and phases, the ten ecosystems, data utilization and output, personnel organization, resource requirements, and schedules and milestones.

14. SUBJECT TERMS

Forestry	Automatic data processing	
Rangeland (grassland)	Land Satellite	
Remote sensing applications	Ecosystems	

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1. SUMMARY

To prepare for future nationwide forest and grassland renewable resources inventories using automatic data processing (ADP) remote sensing technology, the National Aeronautics and Space Administration (NASA) and the U.S. Department of Agriculture, Forest Service (FS) have agreed to divide the continental United States into ten forest and grassland ecosystems for careful study. By examining the similarities and anomalies in the different ecosystems, such a study could serve as a prelude to a possible future NASA applications systems verification test (ASVT) project on forestry applications and could also aid the FS in designing remote sensing methods to implement the *Forest and Rangeland Renewable Resources Planning Act* of 1974 (Public Law 93-378). This act requires the periodic assessment and programming of nationwide activities and opportunities grouped into these six systems: (1) timber, (2) range, (3) water, (4) fish and wildlife, (5) outdoor recreation and wilderness, and (6) human and community development. The first three systems appear to be more amenable and potentially achievable via remote sensing methods. Hence, the Ten-Ecosystem Study (TES) was designed to meet the following primary objectives:

- To investigate the feasibility of state-of-the-art ADP remote sensing technology to inventory forest, grassland, and inland water areas by administrative boundaries in the ten ecosystems of the United States.
- To identify problems and recommend solutions that are specific of individual sites or ecosystems.
- To recommend the definition and requirements of an integrated ADP system to support a nationwide forest and grassland ASVT.

As a feasibility study, TES is designed to play two roles:

- It will perform a *type separability study* to determine the range of possibilities for mapping forest, grassland, and inland water details and the corresponding mapping accuracies obtainable by ADP analysis of remotely sensed data.
- It will conduct a *simulated inventory study* to determine how successfully ADP technology can extend limited ground truth for large area inventories.

Secondary objectives of TES include the determination of type mapping accuracies at different hierarchic levels, the establishment of best season(s) for Land Satellite (Landsat) analysis for each of the ten ecosystems, and the transfer of the project findings to the FS via evaluation workshops.

TES will be an ADP study using Landsat multispectral scanner (MSS) data as the mapping data base. Aircraft photographs will be used in a supportive role and will be interpreted as the basic source of ground truth. To provide a common basis of ground truth imagery, primarily NASA 1:120 000-scale color-infrared (CIR) photographs will be used.

The two modes of *type separability* and *simulated inventory* operation in TES logically define the extent of ground truth to be employed in the study. The former will utilize all available ground truth, whereas the latter will seek to use as little ground truth as is necessary. The former ends with the determination of possible ADP classification accuracies of known features (better known as *training signatures*), and the latter is evaluated by the overall map accuracy and acreage accuracy of final products produced by extending a prespecified amount of ground truth to the entire site.

As presently structured, TES will be conducted between April 1976 and September 1978, using a total of a 17 man-year-equivalent (MYE) effort in addition to management and supporting services. Peak loading requires 10 project personnel for part of fiscal year (FY) 1977.

2. INTRODUCTION

2.1 FORESTRY APPLICATIONS PROGRAM (FAP)

FAP was established in 1971 at the Johnson Space Center to support the Southern Region of the FS and, since 1976, to support FS Headquarters. The objectives of FAP are to develop, test, evaluate, and transfer remote sensing technology to the FS for inventorying forest resources (refs. 1 to 3).

Between 1971 and 1975, many small and localized studies were conducted, using no more than a 3-MYE effort and investigating no more than 50 000 hectares (125 000 acres), except in the 1975 Tri-County Pilot Study (TRICPS), as indicated in reference 4. TRICPS concerned an area of 650 000 hectares (1 600 000 acres). ADP and conventional photo interpretation analyses were performed in feasibility studies and technology development.

From FAP's ADP analyses (refs. 4 to 8), the following feasibility conclusions have been drawn. (a) Type mapping accuracies larger than 90 percent are feasible at gross forest and grassland levels using Landsat MSS data. (b) Type mapping by administrative boundaries is feasible using the IMAGE-100 interactive computer system. (c) Areal measurements larger than 650 000 hectares (1 600 000 acres) are feasible to within ±7-percent of U.S. forest survey figures on gross levels. (d) Position accuracy is feasible to within ±2 picture elements (pixels) of ground position; for example, ±160 meters (±524 feet) on Landsat. (e) Accuracies for detailed types are feasible at a range between 60 to 90 percent using aircraft MSS data at an 8-meter (26-foot) resolution, and 5- to 10-percent improvement is possible with resolution degradation of up to 24 meters (78 feet). (f) Post-processing via a FAP-developed algorithm allows the production of "cleaner" resource maps and improvement of classification performance.

Other researchers have drawn similar conclusions (refs. 9 to 18). Reference 9 is a report on Landsat MSS studies of Georgia, South Dakota, and Colorado, in which ADP classification results were reported to range from 56.2 to 97.9 percent for softwood and 46.0 to 75.1 percent for hardwood. Reference 10, a study on forest and grassland in southeast Texas, reports 91-, 70-, and 85-percent accuracies for softwood, hardwood, and grassland, respectively. Reference 11 cites 89- and 93-percent accuracies for softwood and hardwood, respectively, in mapping the wetlands of southeastern Michigan. Temporal classification results of softwood and hardwood in Ontario, Canada, were within 90.9- and 74.9-percent accuracies, respectively (ref. 12). Two studies of a mountainous terrain site in Colorado using multiple data sets (Landsat and Skylab data) cited comparable accuracies (refs. 13 and 14). References 15 and 16 reinforce the conclusion of data resolution degradation ranging from a few meters to 64 meters (208 feet); the best ADP analysis was obtainable at approximately 32 meters (104 feet). In references 15, 17, and 18, postprocessing by relabeling classification maps by some kind of majority rule is advocated. These conclusions, among others (refs. 19 to 21), have demonstrated that analyses of satellite remote sensing data hold promise for monitoring certain types of nationwide or even global resources.

2.2 TES BACKGROUND

After performing small, localized studies and deriving the aforementioned feasibility conclusions, FAP personnel felt the necessity to investigate the feasibility of intermediate- to large-sized application studies. This need was further justified after the *Forest and Rangeland Renewable Resources Planning Act*, Public Law 93-378, was passed in 1974, authorizing the FS to assess and plan programs for monitoring and utilizing nationwide resources. This act requires nationwide activities grouped into six systems: (1) timber, (2) range, (3) water,

(4) fish and wildlife, (5) outdoor recreation and wilderness, and (6) human and community development. The first three systems appear to be more amenable and potentially achievable via remote sensing methods. Hence, a study to investigate forest and grassland ecosystems and to determine the feasibility of using a unified set of remote sensing methodology for forest, grassland, and inland water inventories in these ecosystems seemed to be a logical extension of FAP's investigations. Such a study, along with others, will aid the FS in designing remote sensing methods to implement the Act. In addition, it will serve to identify an overall ADP system for a possible NASA ASVT project on forest and grassland, following the current Large Area Crop Inventory Experiment (ref. 21) beyond 1978.

To extend and improve the technology and methodology developed in previous investigations (refs. 4 to 18), this new study should specifically (1) test and evaluate the feasibility of using a unified set of methods and procedures in a nationwide study; (2) identify and recommend solutions to analysis problems that are specific of different ecosystems in the United States; (3) determine the type mapping accuracies at different levels of hierarchy in the ecosystems; (4) determine the season(s) that offer the greatest potential for type mapping; and (5) check, streamline, and develop procedures culminating in the definition and requirements of an integrated ADP system to support a future ASVT.

NASA and the FS have jointly determined that the vegetation cover types in the 49 states of the continental United States can be categorized into ten ecosystems (see section 4) for such a study, even though the *Resources Planning Act Assessment* (ref. 22) divides the United States into 43 vegetation systems. Each ecosystem is different because of its unique stand composition, terrain, aspect, elevation, soil, and management practices and thus needs to be studied separately. For this reason, TES was initiated.

3. TES

3.1 OBJECTIVES

TES is an ADP study using Landsat data, supporting aircraft imagery, and ancillary information for performing a forest, grassland, and inland water inventory of chosen sites within the ten ecosystems in the United States. Ancillary information includes data on the site/ecosystem obtained via resident foresters, statistical publications, literature, and qualitative information obtained from the site familiarization trips.

The primary objectives of TES are to

- Investigate the feasibility of state-of-the-art ADP remote sensing technology to inventory forest, grassland, and inland water areas by administrative boundaries in the ten ecosystems of the United States.
- Identify problems and recommend solutions that are specific of individual sites or ecosystems.
- Recommend the definition and requirements of an integrated ADP system to support a nationwide forest and grassland ASVT.

Secondary objectives of TES include:

- Determining type mapping accuracies at different levels of hierarchy in the ecosystems.
- Establishing the season(s) that offer the greatest potential for type mapping in each ecosystem.
- Providing the FS with project findings and conducting evaluation workshops.

