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FOREST RESOURCE INFORMATION SYSTEM

PHASE II DEMONSTRATION REPORT

including the period

1 January 1979 to 30 April 1979

Prepared for

NATIONAL AERONAUTICS and SPACE ADMINISTRATION

Johnson Space Center
Earth Observations Division
Houston, Texas 77058

Contract: NAS 9-15325
Technical Monitor: R. E. Joosten/SF5

Submitted by:

The Laboratory for Applications of Remote Sensing
Purdue University
West Lafayette, Indiana 47906

Principal Investigator: R. P. Mroczynski

A

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INDEX

P

LIST OF FIGURES

LIST OF TABLES

FRIS PROJECT OVERVIEW

The Forest Resource Information System Project (FRIS) is a cooperative effort between the National Aeronautics and Space Administration (NASA) and St. Regis Paper Co. (STR). Purdue University's Laboratory for Applications of Remote Sensing (LARS), under contract to NASA, will supply technical support to the project.

FRIS is an Application Pilot Test (APT) Project funded by NASA. The project is interdisciplinary in nature involving experties from both the public and private sectors. FRIS also represents the first APT to involve a large broad base forest industry (STR) in a cooperative with the government and the academic communities.

Purpose

The goal of FRIS is to demonstrate the feasibility of using computer-aided analysis techniques applied of Landsat Multispectral Scanner Data to boraden and improve the existing STR forest data base, thereby creating the foundation of a dynamic information system. The successful demonstration of this technology during the first half of the project will lead to the extablishment by STR of an independently controlled operational forest resource information system in which Landsat data is expected to make a significant contribution. FRIS can be viewed by the user community as a model of NASA's involvement in practical application and effective use of space technology. Additionally, FRIS will serve to demonstrate the capability of Landsat MSS data and machine-assisted analysis technology to private industry by:

- o Determining economic potentials,
- o Providing visibility and documentation, and
- o The ability to provide timely information and thus serve management needs.

The ultimate long term successfullness of FRIS be measured through future development of remote sensing technology within the forest products industry.

Scope

FRIS is funded as a modular or phase project with an anticipated duration of three years. The original project concepts were developed in 1973, and a formal project plan was submitted to NASA by STR in 1976. The project officially began in October 1977 after the signing of a cooperative agreement between NASA and STR; and after the completion of contractual arrangements with Purdue University.

Organization

The organization of FRIS is depicted in the chart that follows. Since FRIS is a cooperative involving three independent agencies, a steering committee consisting of a project manager from each institution was formed to provide for overall guidance and coordination. Operationally, both STR and LARS have project managers and project staff to insure for the timely completion of activities within the project. The NASA technical coordinator monitors project activities and provides a liaison between the STR and LARS staffs. The solid lines on the chart indicate the flow of management responsibility. The dash lines reflect the technical and scientific interchanges between operating units.

FRIS Organization

Steering Committee

ASVT Project Manager
NASA Technical Monitor
FRIS Project Manager

Resource and Technology Department/ STR	NASA Johnson Spacecraft Center	LARS/ Purdue University
Computer Systems		Systems Design
Cartographic Systems		Mapping Unit
Forest Sampling Systems		Classification Unit
Cost Analysis		Cost Unit

ACKNOWLEDGEMENTS

The scope of this report in terms of technical detail and background is well beyond the productive capacity of a single individual. The principal investigator, and editor, are grateful to a number of individuals who have made this, and previous quarterly reports possible. Special thanks are due also to the other members of the FRIS Steering Committee, Bob Barker of St. Regis and Rig Joosten of NASA, for their patience and understanding. The principal investigator is especially indebted to Brenda Prather for her tolerance and patience in typing this manuscript.

Staff contributing to this report include:

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1.0 INTRODUCTION

This report is a review of the past activities and accomplishments of the Demonstration Phase of the FRIS Project. As the project grew, and as the project's staff began to understand both the technology and the application, tasks which had been defined in the Project Plan were adjusted to meet the present situation. Various sections of this report describe in detail these modifications and discuss their overall impact to the Demonstration.

1.1 BACKGROUND AND PHASE II OBJECTIVE

The second Phase of FRIS was defined as a fifteen-month pilot demonstration period. This portion of the project was designed to address the FRIS goal:

> To evaluate existing technology and as appropriate, to develop new techniques of utilizing remotely sensed data to quantify forest resources.

Never before had a project been defined to specifically address the suitability of applying an "off-the-shelf" technology to meet an existing operational industrial forestry need. The demonstration Phase of FRIS filled a number of unique requirements. These were:

- An evaluation of existing technology to meet a well-defined industrial forestry objective;
- Training for the user in applying the technology;
- Training of the technologist in understanding the application, and more importantly the environment in which the technology would be applied; and
- A test bed for developing a future St. Regis remote sensing capability.

In order to meet these requirements the overall demonstration objective was defined:

> To provide St. Regis Paper Company, through a demonstration of computer-aided Landsat analysis, information concerning the economic feasibility and practical applicability of this technology for forest inventory.

Our ability to meet this overall objective is summarized in Section 1.2. Issues that developed during the 15-month demonstration while pursuing this objective are discussed in Section 1.3.

1.2 SUMMARY OF ACCOMPLISHMENTS

The sections that follow will describe in detail the various activities that comprised the Phase II demonstration. A summary of these materials follows:

- o A classification approach for FRIS was defined and tested.
- o Results of three FRIS test sites appear to provide anticipated Level I information.
- o An evaluation procedure has been defined and tested. Although the procedure is "workable", it is time consuming and requires improvements.
- o A FRIS map digitizing approach has been defined and tested and works well.
- o The projects greatest technological challenge appears in the area of Landsat data preprocessing.
- o Ancillary software available from vendors such as Harvard University and M & S Computing may help alleviate some preprocessing hurdles.
- o The confusion associated with Landsat 3 data formats has largely restricted a quicker solution to the preprocessing dilemma.
- o Various geo-referenced data base software systems were evaluated. Examples of one system are presented.
- o A remote terminal to the LARS computer has been installed in Jacksonville, FL as an aid to Technology Transfer.
- o LARS staff have suggested various alternatives for consideration during St. Regis staff deliberations in developing a FRIS preliminary design.
- o Details are presented that describe software components to the system.
- o Preliminary FRIS costs including hardware, software and people are presented.

  A list of technology transfer activities conducted during Phase II is given.

A complete discussion of the above items begins in Section 2.0.

1.3 FRIS TECHNICAL ISSUES

The intention of the demonstration phase of FRIS was to provide an assessment of the feasibility of using computer-aided analysis of Landsat data as a component to a forest resource information system. At the onset of the Project, Phase II was designed as an application of an "off-the-shelf" technology, specifically the LARSYS classification approach, to a user defined need. However, the demonstration was much more involved than originally anticipated. This section will highlight the outstanding technical issues that have developed over the last 15-month period.

Technically, Landsat MSS data and computer-aided analysis techniques are capabile of providing a level of information useful to forest inventory. This fact has been well documented by a number of investigators and is supported by the results presented in Section 2.1 of this report. There are, however, a number of items - albeit issues - that are not extensively referenced in the literature.

During the demonstration phase we have made a hard evaluation of the key issues which are included under the broad categories of; a) Landsat data acquisition, b) Landsat preprocessing and, c) technology transfer. This activity was necessary in order that we could critically evaluate the future of an operational FRIS. Not all of these issues, presented with discussion below, have been resolved to our satisfaction. As we embark upon Phase III, a number of these items remain without solution, therefore leaving our course of action throughout Phase III well defined.

<u>Ability of Landsat data to meet FRIS Timelines</u>

This issue is aimed at general FRIS scheduling. Specifically, the ordering and preprocessing cycle, EDC performance and new Landsat format costs.

A. Can the Landsat data be, selected, ordered and received from EDC, preprocessed, and classified in the timeframe that is required to meet the FRIS updating cycle?

-- The FRIS data window for Landsat are the months of November and December. Shortly after this period the data must be previewed, and scenes selected that cover the required Resource Units with a minimum cloud cover. We are aware of delays in the current acquisition of preview information from EDC that would totally eliminate the utility of Landsat data to FRIS because the data would no longer be timely. Historically, improvements in turnaround are always forth-coming, but factually none have been noted.

-- Following scene selection CCT turnaround must be improved over the current four to six weeks currently being experienced.

-- CCT preprocessing presently requires another four to six weeks depending upon the complexity of the data set required. Possibly new Landsat 3 formats would help shorten this time. However, we have little experience with this new format and therefore must rely on operational and software improvement to meet the three-to-four day turnaround required.

-- Classification of Landsat data currently poses few problems with turnaround. However, we have only classified independent test areas and have not attempted more than one test area at a time. Algorithms other than a maximum likelihood could be employed, and computer time scheduling could be used to help alleviate any serious bottlenecks.

B. New Landsat 3 products may have a positive impact on timeliness if:

a) EDC can provide a check pointed data for the southeast,

b) The new data will help decrease FRIS preprocessing,

c) The cost of the new format data will not outweigh the benefits it provides in timeliness.

-- Since the launch of Landsat 3 we have anxiously anticipated receiving the new geometrically corrected CCT from EDC. We have been disappointed by the delays GSFC and EDC have been experiencing. We are further disappointed with the low priority GSFC has placed on the southeast for digitizing checkpoints which are necessary for EDC to process geometrically corrected data. Currently, it appears that EDC will not be able to provide geometrically corrected data for FRIS by the end of the project. Therefore, we will be required to provide a dual preprocessing implementation to account for old and new format data.

-- Based on our current knowledge we can assume that the new Landsat format will markedly decrease preprocessing time of the CCT and measurably benefit an operational FRIS. However, this assumption cannot be proven until we can actually run tests on the new data. We have requested the GSFC checkpoint two test scenes so that these tests can be run.

-- Landsat data is remarkably inexpensive to purchase. However, this cost is rapidly overshadowed by preprocessing cost that are deemed necessary, prior to analyzing the data. Hopefully, any increased cost of data purchase from EDC will be offset by increases in savings in the preprocessing. If such savings cannot be realized the utility of the new format Landsat will be seriously questioned.

Suitability of Landsat data as input to a Forest Resource Information System.

This issue addresses the precision which Landsat information can be related to the ground, and the acceptance of this form of information to the user.

-- Presently we are able to precision register Landsat data to a rms error of ± .5 pixel to selected map control points. This has been sufficient for most projects, especially when the map control is a 7½ minute USGS quadrangle map. We have maintained this same accuracy for FRIS data, although we question the accuracy inherent in the FRIS maps, especially the positional accuracy of OA boundary lines. Given that we attain this accuracy by selecting a cluster of control points around a Resource Unit, we question if this accuracy can be attained from Landsat 3 data where the control points are scattered throughout the entire scene? Furthermore, is a rms error of ± .5 pixel a reasonable level of detail given in precise base-line maps?

-- Registration to a map base is currently a costly process. These costs may decrease with Landsat 3 data, but registration accuracy may not improve. Is it reasonable to consider new registration schemes to improve overall registration accuracy? Or, conversely is current accuracy suitable for FRIS needs?

-- A map is nothing more than a representation of features on the earth's surface. Classification schemes to make maps, including forest type maps, have weathered the test of time. Obviously, classified Landsat data can be treated as a map, and can provide a subset of the information currently available in map form. Given the accuracy and repeatable quality of the classification can auxillary information be included in the final map manuscript that will make the map acceptable to the user?

Possibility for a Successful Technology Transfer Effort

This issue will address the items that we feel are necessary for a successful implementation of remote sensing technology within the user community.

-- The long-term committment by the user to support the establishment and continued maintenance of a remote sensing analysis capability is critical to a successful implementation. Implicit in this committment is the support of personnel that are capable of maintaining the operational status quo and the encouragement and support of management to develop new capability as the technology grows.

-- User committment may require a deviation from the "norm" of standard business operations. Hardware, software and personnel that are necessary to support a successful operational FRIS may not be the typical components of the in-place corporate computer system environment. These components must be accepted and supported by higher management in order for the benefits of the technology to be realized.

-- The user must be willing to supply a pool of people that can be trained in the fundamentals of remote sensing. Furthermore, the remote sensing staff should be capabile of maintaining and upgrading their users level of knowledge with regards to changes in the technology.

-- Lastly, the user must understand that remote sensing is not a "cook book" technology.

2.0 WORKING UNIT ACTIVITIES

The following sections will serve to document the results of the projects Phase II activities. Generally, all Working Units were able to meet their projected milestones. The only exception was in the area of data preprocessing. Due to the added task of digitizing and overlaying ownership boundaries for all test sites, this activity has lagged behind its projected timeline. However, we feel that sufficient repeatability in classification performance was achieved with three test sites so as not to affect the demonstration.

2.1 CLASSIFICATION UNIT

2.1.1 CLASSIFICATION PROCEDURES

The primary objective of this unit was to provide a demonstration of the utility of computer-aided Landsat classification techniques to industrial forest resource management. To accomplish this goal, four Test Areas have been identified from approximately 680,000 hectares (1.7 million acres) of St. Regis controlled lands in the southeast. Each area will be classified with a set of procedures that were developed during the early stages of Phase II. Through the use of pre-defined classification procedures, we will in effect have replications of classification results for four physiographic sub-provinces in which the St. Regis Paper Company controls land. Evaluation of the performance of these classification replicates will provide the project staff information needed to assess the operational feasibility of computer-aided Landsat analysis to St. Regis forest management operations in the southeast.

In order to insure that only variations in test area differences due to sub-province location and not variations in classification approach would occur, a uniform set of classification procedures were developed. A schematic of this approach is illustrated in Figure 2.1.1-1. The subroutines (identified in the text as *NAME) all currently exist as part of the documentation for LARSYS Version 3.1 or LARSYSDV, the image processing systems developed and used at Purdue. In its current configuration this approach is interactive, that is the analyst can intercede during any portion of the classification sequence. This capability has been a valuable asset to the technology transfer activity. For an operational application the procedures would be streamlined to a point where little interactivity is necessary. Also if feasible the programs should be optimized for the computer in which they would reside.

As a point of departure in developing an operational Landsat image processing and classification subsystem for FRIS, we have identified, in outline form, a procedure for the computer-aided analysis. This scenario is as followed throughout the Phase II classifications.

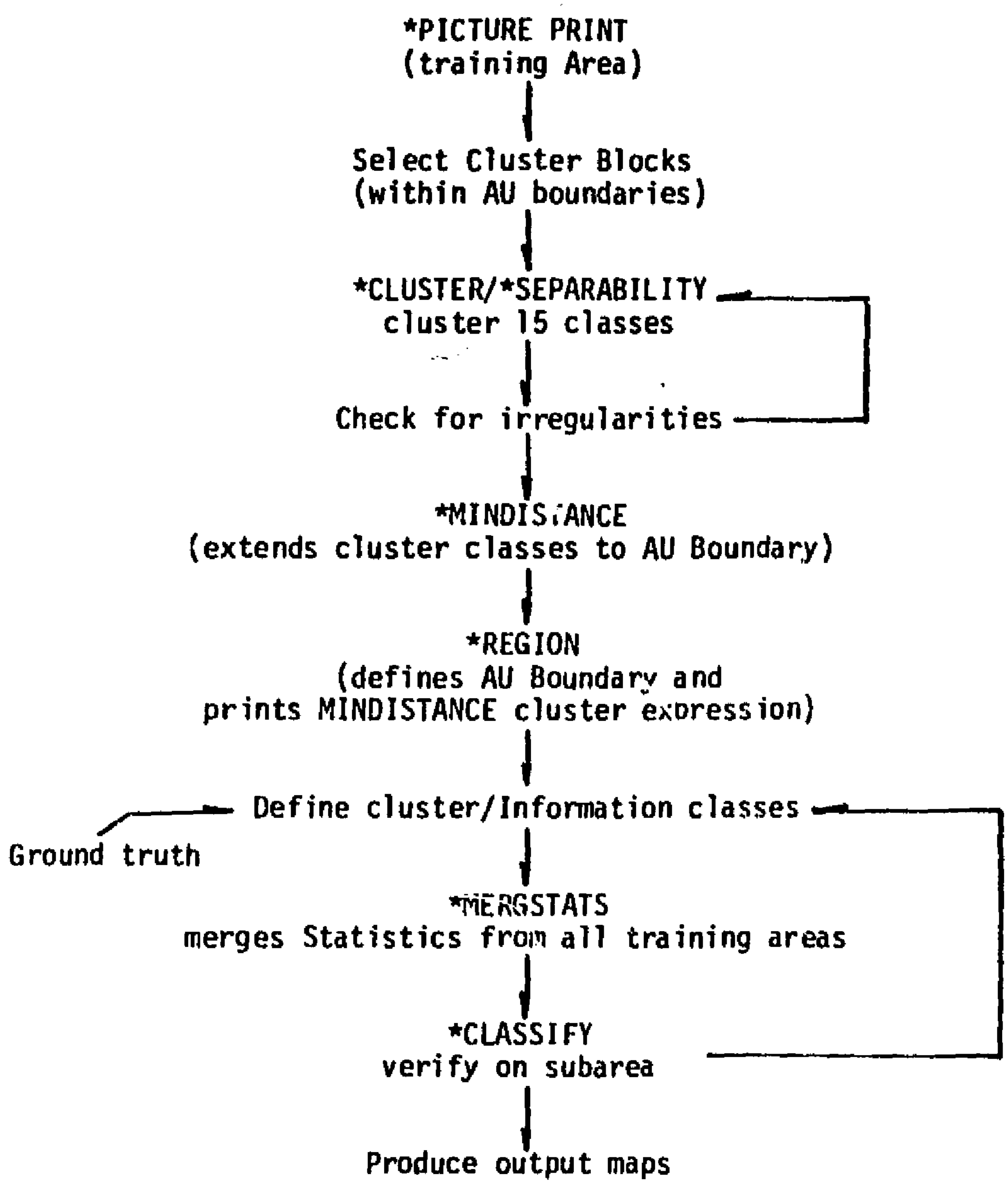


Figure 2.1.1-1 Flow diagram for FRIS classification procedures.

A. Data Set Generation

1. Define permanent training units. These should:

   a. be large and diverse enough to include the range of expected spectral classes; viz covertypes, within the tract.

   b. be geographically representative of the tract.

   c. represent a cross-sectional profile of the tract, both in terms of geology and vegetation.

   d. endeavor to include entire Administrative Units or similar geographically referenced areas.

   e. at the scale of the source maps, be flexible to allow for partial area replacement if required.

2. Clear acetate overlays should be obtained:

   a. for each Unit selected for training.

   b. updated in response to significant cultural change.

   c. permanently archived for immediate reference.

3. Boundary annotation should be made for:

   a. all Administrative Unit boundaries within each test area including the training units.

   b. all AU and Operating Area boundaries.

B. Classification Training Procedures as outlined in Figure 2.1.1-1

1. To be carried out on each training unit within each tract.

2. Generate line printer output (PICTURE PRINT) for each training unit defined in A above.

   a. For a given run (scene) line and column range with appropriate interval will be defined such that the range in both lines and columns will encompass the entire training unit.

   b. Gray scale. *PICTURE PRINT/*G DATA displays only one channel at a time. The channel best suited to locational information should be used; i.e., one of the visible channels. Optional step if area is known. Used primarily to pick cluster blocks.

   c. Unless the analyst has preference, the symbol array offered by the default option is generally satisfactory for this gray scale print-out.

3. Select cluster blocks within selected Administrative Units.

   a. Blocks will fall wholly within the boundaries of the AU in such a way as to be as inclusive as possible.

b. As many rectangular blocks will be generated as needed to properly represent the range of conditions within the unit.

c. For efficiency, Cluster blocks should range from 2500 - 4000 pixels (50 x 50 - 70 x 70) - blocks do not have to be square.

4. Cluster/Separability *CLUSTER/*SEPARABILITY

a. In clustering an arbitrary 15-classes will be designated based upon the standard size defined in 3c above. Other sizes will be considered as exceptions to this rule.

b. Separability will always be run behind Cluster as a matter of form.

*c. Analyst check point - with 15-cluster classes, little or no combining of classes is expected at this stage of the process.

o Check separability means against expected ranges in both the visible and IR for obvious irregularities.

5. Minimum Distance Classifier *MINDISTANCE - Purpose is to extend the 15-cluster classes to the boundaries of the picture-print block.

6. Region definition of Administrative Unit boundaries - *REGION

a. Defines AU within the picture-print block.

b. All area outside Unit boundaries will be null characters to be assigned by analyst.

c. By essentially clustering the entire AU in this fashion, the maximum repeat cluster classes will occur in direct relation to the map overlay. This will facilitate and help verify class definition described and performed later on in these proceedings.

7. Associate Cluster classes with information classes

a. This process done for each training unit within the tract.

b. Statistics deck generated and placed on temporary disk.

c. Utilize data from SEPARABILITY to aid in identifying and combining classes.

d. The overlayed map and associated aerial photographs should also be helpful.

8. Merge the statistics from all training Units.

a. As decks are merged, combine like classes, checklines, with the various unit maps and photographs and other ground truth (updating) as available.

b. Keep going through the MERGE procedure until one classification deck results.

9. Classify - *CLASSIFY

   a. If any doubt exists, classify small sub-unit to verify training.

   b. Select symbols indicative of the classification features to be emphasized.

All classification work to date has followed this approach. Since the classification task is to be operationalized and, therefore, repeatable, we forsee making modifications to the procedures. One of the first major modifications anticipated would involve the CLUSTER sub-routine. Currently only geometric blocks can input to clustering. We would envision a modification that would accept irregular areas, such as AU boundaries to the CLUSTER sub-routine. This change would eliminate the MINDISTANCE and REGION steps from the flow diagram in Figure 2.1.1-1. As experience is gained in performing repeat classifications we anticipate further streamlining of the classification procedures.

2.1.2 DEMONSTRATION RESULTS

During the demonstration, three sites, nos. 1, 2 and 3, Fargo, Picayune, and Columbus, Figure 2.1.2-1 have been classified. Areal comparisons have been made on individual Administrative Units and a summary for each test site has been produced. The individual Administrative Units presented for the Fargo test site are only those with complete boundaries within the test area. This restriction was required because the acreage of Operating Areas within partial Administrative Units could not be determined accurately enough to make the comparisons.

Table 2.1.2-1 presents results of classifications of data collected in December 1976 and December 1977 for Test site 1. Since no changes in Operating Areas are indicated in St. Regis inventory for 1976 or 1977, the areal comparisons are made to only one inventory summary.

Table 2.1.2-2 presents a comparison of areal estimates based on a classification of December 1976 data for Test site 2. The large differences between inventory acreage and classification acreage may be due to management practices and inventory categories used at this site. Many pine stands are in a seed tree category and are carried in inventory as pine, although the stem count is much lower than normally stocked pine stands. This condition is frequently classified into "Other" or "Mixed" classes by the classifier because of the open and scattered crown condition.

Test site 3 results are presented in Table 2.1.2-3. The Landsat classification tends to underestimate pine consistently. However, the Landsat classification also indicates more acreage in the mixed pine/hardwood situation. The acreage discrepency in these classes appears to be a function of mapping criteria, specifically the method used by the field crew when they developed the map. Apparently the field crews tend not to map mixed stands as indicated by the updating information.

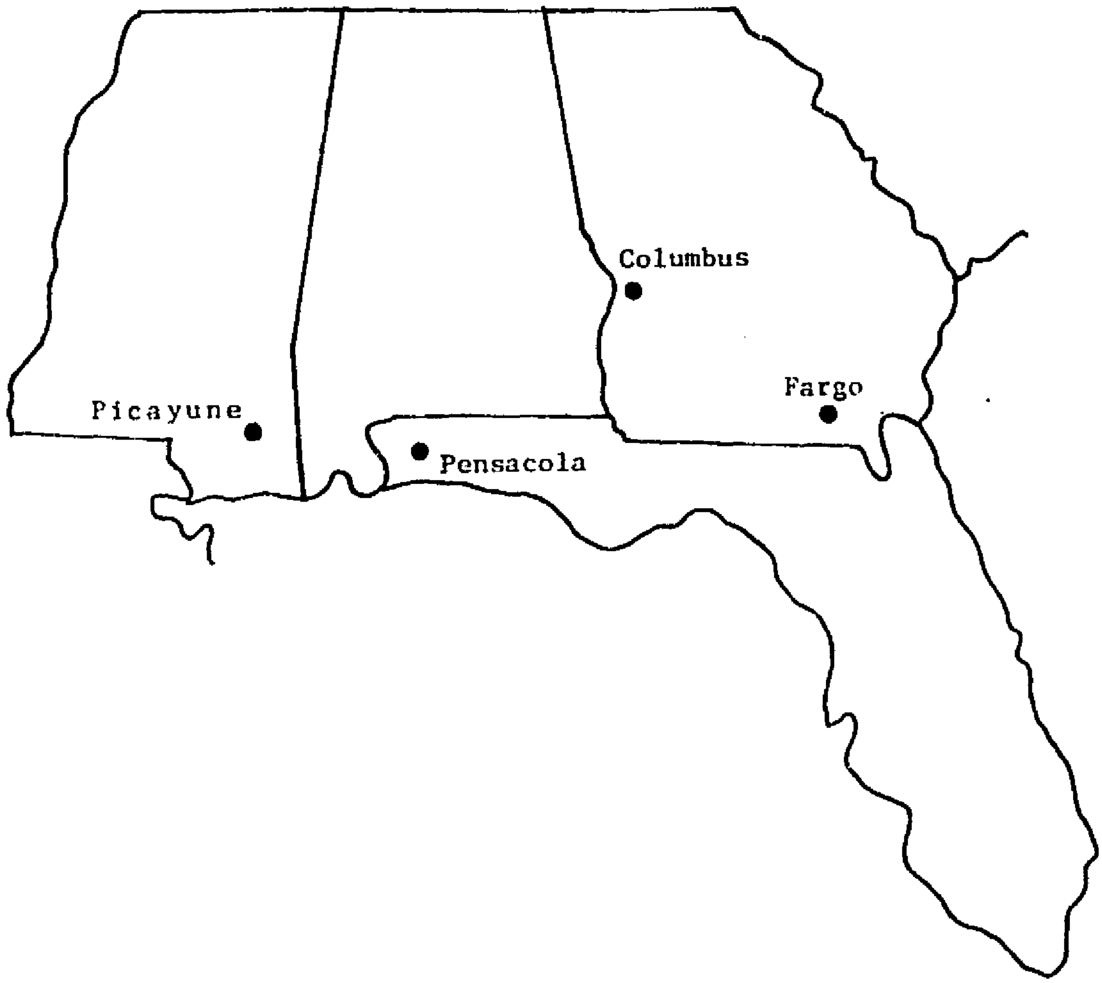


Figure 2.1.2-1 Location of Demonstration Test Sites

Table 2.1.2-1

FARGO TEST SITE

Areal Estimates of Pine vs. Other for 4-channel Classifications of Data Collected December, 1976 and December, 1977.

Administrative Unit	St. Regis Pine	St. Regis Other	Classification (Dec. 76) Pine	Classification (Dec. 76) Other	Classification (Dec. 77) Pine	Classification (Dec. 77) Other
221	1901	1670	2188	1383	1999	1572
222	1574	1052	1621	1005	1326	1300
223	1795	1015	1882	928	1872	938
224	2386	1585	2458	1513	2335	1636
225	1121	1460	1103	1478	1092	1489
226	2341	1393	2098	1636	1993	1741
227	2005	1443	2029	1419	1848	1600
263	1924	1455	1759	1620	1634	1745
264	2394	1630	2268	1756	2367	1657
265	1463	1159	1111	1511	1378	1244
266	2096	1156	1794	1458	1763	1489
267	2347	2054	2276	2125	2220	2181
268	1260	1472	1411	1321	1398	1334
269	1504	1424	1702	1226	1540	1388
270	1758	1562	1821	1499	1658	1662
271	2734	1369	2453	1750	2511	1692
272	836	1524	983	1377	811	1549
273	1770	2277	1819	2228	1657	2390
274	1289	1902	1259	1932	1233	1958
275	1694	1741	1561	1874	1520	1915
276	1494	1394	1587	1301	1367	1521
277	1161	829	1077	913	1057	933
278	1752	2364	1831	2285	1540	2576
279	1265	738	1363	640	1314	689
280	1908	1324	2027	1205	1854	1378
281	2436	1732	2428	1740	2624	1544
282	2216	1886	2528	1574	2360	1742
283	2592	1620	2674	1538	2692	1520
284	388	673	542	519	673	388
Total	52151	42256	51653	42754	49636	44771
% error			(-0.95%)	(+1.18%)	-4.82	+5.95

Table 2.1.2-2

PICAYUNE TEST SITE

Areal Estimates of Pine, Mixed Pine/Hardwood, and Other 4-channel Classifications of Data Collected December, 1976.

	St. Regis			Classification		
AU	Pine	Mix	Other	Pine	Mix	Other
336	1194	1022	82	1320	523	455
337	2569	581	349	2166	760	573
338	1299	474	176	1361	272	316
339	2826	314	121	1812	827	622
340	1968	552	113	790	725	1118
341	2201	835	58	1298	1032	764
342	2244	258	164	1651	362	653
343	861	159	13	475	177	381
352	957	312	96	598	414	353
Total	16119	4507	1172	11471	5092	5235
				-28.8	+13.0%	(+347%)

Table 2.1.2-3

COLUMBUS TEST SITE

Areal Estimate of Pine, Mixed Pine/Hardwood, Hardwood and Other. 4 Channel Classification of Data Collected October 21, 1976.

	St. Regis				Classification			
AU	Pine	Mix	Hdwd	Other	Pine	Mix	Hdwd	Other
41	922		347		918	114	235	2
42	178		551	9	303	234	196	5
43	175	182	875		392	380	459	
44	810	268	218		780	167	349	1
45	583		203		399	153	232	2
46	435		209		379	149	116	
47	1097		303		920	384	92	4
48	664		333		528	305	162	2
49	688		130		464	236	108	10
Total	5552	450	3169	9	5083	2122	1949	26

2.1.3 EVALUATION OF RESULTS

Three classifications were studied: a) a classification of winter 1976 data from Test site 2, b) a classification of winter 1976 and 1977 data from Test site 1, and c) a classification of winter 1977 data from Test site 3. In determining the classification accuracy for all three data sets a procedure of six steps (Figure 2.1.3-1) was followed. In the following paragraphs these steps will be described and the results for the three data sets will be given.

Determine Sample Size

The first step when finding the classification accuracy of a data set is to determine the number of test fields. The confidence interval required for our results will yield this number. That is, St. Regis has required, for ownerships such as Test sites 1, 2 and 3, 95% confidence that the estimate of pine derived from Landsat be within $\pm$ 10% of the inventory pine percent. Mathematically this statement can be written:

(1) $\Pr[|P-p| \geq (.1)P] \leq 1-.95$

where: 1) P is the true (inventory) percent of pine.
2) p is the sample percent of pine.

determine
number of
test fields ⇐ (confidence required)

↓

select test
fields
a. random programs
b. systematic programs

↓

*PRINTRESULTS
map test fields

↓

Overlay
test fields

↓

Record
Landsat and
Inventory categories

↓

Classification Accuracy
and confusion table
from SPSS Crosstabs

Figure 2.1.3-1 Schematic for Accuracy Procedures

In order to derive a formula for the necessary sample size (n) we proceed in the following manner:

<u>Assuming</u> normality, i.e., $p \sim N(P, PQ/n)$

where: $Q = 1 - P$

n is sample size

from (1) we can write

$$Pr\left[\frac{|P - p|}{(1-\frac{n}{N})\frac{\sigma}{\sqrt{n}}} \geq \frac{(.1)P}{(1-\frac{n}{N})\frac{\sigma}{\sqrt{n}}}\right] \leq 1 - .95$$

where: N = the total # of pixels

$$\sigma = \sqrt{\frac{PQ}{n}}$$

by normality we have

$$\frac{(.1)P}{(1-\frac{n}{N})\frac{\sigma}{\sqrt{n}}} = Z_{\alpha/2} = 1.96 \quad \text{from standardized normal tables.}$$

by algebraic manipulation

$$(1.96)^2 = \frac{(.1)^2 P^2 n}{(1-\frac{n}{N})PQ}$$

then

$$(N-n)(1.96)^2 = (.1)^2 \frac{P}{Q} nN$$

and

$$n = \frac{N(1.96)^2}{(.1)^2 \frac{P}{Q} N + (1.96)^2}$$

or

$$n = \frac{(\frac{1.96}{.1})^2 \frac{Q}{P}}{1 + \frac{1}{N}\frac{Q}{P}(\frac{1.96}{.1})^2}$$

The above formula for sample size (n) was applied to all Test sites. The required sample size obtained for Test site 1 was 315 test fields. The required number for Test site 2 was 135 test fields. Test site 3 required 347 samples.

Selection of Test Fields

Two different methods were used to select the test fields. These methods were random sampling (RS) and systematic sampling (SS). Random sampling was used on Test site 1 both dates and Test site 2. Systematic sampling was used to take a second sample of the winter '77 Test site 1 classification. A systematic sample was also used for Test site 3.

When taking either type of sample, single pixels were used as sample units. The systematic sample took every 23rd pixel in the grid shown in Figure 2.1.3-2:

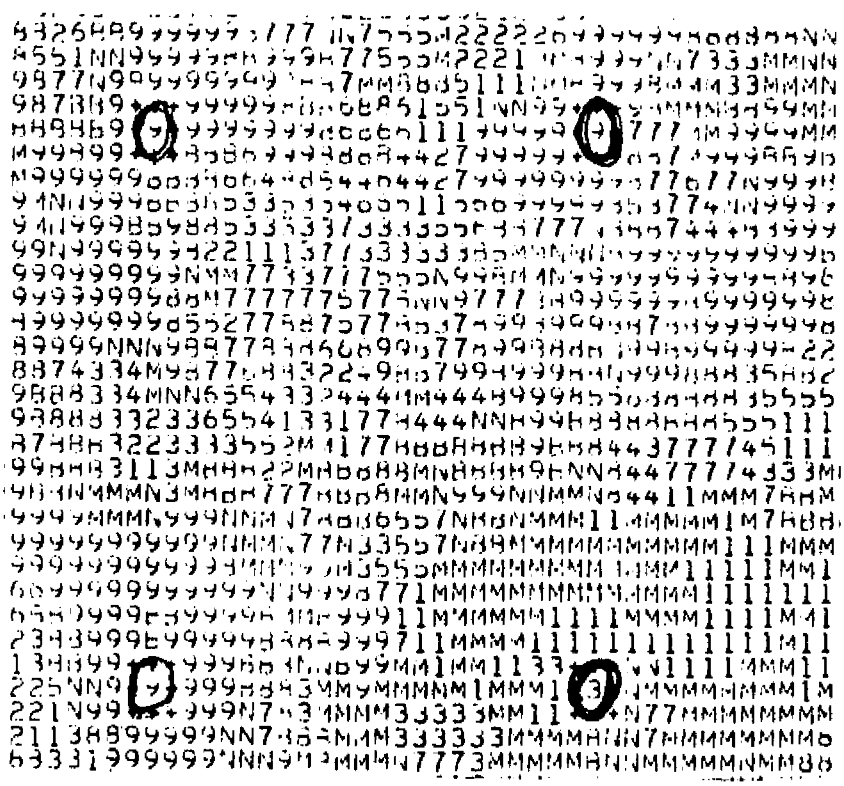


Figure 2.1.3-2 Arrangement of systematic samples in classification.

The number 23 was chosen for two reasons; (1) it would yield a sample size large enough (i.e., n $\geq$ 315), and (2) 23 is a prime number and hence less likely to pick up cyclical error in the data.

Random sampling, although mechanically more difficult to perform, has one important advantage. The sample is totally unbiased by human or machine action. Since there can be a form of cyclical error in Landsat data (due to the fact that 6 scanners record one line of data each), systematic sampling can pose problems.

Systematic sampling, however, has a number of advantages. Samples are more easily taken and often less human error results in finding and recording the samples. Also, every area (e.g., AU) is sampled (not necessarily true in a random sample) and as a result SS can be considerably more precise than a RS.

Both methods of selecting test fields were applied to the Test site 1 classification data. The analyst felt the SS was the preferred method when applied carefully with full knowledge of its cyclical nature.

PRINTRESULTS

The computer program *PRINTRESULTS mapped the SS test fields as shown in Figure 2.1.3-2. Figure 2.1.3-3 shows a portion of a map produced by *PRINTRESULTS with RS test fields.

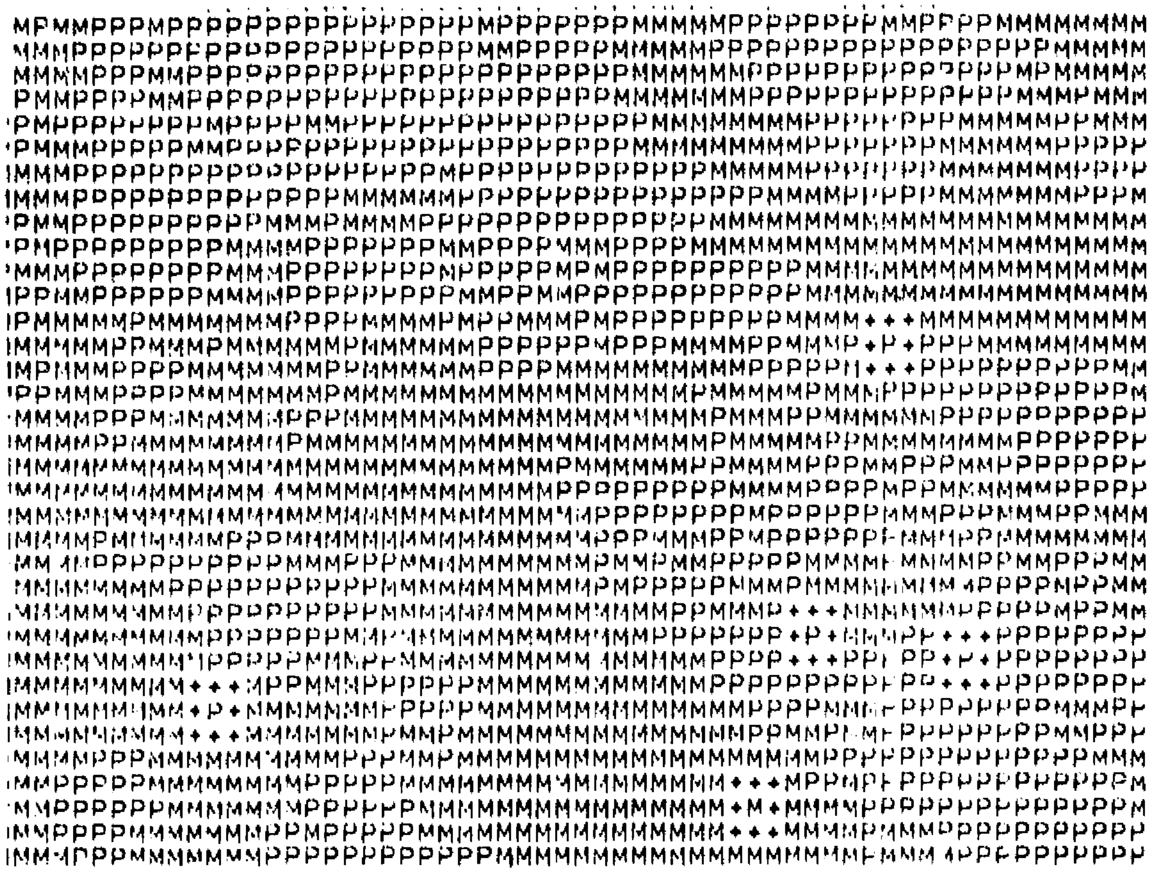


Figure 2.1.3-3 Arrangement of random samples in classification.

Overlay and Record

At this stage both the Landsat classification and the inventory forest type for each test field has to be recorded. The maps produced by PRINTRESULTS and the inventory maps are overlayed, thus locating each test field on the inventory maps. The forest type and classification for each test field are recorded on a chart. Previously, the classifier has decided which Landsat classes represent each forest type.

Classification Accuracy

The forest type and classification recorded above are transferred to computer tape or disk and SPSS CROSSTABS is performed on this data. The resulting output contains a confusion table, classification accuracies and various related statistics as shown in Tables 2.1.4-1 to 5.

2.1.4 EVALUATION OF CLASSIFICATION PERFORMANCE

Winter 1976, Test Site 1

The results of our tests of classification accuracy for the 1976 Test site 1 classification were as shown in Table 2.1.5-1. As one can see in this Table, the classification accuracy of pine is 83%, and the class "other" did not classify very well (only 3 test fields were categorized in this way in inventory). As stated earlier this Table was generated from a RS of 315 test fields from winter 1976 Test site 1 data.

Table 2.1.4-1 Test Site 1 classification performance for the Winter 1976 data. This evaluation is based on a random sample of 315 test fields.

Class	No. of Test Fields	Percent Correct	Updation		
			Pine	Mixed	Other
Pine	182	83.0	151	30	0
Mixed	130	72.3	27	94	2
Other	3	33.3	4	6	1
Total	315				
Overall Accuracy = 78.1%					

Winter 1977, Test Site 1

The results of the tests of classification accuracy for the Test site 1 1977 data (using a RS) were as shown in Table 2.1.4-2. Due to the low accuracy for pine, 58.2%, the larger accuracy for "not pine" and the inconsistent forest type percentages (Landsat predicted 41.3% pine when in fact there was 57.8%), it was suspected that some Landsat classes categorized as not pine were actually pine. That is, not enough classes were included in the pine category. After studying a confusion table of all the Landsat classes, the decision was made to include two more Landsat classes in the pine category. A new SS sample of the 1977 data was taken with the following results, Table 2.1.4-3.

Table 2.1.4-2 Test Site 1 Classification performance for the Winter 1977 data. This evaluation is based on a random sample of 315 test fields.

Class	No. of test fields	Percent Correct	Updating	
			Pine	Not Pine
Pine	182	58.2	106	24
Not Pine	133	82.0	76	109
Total	315			
Overall Accuracy = 68.3%				

Table 2.1.4-3 Test Site 1 Classification performance for the Winter 1977 data. This evaluation is based on a systematic sample of 363 test fields.

Class	No. of test fields	Percent Correct	Updating	
			Pine	Not Pine
Pine	182	89.6	163	52
Not Pine	181	71.3	19	129
Total	363			
Overall Accuracy = 80.4%				

The accuracy of Pine improved substantially to 89.6% whereas the accuracy of not pine decreased somewhat. The overall accuracy attained by the RS was 68.25% (Table 2.1.4-2) which improved in the SS to 80.44% (Table 2.1.4-3). Thus the new definition of two of the Landsat classes substantially improved the classification accuracy of the Landsat data.

Winter 1976, Test Site 2

The results of studying the classification accuracy of the Test site 2 1976 data are shown in Table 2.1.4-4. The classification accuracy of pine is only 58.9% and the accuracy of mixed pine/hardwood is only 45.9% indicating a problem somewhere in the analysis or data. Investigation into this discrepency indicates that visual correlation between the 1976 classification and 1978 aerial photography is generally good. However, a number of Operating Areas in this test site are composed of mixed or heterogenous pine stands. The single test field evaluation procedure is not well suited for this situation and therefore, gives erroneous results. The evaluation procedure is being modified to account for this variability.

Table 2.1.4-4 Test Site 2 Classification performance for the Winter 1976 data. This evaluation is based on a random sample of 135 test fields.

Class	No. of Test Fields	Percent Correct	Updating		
			Pine	Mixed	Other
Pine	95	58.9	56	12	0
Mixed	37	45.9	15	17	0
Other	3	100.0	24	8	3
Total	135				

Overall Accuracy = 56.3%

Winter 1976, Test Site 3

A similar evaluation was performed on Test Site 3. Table 2.1.4-5 indicates the results of this evaluation. According to a randomly selected set of test fields pine was accurately classified 71.2% and "not pine" 67.1%. This site like the previous one contains a fairly large number of heterogenous Operating Areas. Unlike test site 2, this heterogenity is a function of a dissected upland topography more than a result of management practice.

Table 2.1.4-5 Test Site 3 Classification performance for the Winter 1976 data. This evaluation is based on a random sample of 347 test fields.

Class	No. of Test Fields	Percent Correct	Updating	
			Pine	Not Pine
Pine	198	71.2	141	49
Not Pine	149	67.1	57	100
Total	347			

Overall Accuracy = 69.5%

In conclusion a word should be said about the human errors involved in determining classification accuracy. In the process of registering the data, classifying it and determining its accuracy, much human error is added to the data. The ground truth (inventory), itself, has human error associated with it. Even with all this error included in the study, fairly high classification accuracies were obtained.

2.1.5 BETWEEN DATE ACCURACY DETERMINATION

Two different types of tests were run. First a simple linear regression was performed between St. Regis inventory estimates of 29 AU acreages and Landsat acreage estimates of the same AU's. Then a comparison of the average acreage estimates for pine was made.

The regression runs showed a high correlation (Table 2.1.5-1) between the Landsat and STR acreage estimates.

Table 2.1.5-1 Correlation Coefficients between 1976 and 1977 classifications for Test Site 1.

Data		Pine	Not Pine
1976	R	.9531	.91209
	R^2	.90839	.83191
1977	R	.95864	.93490
	R^2	.91899	.87404

A comparison of the average acreage estimates was made using a 2-sample T-Test. Instead of the usual test which assumes independent samples, a test using paired comparisons was run. The paired comparison test takes into account the fact that there are two measurements being made on each AU, by looking at the difference in the measurements for each AU. The calculational formula is virtually the same as the usual 2-sample T-Test except the correlation of the 2 samples enters into the standard deviation used in the test. The hypotheses being tested is:

$$H_o: \mu = \mu_1 - \mu_2 = 0$$

vs.

$$H_1 \mu = \mu_1 - \mu_2 \neq 0$$

where:

μ = mean of the sample of differences

$$(X_{\substack{Landsat\\AUi}} - X_{\substack{STR\\AUi}})$$

μ_1 = mean of $X_{\substack{Landsat\\AUi}}$ ones all i

μ_2 = mean of $X_{STR,\ AUi}$

Table 2.1.5-2 gives the results of this 2-sample T-Test.

Table 2.1.5-2 Results of T-Test

	T Values	
	Pine	Not Pine
1976	-0.28	0.16
1977	2.09*	-2.15*

*significant at α = .05 level but not significant at α = .01.

Hence, the average overall acreage estimates are essentially the same between 1976 Landsat data and St. Regis Inventory. The 1977 Landsat data may not have the same mean as the St. Regis inventory estimates. Since the 1977 Landsat data is so highly correlated with inventory, however, we can conclude that the 1977 Landsat data is either consistently over-estimating or underestimating the actual acreage per AU.

2.2 MAPPING UNIT

The objective of the mapping unjt is to provide the technology and system design elements necessary for delivering remote sensing and ancillary data to FRIS analysts. The remote sensing data preprocessing task involves reformatting, geometric and radiometric correction, and geometric transformation to place Landsat and other data types into FRIS resource unit coordinates. The ancillary data preprocessing task includes digitizing of FRIS resource maps and placing this data in a reference coordinate system and combining certain map features with the remote sensing data. These two data types are very different and one of the challenges of designing the FRIS system is to achieve an optimum interface between remote sensing (image) and resource map (polygon) data types.

In this report section 2.2.1 describes map digitizing activities leading to creation of current FRIS data sets. Section 2.2.2 describes remote sensing data preprocessing as carried out in the course of FRIS analysis and system development. Section 2.2.3 discusses the impact of a system such as the Harvard ODYSSEY data base system for FRIS on the current systems and procedures applied to FRIS. 2.2.4 discusses the implications of Landsat-3 data characteristics and other sensors are discussed. Section 2.2.5 defines what the FRIS preprocessing system should be based on results from Phase I and II of the project.

2.2.1 MAP DIGITIZING APPROACH

This section deals with the steps involved in the creation of an ancillary data set, using St. Regis management maps (Figure 2.2.1-1), and overlaying these as a channel on the Landsat master tape. Four general steps are involved in this process: Map Preparation, Map Digitization, Data Assembly, and Boundary Processing. Descriptions of the activities involved with each step are presented below.

Map Preparation

The management maps to be digitized are carefully examined to ensure that all boundaries close (all boundary lines meet), and that all areas enclosed by boundaries (polygons) are named, either by forest type or a numerical operation area designation. Once the maps are verified and any problems resolved, polygon boundaries are broken down into discrete vectors, each vector having beginning and ending nodes, and left and right area attributes. The area attributes are the only components determined manually, as the digitizing software automatically assigns arc numbers. Also at this point, each map will be assigned a unique file name, in order to facilitate later referencing of the data. Figure 2.2.1-2 is an example of the map elements that are digitized.

Digitizing

The actual creation of the digital map file is accomplished during

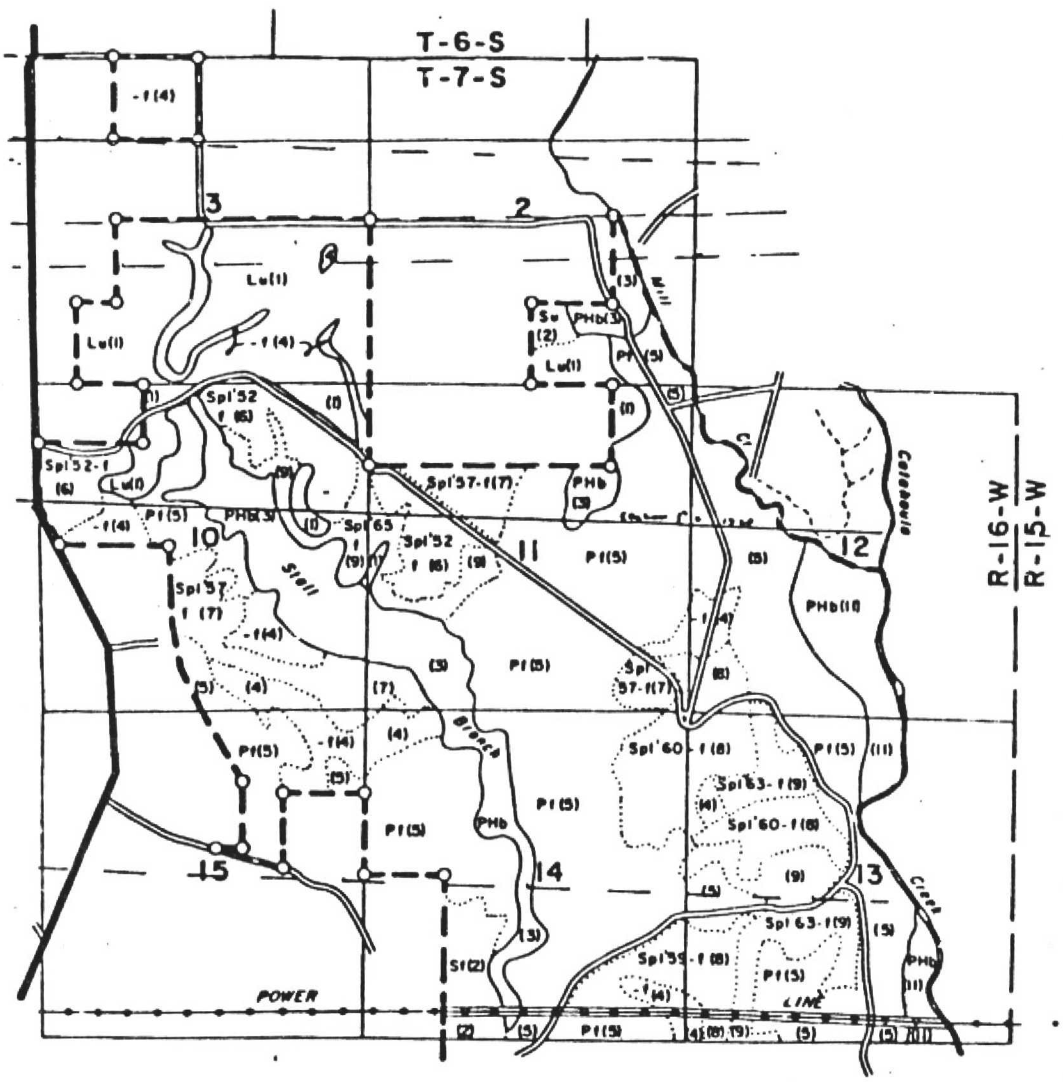


Figure 2.2.1-1 Example of management maps which will be digitized and included as a layer of data within the FRIS data base.

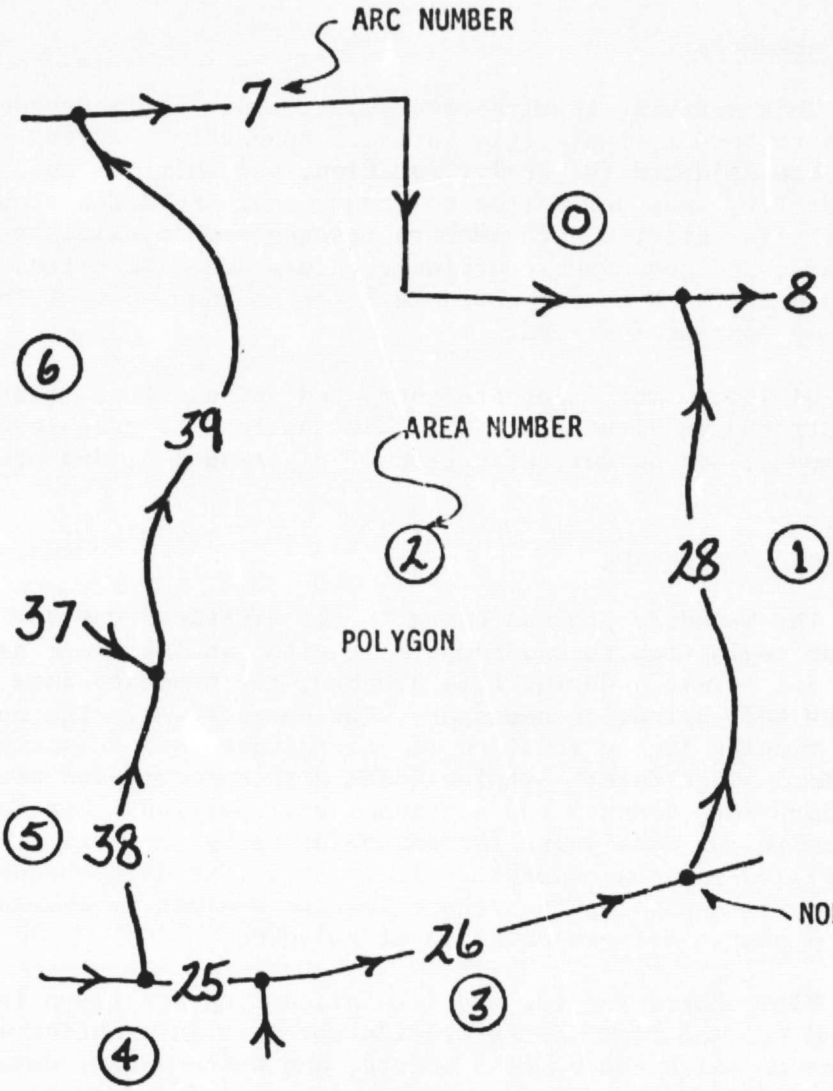


Figure 2.2.1-2 An example of the map elements that are recorded on the digital map data file.

this step. A Talos table digitizer interfaced to a Digital Equipment Corp. PDP 11/34A minicomputer (Figure 2.2.1-3) is utilized in this process. Menu-controlled (Figure 2.2.1-4) software was developed in order to both reduce operator fatigue and minimize error. A color-coded menu placed on the table digitizer provides complete program control for the digitizing software. The map vectors are converted into three digital files stored on disk: an arc file, a left attribute file, and a right attribute file. At the end of the digitizing process, the map vector files are transferred to disk on an IBM 370/148 computer and backed up onto magnetic tape.

Data Assembly

This activity involves manipulation of the independent digitized map files to form a single file for each ownership. During this operation, maps are adjusted for scale, rotation, and shift as needed to attain proper fit, arcs are edited to ensure that arc nodes properly meet, area attributes verified, arc numbers resequenced to eliminate duplicate arc numbers, and redundant coordinate values are eliminated. The results of these operations create new data files so that none of the original data will be lost or modified.