3.2 SCOPE

One site from each of the ten ecosystems in the United States will be studied.[1] Each site will cover one county or 360 000 hectares (900 000 acres), whichever figure is smaller. The establishment of best season(s) will be based on preliminary analysis of eight or less dates spread throughout the year, whereas only two date-data sets will be finally analyzed. Classification maps on test sites will be statistically evaluated, and feature acreages will be compared to established inventory figures. A total of a 17-MYE effort will be expended between April 1976 and September 1978, with a peak of 10 project personnel required in early 1977.

TES will be an ADP study using Landsat MSS data as the mapping data base. TES scientists, aided by FS foresters resident at or near the sites, will use aircraft photographs in a supportive mode as the basic source of ground truth and analyze them by photo interpretative methods. To provide a common basis of ground truth imagery, primarily NASA high-altitude flight 1:120 000-scale CIR photographs will be used. When available, color or black-and-white, small- or large-scale photographs collected by the FS will also be used to supplement the NASA high-altitude flight photographs. To further supplement information obtainable by photography, a site familiarization trip for each site will be made by TES scientists at the beginning of each site analysis. To aid ADP analysis, TES personnel will also utilize remote sensing application publications, research reports, and personal knowledge from FS contacts.

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[1]It turned out that one site was selected to represent two ecosystems; hence, only nine different test sites were required.

3.2.1 TES AS A FEASIBILITY STUDY

Webster's dictionary defines *feasible* as "possible, reasonable, and capable of being used successfully." As a feasibility study, TES is designed to play two roles.

- It will perform a *type separability study* to determine the range of *possibilities* for mapping forest and grassland details and the corresponding *reasonable* mapping accuracies obtainable by ADP analysis of remotely sensed data.
- It will conduct a *simulated inventory study* to determine how *successfully* ADP technology can extend limited ground truth for large area inventories.

These two modes of operation will be reflected in the different technical approaches used in the TES.

3.2.2 EXTENT OF GROUND TRUTH

It is well known that if 100 percent ground truth were available, an ADP analysis would peak its performance. In the *type separability study* mode, all available ground truth must be used to determine classification accuracies of forest and grassland features. In the *simulated inventory study* mode, the effectiveness of remote sensing techniques must be studied, and a limited prespecified amount of ground truth can only be used in ADP analysis, which is evaluated by the overall map accuracy and acreage accuracy.

In the TES, "ground truth" is the interpreted aircraft photograph. In the *type separability* mode, all interpretation will be used for spectral signature acquisition and classification accuracy determination. In the *simulated inventory* mode, aircraft imagery corresponding to 10 percent of the site [approximately one-half of a 1:120 000-scale, 23-centimeter (9-inch) frame located on a representative portion of the site] will be used for training field selection and spectral signature acquisition. The MSS data of the whole site will be classified using these signatures. If time permits, 10 percent of the ground truth area will be varied in size and location to determine the optimal mix of ground truth and ADP analysis.

3.3 ANALYSIS LEVELS

TES will investigate three levels of hierarchy (presented in table I). The Level I features are forest, non-forest, and water. In Level II, forest is categorized into softwood and hardwood, non-forest into grassland and "others," and water into census water and non-census water. Level III features are comprised of timber and grassland types specific of the ecosystem (see section 4).

TABLE I.– TES ANALYSIS LEVELS

Level I	Level II	Level III[a]
Forest	Softwood Hardwood	Timber types specific of ecosystem; e.g., pine, spruce, fir under softwood; oak, maple, elm under hardwood; also mixed softwood-hardwood under softwood
Non-forest	Grassland	Grassland and shrubland types specific of ecosystem; e.g., sagebrush, piñon, juniper, mountain meadows, annual grassland
	"Others"	(Including cropland, urban, bare soil, rock, etc.)
Water	Census water Non-census water	

[a]See section 4.

The difference between census water and non-census water lies in the size requirement. The former refers to streams, sloughs, estuaries, and canals more than 200 meters (660 feet) in width and lakes, reservoirs, and ponds more than 16.2 hectares (40 acres) in area. The latter has width and area requirements smaller than 200 meters and 16.2 hectares; and for the compatibility with Landsat data resolution, the minimum width and area requirements will be 1 pixel, approximately 60 meters (200 feet) and 0.4 hectare (1 acre). The minimum size requirement for all other features will be 1 pixel.

In the *type separability* mode of TES, Level II and then Level III classification accuracies will be investigated. When Level II accuracies are reasonable (i.e., in excess of those prescribed in section 3.4), the *simulated inventory* mode will be performed on Level II features. Level I inventory will be the aggregation of Level II inventories and thus will require no additional machine processing.

3.4 PERFORMANCE CRITERIA

In the *type separability* mode, TES will use classification accuracies for evaluation. Level II analysis will be performed first. If the resulting accuracies exceed those prescribed in table II, Level III analysis will be performed. Because Level I features are aggregates of Level II features, Level I accuracies will necessarily be higher than Level II accuracies. Level III accuracies are expected to be lower than Level II accuracies (see ref. 4). Table II tabulates the minimum accuracy requirements. Notice that census water and non-census water are put into the category of water in this table because there is no spectral difference between the two features. Census water and non-census water are thus treated as the same class in the data processing. It is during the postprocessing activity that census water is separated from non-census water based on the size requirements (see section 8).

TABLE II. - MINIMUM ACCURACIES CONSIDERED REASONABLE IN TES LEVEL II ANALYSIS

	Softwood	Hardwood	Grassland	"Others"	Water
Softwood	90%	90%	90%	90%	90%
Hardwood		90%	90%	90%	90%
Grassland			80%	75%	80%
"Others"				75%	80%
Water					90%

In the *simulated inventory* mode (i.e., when the *type separability* study indicates that it is possible to identify Level II features with accuracies higher than those prescribed in table II), TES will produce classificaiton maps and areal figures of Level II features over the entire study site. The accuracy of map with statistical qualification will be evaluated using a statistical sampling approach. Areal figures will be compared to published figures.

4. STUDY SITES

4.1 THE TEN ECOSYSTEMS

For the present TES study, ten broad forest and grassland ecosystems for the continental United States, shown in figure 1, will be defined (ref. 23) based approximately on the map (ref. 24) of forest types. Table III briefly describes each ecosystem and its characteristic vegetation species.

4.2 SITE SELECTION CRITERIA

A potential study site that best meets the following criteria will be selected from each of the ten ecosystems.

1. The selected site will cover one county or less, such that each site is no more than 60 by 60 kilometers (37 by 37 miles) or 360 000 hectares (900 000 acres), or less than 30 by 30 kilometers (19 by 19 miles) or 90 000 hectares 225 000 acres). This limit is imposed by the amount of data that could be processed on the IMAGE-100 with the time and manpower defined for TES. The minimum size of 30 by 30 kilometers corresponds to approximately one IMAGE-100 screenful of Landsat data, or 485 by 485 pixels. The maximum size limit of 60 by 60 kilometers (37 by 37 miles) is governed by ADP throughput rates.

2. The site will fall well within the defined boundaries of the ecosystem in order to avoid problems of transition areas and will be representative of the ecosystem.[2]

3. A portion of the site (about 50 percent) will include a national forest. The national forest will provide an area with extensive inventory and ground truth information.

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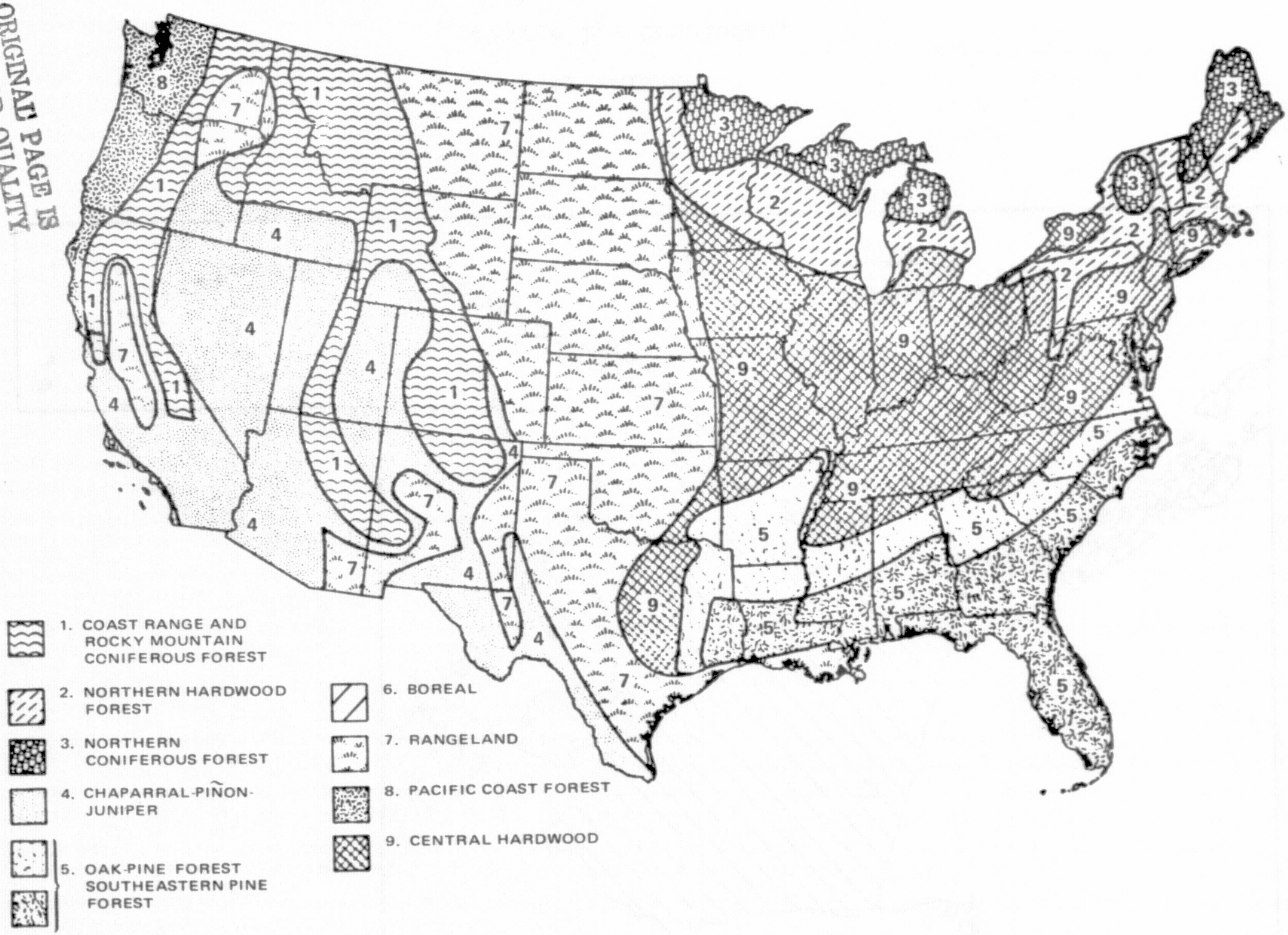
[2]The Kershaw County, South Carolina, site is exceptional and falls within the two ecosystems of oak-pine ecosystem and southeastern pine ecosystem with virtually no transition zone.

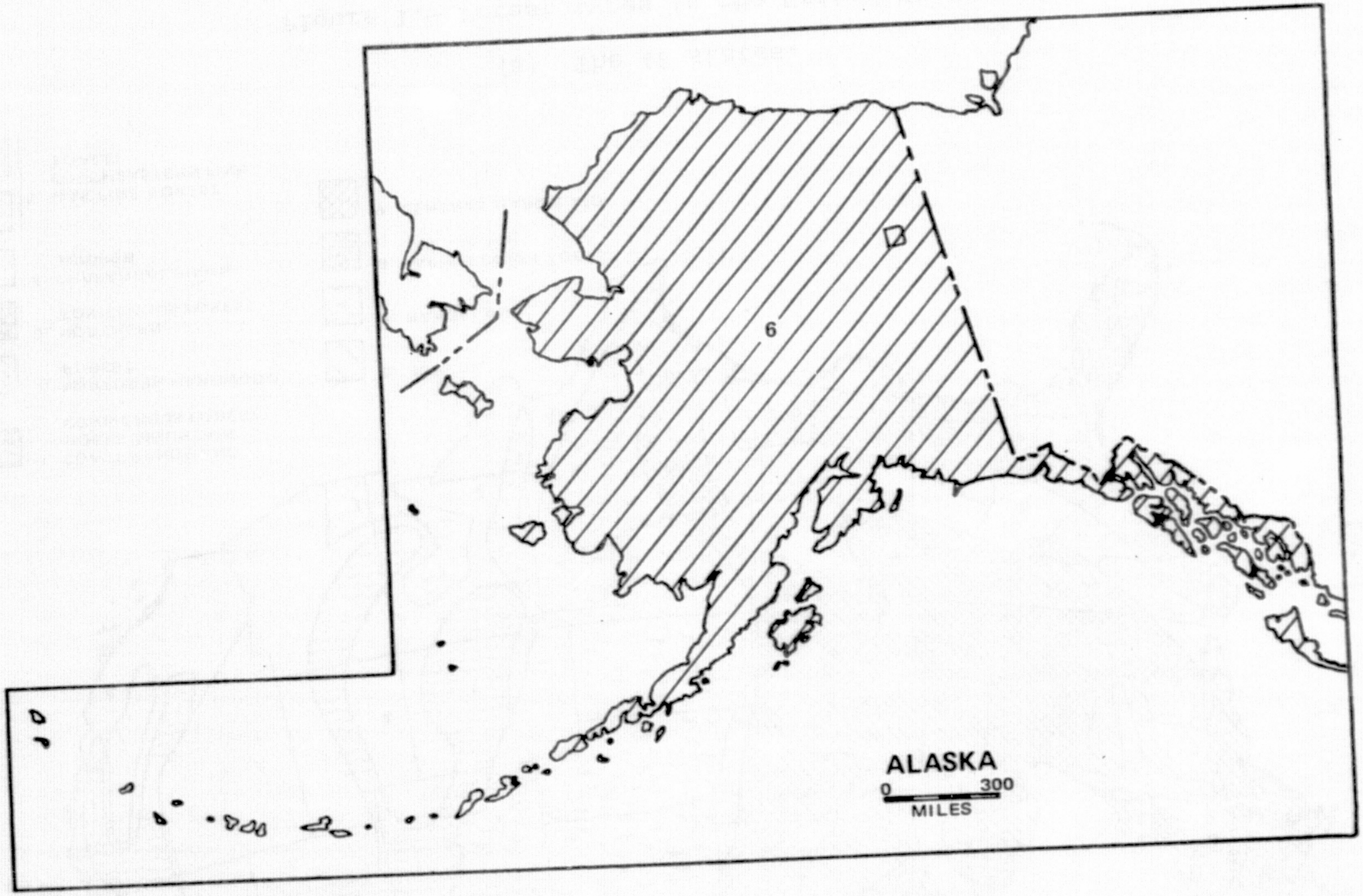
TABLE III.– DESCRIPTION AND DOMINANT VEGETATION SPECIES IN THE TEN U.S. ECOSYSTEMS

Forest ecosystem	Description	Species
Coastal range and Rocky Mountain conifer	Encompasses a complex of forest types covering the Rocky, Cascade, Sierra Nevada, and northern coastal mountain ranges	Douglas fir, western yellow pines, larch, and western white pine
Northern hardwood	Covers much of the northeastern United States from Maine to Minnesota and reaches down the Appalachian Mountains into West Virginia and North Carolina	Beech, birch, maple, hemlock, pine, aspen, and black cherry
Northern conifer	Stretches westward from Maine along the northern tier of the United States to the prairie in Minnesota	Spruce, balsam fir, pines, aspen, and birch
Chaparral/piñon/juniper	Is the noncommercial forest land scattered from the southern California coast throughout the Southwest	Piñon, single-leaf pine, juniper, scrub oak, and sagebrush
Oak-pine	Extends along the Piedmont Plateau and the upper coastal plain from New Jersey to East Texas	Oak, hickory, and southern yellow pine
Southeastern pine	Occurs on the Atlantic and Gulf coastal plains from North Carolina to Texas	Southern yellow pine, bald cypress, the bottom land oaks, tupelo, sweet gum, and hickory
Boreal	Occurs in the State of Alaska	Hemlock, spruce, birch
Rangeland	Occurs in the midwest prairie states from the Canadian border through Texas, with isolated occurrences in some western states	Prairie shortgrass, blue grama grass, bunch grass, sagebrush, mesquite, and southwest broad-leaf woods
Pacific coast	Comprises the coniferous forest along the Pacific northwest coast west of the Cascade Mountain range. Is separated from the coastal range and Rocky Mountain coniferous forest because of the intervening major species and the lower elevations	Douglas fir (coastal form), western red cedar, Sitka spruce, redwood, western hemlock, fir, and red alder
Central hardwood	Reaches from the mid-Atlantic region westward to the prairie states	Oak, hickory, basswood, maple, elm, tulip poplar, pine, and black gum



(a) The 48 states.

Figure 1.– Forest types in the United States.



(b) Alaska.

Figure 1.– Concluded.

It will also afford the opportunity for TES scientists to interface with the FS scientists resident in the national forest area in data processing, evaluation, and site analysis and to transfer project findings. This offers the potential for excellent field background for the test site analysis and evaluation of operational technology applications.

4. At least 80 percent of the site must have NASA high-altitude CIR photographic coverage at a scale of 1:120 000. This requirement is necessary to insure a uniform "ground truth" base for all sites. The data will be used for site familiarization, location of typical forest, grassland, and water features, ADP classification design and evaluation, and the preliminary selection of best season(s) for ADP analysis. Other sources of photography [e.g., the FS, Agricultural Stabilization and Conservation Service (ASCS), and U.S. Department of Agriculture] will be used in the TES when they are available; but they will not be the primary data base for the stated purposes.