Digitized map files are corrected and examined using map-replots illustrated in Figure 2.2.1-5. The map re-plot graphically illustrates arc nodes, arc number, direction of digitization, and area attributes for each arc.

Boundary Processing

The boundary process converts the digitized map vectors to a raster format registered to and compatible with Landsat image data in LARSYS Ver. 3.1 format. During this process, the boundary data are checked for errors and edited, as necessary, for corrections. The output from this step results in the addition of several new data channels, as well as the original image data: original data with superimposed boundaries; a boundary data channel and a channel will polygons represented in digital form with the data value for any point being the area attribute (called the filled-in area channel). It is this last data channel which is most important---enabling the remote sensing analyst to examine only image data from a single polygon or group of polygons.

Flow charts for the map data processing are given in Figure 2.2.1-6a, b, and c. The flow charts provide specific information with regard to the device on which the process occurs, and where backup data is stored. We have estimated the map data processing procedure requires the allocation of resources identified in Table 2.2.1-1.

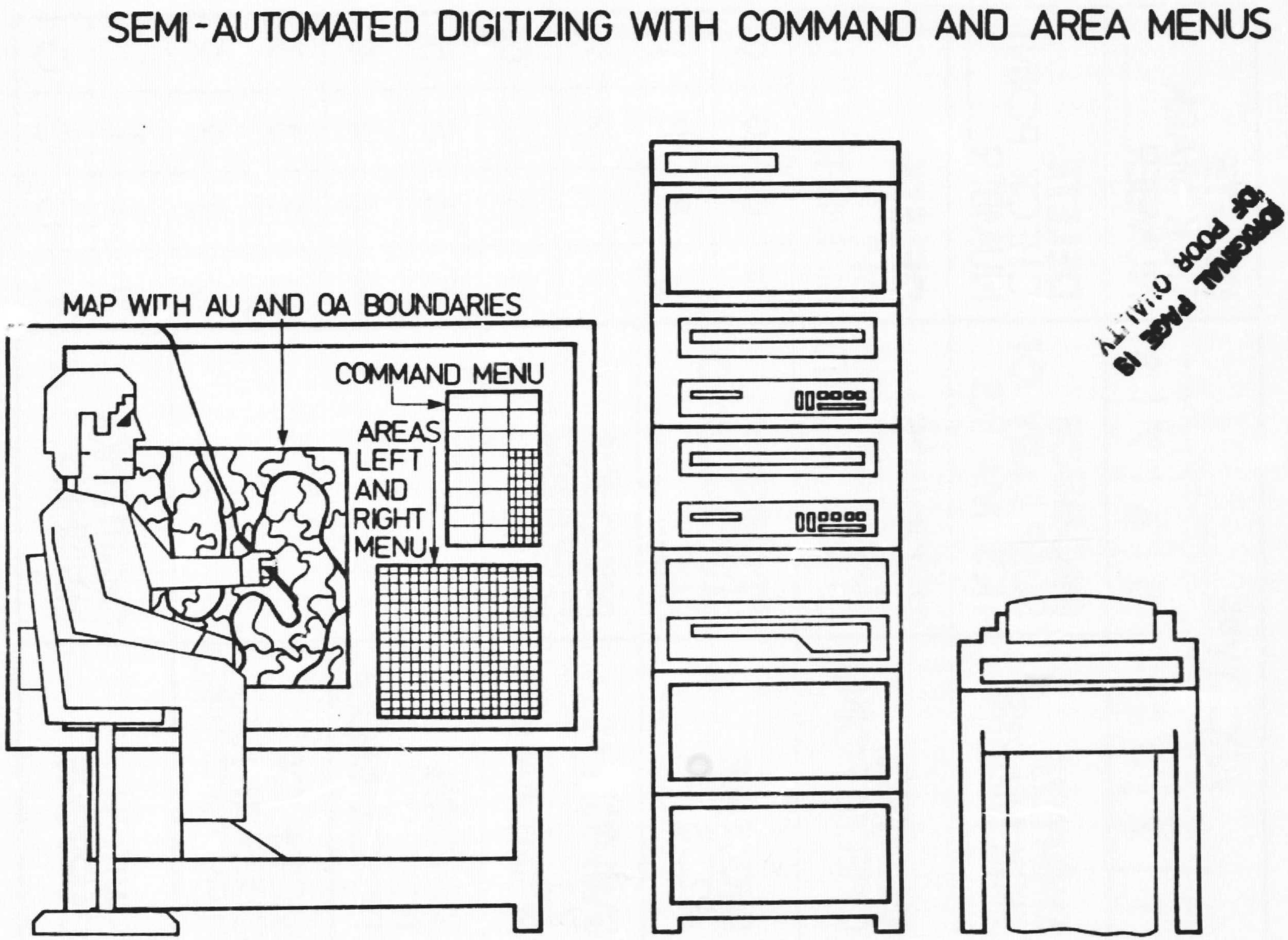


Figure 2.2.1-3 Hardware configuration used for digitizing.

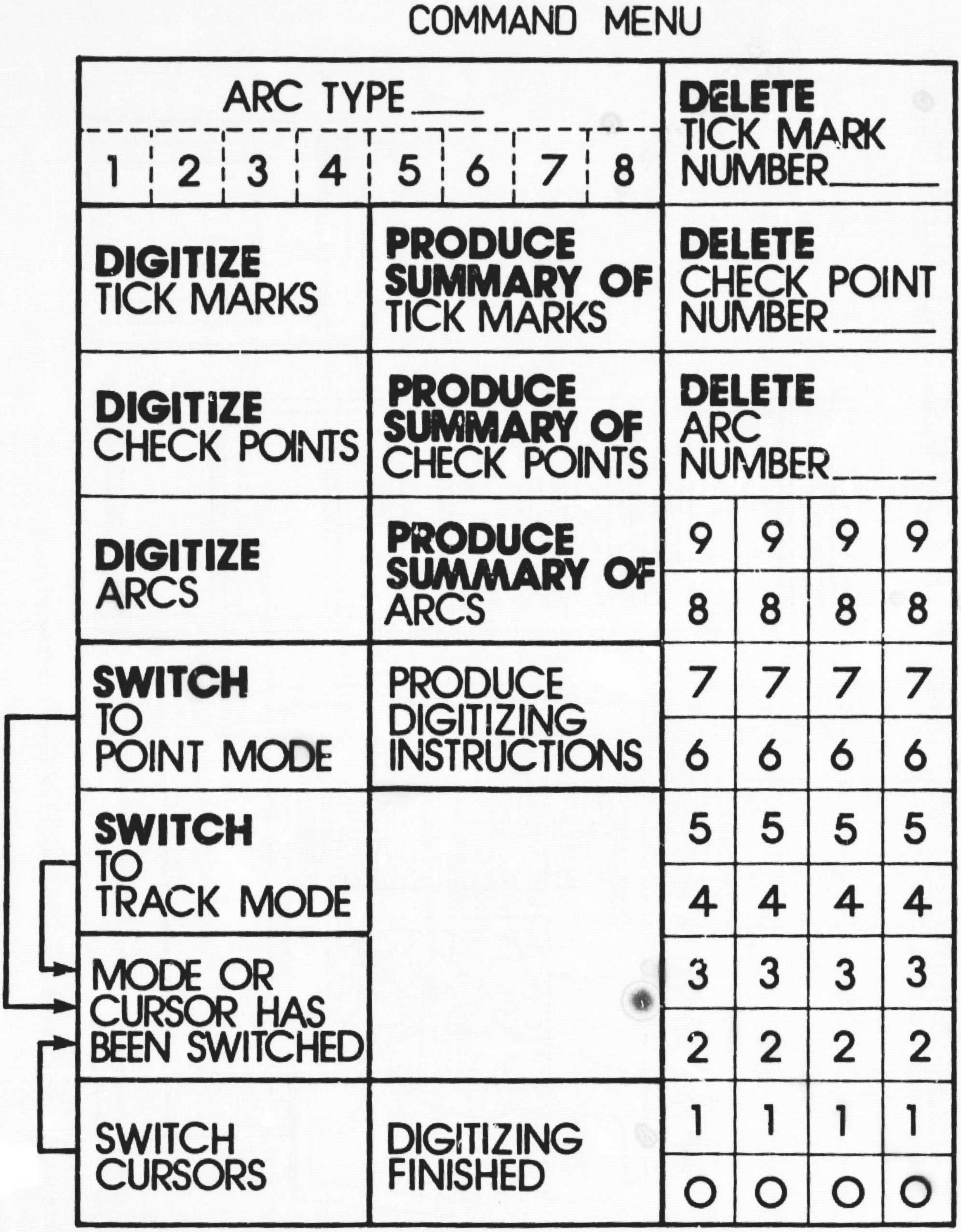
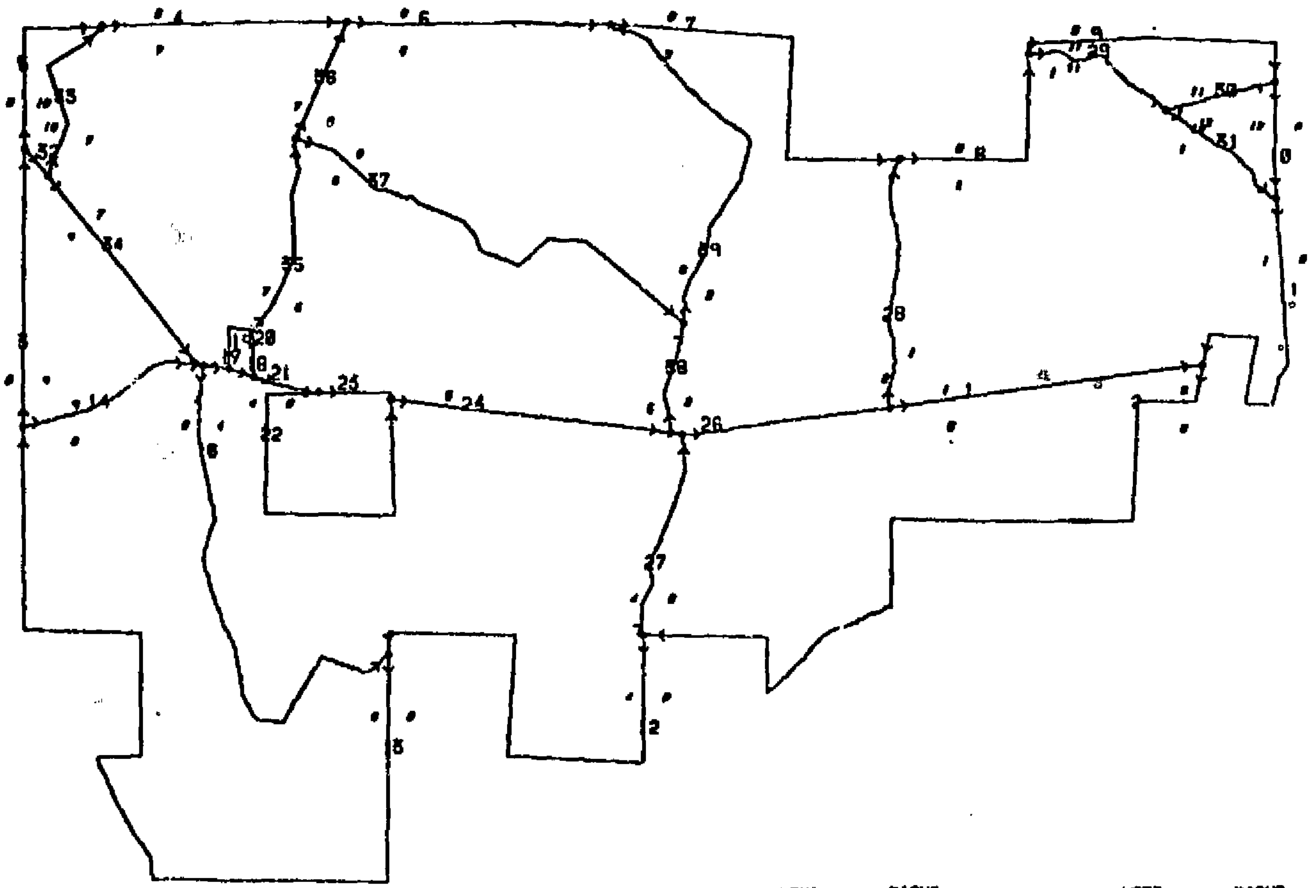


Figure 2.2.1-9 Command menu used for digitizing.



ARC	LEFT	RIGHT	ARC	LEFT	RIGHT
15	7	8	17	7	4
18	8	4	19	7	8
20	5	8	21	5	4
23	5	8	25	2	4
26	2	3	32	10	1

Figure 2.2.1-5 An example of a digitized map file. Arc numbers and area designators should correspond to the table in the lower right of the map.

Table 2.2.1-1 Identification of resources required as a percent of total resources for the major steps in data preparation.

Process	Resources Required (%)
Digitizing	30
Data Edit/Assembly	60
Boundary Processing	10

In order to facilitate processing of digitized map information in a rapid and timely manner, an approach using systems analysis was developed for Test site 1. A Program Evaluation and Review Technique (Martin and others) (PERT) was used to coordinate map preparation, digitization, data editing and assembly and boundary processing for each of the Test sites five management maps. Although actual completion time was approximately twice the predicted completion time, the majority of delays were due to unexpected software errors in the data assembly editing programs and unexpected constraints on personnel resources.

Several techniques to combine the separate management maps into a single, contiguous map grid were investigated. Due to cartographic problems with the maps. primarily the dimensional instability of the map paper, we found that simple adjustments using X and Y shifts, rotation and scale were more effective in matching the maps than using first order least-squares modeling. The use of simple shifts and rotation decreased the total time required to assemble the maps together into a common grid, and did not create internal distortions on individual maps, as did the least-squares modeling.

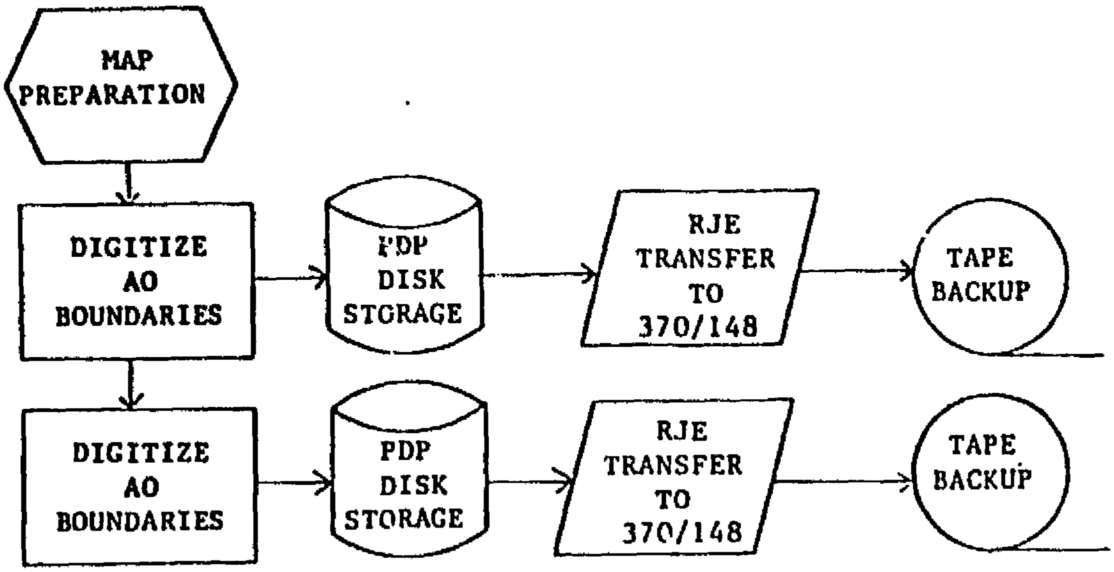
2.2.2 PREPROCESSING ACTIVITIES

FRIS Phase II preprocessing activities were performed for each study test site in the manner identified in Table 2.2.2-1.

Table 2.2.2-1 Sequence of preprocessing activities, and the number of tasks for each of the four FRIS Test Sites.

Preprocessing Activity	Test Site 1	2	3	4
Landsat (CCT to LARSYS)	4	2	2	2
Geometric Correction	5	2	2	1
Image Registration	2	1	1	(in progress)
Precision Registration	4	2	1	(in progress)
Boundary	4	1	1	(in progress)
(No. of Maps)	(5)	(5)	(2)	(9)

MAP PREPARATION/DIGITIZATION



DATA ASSEMBLY

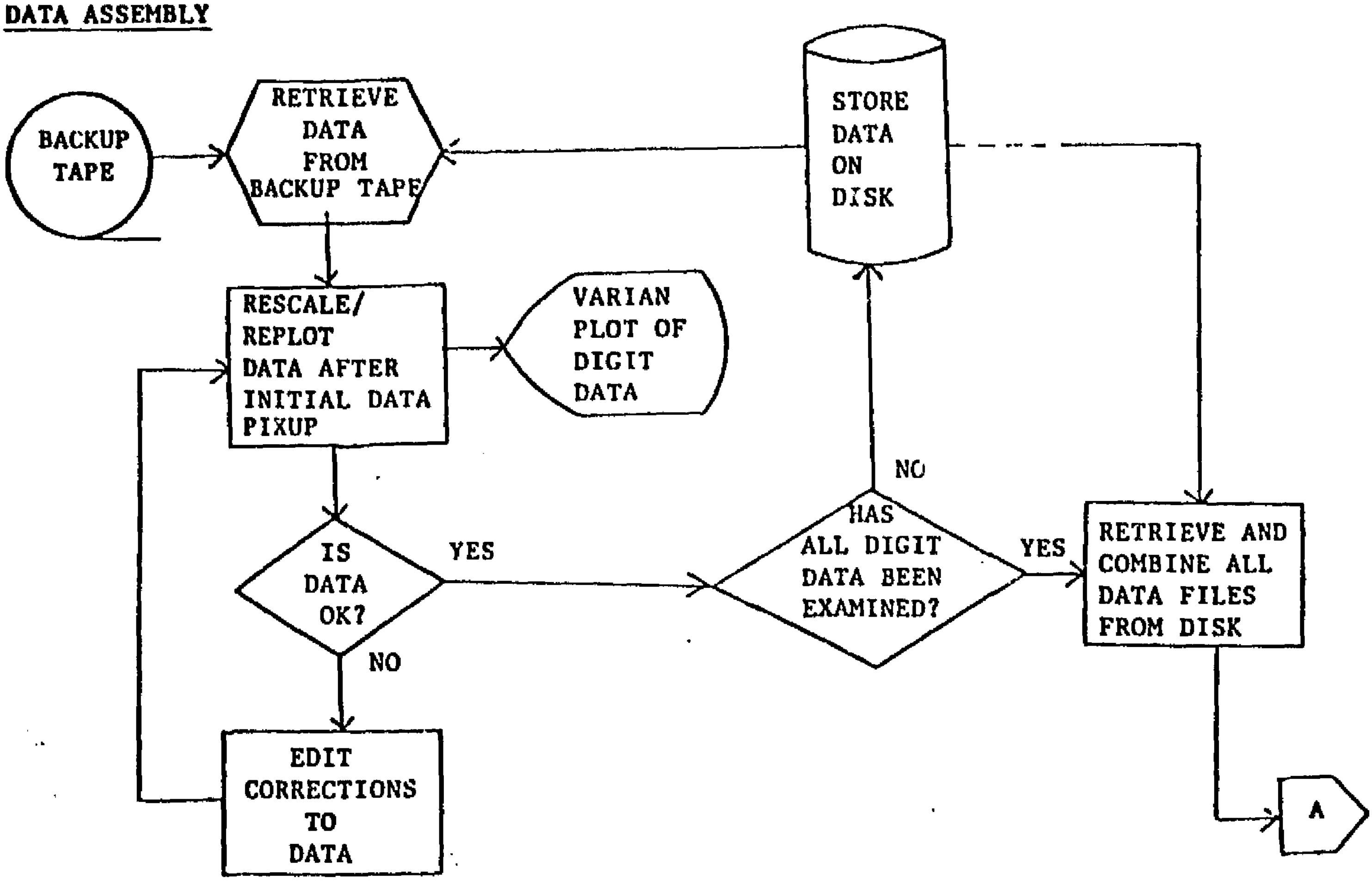


Figure 2.2.1-6a, b, c. Flow charts of the preprocessing steps necessary prior to classification. a) Map Preparation/Digitization, b) Data Assembly, c) Boundary Processing.

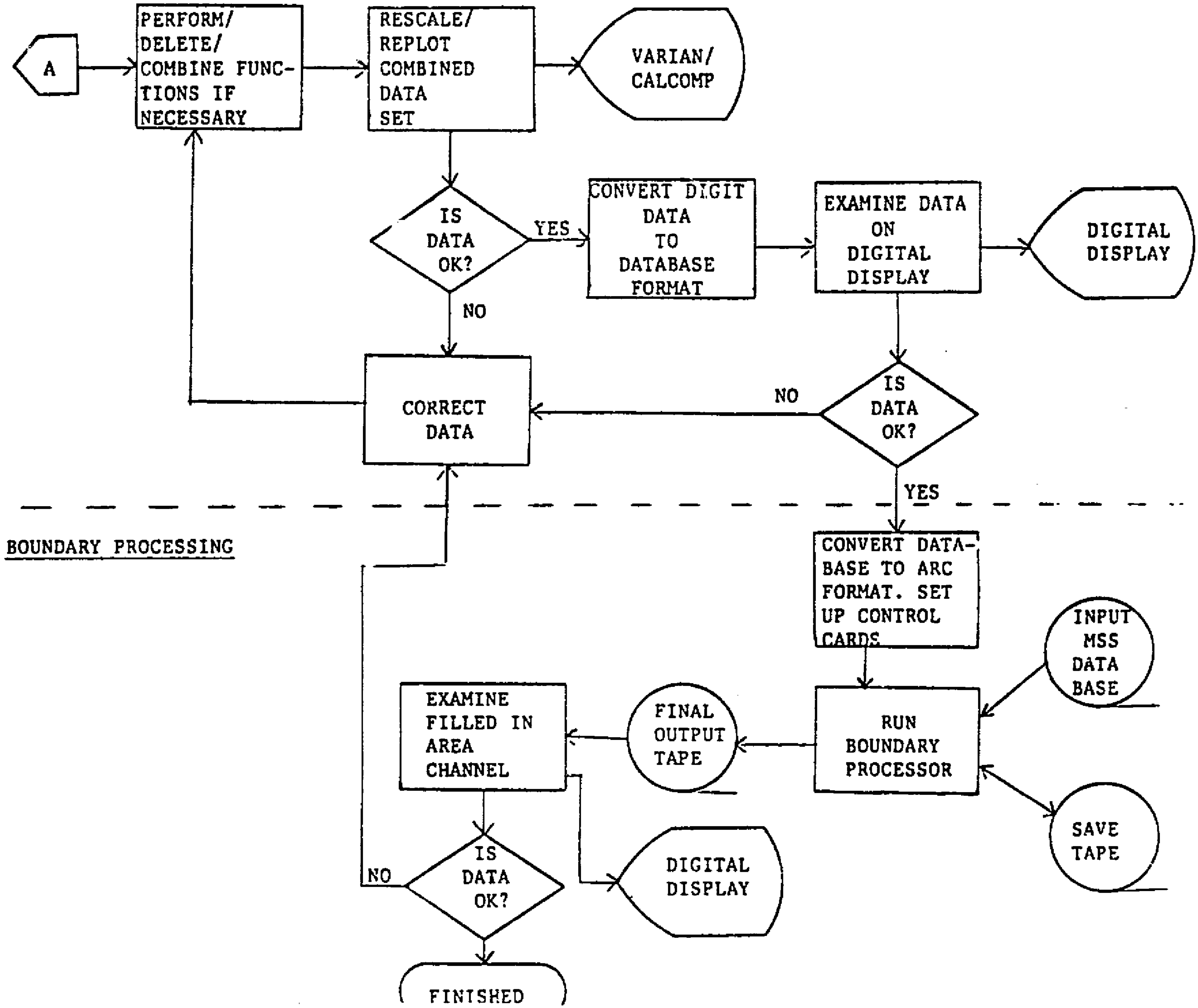


Figure 2.2.1-6a, b, c (continued)

A more complete description of the data runs preprocessed during Phase II is seen in Table 2.2.2-3.

Highlights of preprocessing activities during Phase II include:

1. Refinement of a systems model for an approach to image registration.
2. Development of a numerical method to evaluate checkpoint distribution.
3. Development of a correlation-based weighted adjustment to transformation coefficients.
4. Evaluation of the use of PERT analysis for the management of preprocessing operations (see section 2.2.1).

The preprocessing acitivities performed during Phase II group into five preprocessing areas: Landsat (CCT to LARSYS) reformatting, systematic geometric correction, image registration, precision (map) registration, and boundary processing. Each of these areas will be subsequently described, excepting boundary processing, which was previously described under section 2.2.1.

Reformatting

Landsat CCT to LARSYS reformatting converts the NASA CCT format to LARSYS multispectral image storage tape format. The image data is assigned a unique 8-digit identifier (called a run number) and is entered into the LARS data base. No changes or corrections are made to the image data by this process.

Geometric Correction

The systemacic geometric correction orients the image data to a user perspective. The scene is "squared-up", rotated to a north-south heading, corrected for skew due to earth rotation, and corrected to a user-specified output scale for either an 8:10 (line printer) or 1:1 aspect ratio. It should be emphasized that most of the parameters are not known accurately, thus the corrections are not exact. However, measurements made to USGS topographic maps and other maps indicate about a 1% to 2% scale error.

Precision Registration

Precision registration is the spatial alignment of digital image data to ground control information, usually digitized map coordinates. Corresponding points are located in both the image scene to be registered and a map, a mathematical model is determined to describe the transformation between coordinate systems, and a least-squares approximation is used to describe the "best fit" from the image coordinate system to the ground control system.

Table 2.2.2-3 FRIS Data Reformatting

SITE	DATE	LARS RUN NO.	DESCRIPTION
1	12-7-77	77009400	Scene 605014515
	12-7-77	77009401	1:15840 Geometric Correction Line Printer Aspect
	4-17-77	77003200	Scene 281615042
	4-17-77	77003201	1:24000 Geometric Correction Line Printer Aspect
	12-30-76	76020100	Scene 270815090
	12-30-76	76020101	1:24000 Geometric Correction Line Printer Aspect
	MT	76020102	Multitemporal registration of 76020101 and 77003201 (NN)
	MT	76020103	Precision Registration of 76020102 to AU's Scale 1:158400
	MT	76020104	Same as 76020103 except cubic interpolation
	MT	76020105	Same as 76020103 with ancillary/boundary data
	MT	76020106	Same as 76020104 with ancillary/boundary data
	-	76020107	same as 08 except NN
	MT	76020108	Full site precision registration using 76020102 approximate scale 1:15840 using cubic interpolation
	-	76020109	Currently not assigned
	MT	76020110	Same as 76020108 with ancillary/boundary data
	4-24-74	74032300	Scene 164015274
	4-24-74	74032301	1:24000 Geometric Correction Line Printer Aspect
	4-24-74	74032302	1:15840 Geometric Correction Line Printer Aspect
	MT	74032303	Multitemporal Registration of 76020108 (12/30/76, 4/17/77) with 74032302 (4/24/74) and 77009401 (12/7/77)
	MT	74032304	same as 74032303 except w/ancillary boundary data

Abbreviations = MT - Multitemporal
NN - Nearest Neighbor Interpolation

Table 2.2.2-3 (continued)

SITE	DATE	LARS RUN NO.	DESCRIPTION
2	5-28-78	77003400	Scene 285715305
	5-28-78	77003401	1:24000 Geometric Correction Line Printer Aspect
	12-17-76	76020000	Scene 269515381
	12-17-76	76020001	1:24 Geometric Correction Line Printer Aspect
	MT	76020002	Multitemporal Registration of 76020001 (12-17-76) and 77003401 (5-38-78) Nearest Neighbor Interpolation
	MT	76020003	Precision Registration of 76020002 to composite map grid at 1:15840. (This data set exhibited excessive errors.)
	MT	76020004	Precision registration of 76020002 to composite map grid at 1:15840.
	MT	76020005	Same as 76020004 with ancillary/boundary data
3	5-7-77	77003500	Scene 283615141
	5-7-77	77003501	1:24000 Geometric Correction Line Printer Aspect
	10-21-76	76020200	Scene 263815225
	10-21-76	76020201	1:24000 Geometric Correction Line Printer Aspect
	MT	76020202	Multitemporal Registration of 76020201 (10-21-76) and 72003501 (5-7-77) NN
	MT	76020203	Precision Registration of composite map grid at 1:15840.
	MT	76020204	Same as 76020203 with ancillary/boundary data.
4	12-10-77	77009200	Scene 695315091
	12-10-77	77009201	1:24000 Geometric Correction Line Printer Aspect
	10-22-76	76021100	Scene 263915290

Abbreviations = MT - Multitemporal
NN - Nearest Neighbor Interpolation

Image Registration

Image registration is the spatial alignment or overlaying of images. The registration of Landsat data over the same coverage area but from differing seasons enhances the discriminability between classes involving unresolvable spectral confusion by providing temporal dimensionality to the data. The utilization of image registration techniques for precision geometric correction of Landsat data serves the dual purpose of permitting the use of similarity measures for automatic checkpointing between Landsat and reference data, as well as enabling the creation of land use maps at standard scales with determinable precision.