5. If possible, sites should be located where recent, current, or near-future forest management planning activities are conducted. These locations would provide good ancillary data for TES analysis. In addition, the usefulness of Landsat ADP analysis results could be evaluated by those same foresters.

6. Selected potential sites must have the following Landsat coverage:

   - Site located on one frame
   - $\leq$10-percent cloud cover
   - Temporal coverage, preferably in spring and summer
   - Three good bands per frame, two of which are bands 5 (0.6 to 0.7 micrometer) and 7 (0.8 to 1.1 micrometers)

4.3 SELECTED SITES

Based on the selection criteria, ten preliminary sites were selected. The site selection was finalized after a cooperative evaluation by FAP and the FS; in particular, by the Renewable Resources Supply and Evaluation Techniques Program group at Fort Collins, Colorado. Table IV shows the size of the major county in the sites, geographic location, the national forests located in the sites, the latest NASA photographic mission, and the elevation range in the sites. An abrupt physiographic feature in site V has created a sharp and distinct separation of the oak-pine ecosystem and the southeastern pine ecosystem, with virtually no transition zone between the two. For this reason, it was possible to require only nine test sites to represent the ten ecosystems.

TABLE IV.– THE NINE SITES OVER TEN ECOSYSTEMS AND THEIR DESCRIPTIONS

Site number	Forest ecosystem/study site	Percent of county in study site	Size, acres	Center coordinates of study site, degrees, minutes	National forest	Percent of study site in national forest	Latest NASA photographic mission	Date of coverage	Percent of study site covered	Photographic scale	Range in elevation, ft
I	Coastal and Rocky Mountain conifers/Grand County, Col.	40	1 186 368	4007N10557W	Arapaho	50	248 and 76-096	08/15/73 06/26/76	40 and 100	1:120 000; and 1:120 000, 1:60 000	5000 to 13 000
II	Northern hardwood/ Warren County, Pa.	100	579 200	4144N07916W	Allegheny	65	166	05/17/71	100	1:120 000	837 to 1961
III	Northern conifer/St. Louis County, Min.	40	3 899 072	4753N09212W	Superior	40	TBF	TBD	TBD	TBD	1280 to 1475
IV	Chaparral/San Doval County, N. M.	80	2 377 088	3545N10637W	Santa Fe	70	248	08/02/73	100	1:120 000	5200 to 11 200
V	Oak-pine/Kershaw County, S. C.	95	499 840	3420N08035W	None	0	TBF	TBD	TBD	TBD	220 to 500
	Southeastern pine/Kershaw County, S. C.	95	499 840	3420N08035W	None	0	TBF	TBD	TBD	TBD	220 to 500
VI	Boreal/Ft. Yukon, Alaska	TBD	TBD	6641N14325W	Proposed Porcupine	100	TBF	TBD	TBD	TBD	400 to 1000
VII	Rangeland/Weld County, Col.	20	2 561 024	4045N10420W	Pawnee National Grasslands	100	211	09/21/75	100	1:120 000	5200 to 5700
VIII	Pacific Coast/Jefferson County, Wash.	60	1 155 328	4737N12358W	Olympia	50	73-074A	05/11/73	100	1:120 000	0 to 6700
IX	Central hardwood/ Washington County, Mo.	100	486 400	3757N09559W	Clark	50	289	10/09/74	100	1:120 000	800 to 1370

Code: TBD = to be determined.
TBF = to be flown.

5. DATA UTILIZATION AND OUTPUT

5.1 LANDSAT DATA

TES will primarily analyze Landsat-1 or Landsat-2 MSS data. Landsat-1 and Landsat-2 have an identical MSS with four channels covering the following spectrum: channel 4 (0.5 to 0.6 micrometer), channel 5 (0.6 to 0.7 micrometer), channel 6 (0.7 to 0.8 micrometer), and channel 7 (0.8 to 1.1 micrometers). Channels 1, 2, and 3 are assigned to return beam vidicon data which are not employed in TES. Details on Landsat sensor systems and platforms can be found in references 21 and 25.

Temporal data sets will be used for each site. Each set consists of two dates/seasons of MSS data as determined in a preliminary analysis. Temporal analysis will be performed to investigate its improvement over single-date ADP analysis. The specific date data sets for each site will be reported in TES site reports.

To determine the dates of the digital MSS data to be used in ADP analysis, eight or less frames of Landsat imagery will be preliminarily screened. These frames are in false-color transparencies in 23- by 23-centimeter (9- by 9-inch) formats. A complete list of these data sets is given in reference 26.

5.2 AIRCRAFT IMAGERY

CIR aircraft imagery will be used to support ADP data analysis by aiding the selection of training fields and the evaluation of classification maps. The primary imagery source is from recent NASA aircraft missions. The scale of this imagery is 1:120 000; the imagery was taken with Kodak film type 2443 and a Wratten 12 filter, resulting in an effective wavelength spectrum of 0.5 to 0.9 micrometer. The coverages over each site can be found in table III and in reference 26.

5.3 ANCILLARY DATA

Ancillary data will be used to support ADP data analysis. The data include topographic quadrangle sheets, county highway maps, geologic and hydrologic data, FS timber type maps, the ASCS statistical publications, state almanacs, data resulting from the personal knowledge of the resident foresters and scientists, and published remote sensing literatures. A complete list of these data and their use can be found in the TES procedures document (ref. 27) and in reference 26.

5.4 OUTPUT PRODUCTS

Primary output products from the TES are the project plan, procedures document, site reports, and interim and final reports. State-of-the-art remote sensing ADP technology will be assessed and analyzed in the final report. Identification and recommendation of solutions to ADP problems that are specific of site/ ecosystems will be included in the final report.

Selected statistical summaries of feature acreages and classification maps will be included in the final report. Wherever possible, statistical figures will be compared to historical data from the FS and ASCS. Maps will be evaluated by a statistical sampling procedure (section 8 and reference 27).

A workshop will be held in August 1977 to discuss the interim status and progress of the TES. A second workshop will be held in September 1978 to transfer project findings and final recommendations to the FS and other interested parties.

6. PROJECT PHASES AND PERSONNEL ORGANIZATION

6.1 PROJECT PHASES

The TES will have three phases: Phase I is the planning and data acquisition phase for the investigation; Phase II is the data reduction phase pertaining to the analyses of the nine sites; and Phase III will contain the final analysis, reporting, and evaluation workshops.

Phase I is composed of the following tasks.

I.1 Project planning

I.2 Technical procedures documentation

I.3 Technical procedures testing and timing

I.4 Site selection and acquisition of imagery and ancillary data

I.5 Preliminary photo interpretation analysis

I.6 Acquisition of digital data

Phase II is composed of the following tasks.

II.1 Data compilation and site familiarization

II.2 Preprocessing

II.3 Processing

II.4 Postprocessing (and outputs production)

II.5 Evaluation

II.6 Preparation of site reports

Phase III is composed of the following tasks.

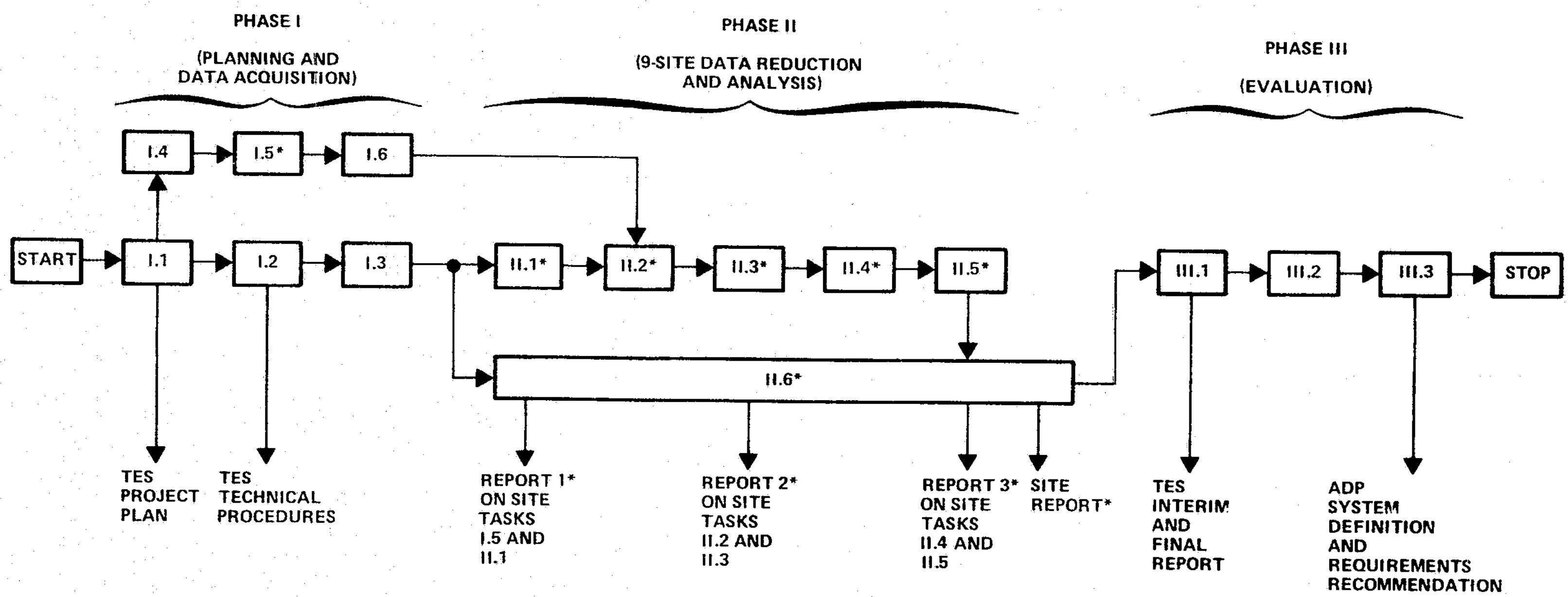
III.1 Analysis and project report preparation