Due to the large amount of computer and personnel resources required during the registration process, a systematic approach to image registration has been developed which attempts to maximize registration precision while minimizing resource costs. The process is essentially a four-step operation:

1. The input data is evaluated to assist the anticipation of any foreseeable problems during the registration process.
2. Control points are located between the reference data to be overlayed.
3. A suitable transformation polynomial is developed between the reference and overlay data sets using least-squares and data adjustment techniques.
4. The data to be overlayed is resampled and placed in the reference coordinate system using the developed transformation function.

The preliminary scene evaluatic is perhaps the most significant portion of the overall registration process in that it determines the approach to registration that must be taken. Each scene should be evaluated for it's spectral characteristics based upon the date in which the data was taken, ground cover, and vegetative growing season. For example, given two Landsat scenes both taken during winter months over a forested area, the best chance for acceptable correlation between scenes would use spectral bands in the near infrared (Landsat band 7).

Consideration should also be given to two components of scene geometry: rotation and scale. If two images are of widely differing scale or ground headings differ by more than about 2 degrees, it will be difficult if not impossible to properly correlate the images.

Other items which should be considered at this time includes checkpointing requirements (affects personnel resource time), final scale of output data (affects total CPU requirements), and specific requests for any special treatment of the data.

The preliminary evaluation should provide an understanding of the steps necessary to complete the registration, whether preprocessing of the data will be needed, the difficulty with which checkpoints will be taken, which channels are to be used for correlation, what geometric distortions are present in the data, and what the final output scale and interpolation method shall be.

A great deal of past research has been performed developing an optimum image registration processor (Svedlow, et al., and others). The systematic approach to image registration to be described (Figure 2.2.2-1) as it's basis the optimum processor described by Svedlow. It is a pragmatic tradeoff between technical considerations and minimization of resource requirements.

An example of a tradeoff between using an optimum processor developed for registration accuracy versus a systematic approach designed to minimize resources is the use of gradient (first-derivative) preprocessing. The gradient image value is described by:

$$|\text{Gradient } X_{i,j}| = \{(X_{i,j+1} - X_{i,j-1})^2 + (X_{i+1,j} - X_{i-1,j})^2\}^{\frac{1}{2}}$$

where $X_{i,j}$ = image sample value at coordinate (i,j).

The use of gradient preprocessing of image data boosts registration performance (evaluated in terms of percent acceptable registration attempts) over utilizing the original imagery. However, when the original imagery is highly correlated ($|\rho| \leq 0.5$) any preprocessing method (or none) works equally well. Thus, no advantage is gained by the preprocessing. Conversely, when using low correlated imagery ($|\rho| < 0.5$) the use of magnitude of gradient preprocessing provides a marked advantage over no preprocessing.

The quantitative measure of the similarity between images (similarity measure) used by the LARS registration system is the absolute value of the correlation coefficient. Although on a time-performance basis an absolute difference measure may be more advantageous, on a performance-wise basis, experimental results have indicated the use of the correlation coefficient as a similarity measure (Svedlow, et al.).

The correlation coefficient $\rho_{1,k}$ is described as:

$$\rho_{1,k} = \frac{n^2\overline{XY}_{1,k} - \overline{XY}_{1,k}}{\{(n^2\overline{X}^2 - \overline{X}^2)\ (n^2\overline{Y}^2_{1,k} - \overline{Y}^2_{1,k})\}^{\frac{1}{2}}}$$

$$\text{where } \overline{XY}_{1,k} = \sum_{i=1}^{n} \sum_{j=1}^{n} X_{ij} Y_i{+1,\ j+k}$$

$$\overline{X} = \sum_{i=1}^{n} \sum_{j=1}^{n} X_i{+1,\ j+k}$$

```
Begin Registration Process;
Conduct Preliminary Scene Evaluation;
Obtain 3 to 5 checkpoints between scenes;
Evaluate points and determine simple Δ(L,C) shifts;
Run low-density (N=25) correlations between images
     using the Δ(L,C) shifts;
Run Affine (six parameter, linear, non-conformal)
     transformation using a 30 checkpoint rejection
     criteria;
Do Automatic Checkpoint Process while RMS errors
     improve by more than 50%
     If average correlation coefficient from previous
          low density correlation is less than 0.5
     Then use gradient images for automatic checkpoint process
          Else use original imagery;
     Run High-density (N=100) correlations between images;
     If correlation acceptance rate is less than 0.2
     Then use affine transform with automatic control points
          Else use biquadratic transform with automatic
          control points;
     End automatic checkpoint process;
Do adjust checkpoint distribution while C_D < 0.7
     Determine distribution coefficient (C_D);
     Rerun transform;
     End of checkpoint distribution adjustment;
Do adjust shift coefficients using correlation weight-adjustment
     while Euclidean error improves by 25%;
     Run low-density transformation;
     Examine Euclidean error;
     End shift adjustment;
Run final registration using determined coefficients;
End Registration process;
```

Figure 2.2.2-1   A systematic Approach to Image Registration

$$\overline{X}^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} X^2_{ij}$$

$$\overline{Y} = \sum_{i=1}^{n} \sum_{j=1}^{n} Y_{i+1,j+k}$$

$$\overline{Y}^2_{1,k} = \sum_{i=1}^{n} \sum_{j=1}^{n} Y^2_{i+1,\ j+k}$$

This provides a measure on an absolute scale ranging from -1 to +1. A value of +1 indicates the two images are identical or differ by a positive constant factor about their means. A value of -1 indicates a negative constant factor about the image means.

Registration position is indicated by the maximum absolute value which is computed about several registration locations. The use of the absolute value is important because certain temporal changes may cause a shift about the mean of the images which would result in a negative correlation coefficient. The falue on the 0 to 1 scale indicates how well the images are linearly related.

The LARS image transformation model uses the form

$$\Delta_X\ (X_A,\ Y_Z) = X_B - X_A$$

$$\Delta_Y\ (X_A,\ Y_A) = Y_B - Y_A$$

where subscripts A and B denote image A and image B, respectively. Checkpoints developed using the image correlator during the automatic checkpoint selection process are used to produce a two-dimensional quadratic polynomial which represents the difference in position of the two images. The polynomials are of the form:

$$\Delta X = A_0 + A_1X + A_2Y + A_3X^2 + A_4Y^2 + A_5XY$$

$$\Delta Y = B_0 + B_1X + B_2Y + B_3X^2 + B_4Y^2 + B_5XY$$

The least squares solution for the coefficients is

$$\underline{\alpha} = (\underline{\beta}^T\ \underline{\beta})^{-1}\ \underline{\beta}^T\ \underline{\delta X}$$

$$\underline{\beta} = (\underline{\beta}^T\ \underline{\beta})^{-1}\ \underline{\beta}^T\ \underline{\delta Y}$$

Where $\underline{\alpha}$, $\underline{\beta}$ are 6 x 1 coefficient vectors for ΔX and ΔY.

$\underline{B}$ is the matrix B_{ij} of powers of X and Y for each checkpoint such that $\underline{B}_{ij} = X_i^k \, Y_j^l$ where i is the number of the ckeckpoints, i = 1, N

k = 0, 1, 0, 2, 0, 1 ,

l = 0, 0, 1, 0, 2, 1 for

j = 1, 2, 3, 4, 5, 6 respectively.

$\underline{\delta X}$, $\underline{\delta Y}$ are N x 1 column vectors between A and B coordinates, $\delta X_i = X_{B_i} - X_{A_i}$

$$\delta_{Y_i} = Y_{B_i} - Y_{A_i}$$

Due to the usage of higher order polynomials as models for the image space transformation, it is important to examine the general distribution of control points throughout an image to be registered. Although most evaluations of checkpoint distributions are interpretive, it was considered that a numerical evaluation would be more satisfactory.

After some experimentation a numerical measure which appears to be satisfactory is a modified form of the Pearson's r product-moment correlation coefficient. Using this method, the coordinates X values are correlated with it's own Y values:

> if the points are distributed evenly the correlation value is (0),
> if the points lie along a straight line the value for the correlation is 1 or -1.

In order to represent a good distribution as a positive number with a value of one, the absolute value of the intercorrelated Pearson's r value is subtracted from one. The distribution coefficient C_D is described by:

$$C_D = 1 - \left| \frac{N \sum_{XY_{i,j}} - (\sum_{X_{i,j}})(\sum_{Y_{i,j}})}{(N \sum_{X_{i,j}}{}^2 - (\sum_{X_{i,j}})^2)^{\frac{1}{2}} \, (N \sum_{Y_{i,j}}{}^2 - (\sum_{Y_{i,j}})^2)^{\frac{1}{2}}} \right|$$

This provides a measure on an absolute scale ranging from 0 to +1. A value of +1 represents a good distribution, a value of 0 a poor distribution. Typically, problems may occur with the transformation if $C_D \leq 0.7$.

Svedlow has suggested that the image correlation coefficient value may be of help in determining the acceptability of an indicated registration position. The systematic approach used for image registration uses this reasoning in the final adjustment of the transformation coefficients. The correlation coefficient is used as a weighting factor applied to the residual remainder of the difference between the predicted coordinate location (using the transformation function obtained using least-squares) and the observed coordinate location (indicated point of registration using the automatic correlator). The average weighted remainders are then added to the shift coefficients of the transformation function, and a test correlation (at the same registration positions) is performed between images. This weighting-adjusting process is continued as long as the Euclidea error between predicted and observed registration locations improves by more than 25%.

The weighting-adjustment may be described by:

$$\delta_A = \frac{\sum_{i=1}^{n} (\rho_i \delta_i)}{N \sum_{i=1}^{n} \rho_i}$$

where:

- δ_A is the amount to be added to the transformation constant.
- ρ_i correlation coefficient (absolute value) at correlation attempt i,
- n total number of correlation attempts
- δ_i - Δpredicted - Δobserved.

The weighting adjustment is computer independently for both X and Y.

The registration system employs two basic resampling schemes to accomplish overaly transformation of images. The first technique is nearest-neighbor resampling, whereby the value of the data point nearest the desired sample location is used to represent the data value at the desired point. The other method combines values of samples near the desired data point in order to estimate the proper value of the desired sample. This is accomplished by a technique employing Lagrangian interpolation, and its implementation in the LARS Registration System is discussed as follows.

The Lagrange interpolating polynomial in two dimensions is:

$$P_n(x) = \sum_{i=0}^{n} L_i(x) f(x_i)$$

where
$$L_i(x) = \prod_{\substack{j=0 \\ j\neq i}}^{n} \frac{x-x_j}{x_i-x_j} \qquad i=0,\ldots,n$$

and $P_n(x)$ is an approximation of an nth order polynomial.

For nth order interpolation, n+1 points are required. Hence, for third order interpolation four points are necessary. Thus for a function f(x,y) with x of order m and y of order n, it is necessary to have m+1 and n+1 points, respectively. The Lagrangian interpolating polynomial for three dimensions is:

$$P_{mn}(x,y) = \sum_{i=0}^{m} \sum_{j=0}^{n} L_i(x) L_j(y) f(x_i y_i)$$

where
$$L_i(x) = \prod_{\substack{k=0 \\ k\neq i}}^{m} \frac{x-x_k}{x_i-x_k} \qquad i=0,\ldots,m$$

$$L_j(y) = \prod_{\substack{\ell=0 \\ \ell\neq j}}^{n} \frac{y-y_\ell}{y_j-y_\ell} \qquad j=0,\ldots,n$$

As an alternative to calculating the Lagrange polynomial coefficients for each data point position, the point to be interpolated is placed within a grid network of points which already has the coefficients determined. The point is placed within a 4 x 4 data matrix f(x,y), with two lines and two columns on either side (see Figure 2.2.2-2). This places the point somewhere in the grid network bounded by data points at (1,1), (2,1), (1,2), and (2,2). Its position within these bounds is determined to the nearest 1/4 sample and this position is used to determine the polynomial coefficients to be generated at program initialization, thereby reducing the overall execution time of the program. The error induced by this method of using discrete intervals versus continuous intervals is considered negligible because the intervals involved are 1/4 pixels.

Using this method, the general form of generating the Lagrange polynomial coefficients is reduced to

$$L_0 = \frac{(x-1)(x-2)(x-3)}{(0-1)(0-2)(0-3)} = \frac{x^3-6x^2+11x-6}{-6}$$

$$L_1 = \frac{(x-0)(x-2)(x-3)}{(1-0)(1-2)(1-3)} = \frac{x^3-5x^2+6x}{2}$$

$$L_2 = \frac{(x-0)(x-1)(x-3)}{(2-0)(2-1)(2-3)} = \frac{x^3-4x^2+3x}{-2}$$

$$L_3 = \frac{(x-0)(x-1)(x-2)}{(3-0)(3-1)(3-2)} = \frac{x^3-3x^2+2x}{6}$$

for positions in both x and y directions. The final Lagrangian interpolating polynomial for three dimensions is reduced to

$$\begin{aligned} p(x,y) = {} & Lx_0Ly_0f(0,0)+Lx_1Ly_0f(1,0)+Lx_2Ly_0f(2,0)+Lx_3Ly_0f(3,0) \\ & + Lx_0Ly_1f(0,1)+Lx_1Ly_1f(1,1)+Lx_2Ly_1f(2,1)+Lx_3Ly_1f(3,1) \\ & + Lx_0Ly_2f(0,2)+Lx_1Ly_2f(1,2)+Lx_2Ly_2f(2,2)+Lx_3Ly_2f(3,2) \\ & + Lx_0Ly_3f(0,3)+Lx_1Ly_3f(1,3)+Lx_2Ly_3f(2,3)+Lx_3Ly_3f(3,3) \end{aligned}$$

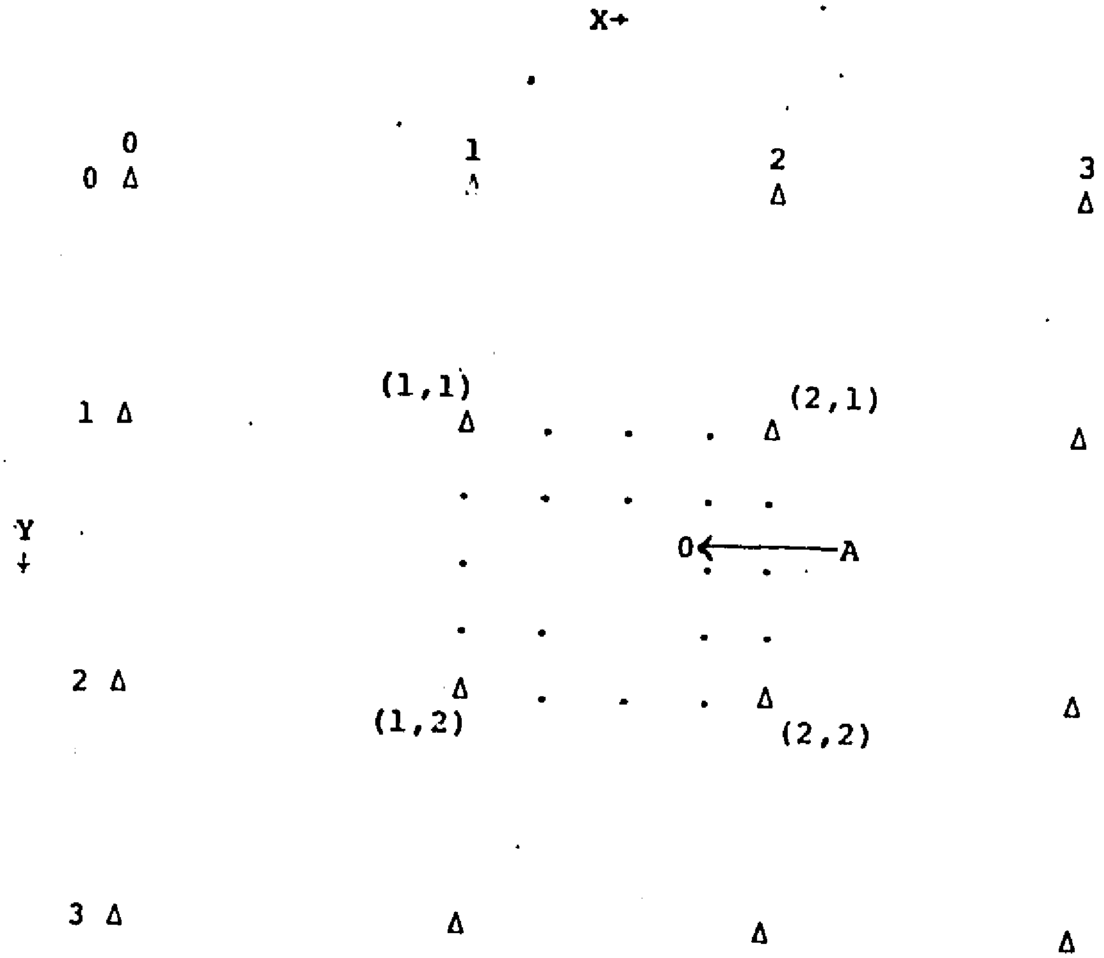


Figure 2.2.2-2 4 x 4 Data matrix surrounding point to be interpolated (point A).

2.2.3 DATA BASE IMPLICATIONS

An underlying assumption from the beginning of the project revolved about the need for a geo-referenced data base management capability. Forest management depends to a large degree on maps. Since Landsat classifications provide only crude maps. some form of cartographic embellishment would be necessary. The graphics part of FRIS would be essential for an operational system.

A Computer Sciences Corporation report on Geographic Information systems (Knapp and Rider, 1978) provided a point of departure for further investigation. Table 2.2.3-1, from Knapp and Rider, indicate the number and characteristics of some geographic information systems currently in use.

The FRIS staff was familiar with some of the systems identified in the Table. We focused our attention on three systems; M & S Computings IGDS; Comarc System Design's CRIS; and Harvard University's ODYSSEY. We felt that as part of the demonstration it was imperative to evaluate the potential tie between the Landsat data and the geographic information system. We approached Harvard with a proposal to test the compatibility of the image processing and graphics systems. A discussion of our evaluation of ODYSSEY follows.

ODYSSEY Implications to Preprocessing

The Harvard ODYSSEY cartographic graphics system is a highly transportable computer graphics software system. The arc (chain) file utility program, HOMER, accomplishes everything the LARS arc editing program PREPDIG is able to, and more. The ODYSSEY software is extremely sophisticated, permitting interactive changes to the file, and immediate visual representation of those changes using a graphics terminal. Among HOMER's capabilities:

- o Full editing capabilities (deleting arcs, points or polygons)-
- o Coordinates stored in Latitude-Longitude may be converted to other projections;
- o Planar transformation of arc coordinates (indexed by arc);
- o Generalization of arc coordinates, reducing the number of points to describe an arc;
- o Plot arcs contained in a "window" of the data;
- o Produce maps at different scales, with labels and annotation.

While visiting Harvard University to evaluate the ODYSSEY software system, FRIS personnel digitized a test map, transformed it to latitude-longitude coordinates, and edited out mistakes in the file in a period of about four hours. Using the current LARS software, the same job would have required about 16 hours.

Table 2.2.3-1 Summary of available geographic information systems from: Computer Science Corporation, 1978 Geographic Information System Survey Interim Report prepared to Contract NAS 5-24350.

STANDARD REPORTING FORM CATEGORIES	ORGANIZATION AND SYSTEM ACRONYM			
	W. E. CATES & ASSOCIATES ADAPT	ALABAMA DEVELOPMENT OFFICE ARIS	BENDIX AEROSPACE	COMPUTERVISION CADDS 3/MAP
PROGRAMMING BASIS & OPERATING INFORMATION				
OPERATIVE COMPUTERS	IBM 370, AMDAHL V6	IBM 370/168	PDP11, PDP10, IBM/370, Z80	NOVA 1200, DCC 116, COMPUTERVISION CGP-100
PROGRAMMING LANGUAGE	FORTRAN IV	FORTRAN IV, PL/1	FORTRAN IV, MACRO ASSEMBLY	FORTRAN, APL, ASSEMBLER
MODE OF USAGE	BATCH	BATCH & INTERACTIVE	BATCH & INTERACTIVE	INTERACTIVE
MEMORY SIZE	256-360K	128-160K	192K	8K & 24K
WORD SIZE (BITS)	32	32	16	16
GEOGRAPHIC DATA TYPE				
INPUT				
LINE	YES	YES	YES	YES
CELL	YES	NO	YES	NO
TABULAR	YES	NO	YES	NO
POLYGON	YES	YES	YES	NO
ANALYSIS				
CELL	–	YES	YES	NO
POLYGON	–	NO	YES	YES
TABULAR	YES	NO	YES	NO
CELL & POLYGON	YES	NO	YES	NO
DATA ENTRY & DATA OUTPUT PRODUCTS				
ENTRY				
AUTOMATIC	YES	YES	YES	YES
SEMI-AUTOMATIC	NO	NO	YES	NO
MANUAL	YES	YES	YES	YES
OUTPUT PRODUCTS				
GRAPHIC	YES	YES	YES	YES
TABULAR	YES	NO	YES	ANALYSIS REPORTS
DIGITAL	NO	YES	YES	NO
ANALYTIC CAPABILITIES				
COMPOSITE MAPPING	YES	YES	YES	–
POLYGON OVERLAY	YES	NO	POLYGON INTERSECTION	–
CELLULAR	YES	YES	YES	–
ABILITY TO VARY SCALE	YES	NO	YES	YES
ABILITY TO VARY RESOLUTION	YES	YES	–	–
AREA MEASURE	YES	YES	YES	YES
SIMULATION AND/OR MODELING	YES	YES	YES	NO
BOOLEAN COMBINATIONS	YES	YES	YES	NO
CORRELATION	YES	NO	YES	NO
REGRESSION	YES	NO	YES	NO
INTERPRETIVE MAPS	YES	YES	YES	YES
DATA STORAGE				
STRUCTURE				
DIRECT ACCESS	YES	NO	YES	YES
SEQUENTIAL	NO	YES	YES	YES
OTHER	N/A	N/A	N/A	N/A
ORGANIZATION				
HIERARCHICAL	NO	YES	YES	YES
POINTER	YES	NO	YES	YES
RELATIONAL	YES	NO	YES	YES
INTERFACE WITH CLASSIFIED LANDSAT DATA				
EXPERIMENTALLY	–	NO	YES	NO
OPERATIONALLY	YES	NO	YES	NO
ACQUISITION CONDITIONS	LEASE, SPECIFIC USER BY PROJECT	–	SPECIFIC USERS ONLY	AS PART OF SUPPLIED SYSTEM
STATUS OF RELEASE	TESTED & EVALUATED	–	PARTIALLY TESTED & EVALUATED	TESTED & EVALUATED
WILLINGNESS TO ADAPT TO HP3000	YES	NO	NO	NO
WITHIN COST THRESHOLD	BASELINE SYSTEM – YES	–	N/A	NO
WITHIN TIME THRESHOLD	TO BE DETERMINED	–	N/A	FOR TURNKEY SYSTEM – YES
CUSTOMER SUPPORT	MAINTENANCE/ CONSULTATION	–	MAINTENANCE/ CONSULTATION	MAINTENANCE
TRANSFERABILITY*	4	4	5	5

*Note: The data presented in this table has been supplied by the individual organizations and has not been verified by Computer Sciences Corporation or NASA

Table 2.2.3-1 continued

STANDARD REPORTING FORM CATEGORIES	ORGANIZATION AND SYSTEM ACRONYM			
	U.S. FORESTRY SERVICE COMLUP	COMPREHENSIVE PLANNING ORGANIZATION	UNIVERSITY OF GEORGIA CONGRID	COMARC CRIS
PROGRAMMING BASIS & OPERATIONS INFORMATION				
OPERATIVE COMPUTERS	CDC 3100	BURROUGHS B6700	BURROUGHS, IBM 360/370, UNIVAC 1100	DATA GENERAL ECLIPSE
PROGRAMMING LANGUAGE	FORTRAN	FORTRAN (BASIC – 4061)	FORTRAN	FORTRAN IV & V
MODE OF USAGE	BATCH	BATCH	BATCH & INTER-ACTIVE	INTERACTIVE & REALTIME
MEMORY SIZE	32K	VARIES WITH PROGRAM	250K	128–512K
WORD SIZE (BITS)	8	VARIES WITH PROGRAM	4	16
GEOGRAPHIC DATA TYPE				
INPUT				
LINE	YES	YES	NO	YES
CELL	NO	NO	YES	YES
TABULAR	NO	NO	NO	YES
POLYGON	NO	YES	NO	YES
ANALYSIS				
CELL	YES	–	YES	YES
POLYGON	NO	–	NO	YES
TABULAR	NO	YES	NO	YES
CELL & POLYGON	NO	YES	NO	YES
DATA ENTRY & DATA OUTPUT PRODUCTS				
ENTRY				
AUTOMATIC	NO	YES	YES	YES
SEMI-AUTOMATIC	NO	NO	NO	NO
MANUAL	YES	YES	YES	YES
OUTPUT PRODUCTS				
GRAPHIC	YES	YES	YES	YES
TABULAR	NO	YES	YES	YES
DIGITAL	YES	YES	NO	YES
ANALYTIC CAPABILITIES				
COMPOSITE MAPPING	YES	YES	YES	YES
POLYGON OVERLAY	POLYGON INTER-SECTION	YES	–	YES
CELLULAR	–	–	YES	YES
ABILITY TO VARY SCALE	YES	YES	NO	YES
ABILITY TO VARY RESOLUTION	–	–	–	YES
AREA MEASURE	YES	YES	YES	YES
SIMULATION AND/OR MODELING	NO	YES	YES	YES
BOOLEAN COMBINATIONS	YES	YES	YES	YES
CORRELATION	NO	NO	NO	YES
REGRESSION	NO	NO	NO	YES
INTERPRETIVE MAPS	YES	YES	YES	YES
DATA STORAGE				
STRUCTURE				
DIRECT ACCESS	NO	YES	YES	NO
SEQUENTIAL	YES	YES	NO	NO
OTHER	N/A	NO	N/A	RANDOM
ORGANIZATION				
HIERARCHICAL	YES	YES	GRID MATRIX NO	NO
POINTER	NO	YES	NO	NO
RELATIONAL	NO	NO	NO	YES
INTERFACE WITH CLASSIFIED LANDSAT DATA				
EXPERIMENTALLY	NO	NO	YES	YES
OPERATIONALLY	NO	NO	–	NO
ACQUISITION CONDITIONS	HANDLING/MAILING	HANDLING/MAILING ONLY	FREE OF CHARGE	LEASE
STATUS OF RELEASE	TESTED & EVALU-ATED	TESTED & EVALU-ATED	TESTED	TESTED
WILLINGNESS TO ADAPT TO HP3000	NO	YES	YES	YES
WITHIN COST THRESHOLD	YES	TO BE DETERMINED	TO BE DETERMINED	YES
WITHIN TIME THRESHOLD	YES	TO BE DETERMINED	TO BE DETERMINED	YES
CUSTOMER SUPPORT	NONE	–	CONSULTATION	MAINTENANCE/ CONSULTATION
TRANSFERABILITY*	5	3	4	2

†Note. The data presented in this table has been supplied by the individual organizations and has not been verified by Computer Sciences Corporation or NASA.