III.2 Evaluation workshops

III.3 ADP system definition

6.2 PROJECT FLOW

The sequential flow of tasks is shown in figure 2. During Phase I, the data processing/analysis procedures will be developed, based on the experience and recommendations from previous FAP investigations (refs. 4 to 8). In particular, TRICPS (ref. 5) documented a set of ADP procedures. The final report of TRICPS (ref. 5) suggests procedural changes and improvement which need further testing and documentation. Multitemporal analysis is also to be attempted in TES instead of single-date analysis in TRICPS. Site characteristics in the ten ecosystems other than the southern pine ecosystem are also different from the TRICPS study site; thus, modified analysis procedures are needed. The exact timing and practicability of these improved procedures will be thoroughly tested, the results of which will be input to the final scheduling of the Phase II study. Test sites were selected according to the criteria set up in section 4.2 and finalized with the FS as presented in section 4.3. Ancillary data (such as soil surveys; topographic maps; timber type maps; administrative type forest maps; and geological, meteorological, and hydrological data) will be ordered. Past literature on analysis of sites will be searched and evaluated (see ref. 27). Aircraft photographs and Landsat false-color imagery will be ordered and screened; they cover these sites on the available multiple dates during the I.5 task of preliminary photo interpretation analysis. With the interpretation of aircraft photographs as "ground truth" and a comparison of the ground truth to the eight interpreted data sets of Landsat imagery, final decision will be made on two best dates of Landsat data of each site (see ref. 27). The corresponding digital data will then be ordered. Note that the I.5 preliminary photo interpretation analysis should not be confused with the *type separability study*, the latter being caused during the II.3 processing task of Phase II. The main purpose of I.5 task is to determine the best two dates of MSS data for ADP analysis.



*Repeated for each site.

Figure 2.— Project flow for TES tasks.

Phase II is the data reduction phase; it consists of six sets of tasks, II.1 through II.6. The data reduction of each of the nine sites (ten ecosystems) will undergo the same six sets of activities but is staggered with respect to one another. (See section 9 for Level II schedules.) For example, task 1 of site II will not start until task 1 of site I is complete and task 2 of site I commences. Each Phase II task is tentatively planned for 1-1/2 months; the timing is tentative until the completion of the Phase I.3 task of testing and timing.

Task II.1 of Phase II is the compilation of all data pertaining to a site and consists of a 1-week site familiarization trip, the results of which will be additional data and information to be compiled about the site. The FS will expedite the collection of information by FAP scientists during these site familiarization trips. Task II.2 (preprocessing) includes registration, input of administrative boundaries, and identification of training areas. Task II.3 (processing) pertains to the process when training signatures are developed and used in data classification. The *type separability study* will be performed here by examining all available training data, after which the *simulated inventory* mode will be performed. Task II.4 (postprocessing) refines classification outputs from task II.3 and outputs classification maps and postprocessed classification maps in the form of color-coded maps and line boundary maps. Task II.5 evaluates these classification maps against ground truth, the latter being composed of FS-supplied information and interpreted information from aircraft imagery. The last task, II.6, consists of a series of four reports on each site. These site reports will be input to Phase II for final analysis and reporting.

Phase III begins in the middle of the data reduction tasks, when an interim report will be prepared; and a workshop will be held in August 1977. After all processing activities have been performed, TES will be concluded by a final analysis and report on the study and summary of feasibility conclusions. The problem areas concerning ADP processing over the different ecosystems will be listed, with recommendations on tentative solutions. Accuracy figures on acreage estimates and representative map output products will be included in the final report. Using the final report as a base, a workshop was held with the FS to transfer the TES project findings to the FS. Finally, the definition and requirements will be recommended for an integrated ADP system to support a nationwide forest and grassland ASVT.

6.3 PHASE II PERSONNEL ORGANIZATION

6.3.1 THE SITE-FUNCTION-TEAM CONCEPT

A site-function-team concept for Phase II project personnel organization has been developed:

a. To provide continuity for data analysis within each site, thus providing in-depth perception of problems and solutions that are specific of individual sites.

b. To provide continuity for each data processing/analysis task from site to site throughout the TES, thus resulting in the best streamlined and unified analysis procedures in each task.

c. To increase flexibility in the mixing of jobs and assignments, thus minimizing possible tedium and interpersonal conflicts while maximizing opportunities for technical competence and self-realization.

d. To ensure that the absence of a few (because of sickness, vacation, on-loan status, leave) will not render severe impact on site analysis and project progress.

Table V illustrates the site-function-team concept. The nine sites are denoted by the Roman numerals, I, II,···,IX, across

TABLE V.– PERSONNEL ASSIGNMENT USING THE SITE-FUNCTION-TEAM CONCEPT

Task†	Site								
	I	II	III	IV	V	VI	VII	VIII	IX
A	1, a, α	2, a, β	3, a, β	4, a, δ	5, a, α	6, a, β	1,* a, γ	2,* a, δ	3,* a, α
B	1, b, γ	2, b, δ	3, b, α	4, b, β	5, b, γ	6, b, δ	1, b, α	2, b, β	3, b, γ
C	1, c, α	2, c, β	3, c, γ	4, c, δ	5, c, α	6, c, β	1, c, γ	2, c, δ	3, c, α
D	1, d, γ	2, d, δ	3, d, α	4, d, β	5, d, γ	6, d, δ	1, d, α	2, d, β	3, d, γ

†The numbers 1 to 6 refer to site scientists; the letters a to d, to specialized analysts; and the Greek letters α to δ, to general analysts.

*Only 6 Site Scientists are needed for 9 sites because of rotation.

the top. The activities are denoted by the Roman capital letters (A, B, C, and D) along the table, corresponding to Phase II tasks II.2, II.3, II.4, and II.5. The manning of tasks II.1 and II.6 is not explained in table V but is discussed in the following paragraphs.

6.3.2 TEAM RESPONSIBILITY POSITIONS

This section further clarifies the titles and primary responsibilities of the four categories of project personnel: site scientist, specialized analyst, general analyst, and site analyst.

6.3.2.1 Site Scientist

The site scientist is a cognizant scientist whose main responsibility is to oversee that analysis activities over a site are carried out from beginning to end. He sees that the overall objectives of the TES are accomplished by drawing conclusions, ensuring quality control, making recommendations, and preparing reports on the site analysis. In addition, he will be responsible for all site administrative matters, including action documentation, resource tracking, management, and scheduling. He needs a fair amount of data processing knowledge, but not the detailed step-by-step knowledge of data processing. A background in natural resources and experience in written and oral presentation are desirable.

6.3.2.2 Specialized Analyst

The specialized analyst specializes in one of the four data reduction activities (preprocessing, processing, postprocessing, and evaluation). He guides and helps the general analyst to perform the data reduction without actually doing the reduction and is responsible for developing training procedures for the TES. The job is to track the status of the data reduction system (i.e., hardware and software), to be aware of difficulties and ways to overcome them in analysis procedures, to develop and follow through on improvements in the software and hardware systems, and to ensure that data reduction procedures are followed uniformly and expedited. He will make formal evaluation and recommendations on the particular function after all sites are completed. A background on the data reduction systems is necessary, and a fair knowledge on the mathematics/programming of the software procedures is desirable. Some photo interpretation experience is also desirable.

6.3.2.3 General Analyst

The general analyst can participate in the four data reduction activities of preprocessing, processing, postprocessing, and evaluation. He needs an operational knowledge of the activities, performs the daily work with the aid of the specialized analyst, and responds directly to the specific site scientist. He will have the opportunity to work with data of almost all the sites and be able to interface with almost everyone in TES. He is probably the analyst to be called for temporary (or future permanent) special job assignment, since he has a working knowledge of all the data processing functions. His background calls for operational knowledge but not necessarily for in-depth knowledge of various systems and procedures.