Table 2.2.3-1 continued

STANDARD REPORTING FORM CATEGORIES	ORGANIZATION AND SYSTEM ACRONYM			
	EARTH SYSTEMS RESEARCH, INC. EPPL/4	EARTH RESOURCES LABORATORY GOBS	DAMES & MOORE GIMS	U S G S GIRAS
PROGRAMMING BASIS & OPERATING INFORMATION				
OPERATIVE COMPUTERS	CDC CYBER 74	VARIAN V–75	CDC6000, IBM 370, UNIVAC 1108, PDP-11	IBM 370
PROGRAMMING LANGUAGE	FORTRAN	FORTRAN IV & ASSEMBLER	FORTRAN IV	FORTRAN IV
MODE OF USAGE	INTERACTIVE & BATCH	BATCH & INTER-ACTIVE	BATCH	BATCH
MEMORY SIZE	40 KW	64K	64K	–
WORD SIZE (BITS)	60	16	32	32
GEOGRAPHIC DATA TYPE				
INPUT				
LINE	NO	NO	YES	NO
CELL	YES	YES	YES	NO
TABULAR	YES	NO	YES	NO
POLYGON	NO	YES	YES	YES
ANALYSIS				
CELL	YES	–	–	–
POLYGON	NO	–	–	–
TABULAR	YES	NO	YES	NO
CELL & POLYGON	NO	YES	YES	YES
DATA ENTRY & DATA OUTPUT PRODUCTS				
ENTRY				
AUTOMATIC	YES	YES	YES	NO
SEMI-AUTOMATIC	NO	YES	NO	YES
MANUAL	NO	YES	YES	YES
OUTPUT PRODUCTS				
GRAPHIC	YES	YES	YES	YES
TABULAR	YES	YES	NO	YES
DIGITAL	YES	–	NO	YES
ANALYTIC CAPABILITIES				
COMPOSITE MAPPING	YES	–	YES	YES
POLYGON OVERLAY	–	–	YES	YES
CELLULAR	YES	–	NO	YES
ABILITY TO VARY SCALE	YES	YES	YES	YES
ABILITY TO VARY RESOLUTION	–	–	–	YES
AREA MEASURE	YES	ACREAGE PROGRAM	YES	YES
SIMULATION AND/OR MODELING	YES	NO	YES	NO
BOOLEAN COMBINATIONS	YES	–	YES	NO
CORRELATION	YES	NO	YES	NO
REGRESSION	YES	NO	NO	NO
INTERPRETIVE MAPS	YES	YES	YES	NO
DATA STORAGE				
STRUCTURE				
DIRECT ACCESS	YES	YES	NO	YES
SEQUENTIAL	NO	YES	YES	YES
OTHER	N/A	N/A	N/A	N/A
ORGANIZATION				
HIERARCHICAL	NO	NO	NO	NO
POINTER	YES	YES	NO	YES
RELATIONAL	NO	YES	YES	NO
INTERFACE WITH CLASSIFIED LANDSAT DATA				
EXPERIMENTALLY	–	–	NO	NO
OPERATIONALLY	YES	YES	NO	NO
ACQUISITION CONDITIONS	HANDLING/MAILING	–	–	SPECIFIC USERS ONLY
STATUS OF RELEASE	TESTED	–	TESTED	TESTED
WILLINGNESS TO ADAPT TO HP3000	YES	–	YES	NO
WITHIN COST THRESHOLD	YES	BASELINE SYSTEM – YES	UNKNOWN	BASELINE SYSTEM – YES
WITHIN TIME THRESHOLD	NO	–	YES	–
CUSTOMER SUPPORT	MAINTENANCE & CONSULTATION	–	MAINTENANCE & CONSULTATION	–
TRANSFERABILITY*	4	3	5	5

*Note: The data presented in this table has been supplied by the individual organizations and has not been verified by Computer Sciences Corporation or NASA.

Table 2.2.3-1 continued

STANDARD REPORTING FORM CATEGORIES	ORGANIZATION AND SYSTEM ACRONYM			
	ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE			COMPUMATRIX, INC EPIC
	GRID II	FIOS	AUTOMAP/GRIPS	
PROGRAMING BASIS & OPERATING INFORMATION				
OPERATIVE COMPUTERS	HP3000, VARIAN, TOSBAC, ICL, IBM, PRIME, UNIVAC, CDC	IBM 360, IBM 370, PRIME	BURROUGHS, ICL, IBM, PRIME, UNIVAC, CDC, TOSBAC VARIAN, HP3000	HONEYWELL 6000, IBM 360, 370
PROGRAMMING LANGUAGE	FORTRAN IV	FORTRAN IV	FORTRAN IV	BASIC, ALGOL, FORTRAN IV
MODE OF USAGE	BATCH & INTERACTIVE	BATCH & INTERACTIVE	BATCH & INTERACTIVE	INTERACTIVE
MEMORY SIZE	64K	64K	32–50K	VARIABLE (18K)
WORD SIZE (BITS)	16 OR LARGER	16 OR LARGER	16 OR LARGER	VARIABLE
GEOGRAPHIC DATA TYPE				
INPUT				
LINE	YES	YES	YES	YES
CELL	YES	YES	YES	YES
TABULAR	YES	NO	YES	YES
POLYGON	YES	YES	YES	YES
ANALYSIS				
CELL	YES	NO	–	–
POLYGON	NO	YES	–	–
TABULAR	YES	YES	YES	NO
CELL & POLYGON	NO	NO	YES	YES
DATA ENTRY & DATA OUTPUT PRODUCTS				
ENTRY				
AUTOMATIC	YES	YES	YES	YES
SEMI-AUTOMATIC	YES	YES	YES	NO
MANUAL	YES	YES	YES	YES
OUTPUT PRODUCTS				
GRAPHIC	YES	YES	YES	YES
TABULAR	YES	YES	YES	YES
DIGITAL	YES	YES	YES	YES
ANALYTIC CAPABILITIES				
COMPOSITE MAPPING	YES	YES	YES	YES
POLYGON OVERLAY	NO	YES	YES	POLYGON INTERSECTION
CELLULAR	YES	NO	YES	–
ABILITY TO VARY SCALE	NO	YES	YES	YES
ABILITY TO VARY RESOLUTION	YES	YES	YES	–
AREA MEASURE	YES	YES	YES	YES
SIMULATION AND/OR MODELING	YES	YES	YES	YES
BOOLEAN COMBINATIONS	YES	YES	NO	YES
CORRELATION	NO	YES	NO	YES
REGRESSION	NO	YES	NO	YES
INTERPRETIVE MAPS	YES	YES	YES	NO
DATA STORAGE				
STRUCTURE				
DIRECT ACCESS	NO	NO	NO	USER OPTION
SEQUENTIAL	YES	YES	YES	USER OPTION
OTHER	N/A	N/A	N/A	USER OPTION
ORGANIZATION				
HIERARCHICAL	NO	NO	NO	USER OPTION
POINTER	YES	YES	NO	USER OPTION
RELATIONAL	NO	YES	YES	USER OPTION
INTERFACE WITH CLASSIFIED LANDSAT DATA				
EXPERIMENTALLY	YES	NO	NO	YES
OPERATIONALLY	NO	NO	NO	NO
ACQUISITION CONDITIONS	LEASE	LEASE	LEASE	LEASE
STATUS OF RELEASE	TESTED & EVALUATED	TESTED & EVALUATED	TESTED & EVALUATED	–
WILLINGNESS TO ADAPT TO HP3000	HAS BEEN ADAPTED	YES	HAS BEEN ADAPTED	YES
WITHIN COST THRESHOLD	YES	YES	YES	BASELINE SYSTEM – YES
WITHIN TIME THRESHOLD	YES	YES	YES	YES
CUSTOMER SUPPORT	MAINTENANCE/CONSULTATION	MAINTENANCE/CONSULTATION	MAINTENANCE/CONSULTATION	MAINTENANCE/CONSULTATION
TRANSFERABILITY*	1	3	1	3

*Note: The data presented in this table has been supplied by the individual organizations and has not been verified by Computer Sciences Corporation or NASA.

Table 2.2.3-1 continued

STANDARD REPORTING FORM CATEGORIES	ORGANIZATION AND SYSTEM ACRONYM			
	JET PROPULSION LABORATORY IBIS	M&S COMPUTING IGDS	H. DELL FOSTER IGS, 330	EARTH SATELLITE CORP LCDMS
PROGRAMMING BASIS & OPERATING INFORMATION				
OPERATIVE COMPUTERS	IBM 360/65, 75, 91 IBM 370	PDP 11/34, PDP 11/70	DATA GENERAL 1200 ECLIPSE NOVA	PDP 11/45
PROGRAMMING LANGUAGE	FORTRAN IV/ IBM ASSEMBLER	FORTRAN & MACRO-11	FORTRAN/DATA GENERAL ASSEMBLY	FORTRAN IV, PLUS (DEC), MACRO-11
MODE OF USAGE	BATCH & INTER-ACTIVE	INTERACTIVE	INTERACTIVE	INTERACTIVE
MEMORY SIZE	200K	256K	64K	64K
WORD SIZE (BITS)	32	16	16	16
GEOG[illegible]PHIC DATA TYPE				
INP[illegible]				
LINE	NO	YES	YES	NO
CELL	YES	NO	YES	YES
TABULAR	NO	NO	NO	YES
POLYGON	YES	YES	NO	YES
ANALYSIS				
CELL	NO	NO	–	YES
POLYGON	YES	YES	–	NO
TABULAR	YES	NO	YES	NO
CELL & POLYGON	NO	NO	YES	NO
ENTRY				
AUTOMATIC	YES	YES	NO	YES
SEMI-AUTOMATIC	YES	NO	NO	YES
MANUAL	NO	YES	YES	YES
OUTPUT PRODUCTS				
GRAPHIC	YES	YES	YES	YES
TABULAR	YES	YES	YES	YES
DIGITAL	YES	NO	NO	NO
ANALYTIC CAPABILITIES				
COMPOSITE MAPPING	YES	YES	–	–
POLYGON OVERLAY	–	POLYGON INTER-SECTION	POLYGON INTER SECTION	–
CELLULAR	–	NO	-	–
ABILITY TO VARY SCALE	YES	YES	YES	YES
ABILITY TO VARY RESOLUTION	–	YES	–	–
AREA MEASURE	YES	YES	YES	YES
SIMULATION AND/OR MODELING	NO	NO	NO	NO
BOOLEAN COMBINATIONS	NO	YES	NO	NO
CORRELATION	YES	NO	NO	NO
REGRESSION	NO	NO	NO	NO
INTERPRETIVE MAPS	NO	NO	NO	NO
DATA STORAGE				
STRUCTURE				
DIRECT ACCESS	YES	NO	YES	YES
SEQUENTIAL	YES	YES	NO	NO
OTHER	N/A	N/A	N/A	N/A
ORGANIZATION				
HIERARCHICAL	NO	NO	NO	NO
POINTER	NO	NO	YES	YES
RELATIONAL	NO	NO	NO	NO
INTERFACE WITH CLASSIFIED LANDSAT DATA				
EXPERIMENTALLY	–	NO	NO	–
OPERATONALLY	YES	NO	NO	YES
ACQUISITION CONDITIONS	ROYALTY PAYMENT	LEASE/LICENSE SALE	SPECIFIC USERS ONLY	–
STATUS OF RELEASE	TESTED & EVALU-ATED	TESTED	TESTED	TESTED
WILLINGNESS TO ADAPT TO HP3000	YES	NO	NO	YES
WITHIN COST THRESHOLD	N/A	NO	FOR TURNKEY SYSTEM – YES	YES
WITHIN TIME THRESHOLD	N/A	YES	FOR TURNKEY SYSTEM – YES	YES
CUSTOMER SUPPORT	CONSULTATION	MAINTENANCE CONSULTATION	MAINTENANCE/ CONSULTATION	MAINTENANCE/ CONSULTATION
TRANSFERABILITY[1]	4	5	5	7

[1]Note: The data presented in this table has been supplied by the individual organizations and has not been verified by Computer Sciences Corporation or NASA

Table 2.2.3-1 continued

STANDARD REPORTING FORM CATEGORIES	ORGANIZATION AND SYSTEM ACRONYM			
	HARVARD UNIVERSITY ODYSSEY	OAK RIDGE NATIONAL LABORATORY ORRMIS	BATELLE PTOLEMY	SOUTH DAKOTA STATE PLANNING BUREAU SDAGIS
PROGRAMMING BASIS & OPERATING INFORMATION				
OPERATIVE COMPUTERS	PDP-10	IBM 360, PDP 10	PDP 11/35	IBM 370/148 (TEK 4051)
PROGRAMMING LANGUAGE	FORTRAN IV	FORTRAN (SOME IBM ASSEMBLY)	FORTRAN	FORTRAN, IBM ASSEMBLER, BASIC
MODE OF USAGE	BATCH & INTERACTIVE	BATCH & INTERACTIVE	INTERACTIVE	BATCH & INTERACTIVE
MEMORY SIZE	45K	120–2000K	48K	18000K
WORD SIZE (BITS)	32	18 OR 32	16	32
GEOGRAPHIC DATA TYPE				
INPUT				
LINE	YES	YES	YES	YES
CELL	NO	YES	NO	YES
TABULAR	YES	YES	NO	NO
POLYGON	YES	YES	YES	YES
ANALYSIS				
CELL	NO	–	NO	–
POLYGON	YES	–	YES	–
TABULAR	YES	–	NO	NO
CELL & POLYGON	NO	YES	NO	YES
DATA ENTRY & DATA OUTPUT PRODUCTS				
ENTRY				
AUTOMATIC	YES	YES	NO	YES
SEMI-AUTOMATIC	YES	YES	NO	NO
MANUAL	YES	YES	YES	YES
OUTPUT PRODUCTS				
GRAPHIC	YES	YES	YES	YES
TABULAR	YES	YES	YES	YES
DIGITAL	YES	YES	NO	YES
ANALYTIC CAPABILITIES				
COMPOSITE MAPPING	YES	YES	YES	YES
POLYGON OVERLAY	YES	POLYGON INTERSECTION	POLYGON INTERSECTION	POLYGON INTERSECTION
CELLULAR	–	YES	NO	–
ABILITY TO VARY SCALE	YES	YES	YES	YES
ABILITY TO VARY RESOLUTION	YES	YES	–	–
AREA MEASURE	YES	YES	YES	YES
SIMULATION AND/OR MODELING	NO	YES	NO	YES
BOOLEAN COMBINATIONS	YES	YES	YES	YES
CORRELATION	NO	YES	NO	YES
REGRESSION	NO	YES	NO	YES
INTERPRETIVE MAPS	YES	YES	NO	YES
DATA STORAGE				
STRUCTURE				
DIRECT ACCESS	NO	YES	YES	NO
SEQUENTIAL	YES	YES	YES	YES
OTHER	N/A	N/A	NO	–
ORGANIZATION				
HIERARCHICAL	YES	YES	YES	NO
POINTER	YES	YES	YES	NO
RELATIONAL	NO	YES	NO	NO
INTERFACE WITH CLASSIFIED LANDSAT DATA				
EXPERIMENTALLY	NO	–	NO	–
OPERATIONALLY	NO	YES	NO	YES
ACQUISITION CONDITIONS	RENEWABLE LEASE		CONTRACT TO CONVERT TO HP	LEASE
STATUS OF RELEASE	PARTIALLY TESTED AND EVALUATED	PARTIALLY TESTED AND EVALUATED	IN-HOUSE RESEARCH TOOL	TESTED
WILLINGNESS TO ADAPT TO HP3000	YES		YES	NO
WITHIN COST THRESHOLD	YES		NO	BASELINE SYSTEM-YES
WITHIN TIME THRESHOLD	YES		NO	BASELINE SYSTEM-YES
CUSTOMER SUPPORT	MAINTENANCE/CONSULTATION		MAINTENANCE/CONSULTATION	MAINTENANCE/CONSULTATION
TRANSFERABILITY*	2	4	3	4

*Note: The data presented in this table has been supplied by the individual organizations and has not been verified by Computer Sciences Corporation or NASA

A data set digitized by a vendor using an automatic line-follower presented an even more dramatic example of the savings of time required to edit an arc file. Harvard reformatted the vendors tape (fixing a problem with the internal structure of the tape, Figure 2.2.3-1 and 2.2.3-2), edited the OA and AU data from four AU's, converted a LARS classification tape to vector format, and then overlayed the classification with the digitized map data within a two-day period. The amount of work necessitated by this process at LARS would be near one man-month using our current software and techniques.

The ODYSSEY system permits a non-image processing registration capability. Permitting the necessary transofrmation of both map data and classification data to a common grid system in vector form effectually produces a registered data product that can be accessed by attribute information without expensive computer processing or large memory requirements. This will also further reduce the man-time required to combine the data in an operational system.

Non-image registration of map and classification data also permits storage of all data into a single grid system accessible as a data base. Rather than a complex storage system of image data at the National Computer Center, the map/classification/ploygon overlay could be stored on disc accessible by a minicomputer at a regional site. Storing the polygon and attribute information accessible in a common geographic grid achieves the same end result as mosaicing the Landsat imagery before classification, with the added benefit of providing more timely access to the mapping data.

A potential scenario for the creation of a multi-source data set using the ODYSSEY system could be as follows:

1. Landsat data is received at NCC and is reformatted to LARSYS format. A gray-scale image is produced, and the area of interest determined.
2. The area of interest is geometrically corrected on the IBM/370 at NCC. Although technically this step is unnecessary, it is desirable as an analyst must be able to positionally relate to his data.
3. During steps 1 and 2 (or prepared in advance), the maps are digitized.
4. The geometrically-corrected data is check-pointed to the map reference grid.
5. A remote sensing analyst classifies the Landsat data.
6. In the same time frame as step 5, the map data information is cleaned, assembled (if necessary), and checked for accuracy.
7. The completed classification is converted to a vector format, and then overlayed onto the map, using the ODYSSEY system.

At this point, data is available to add other attribute information or additional classification information. Only reformatting, geometric

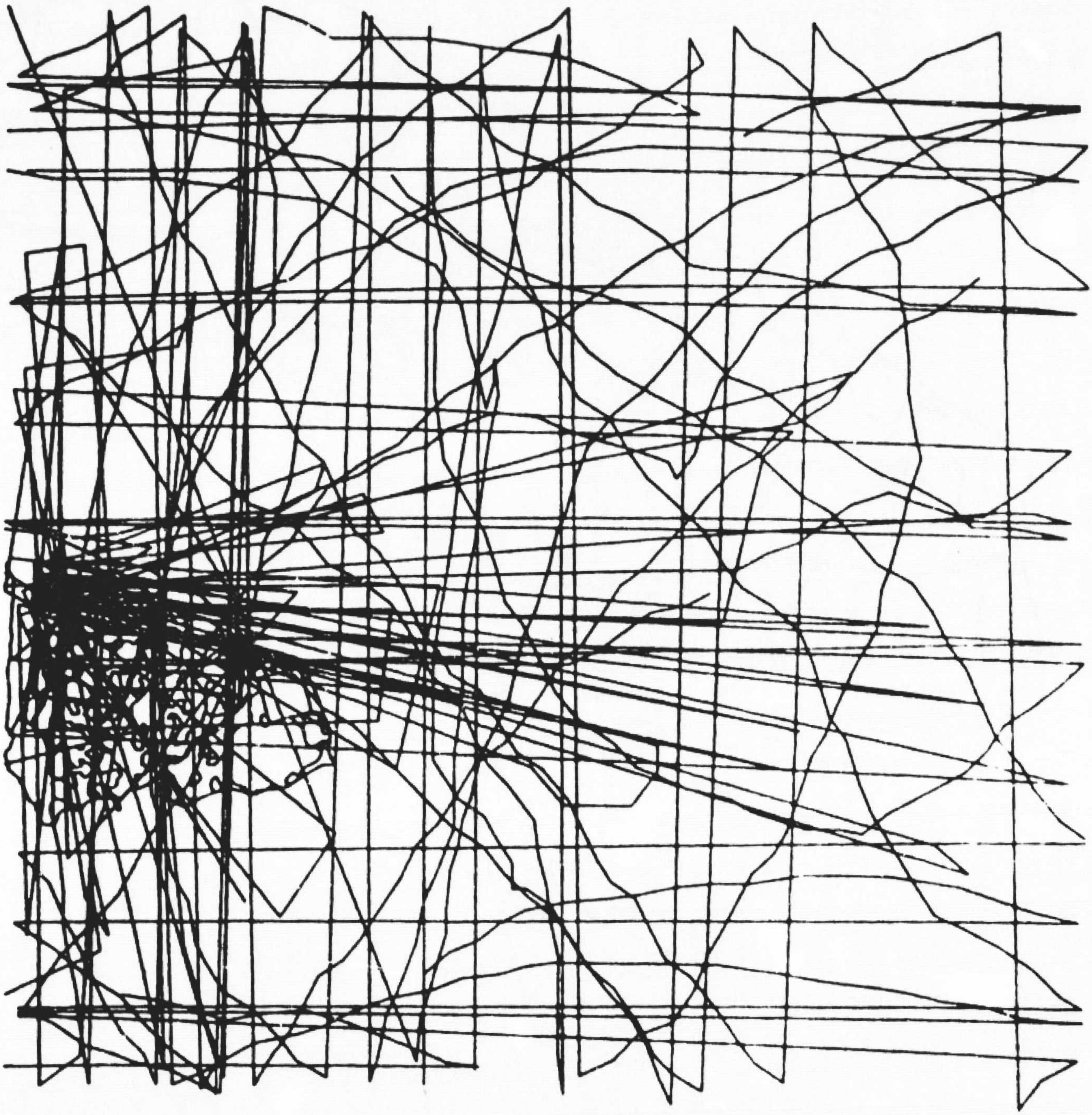


Figure 2.2.3-1 Vendor Digitized Map Data before using ODYSSEY software to edit the data.

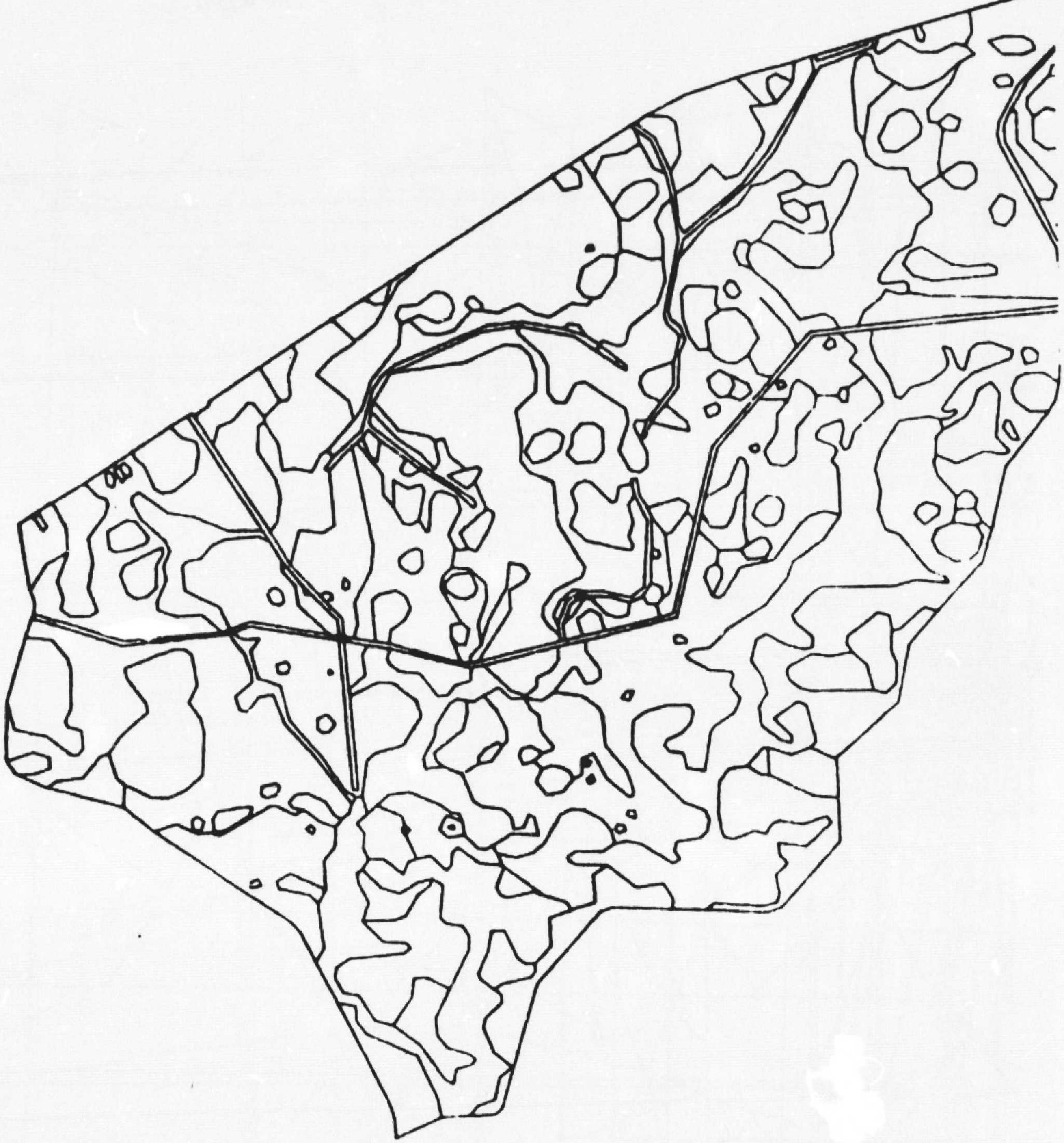


Figure 2.2.3-2 Vendor Digitized Map Data after using ODYSSEY software editing routines to clean data.

correction and classification are performed on a large main-frame computer. Digitization, map cleanup, and data registration are performed on the minicomputer.

The implication of the ODYSSEY software is that project delays should not occur during the digitizing and classification procedures, rather than during the procedures involving image registration and arc data editing/cleanup. This is seen as a potential reduction in personnel effort of 80 to 120 man-hours.

Recommendations

In summary, this appears to be a sophisticated, viable approach to the problems of adding ancillary data in a workable form. It is important, however, to recognize some significant drawbacks to the system:

1. The system's sophistication also presents one of its major faults: a very complex control syntax is required to run the system programs. Although well-documented, it will require a significant training effort to learn to use the software.
2. The system currently lacks adequate manipulation and access to ancillary attribute data. At the present time, this item alone prevents this cartographic data base system from becoming a cartographically-based management information system. It should be noted, however, that all of the software "hooks" are there, and that attribute management is planned for distribution in the very near future.
3. The complexity and sophistication of the system probably will require programming support form the user's end. Harvard does support the user with software support.

These drawbacks should not necessarily preclude a workable implementation of an ODYSSEY-based system, given the appropriate technical support and training from the user's end.

2.2.4 LANDSAT III IMPLICATIONS AND IMPACTS

Remote sensing data acquisition and delivery is perhaps the most critical element of the FRIS system development activity since it is an external and somewhat concertain process. That is, the preprocessing and analysis software, the hardware, the FRIS organization are basically under control of the user but the data source and delivery mechanism are not. Without smooth and timely flow of presently known data for at least 10 years the remote sensing aspect of FRIS will not succeed.

The near term source of remote sensing data is Landsat III which is producing good quality four band multispectral scanner data and single band return beam vidicon data. The MSS was to include a fifth thermal band but this sensor has failed and the current data is essentially the same as Landsat I and II data. The RBV has been reduced to one band (.505 - .75 μm) from the three on earlier systems and is producing high resolution imagery (19 m) in frames of 99 x 99 km. Four frames are obtained for each Landsat frame. The total area covered is 183 km by 181 km.

A new ground processing system is being implemented by NASA Goddard and the EROS Data Center which will produce geometrically and radiometrically corrected CCT data for both the MSS and RBV. The capability will have a significant impact on the FIRS preprocessing requirements.

Both MSS and RBV data will be available geometrically corrected to a specific projection as well as in uncorrected form with the correction function specified. The standard projection will be Space Oblique Mercator (SOM) with Universal Transverse Mercator (UTM) available as an option. The correction imagery produced by this system will not visually appear different from previous uncorrected imagery; however, the pixels are placed in a precise coordinate grid which is clearly defined mathematically with respect to the earth.