6.3.2.4 Site Analyst

The main job of the site analyst is to develop procedures for collecting pertinent site ancillary data. This includes developing a plan for the site familiarization trip and coordination with on-site FS scientists. He participates and collects all pertinent information during the trip and recollects and compiles all data and imagery after the trip. He also helps the site scientist to compile the electronic data, ancillary information, statistical publications, maps, and aircraft photographs.

Field experience, discipline knowledge in forestry, biology and geography, and an understanding of the possibility of being frequently on the road are necessary requirements.

6.3.3 SITE-FUNCTION INTERACTION

Each row/column position in the matrix of table V has three entries, lowercase Roman letters, an Arabic numeral, and lowercase Greek letters. These three entries correspond to three team members, each with a different function. The Arabic numeral (1,2,···,6) denotes the site scientist, who takes from end to end all analysis activities of sites I to IX. Because of the possibility in rotation of site scientist assignments, there is a need for only six site scientists instead of nine for all nine sites, as shown in table V. The lowercase letters, a, b, c, or d denote the specialized analyst who specializes in activities A, B, C, or D. The Greek letters α, β, γ, and δ denote the general analyst who is the third constituent of a team in each site activity. Notice the rotation pattern of the general analysts who participate in all tasks and almost all sites working one time or another with all site scientists. The pattern expressed in table V is noted to be one of many possible patterns that satisfy the nonoverlapping requirement of manpower loading when the time scale is visualized in table V. For example, site I, task A (abbreviated I/A), occurs in the first period; I/B and II/A occur in the second period; I/C, II/B, and III/A occur in the third period. That is, at any one time (duration of each planned activity), each of 1,···,6, a,···,d, α,···,δ has only one primary assignment according to the matrix in table V.

Phase II, activity II.1, will be attended by three people for any one site. The site scientist plus two site analysts, denoted by μ and ϕ, will compile the data and information on each site. These three people will take a 1-week trip to the site to (a) familiarize themselves with the site characteristics and anomalies, (b) field-check preplanned locations for the sake of training signatures acquisition and for future evaluation of classification results, and (c) coordinate with onsite FS scientists to gain more knowledge of the site and to gather the pertinent ancillary information from the FS. Because of the sequential nature of the site activities, only two site analysts will be required.

Phase II, activity II.6, consists of a series of four reports on each site. The site scientist will be responsible for this activity with the aid of a publications coordinator. Thus, except in task II.6, all tasks will be manned primarily by three people. Two analysts out of the three (the third being the site scientist) are the main analysis/processing agents. As experience is gained more and more thoroughly during the initial training and Phase II operation, three different agents are less needed in each activity; this will be more so for the specialized and general analysts. Therefore, the absence of one, or even two, agents in each task can be tolerated for a short while without severe impact on overall site analysis project progress. This arrangement also tends to minimize on-the-job tedium and possible interpersonal conflicts because of long-term on-constant-job description interaction. Yet, any particular activity will be carried out with the fullest benefit from thorough experience and expertise. Additionally, the variability in job responsibilities (perhaps the most significant design aspect) affords choice by, and flexible placement of, existing FAP personnel, each of whom has different goals and visions of pride in specific functions.

6.4 TES MANAGEMENT

Overall FAP management is discussed in reference 1. This section only discusses the technical management of the TES. As shown in figure 3, a principal scientist manages all site scientists, site

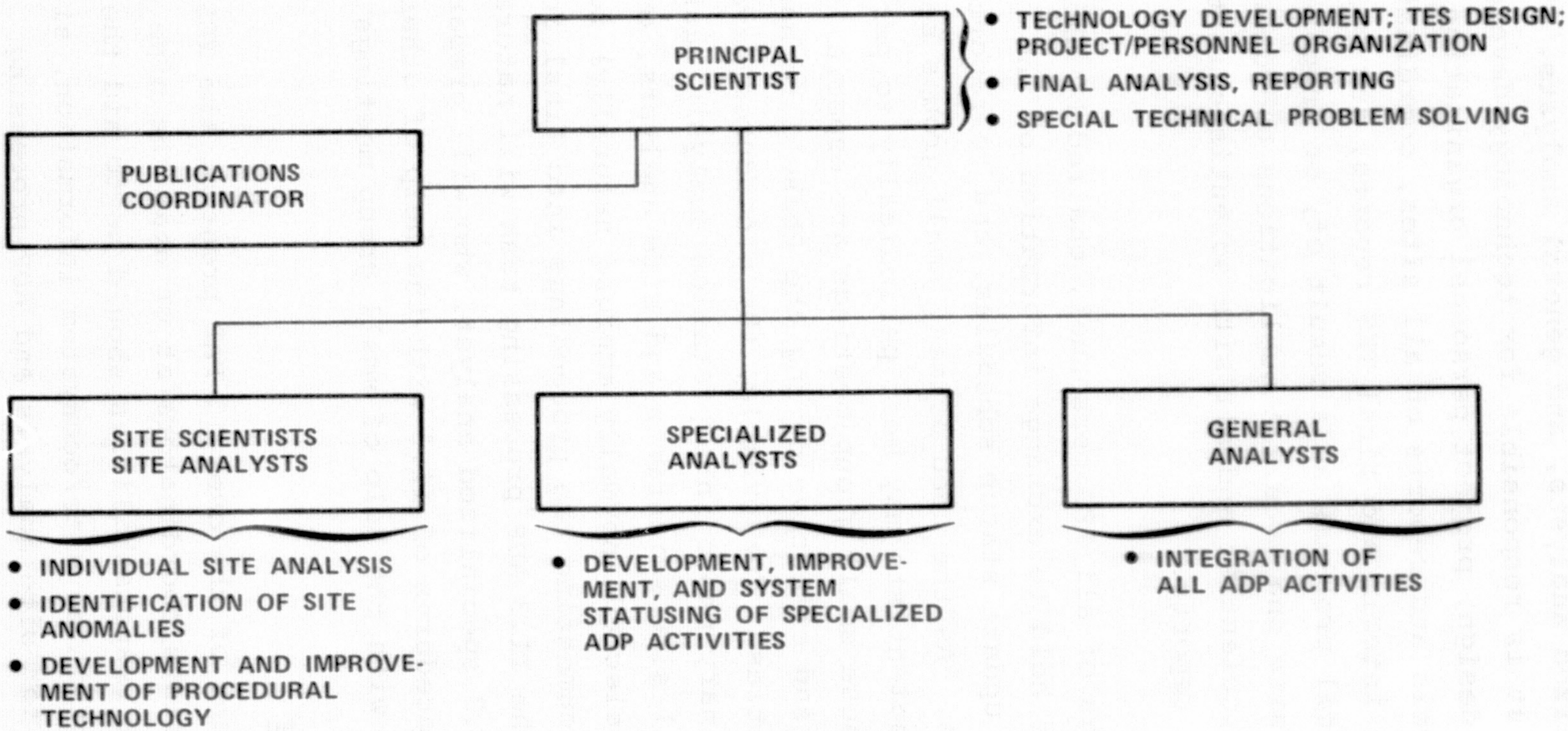


Figure 3.— TES project technical management.

analysts, specialized analysts, and general analysts. The principal scientist is responsible for technology development, TES experimental design, project personnel organization, final approval of analysis and reports on all sites, coordination and production of the interim and final TES reports, and solutions to special technical problems as a result of, or in parallel with, individual site analyses. A publications coordinator will aid the principal scientist and all site scientists in the preparation of project reports.

Weekly TES meetings of all TES personnel, chaired by the principal scientist, will be held to exchange information on the problems and solutions, to update status schedules, and to report on project milestones. As the need arises, small groups selected by the principal scientists may meet periodically to perform special tasks. These small group meetings are especially necessary, productive, and effective during the Phase I technology development activities. For example, the procedures development of the I.5 preliminary photo interpretation analysis task will be discussed by all site scientists and site analysts, out of whom one will be selected (normally emerged naturally) to be responsible for documenting the proceedings into final form. As another example, the II.3 ADP processing task will naturally be assigned to the II.3 specialized analyst, who will prepare the final technical procedures of II.3 with the help of other designated analysts and with the help of small group meetings.

6.5 FS INVOLVEMENT

Besides FS management of the overall FAP program, the TES calls for FS scientists/coordinators at or near the nine selected study sites. Their responsibilities should be to aid the TES site analysts in obtaining site/ecosystem information, site data, and ancillary data for site analysis and ADP processing. They should help the site analysts to coordinate and expedite the site familiarization trip. They should aid the TES in its final evaluation of ADP products by providing additional ancillary information or even possible independent evaluation. The identification of, and liaison with, these FS resident site/ecosystem scientists should initially be made through the FAP project manager. The FS scientists should be invited to the evaluation workshops of Phase III and possible follow-on after the conclusion of the TES.

7. RESOURCE REQUIREMENTS

7.1 MANPOWER

Section 6 has indicated that the TES essentially needs six site scientists, two site analysts, four specialized analysts, and four general analysts, plus the principal scientist and a publications coordinator; FAP project management is additional. However, by the nature of the jobs, the site analysts and the specialized analysts will not require full-time manning. It appears feasible to assign 11 FAP scientists (including one vacant position) to the 16 (6+2+4+4) positions of site scientists, site analysts, specialized analysts, general analysts, and publications coordinator without excessive burden to each individual. That is, some people will have dual assignments, primary and secondary (acting). There will be four primary site scientists, two primary specialized analysts, three primary general analysts, one primary site analyst, and one primary publications coordinator, as shown in table VI.

The TES will require a total of a 17-MYE effort, manned by a peak of 10 people over the period between April 1976 and September 1978. The distribution according to the three phases is a 4 MYE in Phase I (April 1976 to January 1977), an 11 MYE in Phase II (August 1976 to July 1977), and a 2 MYE in Phase III (April 1977 to August 1977 and June 1978 to September 1978) as shown in table VII.

In addition to this 17 MYE are FAP project management (plus secretary) at 1/4 MYE per month (3 MYE per year, 7-1/2 MYE total for TES), and support services including technical publications and cartographic work at 1/4 MYE per month (3 MYE per year; 7.5 MYE total for TES).

TABLE VI.– TES PERSONNEL ASSIGNMENT PLAN FOR PHASE I AND PHASE II DATA ANALYSIS TASKS

Phase I and II tasks	Sites									Position
	I	II	III	IV	V	VI	VII	VIII	IX	
I.5	SS1 SA1 6/15-7/15/76	SA1 SS4 7/1-8/1/76	SS4 SS2 7/15-8/15/76	SS2 STA 8/1-9/1/76	STA SS1 8/15-9/15/76	STA SS4 9/1-10/1/76	SS4 GA3 9/15-10/15/76	GA3 SS2 10/1-11/1/76	SS2 SS1 10/15-11/15/76	Photo interpreter Photo interpreter
II.1	SS1 GA3* STA 8/1-9/15/76	SS3 GA3* STA 9/15-11/1/76	SS4 GA2 STA 10/1-11/15/76	SS2 GA1 STA 11/1-12/15/76	SS1 GA3* SA1* 2/1-3/15/77	STA SS1* – 6/15-8/1/77	SS4 PC* STA 8/1-9/15/77	SS3 SA2 STA 9/15-11/1/77	SS2 GA3* – 11/1-12/15/77	Site scientist Site analyst Site analyst
II.2	SS1 SS3* GA2 9/15-11/1/76	SS3 SS3* GA1 11/1-12/15/76	SS4 SS3* GA1 12/15/76-2/1/77	SS2 SS3* GA3 2/1-3/15/77	SS1 SS3* GA2 3/15-5/1/77	STA SS3* GA1 8/1-9/15/77	SS4 SS3* SA2* 9/15-11/1/77	SS3 SS3* GA3 11/1-12/15/77	SS2 SS3* GA2 12/15/77-2/1/78	Site scientist Specialized analyst General analyst
II.3	SS1 SA2 SA2* 11/1-12/15/76	SS3 SA2 GA3 12/15/76-2/1/77	SS4 SA2 GA2 2/1-3/15/77	SS2 SA2 GA1 3/15-5/1/77	SS1 SA2 SA2* 5/1-6/15/77	STA SA2 GA3 9/15-11/1/77	SS4 SA2 GA2 11/1-12/15/77	SS3 SA2 GA1 12/15/77-2/1/78	SS2 SA2 SA2* 2/1-3/15/78	Site scientist Specialized analyst General analyst
II.4	SS1 GA1* GA2 12/15/76-2/1/77	SS3 GA1* GA1 2/1-3/15/77	SS4 GA1* SA2* 3/15-5/1/77	SS2 GA1* GA3 5/1-6/15/77	SS1 GA1* GA2 6/15-8/1/77	STA GA1* GA1 11/1-12/15/77	SS4 GA1* SA2* 12/15/77-2/1/78	SS3 GA1* GA3 2/1-3/15/78	SS2 GA1* GA2 3/15-5/1/78	Site scientist Specialized analyst General analyst
II.5	SS1 SA1 SA2* 2/1-3/15/77	SS3 SA1 GA3 3/15-5/1/77	SS4 SA1 GA2 5/1-6/15/77	SS2 SA1 GA1 6/15-8/1/77	SS1 SA1 SA2* 8/1-9/15/77	STA SA1 GA3 12/15/77-2/1/78	SS4 SA1 GA2 2/1-3/15/78	SS3 SA1 GA1 3/15-5/1/78	SS2 SA1 SA2* 5/1-6/15/78	Site scientist Specialized analyst General analyst
II.6	SS1 PC 3/15-5/1/77	SS3 PC 5/1-6/15/77	SS4 PC 6/15-8/1/77	SS2 PC 8/1-9/15/77	SS1 PC 9/15-11/1/77	STA PC 2/1-3/15/78	SS4 PC 3/15-5/1/78	SS3 PC 5/1-6/15/78	SS2 PC 6/15-8/1/78	Site scientist Publications coordinator

*Secondary (acting) assignment.
4 Primary site scientists: SS1, SS2, SS3, SS4
2 Primary specialized analyst: SA1, SA2 (vacant)
3 Primary general analyst: GA1, GA2, GA3
1 Primary site analyst: STA
1 Primary publications coordinator: PC

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TABLE VII.– MANPOWER REQUIREMENTS IN MAN-MONTHS AND MYE FOR TES IN ADDITION TO FAP MANAGEMENT AND SUPPORT SERVICES

Phase	Total manpower, man-month (MYE)	Manpower per month (man-month)																													
		FY 1976			Transition			FY 1977												FY 1978											
		A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
I	52(4)	6	9	9	9	7	6	3	3																						
II	136(11)*					2	3	6	7	6	6	8	10	9	7	7	6	6	8	6	7	8	7	7	7	5	3	3	2		
III	24(2)														3	3	3	3										3	3	3	3

*The numbers showing manpower per month have been rounded off; hence, total manpower shown here does not equal their sum.

7.2 INSTRUMENTS

Special data processing and optical photo interpretation instruments are required in TES. Their requirements are tabulated in table VIII by the instrument-hour or by job requirements.

7.3 SPECIAL DATA AND TRAVEL BUDGET

Because of the bulk of data required by TES and the large number of site familiarization trips in TES, their budgets are estimated (see tables IX and X). The data are to be ordered in Phase I of TES. The site familiarization trips are scheduled to take place between August 1976 and November 1977 (see section 9). A one-man 3-day trip per site is also planned at the end of each site analysis for results verification and evaluation. This budget amounts to approximately another $3600.00 during the period of February 1977 through July 1978.

TABLE VIII.– TES SPECIAL INSTRUMENT REQUIREMENTS

Special instruments	Requirements										Units of requirement
	FY 1976	Transition	FY 1977				FY 1978				
	4th qtr		1st qtr	2nd qtr	3rd qtr	4th qtr	1st qtr	2nd qtr	3rd qtr	4th qtr	
Image 100	130	195	195	195	156	156	195	195	130	120	Console hour
Passive Microwave Imaging System Data Analysis Station	52	78	78	78	78	78	78	78	78	78	Console hour
Bendix 100/NOVA 1220				4	6	6	6	6	4	2	Job } One job is 60 by 60 kilometers at three scales of 1:250 000, 1:125 000, and 1:60 000
Gerber plotter				4	6	6	6	6	4	2	Job }
Earth Resources Interactive Processing System		39	39	39	24	39	39	24	12		Console hour
FR-80 microfiche		52	52	52	30	52	52	30	15		Frame
Production film converter		52	52	52	30	52	52	30	15		Job, each 500 by 500 pixels
Univac 1108/1110 computer	6	8	8	8	10	10	10	10	10	6	Console hour
Kargl reflecting projector/rectifier			30	30	30	30	30	30	30		Console hour

TABLE IX.– BUDGET REQUIREMENTS FOR ORDERING SPECIAL DATA FOR TES

Data type	Price per unit, dollars	Overlap allowance	Number of data sets per site	Number of sites	Total price, dollars
Digital Landsat MSS data	200 / four tapes for one Landsat frame	Additional 50%	3	9	8,100
Landsat false-color 9-by-9 inch imagery	60 / Landsat frame, special process		8	9	3,600
Aircraft CIR 9-by-9 inch imagery	12 /frame		25	9	2,700
DAS film transparency	5/transparency		40	9	1,800
9-by-9 inch color prints for site analysis and report	10/frame		25	9	2,250
35-mm slides	0.4/frame		100	9	360
				Total ($)	18,810

TABLE X.— TRAVEL BUDGET REQUIREMENTS FOR SITE FAMILIARIZATION ON TRIPS FOR TES FROM AUGUST 1976 TO NOVEMBER 1977

[3 people per trip, 5 days per trip]

Round trip air fare	$250.00	
Subsistence and lodging	25.00	× 5 (5 days per trip)
	$375.00	
Three people per trip	× 3	
	$1,125.00	
Car rental	+ 150.00	
	$1,275.00	
Small aircraft cruise	+ 240.00	(@ $40/hour @ 6 hours)
	$1,515.00	
Total 9 trips	× 9	
	$13,635.00	

8. TECHNICAL APPROACHES

In addition to the general description in section 6.1, a few areas need further discussion. These are tasks I.5, II.1, II.2, II.3, II.4, II.5, and II.6, which correspond to preliminary photo interpretation and analysis, data compilation and site familiarization, preprocessing, processing, postprocessing (and outputs production), evaluation, and documentation.