Availability of corrected data will eliminate the need for most of the costly and time consuming geometric correction and registration operations in the FRIS preprocessing system. A problem which possibly will exist with the new system in uncertainty with regard to data format and delivery time. The FRIS system could utilize with the fully corrected or uncorrected form of the data. Different FRIS system capabilities would be needed to handle these two forms. Furthermore, problems and backlogs in the control point location and correction system at NASA Goddard could result in unavailability of corrected data at least in a time frame that would be useful. This would require that FRIS have the capability to geometrically correct the data as a backup capability. Thus, the additior of greatly improved data preprocessing capability to the NASA Landsat data supply system has in fact greatly complicated the FRIS design due to increased uncertainty in what will actually be available.

Another impact on FRIS is the uncertainty in what future the satellite sensor systems will be. Indeed there will no doubt be satellite earth resources remote sensor systems providing data for the forseeable future; however, the nature of these systems is unknown. For a FRIS user such as St. Regis to invest in and amortize such a system a five to ten year operating period with a known cost and system structure must be achieved. If Landsat III data in the planned format could be assured until 1990 the FRIS investment could be better justified.

Finally, the FRIS system could potentially make use of several remote sensing data types and preprocessing flexibility is advisable to enable these data to be handled. In addition to Landsat MSS and RBV data there currently aircraft systems which can produce MSS and side looking imaging radar data which may be needed. Radar imagery may be needed to conduct forest stand inventory if no clear satellite passes are acquired in the required time window. Aircraft MSS data could be obtained during a good weather period not coincident with a satellite coverpass. Also, future satellite systems will include imaging radar and advanced MSS systems such as Thematic Mapper which will be of value to FRIS. Thus, the conclusion from these considerations is that the FRIS preprocessing "front end" should be flexible so that a variety of input data types and formats can be handled without significant reprogramming and restructuring of the system. The next section describes the preprocessing structure proposed for the FRIS system.

2.2.5 PLAN FOR PHASE III-REQUIREMENTS FOR NEW REFORMATTING SOFTWARE

The requirements for the FRIS "front end" as developed in Phase II and discussed above have the key characteristic of flexibility. Without flexibility the software may be unable to cope with the forms of data which at different points in time are presented to it. Current preprocessing functions to transform uncorrected un-control point referenced Landsat imagery to FRIS resource unit coordinates is described in Section 2.2.2. The basic capabilities embodied in that process are recommended to be included in the FRIS system to handle the cases where geometrically corrected data is not available. Additional elements are needed to handle the other cases and this section outlines the proposed total preprocessing system which may include more capabilities than would be implemented in Phase III and IV.

The central element of the proposed FRIS preprocessing system is the Standard Input Image Data Set. This concept was arrived at as the only feasible approach to handling the variety of data types and correction formats which may be presented to FRIS. The unique feature of the Standard data set is that it is self describing with respect to its geometry. This is achieved by storing parameters in the ancillary data records which define location, scale, projection etc. of the image data.

The FRIS preprocessing system would then be structured around the standard data set input. All forms of input data would be transformed to the standard and the FRIS system would generate the needed data sets for analysis from the standard. This approach relieves the FRIS system of the vagaries of the input format and allows a fixed set of software routines to be developed to provide the specific areas and channel combinations needed for analysis and input to the data base. This is basically the approach followed in the LARSYS system in which all data is reformatted to the standard LARSYS 3 format and all user programs are designed to read this format and no other. The concept set forth here essentailly moves the point of standardizations back one step so that the preprocessing and geometric transform matrices software interfaces with a standard format as does the LARSYS analysis system.

The structure of the FRIS "front end" as envisioned here is diagrammed in Figure 2.2.5-1 for a subset of possible data types. For data types that have not been corrected and for which no correction function is supplied a control point location and correction function derivation step must be carried. This process is indicated by the blocks in the lower left of the figure with the appropriate data types flowing in. A standard set of control points would be stored and called up at the time of processing. Control points would be pinpointed by an operator and the distortion function computed and combined with the image data to form a standard input data set.

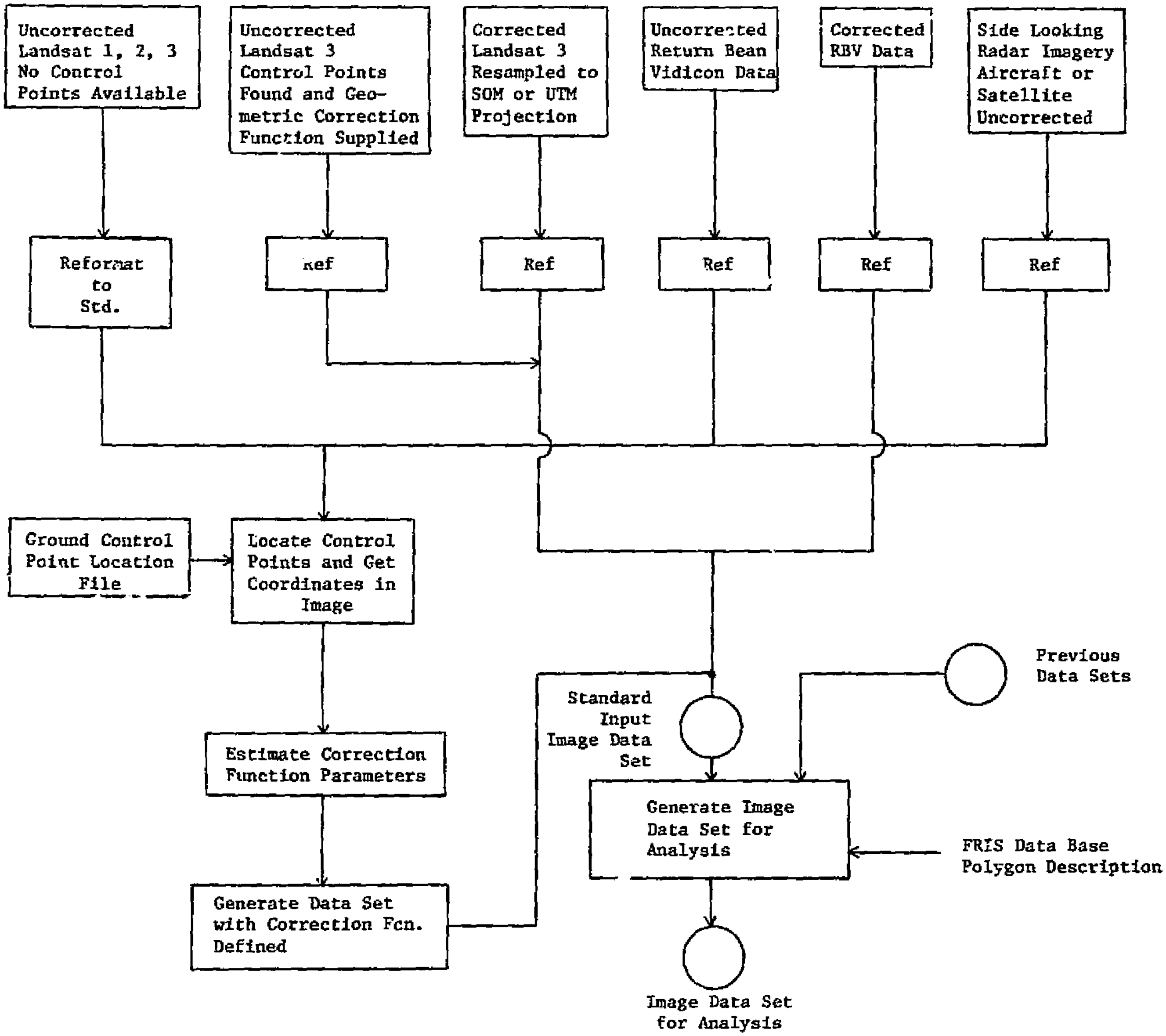


Figure 2.2.5-1 Structure of proposed FRIS reformatting scheme.

If the input data was in one of the corrected formats then a reformatting operation would be performed to place the data in the standard format and no control pointing operations would be required. The goal of these steps is to present the standard data set to the FRIS transformation processor so that the source of the data is not apparent other than by a designator in the ancillary data.

The analysis image data set generation block denotes these operations needed to transform and combine the input data to provide data sets specifically required by the analysts.

2.3 SYSTEM DESIGN

2.3.1 INFORMATION NEEDS DEFINITION

As an initial step in developing the remote sensing components of a FRIS we undertook a task to define broad areas of St. Regis information needs. This activity was pursued in conjunction with St. Regis staff who identified areas and generic types of information necessary for the system to be functional. Obviously, the components of a total Forest Resource Information System would address a broad arena of management needs. Therefore, our task had to be focused on just those components which can be somewhat addressable with Landsat data.

Information systems came into vogue because of their ability to manipulate vast quantities of data and provide management with various alternatives that can be used to make decisions. The quality, more so than quantity, of data being manipulated becomes important. Professional managers of forest resources must rely on inventory data, for the purpose of making decisions. These data are constantly being revised so that they reflect the current state of the resource. In order to account for the many and varied requirements of management it becomes necessary to utilize computer based information systems minimally just to track and sort the glut of data from the field. With this increased capacity for data manipulation more pressure is being placed on inventory systems to meet these data demands.

Given this thesis we set out to evaluate three survey methods that can provide inventory data to an information system. Traditionally, forest inventory is a never ending cycle, because forest resources occupy vast areas of land and their management and growth are dynamic in nature.

Table 2.3.1-1 presents an overview for FRIS information needs for ground, photo and Landsat survey types. At this stage each survey type is considered as a stand alone system. The information requirements are segmented into three categories:

A. Physically measureable phenomena

B. The managements constraints that may be imposed on survey type, and

C. The fact that any inventory information derived by a survey type should be accessible through a data base.

Table 2.3.1-1 represented a first iteration of the information needs definition task. However, it should be obvious from the Table that none of the survey types are optimum as a stand alone system. Traditional ground inventory methods fall short of providing the overview capable when aerial methods are utilized. Likewise, aerial photography cannot address many of physical measureables so necessary to meet forest quality and volume needs.

Table 2.3.1-1 FRIS Information Needs Matrix

Requirements:	Survey Type: Ground	Photo	Landsat
A. Physical Measurements:			
Objective: to provide information relative to the physical characteristics of forest resources in terms of their composition, location, areal extent and quality. Such measurements should relate to -			
1. Stand Type	++	+	+++
2. Stand Area	+++	++	+
3. Stand Volume	+	++	+++
4. Stand Quality	+	++	+++
5. Stand location	+	++	++
B. Constraints			
Objective: to quantitively evaluate the effect of limitations in the form of monitary, political, technical or operational in developing an operational FRIS. The following factors will be considered -			
1. Physical related to the natural composition of the forest ecosystem.	++	++	++
2. Monitary relating to the cost of acquiring and implementing a new technology.	++	++	+++
3. Technical related to the capability to utilize the data to provide information.	+	++	++
4. Operation relating to the suitability of implementing a technology.	++	++	++
5. Political related to the continued ability to independently acquire information to manage a resource.	+	++	+++
C. Data Base			
Objective: to evaluate the suitability of a remote sensing data base to be responsive to management needs. Items to be considered:			
1. Repeatibility of physical measurements.	+++	++	+
2. Suitability to manipulate boundary information by type -			
a. AU	+++	++	+
b. OA	+++	++	+
c. Ownership	+++	++	+
d. Political	+++	++	+
3. Value of automated map deviation.	+++	++	+

Key:

A most (+) to least (+++)

B & C least (+) to most (+++)

Landsat, can be timely and offers repetitive coverage over broad areas and may be economically advantageous for addressing certain information needs. However, Landsat cannot provide the specific information required by management. Therefore, some combination of systems is required.

Using the requirements defined in Table 2.3.1-1 we set out to develop a scenario for the operational use of a FRIS. The material that follows presents an idealized system, and represents a "first-cut" at describing the systems requirements.

FRIS Scenario

St. Regis will have one or two regional remote sensings laboratories. During the updating cycle (January to March), land managers will come into one of the regional centers and work with an inventory control forester in updating their lands. The updating sequence would take the following form:

1. Sitting at a CRT, the manager would call up a specific AU from the data file. Prior to this point in time, Landsat data for the current year (fall data set) would have been classified and included in the ownership data base. The Landsat classification could conceivably be called up on a second color display so that the manager can view the current status as depicted by the Landsat classification.
2. For the particular AU in question the manager would go through OA-by-OA identifying the disposition of each particular parcel of land. (i.e.: disposition refers to any specific management activity that could have occured on a parcel of land.)
3. Required changes in OA boundaries could be handled directly on the CRT with the aid of a light pencil. These changes would modify the cartographic data file, updating it for the current inventory year. Changes in land disposition or in OA boundaries would be filed on a computer record for additional editing.
4. When the AU was completely updated, the manager would have the option of reviewing the updated files, making necessary corrections and transferring the new updated data base to the main management information system file.

With such a system in place the updating cycle would be completed with greater speed and possibly greater accuracy than is currently possible. Managers would therefore be able to devote more time to land management problems and less time to the bookkeeping problems that are currently associated with the updating system.

Having developed these concepts, we were better equipped to begin defining the specific system components. Our first step was to evaluate how the existing image processing capability would meet the FRIS needs.

2.3.2 EXISTING SOFTWARE CAPABILITIES

Examination of current software capabilities at LARS was subdivided into two areas. The first was an examination of current capabilities. This was conducted in order to determine the magnitude of effort that would be required to convert the available software to operational FRIS requirements. This review would also provide a list of functional image processing requirements for FRTS.

The second area consisted of making modifications to existing software that would be required to an operational FRIS. In addition to modifications within LARSYS, which are discussed in this section, a number of efficiencies were incorporated in the digitizing software. A discussion of the stream-lining of the map digitizing process is included in Section 2.2.2.

LARSYS Capabilities

Presently the capability exists at LARS to construct a data set containing Landsat data and ancillary data from digitized map information. Currently this is done by using several sets of undocumented quasi-operational software, an exorbitant amount of manual editing, and special one-time programs written to handle the idiosyncracies of each construction activity. To transfer this technology in its present state would not only require the transfer of the programs but also the transfer of personnel who are intimately familiar with this underdeveloped software.

To successfully transfer this technology the software as it presently exists would have to be cleaned-up and documented. Also additional software would have to be written to eliminate a significant portion of the manual processes.

Table 2.3.2-1 gives a step-by-step outline of the processes and software which would be transferred. A flow chart of the steps presented in Table 2.3.2-1 is given in Figure 2.3.2-1. Information in the Table is based upon software which currently exists and the implementation of additional software to streamline the process of constructing such data sets. Table 2.3.2-1 indicates the status of the software defined the previous Table and figure. Table 2.3.2-3 defines the general function each software routine performs.

Software Modifications

During this phase, two modifications have been made to LARSYS processors and another program was modified to meet LARSYS standards. The COPYRESULTS processor in LARSYS was modified to permit analysts to change class and pool names on a classification results tape. This was desirable for the cases when the computer selected classification classes based on spectral characteristics only and the analyst later wanted to give the classes a name meaningful to the intended user of the data, without the expense of rerunning the classification.

Table 2.3.2-1 Steps in Process Necessary to Classify Landsat Data.

1. Reformat Landsat data set(s)
1.5 Grayscale plots
2. Assemble Landsat data base over area of interest
   a. frame connections end-to-end
   b. frame side-to-side digital mosaicing
2.5 Grayscale plots
3. Multitemporal overlay
   a. choose base run
   b. locate initial starting area for auto correlator
   c. run auto correlator
   d. determine transformation
   e. check accuracy of fit
   f. do multitemporal registration
3.5 Grayscale plots
4. Find ground control points on maps and in Landsat data for the precision registration
5. Prepare maps for digitizing
6. Assign area numbers to the area types
7. Digitize map
8. Clean up digitized data (delete arcs in error, etc.)
9. Replot map
10. If it looks good go to step 13
11. Correct errors using graphical editor
12. Go to step 9
13. If there are additional maps go to step 7
14. Fit maps together
15. Replot entire area
16. If it looks good go to step 19
17. Correct error using graphical editor
18. Go to step 15
19. Convert to appropriate grid
20. Determine transformation for precision correction
21. Check accuracy of fit
22. Do precision registration
23. Run Boundary for each boundary type
24. If errors are encountered redo whatever is necessary
25. Data analysis - produce classification results
26. Extract needed information for reports and displays
27. Use classification and ancillary data to indicate areas in need of remapping
28. Produce new maps where needed
29. Digitize changes, etc.

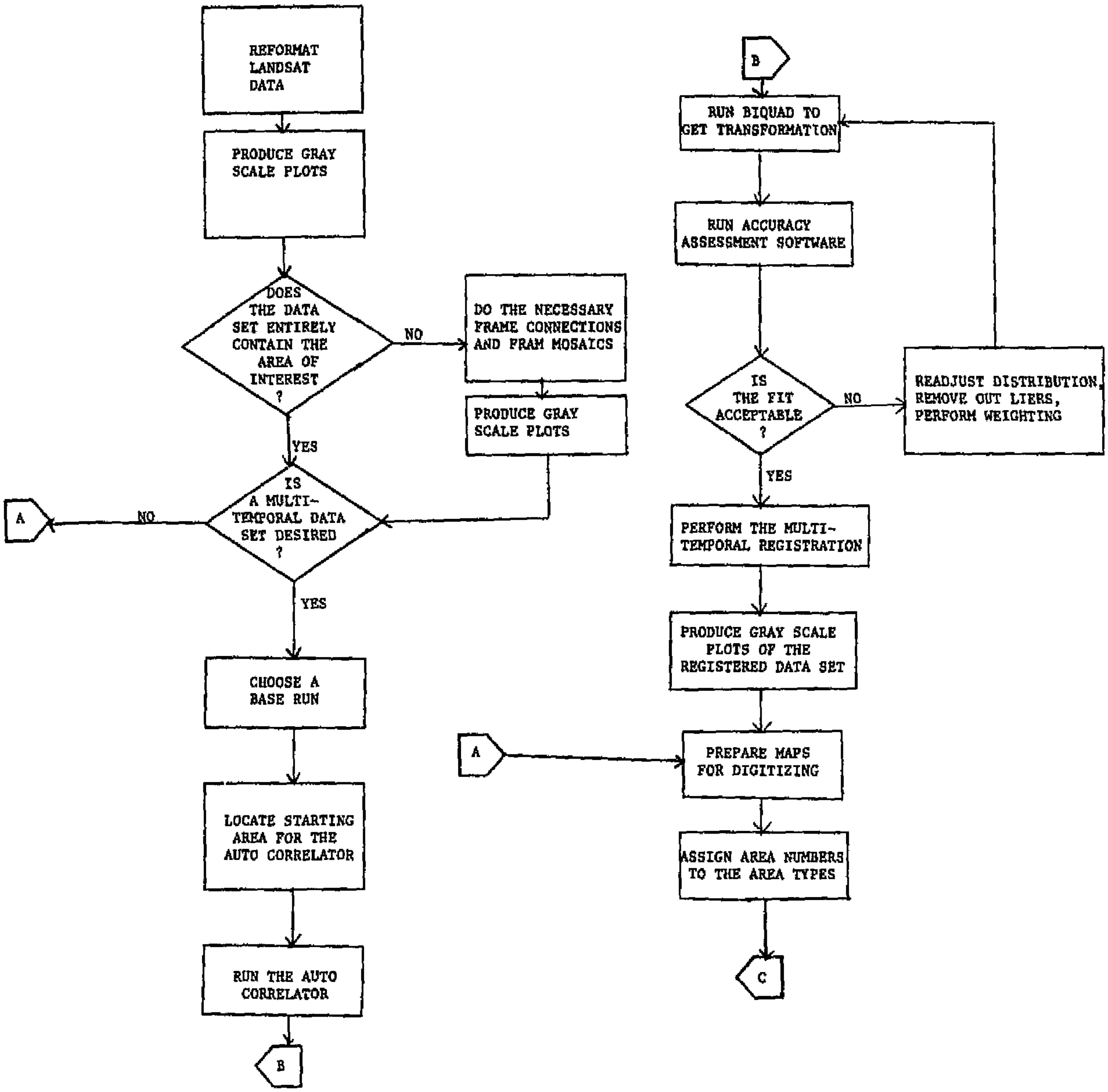


Figure 2.3.2-1 Flowchart for the proposed FRIS.

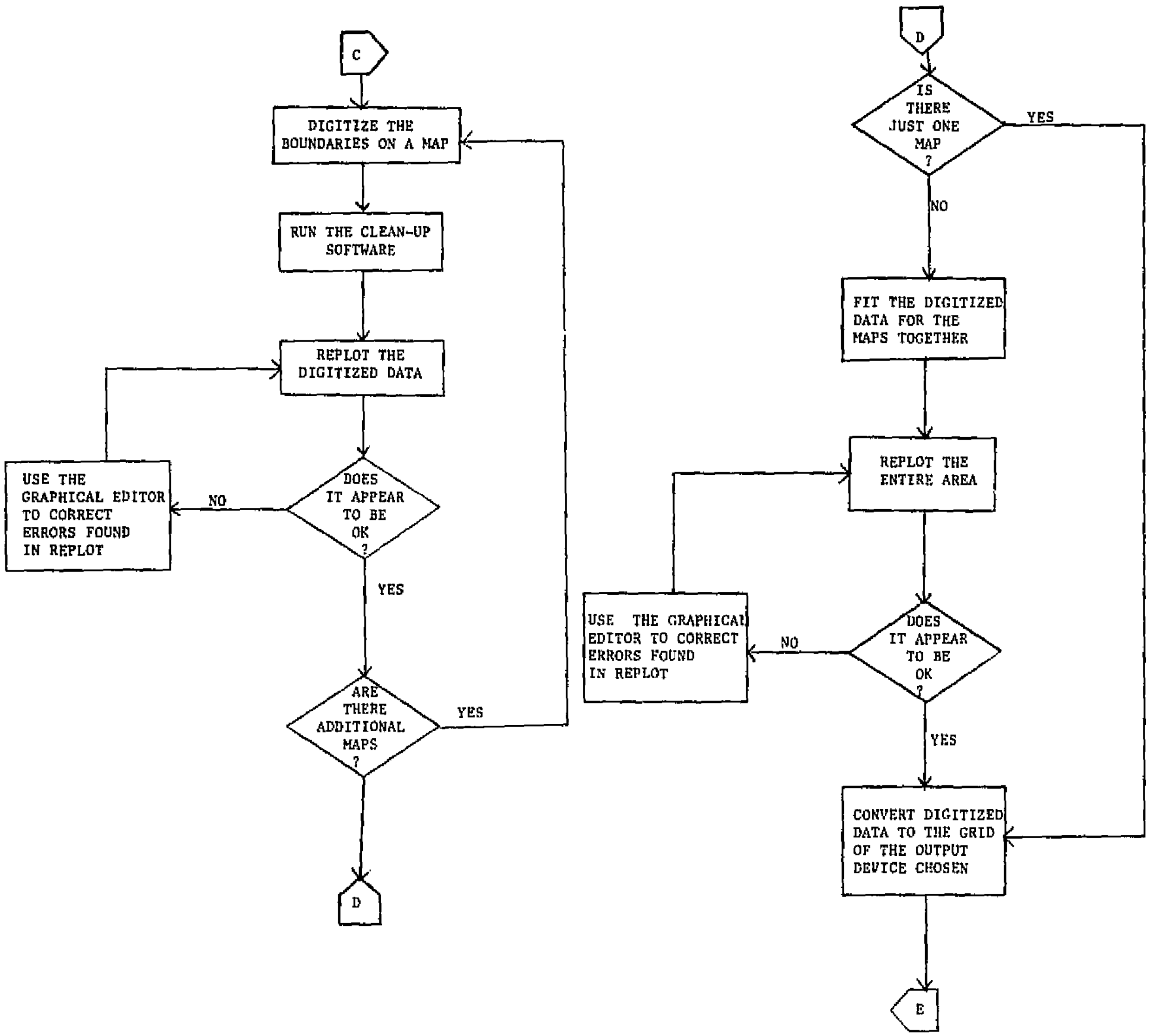


Figure 2.3.2-1 continued

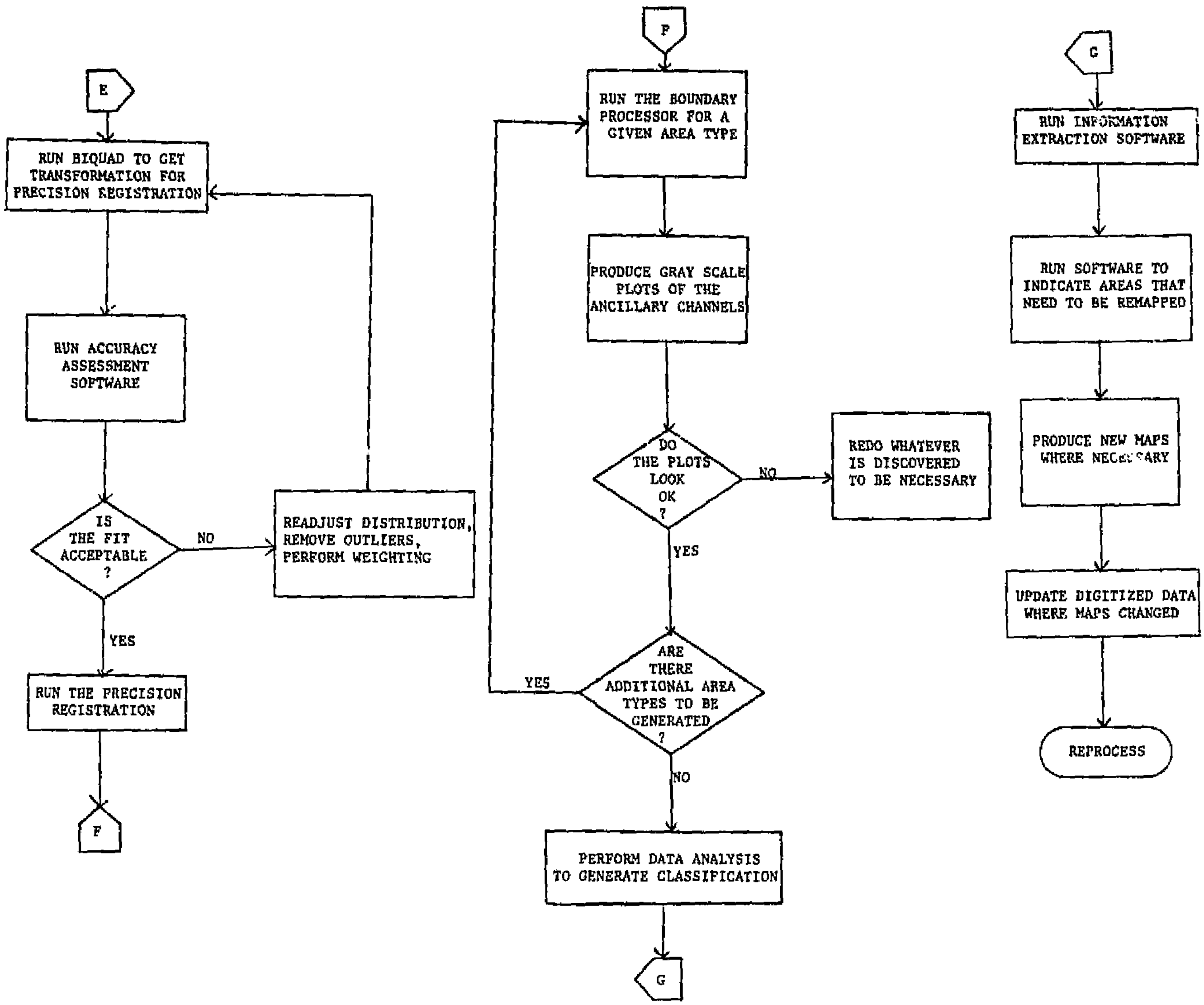


Figure 2.3.2-1 continued

Table 2.3.2-2 Status of Software needed to complete the processes defined in Table 2.3.2-1.

Software Needed	Indicated by Step #	Status	Implement* on:	Amount of Work Needed
REFERTS	1	yes	370	rewrite
GDATA	1.5,2.5,3.5	part of LARSYSDV	370	refine
CONNECT	2a	yes	370	refine
MOSAIC	2b	no (possibly avail)	370	write or obtain
AUTOCOR	3c	yes	370	refine
BIQUAD	3d,20	yes	370	refine
FITACC	3e,21	some	370	write additional
REGSYS	3f,22	yes	370	rewrite
DIGIT	7,29	yes	PDP	refine
CLEANUP	8	some	PDP	convert to PDP
REPLOT	9,15	yes	PDP	convert to PDP
GEDIT	11,17	no	PDP	write
MAPFIT	14	no	PDP	write
CNVTGRID	19	some	PDP	write
BOUNDARY	23	yes	370	rework
LARSYS	25	yes	370	refine
LARSYSDV	25	yes	370	refine
INFOEXT	26	some	370	write
INDUPDAT	27	no	370	write

*370 indicates a mainframe of the IBM 370 Series or similar
PDP indicates a mini-computer such as a PDP 11/34 or 11/70

Table 2.3.2-3 Definition of the functions performed by software

Software	Function
REFERTS	Reformats Landsat data from NASA CCT format to a format that is compatible with the other software.
CONNECT	Digitally fits Landsat frames together end-to-end.
MOSAIC	Digitally fits Landsat frames together side-to-side.
AUTOCOR	Locates control points based on digital similarity between two data sets.
BIQUAD	Given control points it performs a least squares regression to produce a biquadratic transformation.
FITACC	Given the control points and residual errors, graphically presents trends in residual errors.
REGSYS	Given a transformation assembles the data sets be registered.
DIGIT	Digitizing software to convert lines on a map to a series of x and y coordinate pairs which are grouped into 'arcs' and have 'area lefts' and 'area rights' associated with each 'arc'.
CLEANUP	Delete indicated arcs and insure end points coincide where necessary.
REPLOT	Replots digitized data at desired scale and indicates 'arc' numbers and 'area' numbers.
GEDIT	Graphical editor for adding and deleting arcs, changing area numbers, and other needed functions.
MAPFIT	Fits digitized maps together according to tick marks, also examines area numbers to determine what arcs at the edges of the maps must be modified. It also determines which arcs become coincident and reduces them to one arc.
CNVTGRID	Converts digitized data from hundredths of inches to units in terms of lines and columns on the chosen output device. It also deletes points which become coincident in the new grid and produces input ready for BOUNDARY.
BOUNDARY	Converts digitized polygons to a grid format.
LARSYS	LARSYS Version 3.1 contains to software needed to do the data analysis.
LARSYSDV	Contains software such as GDATA which is used to generate grayscale plots of the Landsat data.
INFOEXT	Given a data base consisting of Landsat data, ancillary data, and classification results produces information based on a combination of the different information channels.
INDUPDAT	Compares digitized map channel with classification and notes inconsistencies.

The second LARSYS modification was to the PRINTRESULTS processor. On a classification results tape there are generally two pieces of information stored for each point classified--the class assignment and the probability of correct classification for that point. PRINTRESULTS was modified to be able to optionally print a map and/or tables of specified probability of correct classification ranges. This tool will be useful for determining if there are areas of such low probability of being correct that a new class should be defined.

The third software modification involved rewriting a program called CHANGE, which compares two classification results files and records changes in a third, LARSYS results tape format file. This program is used to detect how an area is changing over a period of time or to compare the differences in results from using different analysis techniques or classifiers.

Modified Software Availability

Currently the modified software resides on the St. Regis computer ID's personal disk storage. A LARSYS update is scheduled to take place before the end of FY 79 and the modified COPYRESULTS will be placed in the online LARSYS system. The enhanced version of PRINTRESULTS and the CHANGE programs will be placed on the developmental (LARSYSDV) system disk to provide easier access to this software.

COPYRESULTS

This LARSYS processor was modified to permit class and pool names to be reassigned by copying an esisting classification results file to another tape where the new names are substituted. Two additional input cards may be input to this processor to exercise the new option. They are:

CNAMES cname1, cname2, ...
PNAMES pname1, pname2, ...

where cnamei and pnamej are the new names to be given to class i and pool j respectively. When these cards are used, the program then substitutes the new names for the existing names before copying that portion of the file to the new tape. In appendix A you will find a copy of the control card reference file for COPYRESULTS and the revised program abstracts.

PRINTRESULTS

Seven subroutines in the LARSYS PRINTRESULTS processor were modified to permit the input of two additional control cards, one requesting a map using the percent probability of correct classification number and the other assigning symbols to the probability ranges. The modifications then permit the programs to read the percent probability numbers off the designated classification results tape, to assign "class" numbers to each point based on which probability range the point falls in and to then print a probability map and/or tables. The two additional input cards are of the form:

```
PROBABILITY   R1,R2,...
PSYMBOLS      P1,P2,...
```

where R1, R2,... are entered in decreasing order and are the lower percent probability for that interval (e.g., the first interval would be 100% down to R1%). Pi is the symbol to be assigned to the i-th percent probability range. Eight default ranges and symbols are supplied by the program, so the probability option can be requested with only a card of the form:

```
PROBABILITY
```

See Appendix A for the revised control card reference file and program abstracts.

CHANGE DETECTION

The program called CHANGE, which compares two classification results files, was originally coded as a stand-alone program with one subroutine which performed the actual comparison. Since LARSYS format results files are expected for input and created as output, this program was reworked to conform with LARSYS standards and to be callable from the LARSYSDV system. It was divided into four subroutines. The supervisor, CHASUP, receives control from the LARSYS monitor routine when a *CHANGEDETECTION card is encountered as input, and calls the other routines. The reader routine, CHARDR, reads and interprets each control card, assigns values to variables and mounts and positions the necessary tapes. Control then passes to the main subroutine, CHANGE, to read information from the two input classification files and write the corresponding records on the output file. The point-by-point comparisons are made by calling the subroutine COMPAR after each line has been read from the two input files. The source for the COMPAR subroutine had to be recreated since the original source could not be located.

The heart of this program is a logical array which is initialized according to the classes the user requests. (See Control Card Reference file, Appendix A). If every possible class combination were to be generated, and the first classification had M classes while the second classification had N classes, then M x N output classes would be generated! Many of these class combinations may be of no interest to the user, so he must define each output class of interest. Any combinations not defined are put into a default class called *CHANGE*. As an example of how classes are defined, consider the case where an analyst is interested in which classes changed from water on date 1, to bare soil or green vegetation on date 2. If class 6 in date 1 is water, classes 1 and 2 in date 2 are soil, and classes 5, 7, 8 and 9 are green vegetation in date 2, the following might be included in the control card input:

```
CLASS H20-SOIL
BASE 6
COMPARE 1, 2
CLASS H20-VEG
BASE 6
COMPARE 5, 7, 8 9
```

Then all points falling in class 6 (water) in the first classification and classes 1 or 2 (soil) in the second classification would be assigned to the class H2O-SOIL on the output results file, and all points assigned to class 6 (water) in the first classification and classes 5, 7, 8 or 9 (green vegetation) in the second classification would be put in the class H2O-VEG on the output results file.

Maps and tables of these change detection results can be obtained through use of several existing LARSYS processors such as PRINTRESULTS.

Work to be Completed

Currently the change detection program uses three tape drives which aren't readily available during the day. The option to permit one of the results files to reside on disk storage is currently being debugged. Program documentation for each subroutine still needs to be written and the user documentation needs updating.

2.3.3 PRELIMINARY SYSTEM DESIGN

Preliminary system design work began in earnest during the July to September quarter. Within the project structure a system design group was identified. This group had the task of addressing the FRIS computer requirements. The group was composed of personnel from; St. Regis Corporate Offices, The Corporations Computer Center, Southern Timberlands Division, and LARS.

The group's first meeting was at the St. Regis National Computer Center in Dallas, Texas. The day-and-a-half session was held during the latter part of August. The purpose of this meeting was to:

A. Acquaint the National Computer Center with FRIS and its impact on the St. Regis data processing activity.

B. Acquaint staffs within each organization that would be involved in the System Transfer phase.

C. Review the options relating to the JAX-LARS remote terminal link.

D. Identify actions relative to development of a preliminary system design and establish a time table.

A number of briefings were given; covering the FRIS Project, the physical basis of remote sensing, the future outlook for computing within St. Regis, and the computational requirements necessary to support LARSYS. There was also a detailed discussion on the various considerations necessary to implement a data base. General considerations revolve about; 1) the form of the data input, 2) types of data manipulation desired, and 3) the types of output products needed.

Growing from the above discussion a committee was formed to develop the FRIS Preliminary System Design. The primary responsibility given to this committee was to assess the various data base and image processing software that is commercially available that would meet the FRIS objectives. As much information as possible would be collected and presented to the group on 1 November 1978 in order to explore alternatives and costs. This information was a prerequisite to help develop an implementation schedule which would be necessary in order to move into the Phase III System Transfer task.

Prior to the 1 November meeting, LARS Staff would develop a number of straw-man system proposals. These proposals would range across a broad gamut of capabilities from nothing more than a remote job entry station upwards to a corporate remote sensing facility.

Items which would be considered during the development of these straw-man proposals would include:

A. Communications Network

- identify locations between which information would be expected to flow.

B. Resource Requirements

- identify the system components which include:

  Hardware
  Software
  Man-power

C. Costs

- financial requirements to include both start-up and operational costs.

D. Documentation

- define the level of software and user documentation necessary for the system.

E. Transferability

- addresses the ease which the technology can be transferred, and implemented at St. Regis.

F. Languages

- identifies software programming languages.

G. Interface

- describes how the user would utilize the system.

Prior to developing any straw-man proposals we developed a set of guidelines in the form of assumptions and constraints. These were as follows:

<u>Assumptions</u>

- o Satellite-borne remote sensors data contain information that can be valuable to managers of forest resources.

- The resolution of satellite remote sensors systems contains sufficient detail to provide information about the smallest management unit, the operating area.
- Computer-aided remote sensor data analysis techniques used as an aid to forest management can be:

    a. quantitative
    b. repetitive
    c. semi-automated, and
    d. cost-effective

- Classified remote sensor data can be efficiently merged with other information sources to yield accurate geographically referenced information, that is both timely and widely accessible within STD. (The above ability of is dependent on implementation of an automated STD data base.)
- The remote sensing technology (both hardware and software) are transferable, and can, therefore, provide STD an independent, stand alone remote sensing analysis capability.
- There will be a continuity in the flow of satellite-borne digital remote sensor lata over the forseeable future.

<u>Constraints</u>

- The remote sensing/data base components of FRIS must be specifically designed for STD application.
- As soon after the completion of the ASVT as possible, STD should have an independent, completely operational remote sensing data analysis capability.
- The remote sensing components of FRIS (both hardware and software) must be attractive (?) in terms of cost to management, i.e.:

    a. reasonable start-up and operating costs,
    b. relatively quick (5-year) pay-back period,
    c. potential cost-efficiencies or cost-reductions or cost-avoidance associated with the technology, and
    d. require a minimum of new human resources.

- The FRIS design should utilize existing human and computational resources where feasible and be easy to implement.
- The quality of information from a FRIS should not be degraded beyond its current level.

Keeping these in mind, and using LARSYS as a foundation, we developed four alternative straw-man documents. The example that follows, Table 2.3.3-1 reflects what the design committee felt would be a workable system. This example system was to serve as a model not as the ultimate answer to fill the FRIS need.

Table 2.3.3-1 Straw-man System Proposal for FRIS

I. Information Flows
   A. Landsat data maintained at NCC
   B. Graphical data maintained at JAX

II. Resource Requirements
   A. Hardware
      1. NCC
         a. 2 - 9600 baud modems
         b. 1 - 4800 baud modem (just during conversion effort)
         c. 1 - multiplexor
         d. 1 - multiplexor (just during conversion effort)
      2. JA X
         a. 2 - 9600 baud modems
         b. 1 - multiplexor
         c. RJE Station
            i. Printer
            ii. Card Reader
            iii. Card Punch
         d. 4 - CRT's
         e. PDP 11/34 (32K)
            i. 32K additional storage
            ii. Floating Point Hardware
            iii. RJP04-AA Disk with control unit 44M words
            iv. RP04-AA Disks 44M words
            v. TJU16-EA Tape Drive with control unit
            vi. DECwriter II Operator's console
            vii. LP11-VA Line Printer
            viii. TALOS table digitizer
            ix. Tectronix Graphics Terminal
            x. Versatec 8242 elerrostatic plotter
            xi. Optronics Color write system
            xii. COMTAL Color Display
      3. LARS (just during conversion effort)
         a. 4800 baud modem
         b. CRT's
         c. multiplexor
   B. Software
      1. NCC
         a. REFERTS
         b. TAPEDT
         c. COMRUN
         d. Geometric Correction
         e. REGSYS
         f. BOUNDARY
         g. LARSYS
            i. TAPUTL
            ii. LISTRESULTS
            iii. COPYRESULTS
            iv. PUNCHSTATISTICS
            v. IDPRINT
            vi. DUPLICATERUN

vii. TRANSFERDATA
viii. PICTUREPRINT
ix. CLUSTER
x. SEPARABILITY
xi. CLASSIFYPOINTS
xii. PRINTRESULTS
h. LARSYSDV
i. GDATA
ii. GRESULTS
iii. MERGESTATISTICS
iv. MINIMUMDISTANCE
v. REGION
i. Classification Grid to Vector Conversion
j. Output Products (New Software)
i. Film writer
ii. Color Display
k. GCS
l. Runtable Update
2. JAX
a. ODYSSEY
b. Imaging Interface Software
i. Grayscale plotting
ii. Film writer
iii. Color Display
c. FORTRAN IV+ Compiler

III. Costs
A. Hardware
1. NCC
a. 2 - 9600 baud modems $420/month
b. 1 - 4800 baud modems (temporary $140/month
c. 1 - multiplexor CODEX 880 $360/month
d. 2 - phone lines to JAX $1,600/month
e. 1 - phone line to LARS (temporary) $800/month
f. 1 - multiplexor (temporary) $360/month
2. JAX
a. 2 - 9600 baud modems $420/month
b. 1 - multiplexor CODEX 880 $360/month
c. Data 100 RJE station $1,450/month
i. Printer
ii. Card Reader
iii. Card Punch
d. 4 - CRT's $950 each
e. PDP 11/34 (32K) $9,050
i. 32K $3,400
ii. Floating Point Hardware $5,900
iii. RJP04-AA $36,750
iv. RP04-AA $32,340
v. TJU16-EA $18,850
vi. DECwriter II $2,000
vii. LP11-VA $11,800
viii. TALOS 600 $5,900

- ix. Tektronix 4014/4015 — $12,000
- x. Versatec 8242 — $38,900
- xi. Optronics — $60,000
- xii. COMTAL — $75,000
- xiii. Maintenance — $600/month

3. LARS (temporary)
   - a. 4800 baud modem — $140/month
   - b. CRT's 3 @ $70/month — $210/month
   - c. multiplexor — $360/month

B. Software Purchase
   1. ODYSSEY — $10,000
   2. FORTRAN IV+ — $3,000

C. Total Costs
   1. One-time Purchase — $328,690
   2. Monthly — $5,210
   3. Temporary LARS site (monthly) — $2,010

IV. Documentation (Existing)
   - A. LARSYS Users Manual
   - B. LARSYS System Manual
   - C. LARSYS Test Procedures
   - D. Program Abstracts

V. Transferability (in terms of conversion effort)
   - A. Reformatting
     Moderate to Difficult
   - B. LARSYS
     Moderate
   - C. ODYSSEY
     Simple

VI. Languages
   - A. Reformatting
     1. FORTRAN IV 90%
     2. BAL 10%
   - B. LARSYS
     1. FORTRAN IV 95%
     2. BAL 5%
   - C. ODYSSEY
     1. FORTRAN IV 100%

VII. Interfaces
   - A. ODYSSEY to LARSYS
     via BOUNDARY Software
   - B. LARSYS to ODYSSEY
     via Classification Grid to Vector Conversion Software

2.3.4 SYSTEM TRANSFER PHASE RECOMMENDATIONS

After reviewing the straw-man design proposals the Preliminary Design Committee determined that more detailed information was needed in the areas of:

Landsat data preprocessing
Image processing
Hardware/Software configurations, and
Data base management and Graphics systems

Four subgroups of the original committee were formed. Each group was tasked to develop a detailed report for their specific area of responsibility. Timelines were developed for the report completion dates. The information and recommendations from the committee sub-group reports would be factored into the preliminary plan that would be presented to management at the end of Phase II. A summary of the material prepared by these four subgroups follows.

Landsat Data Preprocessing

Landsat data should be prepared at the St. Regis National Computer Center in Dallas, Texas. The current software sets could be transferred from LARS with relative ease. However, modification would be necessary to convert the software so that it would run under a different operating system and compiler. Certain changes in operational procedure would be required so that the preprocessing programs would run in the NCC batch environment. Under these procedures, the Jacksonville FRIS site would:

1) Initiate batch preprocessing jobs
2) Print map registration error direction and magnitude information
3) Initiate error adjustments
4) Print gray scale map of Landsat data.

The implementation of LARS existing preprocessing software would initially meet the FRIS requirements. Problems may arise in the future because of the large core requirements of the geometric correction programs. This will be especially critical with the increased data loads anticipated from the Landsat D, Thematic Mapper System, However, bu the time this data source becomes available we anticipate that NASA/EDC will provide the user with geometrically corrected data, thereby, alleviating this operation from the data preprocessing sequence.

Image Processing

Classification procedures developed for this project must meet certain requirements. If the system is to satisfy our needs, it must be accurate, repeatable, and timely. These requirements are at the heart of an operational system. The system envisioned must be able to classify forest lands to at least a broad species level. This is extremely important when considering a change detection capability. The classifications must be repeatable over the range of site and topographies encountered. Repeatability should also apply to the same land areas but at different times in a year. Lastly, the operational system needed to classify portions of 20 Landsat scenes must be timely if it is to become a part of the updating system.

Other factors to consider in a classification system are: establishment, maintenance, time frame, and cost. These considerations are vital to the systems transfer to the St. Regis National Computer Center (NCC).

Indications to date are that the LARSYS software satisfactorily meets these requirements. Therefore, implementation of LARSYS Ver. 31. and portions of the developmental software, LARSYSDV, is strongly recommended. Implementation of the image processing software at NCC rather than on a mini-computer at Jacksonville is preferred for two reasons.

1) This software is currently operational on a large machine and has been written to reside on a mainframe, and
2) Certain efficiencies exist of the image processing and data preprocessing software reside on the same machine.

Although, implementation of this software at NCC is considered straightforward, certain procedural modifications will have to be considered. Specifically, the software will have to be modified to run under the NCC operating system. This would require rewriting some of the Fortran calls and modifying the assembler code. The greatest impact would be to the analyst who currently operates in a virtual machine environment. The operational FRIS/LARSYS would run in a batch environment, therefore, requiring modifications to the classification procedures. None of these problems appear insurrmountable.

Hardware/Software Configuration

The ultimate objective of the FRIS project is to be able to bring a variety of data sources (which include Landsat satellite imagery) to bear on the problems of forest management. This means the data must be available to the Forest Simulation model and also to the people managing the woodlands activities. Early in the FRIS project it became apparent that a geo-referenced data management capability was essential to the effective control of the information in the system. The data base, satellite imagery, and Simulation model requirements placed on FRIS can be transformed into the following capabilities.

1) Ability to handle large quantities of data effectively (10 to 100 megabytes)
2) Ability to interface with the existing Simulation model currently run at NCC
3) Ability to operate interactively with asynchronous data arriving at rates possibly in excess of 200 data groups per second.

The first two requirements can be satisfied by the large machines at the NCC in Dallas, Texas. The third requirement (arising from use of the table digitizer) can only be satisfied by an on-side minicomputer. This forces us to the acceptance of an on-site computer which can communicate with NCC at Dallas in a fashion acceptable to all and also carry the cartographic loads imposed. This study considers the hardware/software requirements imposed by this configuration.

In the course of this study, a number of alternative systems were considered. It is important that the reader understand that the computer technology is moving extremely swiftly. Our recommendation represent the current state of that technology. One can reasonably expect that the hardware will be cheaper and the software better by the time St. Regis is prepared to make a commitment.

The general configuration considered consists of a mini-computer in Jacksonville, The mini-computer should include the following options and peripherals.

1) Programmer/operator console and printer
2) 300 line per minute printer
3) Two magnetic disk drives having a minimum capacity of 44 megabytes per drive.
4) Magnetic tape drive
5) Floppy disk drive
6) Table digitizer (30 x 30 working surface)
7) Drum plotter at least 30 inches wide
8) Graphics CRT at least 17 inches diagonal
9) Bisynchronous and SDLC communications capability
10) 256,000 bytes of core or MOS memory
11) Floating Point Hardware
12) Alphanumeric CRT
13) EOA or [illegible] 22 interfaces for all asynchronous devices

The following software must be resident on the minicomputer.

1) Operating system capable of supporting up to four partitions of interactive or batch activity
2) Fortran compilar
3) Geo-referencing data base, such as ODYSSEY
4) HASP or other IBM-compatible RJE emulator (Bisynchronous and SDLC)
5) Control routines for all peripherals (Fortran callable)

All of these software requirements except the data base requirements (number 3) should be the responsibility of the computer vendor.

The following software must be available at the NCC computer -

1) LARSYS - preprocessing and classification routines
2) A standard IBM system for support of remote job entry (RJE)

Proposals were obtained from three minicomputer vendors. These proposals were meant to show the vendor to vendor consistency for any given capability and also the range of capability available from most vendors. Just because a given computer is not considered here does not mean the computer has been or should be eliminated from consideration. As stated before, the rapid development of this technology dictates the alternatives be reevaluated when it is time to purcahse. Hardware and software costs ranged from approximately $173,000 to $200,000, excluding the data base management capabilities. Monthly equipment maintenance ranges from $1,000 to $2,000.

Data Base Management and Graphics System

An important component of an operational FRIS will be the data base management and graphics subsystem. It is within this portion of the FRIS framework that the interface between image processing, cartographics, and inventory attributes occur. Therefore, this subsystem should possess the following attributes:

1) Capability to input, update and output map data
2) Associate tabular data with map data and the capability to input, update and output it.
3) A grid/vector two-way interface
4) Hooks for future additions of capabilities.

Furthermore, this subsystem should be interactive in nature and easily accessible to the FRIS user community.

With this background in mind a number of "systems" were considered. Table 2.3.4-1 lists the systems and summarizes their attributes. Based on this preliminary review three systems; IDGS/DMRS, CRIS, and ODYSSEY were selected for more detailed evaluation. Marketing policy of the vendors of the first two systems, quickly dropped them from consideration.

Personnel from Harvard University's Computer Graphic Laboratory were contacted, and agreed to cooperate in a demonstration of ODYSSEY capability. The following materials were sent to Harvard for purposes of the demonstration:

1) A map of four administrative units
2) Documentation of map content
3) Digitized 9-track tape containing information in 1 above.
4) Digitized tape documentation
5) LARSYS results tape of a classification of the map in 1 above.
6) Documentation of the LARSYS results tape format.

With the above data we requested that Harvard demonstrate the following:

1) Conversion of the Landsat classification from a grid to vector format.
2) Aggregation of spectral classes to information classes indicated by the map.
3) Inclusion of attributes; AU, OA, and Forest Type information for each layer of information.
4) Overlay of all information layers.
5) Graphical representation of where the map and the classification are in agreement.
6) Representation of classification attributes based on map boundaries.

Table 2.3.4-1 Data base systems that were considered during the FRIS preliminary system design task.

ERDAS

This system (Earth Resources Data Analysis System) is Landsat oriented and currently addresses data analysis in grid format only. For this reason it does not possess the vector graphics capabilities required in FRIS.

IDIMS

This system (Interactive Digital Image Manipulation System) is image oriented, enabling correction, classification and display of Landsat data. Stereo analysis is also addressed. An Earth Resources Inventory System (ERIS) has been developed to support remote sensing-based inventories. ERIS is essentially a tabular data storage and retrieval system. IDIMS does not possess the vector graphics capabilities required in FRIS.

IBIS

This system (Image Based Information System) was initially developed to permit the processing of Landsat thematic maps showing land use or land cover in conjunction with census tract polygon files to produce a tabulation of land use acreages per census tract. The basic approach is to manipulate data in grid format. IBIS does not possess the vector graphics capabilities required in FRIS.

LARSYS

The LARSYS system, along with a family of associated software modules, is also oriented toward Landsat data and the grid format. As with ERDAS, for example, the LARSYS approach is to convert basic polygon data such as an Administrative Unit into a grid type format for processing. The system does not, by itself, possess the vector graphics capabilities required in FRIS.

USGS

It has been learned that, while the USGS is in pursuit of a geo-based information system, no product will be available for evaluation within the time constraints of the FRIS project.

USFS

The U.S. Forest Service is currently involved in a project to evaluate existing Forest Service software relating to both grid and vector data processing. The top software for each approach has been identified, although only Forest Service developed software was considered in the evaluation. Testing is now underway to explore integrating this software into a single system which could be applied throughout the Forest Service. It does not appear that a product will be available within the time constraints of the FRIS project.

IGDS/DMRS

The M & S Computing System (Interactive Graphics Design System/Data Managemeng and Retrieval System) has grown over the last several years from a graphics design package into a comprehensive graphics/data base management system. Although initially used for engineering design purposes, the system has seen growing cartographic use and has recently been brought into operation in the forest products industry.

The strengths of the system include a strong graphics capability (with all of the so called bells-and-whistles) and a powerful, generalized data base management system. No other graphics system examined surpasses the M & S Computing capability in these areas.

The major weakness with this system lies in the missing link between vector and grid data types. This capability would have to be developed. Other problems include the fact that it is not supported on machines other than the PDP 11/34 and 11/70 and that the source code is not normally available. The capabilities provided by the data base management software should, however, make obtaining source code unnecessary.

This system appears to be a viable FRIS alternative.

CRIS

This system (COMARC Resource Information System) is a hybrid of software obtained from various sources with that developed by COMARC to support various cartographic and analysis activities. The system has been very aggressively marketed and is now in use in the forest products industry.

The strengths of the COMARC system include good graphics, special applications software tailored to natural resource applications, and an ability to pass between vector and grid data structures in at least one direction.

It's weaknesses include medium to low transportability, no comprehensive, generalized data base management software, and no possibility to obtain the source code.

This system appears to be a viable FRIS alternative.

ODYSSEY

The ODYSSEY system is currently in the later portion of its initial development and testing at Harvard University. The individuals involved with its development maintain the system will be open-ended and, as such, will never be a "finished product". The approach is basically to design a system to which new modules can be easily added over time. The system itself is oriented towards processing, and a data base management system (such as DMRS) is not an objective.