Because of the length of these discussions and the need for complete procedures documentation, these detailed discussions are documented separately in reference 27.

9. SCHEDULES AND MILESTONES

The TES activities will be tracked on an integrated system of schedules Levels I, II, and III. These three levels of schedules will provide standard displays of time phase activities and events, which will assist managers in decision-making and project statusing in various degrees of details. Level I and II schedules are displayed in figures 4 and 5. Level III schedules will only be found in TES procedures document (ref. 27) and concern tasks I.5, II.1, II.2, II.3, II.4, II.5, and II.6, all of which are per-site 6-week repetitive activities.

Four assumptions have been made in developing all project schedules: (a) hardware is available at the time requested, (b) turn-around time for batch computer runs is no more than 48 hours, (c) data/imagery requested is delivered on time, and (d) project staffing remains at the levels required.

For a general description of the three phases of the TES, refer to section 6.1.

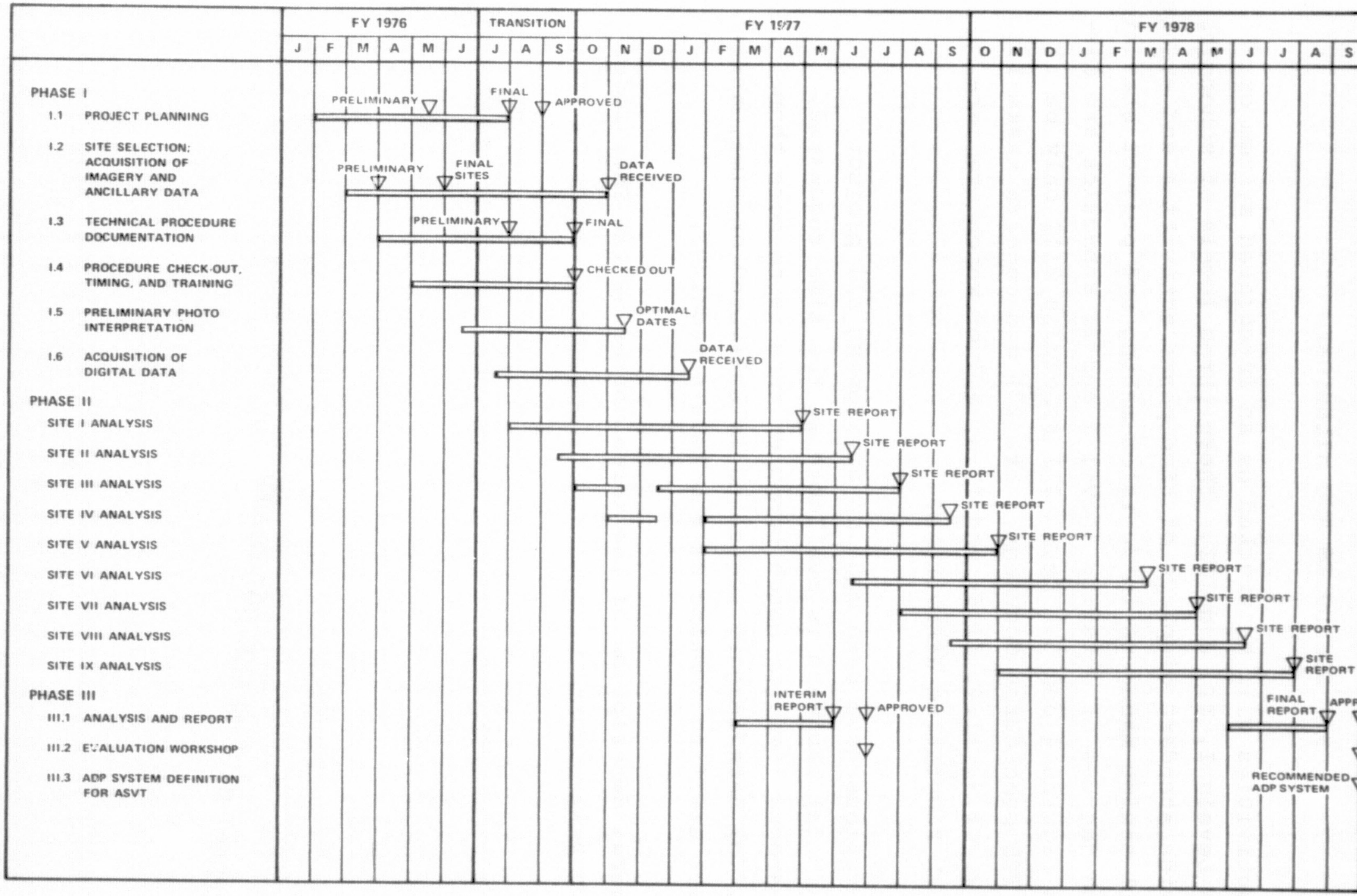

Figure 4.— TES Level I schedule.

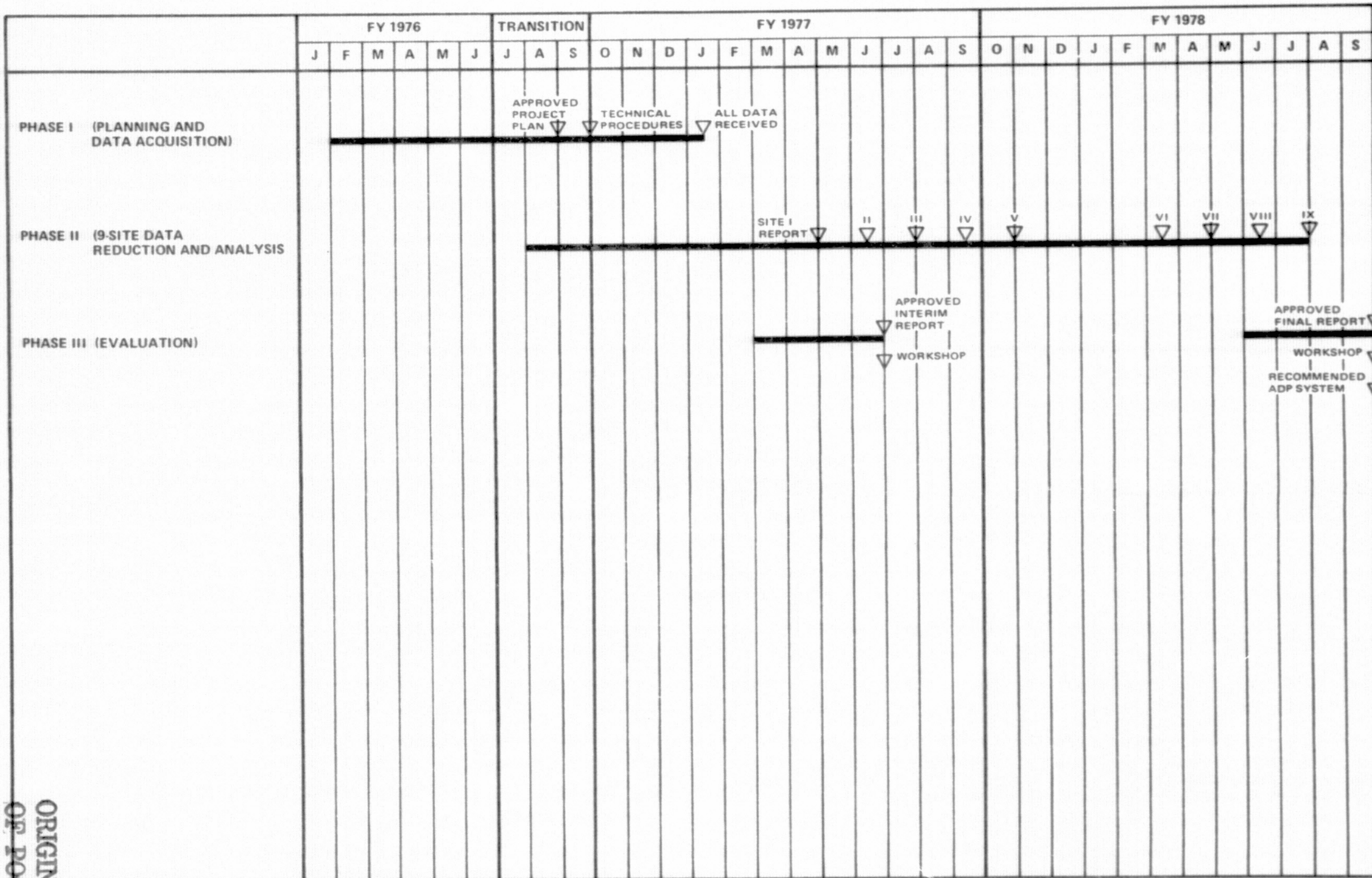

Figure 5.— TES Level II schedule.

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