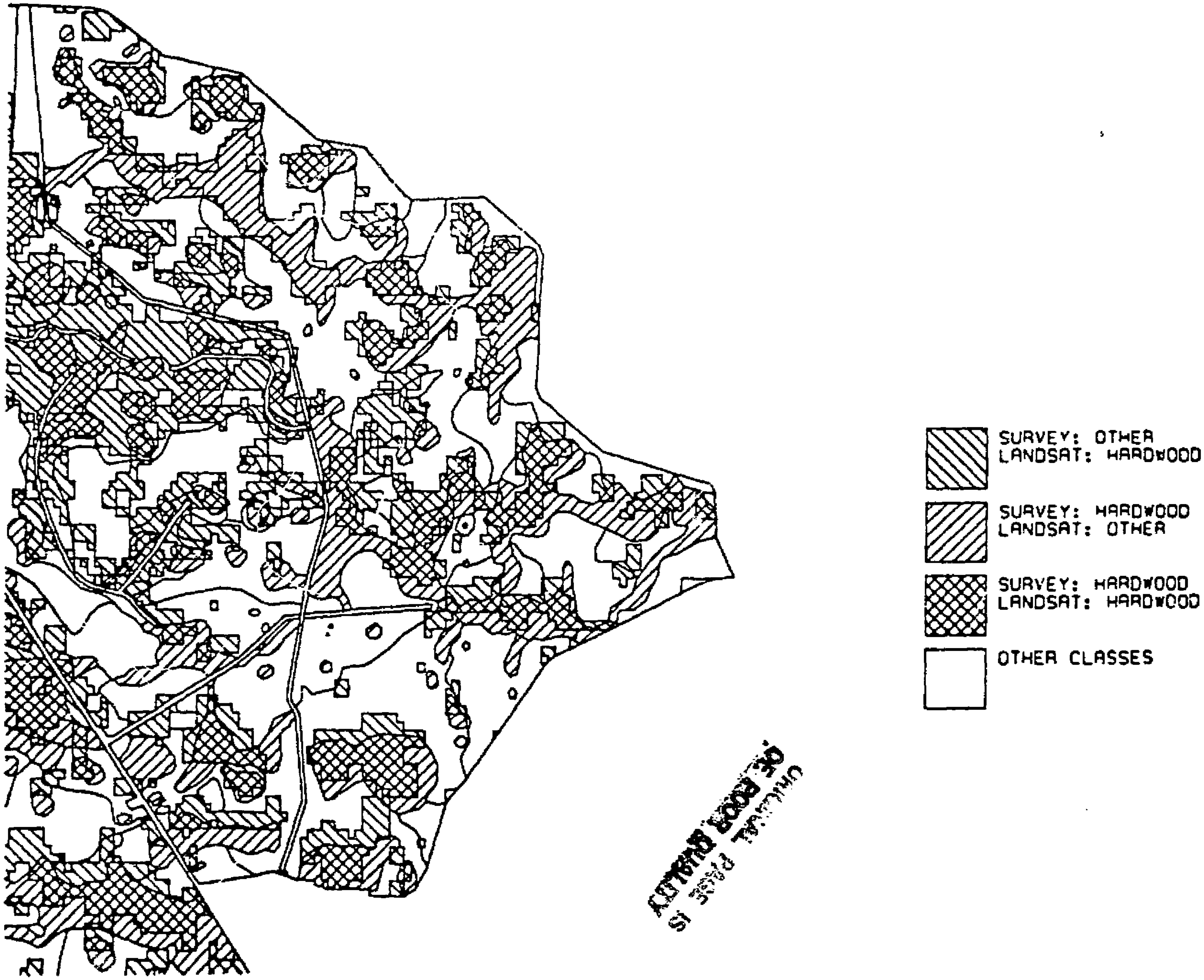
The strengths of ODYSSEY lie in its high degree of transportability, an ability to handle many data formats from various sources, and a two-way grid and vector interface capability. From all reports, the overlay processor now being tested is very efficient and is designed to support a variety of additional capabilities. Source code for all system software is provided.

The weaknesses of ODYSSEY include relatively low powered graphics, batch oriented digitizing and a weak data base management capability.

This system appears to be a viable FRIS alternative.

The ODYSSEY software was successfully able to demonstrate that a capability exists to interact the Landsat grid data format with map polygons. Figures 2.3.4-1 and 2.3.4-2 represent examples of output for the last two items of our request to Harvard. However, since ODYSSEY does not contain as extensive level of attribute management and data base management required by FRIS, more study will be required before a final recommendation can be made.

Figure 2.3.4-1 ODYSSEY output showing the agreement between a Landsat classification and AU maps.



C-2

Figure 2.3.4-2 ODYSSEY output demonstrating the shading capability to differentiate between Landsat and map classification.

2.4 BENEFIT/COST UNIT

Conceptually, benefits or values derived from improved information are easily hypothesized; however, the quantification and estimation of these values is an extremely difficult task. In the following discussion, the value of information arises from the attributes of data which make an impact on or influence decision making. While, data is a collection of facts and figures which have not been analyzed and/or arranged in an useful order. This distinction is important because the value of FRIS is not in the data collection phase, but in the development of information used by managers at all levels of the firm in decision making.

Sections 2.4.1 and 2.4.2 will discuss the value of information and outline the problems in the measurement. Section 2.4.3 will provide an oeverview of system costs.

2.4.1 VALUE OF INFORMATION

The value of information is, therefore, the usefulness of analyzed and sorted data in improving the decision making of managers. Three components of value can be identified and assessed to determine the value of the information system. They are:

1) the relevance of the information to the decisions to be made,

2) the timeliness of the information, and

3) the accuracy of the information.

Relevance is the degree to which appropriate information is made available for decision making. While seemingly obvious that only information which is relevant would be provided to the decision makers, all information from a data base should be reviewed in the light of this criterion. Since any information created for its sake only is a misallocation of manpower and equipment. For the current project the relevance question has been addressed in the Southern Timberlands Division's "Forest Resource Information System - The Rational and Approach, Who Needs a FRIS." Relevance is assumed to be satisfied by this report; and therefore, the value of information is assumed to be at a maximum and constant with respect to relevancy.

Timeliness is an important component of the value of information. Yet for reasons cited in the next section, the value of timeliness is probably the hardest value to quantify. Value due to timeliness may arise from a competitive advantage even when other firms receive equal information, but at a later time. Timeliness can stimulate improved decision, because managers have more time to consider the scope and depth of the problem when timely information is provided. Finally in the competitive business world, the value of information declines rapidly with the passing of time. Therefore, any information system must provide rapid data handling and timely retrieval of information.

Timeliness can be measured by calculating the difference in profit earned by a firm when using a more timely information system as compared to a slower information system. The calculation of this difference is replete with many problems due to the various cost savings and added values which might occur. Some of these items are the reduction of time spent on routine decisions, the added value from time saved but expended on more difficult (less certain) decisions, the reduction of time in updating "old" information, the increased productivity stemming from a better understanding of real world situations due to the timeliness of the information. Thus, there are a great many cost savings and added values which may occur and an adequate method of measuring and quantifying them has not been devised.

The accuracy of information involves the degree, if any, of biasness and the amount of variance or uncertainty surrounding the information. If bias is known it can be corrected and the information derived is not affected. If bias is unknown it is assumed to not exist and the information derived is not affected. Bias may arise in the statistical manipulation of the data during the collection and analyzing phases of the information system. The existence of bias is usually determined from statistical theory and should be identified by the data analyst and corrected during data processing.

In summary, the value of information derived from the implementation of FRIS will be the improvement in decision making and the increased efficiency in asset management. Value from FRIS may originate from the following areas of STD's management:

(1) Decreased response time to management requests about available resources and potential investment opportunities;

(2) More accurate estimates of acreage and improved management control of current cultural activities resulting in better forest management and improved planning;

(3) Reduction in a manager's time devoted to data analysis which coupled with more certain information should allow more time for decision making.

2.4.2 MEASUREMENT PROBLEM

The problem of measurement of the value or benefit of FRIS requires consideration. The values outlined in the previous section are conceptually nice. but almost impossible to quantify. This enumeration problem stems from the non-market nature of the benefits, the consideration of private versus social benefit, and the uniqueness of each individual manager. The only way to estimate "improved" decisions is to compare before and after profits. If the profits, all other things constant, increase following implementation of FRIS, this would indicate improved decision making. The assumption of all other facts constant will certainly be violated, and there is no basis on which to estimate the change in profit. This is particularly true when one realizes that each manager utilizes information differently in his decision making process. Thus, each attribute of information will have a different value to each manager. These problems limit the estimation of benefits.

Another area which distinguishes the present study from previous studies of the value of Landsat information in forest management is the focus on the individual firm rather than on society. Measures of social benefit are normally derived from consumer surplus and shifts in the industry marginal cost (supply) curves. For STD, the adoption of FRIS does not cause shifts in the industry supply curve or necessarily increase benefits to society except indirectly through improved efficiency. Therefore, the common anaytical tools used to measure public investment benefits are of limited use in assessing the value of a private investment.

The values of FRIS, which are seemingly most easily measured, are the cost savings or increased in productivity in STD's personnel. However, these benefits are usually paper savings which are difficult to use in project justification. Also, the magnitude of these benefits is highly dependent on the actual management policies and objectives of the firm implementing such a system.

2.4.3 SYSTEM COST

The costs discussed herein relate to the implementation of FRIS including capital costs, data establishment costs, operating costs and maintenance costs. Table 2.4.3-1 breaks these major areas down into their principle components. Since all of these costs are highly dependent on the total systems design, estimated costs are given as ranges and computer time is in terms of LARS's 370/148 computer.[1] Tables 2.4.3-2 to 5 show the costs estimates for each of the areas listed on Table 2.4.3-1. Table 2.4.3-6 provides a summary of these tables.

The reader is cautioned to understand the assumption under which these estimates are offered. First, they are aggregates of detail estimates and the errors are not necessarily compensating. Second the preprocessing and data establishment costs are based on LARS's research experiences and non-optimized methods of performing these tasks. The addition of software such as Harvard's ODYSSEY will (hopefully) reduce both the man-time and computer time involved in preprocessing and data establishment. Third, the existence of appropriately trained personnel is assumed. Fourth, all figures must be adjusted and refined for any specific implementation and systems design. For example, because the actual systems design may call for data links, line charges would have to be added. The addition of graphic terminals or other peripherals could substantially change the capital cost estimate. Therefore, the cost displayed here should be considered as very general estimation of the actual costs of any specific system.

---

[1]Conversion of these times to other machines is left to the reader.

Table 2.4.3-1 Project Costs by Major Area

Capital Costs	Data Establishment Costs
1) Hardware	1) Digitizing Ancillary Data
2) Software	2) Registration
3) Facilities	

Operating Costs	Maintenance Costs
1) Data Acquisition	1) Hardware
2) Reformatting	2) Software
3) Preprocessing	3) Data Base
4) Classification	

Table 2.4.3-2 Capital Costs

Hardware	
Minicomputer w/standard input/output devices	125,000-200,000
Table Digitizer	5,000- 6,000
Plotter	11,000- 12,000
Software	
PREPROCESSING	13,500- 55,000
LARSYS (conversion cost)	130,000[1]
Minicomputer operating software	6,300
Facilities[2]	- -
Total	290,800-409,300

[1]Costs borne in part by the Applications Pilot Test.

[2]No cost estimate is given for space, the reader can supply appropriate estimates.

Table 2.4.3-3 Data Establishment Costs[1]

	CPU-HRS	MAN-HRS
Digitizing[2]	2100	48,000
Registration	180	2,300
Total	2280	50,300

[1] Costs are without the use of ODYSSEY or similar software.

[2] Assume digitizing of AU and OA boundaries only.

Table 2.4.3-4 Operating Costs (Annual)

	Cost	CPU-HRS	MAN-HRS
Data Acquisition (20 frames @ $200/frame)	$4,000		
Reformatting (20 frame)		4	40
Preprocessing[1]		78	930
Classification[2]		63	405
Total	$4,000	145	1375

[1] Without ODYSSEY or similar software

[2] Maximum Likelihood Classification algorithm in LARSYS Ver. 3.1 .

Table 2.4.3-5 Maintenance Cost (Annual)

	Cost	MAN-HRS
Hardware (10% of initial capital cost)	14,000-22,000	
Software rental	1,350- 2,500	
Data Base (Data Base Manager)		2,000
Total	15,350-24,500	2,000

Table 2.4.3-6 Summary of Costs

	Cost	CPU(HRS)	MAN HRS
Capital Investment	$290,800-409,300	-	-
Data Establishment Cost	-	2280	50,300
Total Initial Cost	$290,800-409,300	2280	50,300
Operating Cost (Annual)	4,000	145	1,375
Maintenance Costs (Annual)	15,350- 24,500	-	2,000
Total Annual Costs	$301,150-473,800	2425	53,675

2.5 MANAGEMENT UNIT

The primary responsibility of this Unit involved the day-to-day operation of Phase II. One responsibility, however, was not operational in nature. All technology transfer activities were included in this Unit. The remainder of this section will describe the Phase II technology transfer activities.

2.5.1 TECHNOLOGY TRANSFER

A goal at the onset of FRIS was to provide StR with an independent, stand-alone system. The quality of independence indicates a desire on the part of the user to acquire sufficient knowledge to "... do it himself!" Technology Transfer is therefore, an important part of the FRIS Project. Indeed, a significant effort during Phase III is allocated specifically to this task. Since no system can operate without people, the Technology Transfer effort will develop the people part of the system.

During the demonstration phase Technology Transfer was more informal, but ever present activity. LARS staff provided both formal and individualized training sessions on a number of occasions throughout both Phases I and II. Some technology was transferred whenever the project staffs would meet, whether it be:

- To digitize and prepare data sets
- To classify a training site
- To give a tutorial presentation to StR, LARS or NASA, or
- To develop a framework for the system design.

Needless to say, a summary of the many, individualized activities will not be presented here. However, information is provided regarding the more formal Technology Transfer exchanges.

<u>Phase I</u>

The Technology Transfer activity began in ernest in November, 1977, at LARS. Primarily two activities were initiated at this time; 1) LARSYS training, and 2) initiation of a data base dialog. The LARSYS training consisted of:

- "Hands-on" classification experience for two StR analysts. The Sam Houston National Forest data was used because it was available in-house, whereas FRIS data was not available till January, 1978. The training objective was to generate Levels I and II classifications.

The second activity was designed to intorduce both StR and LARS staffs to the FRIS data base problems. Discussions were centered on:

- Review of data base developments
- LARS data base experiences
- Demonstration of equipment
- Identification of StR requirements in terms of:
  - map resolution
  - data elements required
  - source documents including their: scale, format, coordinate system in use
  - required accuracy

These meetings, in addition to some joint project overview sessions formed the basis for the Phase I Technology Transfer activities.

Phase II

Technology Transfer during Phase II consisted of formal training, study materials and informal working sessions. Part of the study material provided StR consisted of a set of LARS remote sensing minicourses. The minicourses are a packet of slide/tape/study guides designed for self-study. Table 2.5.1-1 gives a list of the minicourses provided StR.

Table 2.5.1-1 Titles of LARS minicourses provided to StR as part of the Technology Transfer training materials.

- The Physical Basis of Remote Sensing
- Multispectral Scanners
- Interpretation of Multispectral Scanner Images
- Spectral Reflectance Characteristics of Vegetation
- Spectral Reflectance characteristics of Earth Surface Features
- Pattern Recognition in Remote Sensing
- Typical Steps in Numerical Analysis

In addition to the minicourses, various LARSYS User's Manuals, Systems Manuals and Information Notes, including:

"An Introduction to Quantitative Remote Sensing", and

"Pattern Recognition, a Basis for Remote Sensing Analysis."

were provided to StR for background reference.

Formal training during Phase II consisted of a special workshop in Jacksonville for eight StR staff. In addition, three StR staff attended the Advanced Analysis Short Course at Purdue, through project sponsorship. Table 2.5.1-2 gives the outline for the special short course given in Jacksonville.

Formal Technology Transfer activities were limited to these areas. Specifically, these activities were prusued in order to begin developing a foundation of knowledgable individuals within StR. Since the primary objective during the demonstration was not Technology Transfer, we felt that this level of activity was sufficient. In retrospect we would not change this initial evaluation. More ground was covered through informal exchanges than could ever have been handled in a classroom environment.

Table 2.5.1-2 Outline for special short course in Jacksonville, Florida.

Day 1 - Introduction to Remote Sensing

- o The Electromagnetic Spectrum and Remote Sensing Instrument Systems
- o Spectral Characteristics of Earth Surface Features
- o Multispectral Scanner Systems
- o Landsat and Thematic Mapper Data Characteristics

Day 2 - Case Study Workshops

- o The Supervised Training Field Approach and Interpretation of Spectral Characteristics
- o The Multi-Cluster Blocks Training Approach

Day 3 - Pattern Recognition Techniques

- o The Theory and Concepts Involved
- o Various Techniques and Approaches to Computer-Aided Analysis
- o Limitations in Computer-Aided Analysis of MSS Data
- o Applications to St. Regis

2.5.2 REMOTE TERMINAL

During this phase, agreement on the design for the initial remote terminal configuration between Purdue/LARS and St. Regis in Jacksonville, Florida was reached. This configuration is a modified version of previous options considered. Since St. REgis already has an IBM 3776 remote job entry terminal, it will be used to communicate with the Purdue/LARS computer at scheduled times or when not connected to the St. Regis National Computer Center in Dallas, Texas. This terminal has a card reader, dual-drive diskette storage and a printer. Job control cards for the Purdue/LARS computer could be entered into a file on the diskette storage or key-punched on cards. These control cards could then be submitted to the computer from the IBM 3776 terminal by designating the appropriate batch machine parameters on the initial cards. However, primary use of this terminal is anticipated to be for receiving printer files on the IBM 3776 printer.

Preparation of most job control files and initiation of job execution will usually take place from a DECwriter LA36 typewriter terminal. Both terminals will communicate with the Purdue/LARS computer via a telephone line and two 4800 bps modems, one at each location. The DECwriter terminal will operate through a secondary (reverse) channel in the modem at 110 bps. The telephone line was installed by November 27, 1978, and then placed in suspended status due to long lead times quoted by modem companies. We were hoping to obtain used ICC modems from Racal/Milgo but the 4800 bps modem with a secondary channel (which we need) was no longer in stock. We learned that one of our remote terminals was disconnecting, and learned that one of their modems was available. Racal/Milgo located a second modem which was received by February 1, 1979. Several delays were encountered while IBM completed installation of the ports into the IBM 3705 communications controller, software was installed to recognize the St. Regis terminal and cables and phone wire were sent to St. Regis.

Figure 2.5.2-1 illustrates the terminal hardware configuration we are working toward. St. Regis is responsible for providing the two terminals and a modem selector switch to connect the IBM 3776 batch terminal to the desired computer. Purdue/LARS ordered the telephone line, two modems and ports into the IBM 3705 communications controller at LARS. Problems with the modems and phone line were diagnosed and corrected at the end of March and the DECwriter was operational April 5 with the rewiring of a connecting cable. Signals are being passed on the IBM 3776 line, and IBM located a bad cable, but the terminal has not been successfully signed on yet. Dumps of line activity logs are being studied to determine where the problem lies.

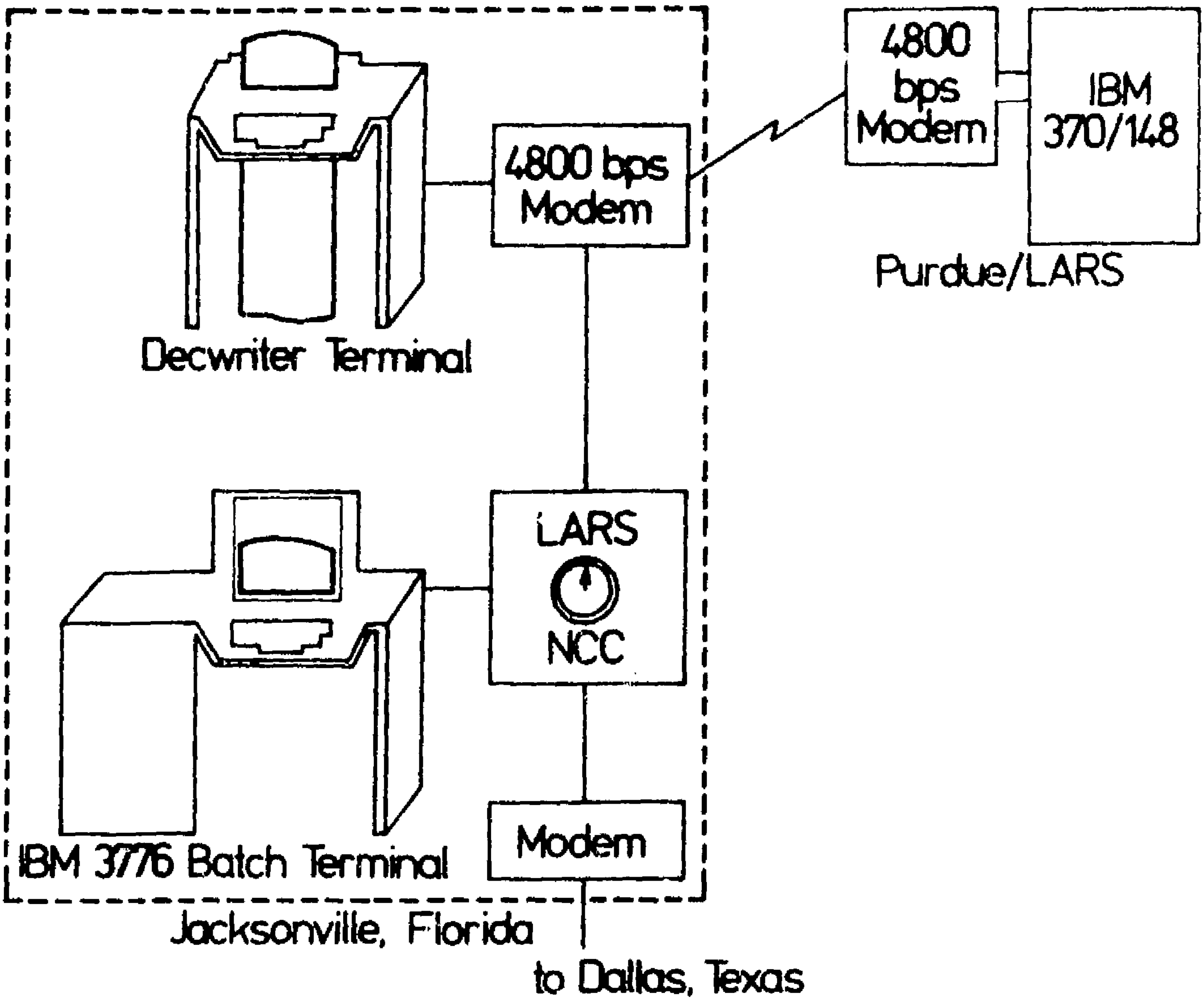


Figure 2.5.2-1 Remote terminal hardware configuration at Jacksonville.

3.0 REFERENCES

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4.0 APPENDIX

LARSYS CONTROL CARDS

COPYRESULTS

REQ	KEY WORD(COL.1)	CONTROL PARAMETER	FUNCTION	DEFAULT
•	*COPYRESULTS	(NONE)	SELECT RESULTS FILE COPYING FUNCTION.	(NONE)
•	FROM			(NONE)
		TAPE (TTT)	TAPE NUMBER TO BE COPIED.	(SEE THE)
		FILE (FF)	FILE TO BE COPIED.	(CONTROL CARD)
		DISK	RESULTS COPIED FROM DISK.	(DICTIONARY)
		ALL	COPY ALL TAPE FILES.	
•	TO	TAPE (TTT)	TAPE TO RECEIVE COPIED FILE.	(NONE)
		FILE (FF)	POSITION OF COPIED FILE ON NEW TAPE.	(EITHER FILE OR) (INITIALIZE MUST)
		INITIALIZE	INITIALIZE NEW RESULTS TAPE. (REQUIRED WHEN USING NEW TAPE)	(BE SPECIFIED.)
	PRINT	NOLIST	SUPRESS LISTING OF FILE INFORMATION.	LIST ALL FILE INFORMATION
	CNAMES	C1,C2,...	CHANGE CLASS NAMES TO C1, C2, ... FOR CLASS ONE, CLASS TWO, ...	NO NAME CHANGES
	PNAMES	P1,P2,...	CHANGE POOL NAMES TO P1, P2, ... FOR POOL ONE, POOL TWO, ...	NO NAME CHANGES
	END	(NONE)	END OF FUNCTION.	(NONE)

LARS Program Abstract 263

MODULE IDENTIFICATION

Module Name: RESRDR

Function Name: COPYRESULTS
LISTRESULTS
PUNCHSTATISTICS

Purpose: Reads function control cards for RESSUP load module

System/Language: CMS/FORTRAN

Author: S. K. Hunt Date: 11/07/72

Latest Revisor: Jeanne Etheridge Date: 04/04/79

MODULE ABSTRACT

RESRDR causes COPYRESULTS, LISTRESULTS, and PUNCHSTATISTICS cards to be read and then interprets them. The cards are error checked for completeness and validity. Then the required classification results tape is mounted and positioned to the correct file. The user is informed of his selections and control returns back to the caller.

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Revised April 1979

1. Module Usage

RESRDR

CALL RESRDR

This routine interprets the function control cards and puts the results into variables located in RESCOM. All results are validated and any required tapes are mounted.

2. Internal Description

After initialization of variables, CTLWRD is called to read and interpret the key words. An unexpected end of file for the control card input results in ERPRNT being called to terminate execution. After CTLWRD has determined the key word, a branch is made to sections of code to further interpret each of the possible cards. CTLPRM and IVAL are used to assist with this interpretation. After the END card is detected the user's requests are checked for completeness and validity.

Once all inputs are complete MMTAPE is called to mount any required classification results tapes. The user's requests are written on the line printer and control is returned to the caller.

Complete list of subroutines called by RESRDR:

TSTREQ	LOCATE
CTLWRD	BCDFIL
ERPRNT	RTMAIN
CTLPRM	
IVAL	
MMTAPE	

Commons used in RESRDR:

GLOCOM
RESCOM

3. Input Description

RESRDR does not actually perform any reading operations. It does invoke CTLWRD which performs reads to the control card input stream (card reader or typewriter). In addition MMTAPE performs the mounting, reading, and initializing of the classification results tape.

4. Output Description

File name - Information and Error Messages
DSRN - PRNTR and TYPEWR
Device type - Printer and Typewriter
Usage - Output
Description - Message numbers are listed below, for text see User's Manual.

MESSAGES

INFORMATIONAL	ERROR
188	459
189	581
190	582
191	583
192	584
	585
	586
	587
	588
	589
	590

File name - Request Selection Summary
DSRN - PRNTR
Device type - Printer
Usage - Output
Description - List of all control cards input and options requested.

5. Supplemental Information

See LARSYS System Manual for a description of how to create control card reading routines.

6. Flowchart

Not Applicable

LARS Program Abstract 261

MODULE IDENTIFICATION

Module Name: COPY Function Name: COPYRESULTS LISTRESULTS PUNCHSTATISTICS

Purpose: Performs results utility function (copy, list, punch)

System/Language: CMS/FORTRAN

Author: S. K. Hunt Date: 11/20/72

Latest Revisor: Jeanne Etheridge Date: 04/04/79

MODULE ABSTRACT

COPY fulfills all of the requests for the Copyresults, Listresults, and Punchstatistics functions. It reads the classification results file then copies, lists, or punches statistics according to the flags set in RESRDR. Upon completion of the task control is returned to RESCOP.

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1. Module Usage

COPY

```
CALL COPY(CHAN,CSEL,FRQUP,FRQLW,POLNAM,POLPTR,POLSTK,
          COVMTX,AVEMTX,BUF)
```

Input Arguments:

CHAN - INTEGER*2, Array of channel numbers read from the results file.

CSEL - INTEGER*2, Array of calibration codes used for each channel.

FRQUP - REAL*4, Array of upper wavelength band values for each channel.

FRQLW - REAL*4, Array of lower wavelength band values for each channel.

POLNAM - REAL*8, Array of names assigned to each pool used in classification.

POLPTR - INTEGER*2, A 2 by i matrix where i = the number of pools. POLPTR(1,i) = the number of classes in pool i, and POLPTR(2,i) = the location of the first class for the pool in POLSTK.

POLSTK - INTEGER*2, Array of class numbers of all classes in the statistics deck grouped by classification pool.

COVMTX - REAL*4, Lower half covariance matrices for each pool.

AVEMTX - REAL*4, Mean vector for each pool.

BUF - INTEGER*2, Buffer array to read in each line classified.

COPY is the main processor for the utility (results tape) load module. It either copies results tapes, lists results tapes, or punches statistics decks from results tapes.

2. Internal Description

COPY reads the first two records from the classification results file and prints header information on the line printer concerning the tapes and files used. If the user didn't request NOLIST then channel, calibration, and class information is printed on the line printer. Class weight information is also printed if weights were used in the classification. If copying is requested, the first two records are written on the output tape; if requested, pool names are changed to new pool names in record two. The stat deck is either read, read and copied, or read and punched; if requested in Copyresults, class names are replaced with new class names. The covariance and mean matrices are then read and copied if requested. Each area classified is then either read or read and copied. After the last area is processed the copy output tape is terminated by a file mark, check record, and two file marks if copying was requested. The input file will be positioned at the beginning of the next file if the results were on tape. Return is then made to the caller.

Complete list of subroutines called by COPY:

ERPRNT	TOPFS
TOPRF	
TOPEF	
TOPBF	

Commons used in COPY:

RESCOM
GLOCOM

3. Input Description

File name - Classification Results File
DSRN - CLASSR or MAPTAP
Device type - Disk or tape
Usage - Input
Description - See LARSYS System Manual for detailed description

4. Output Description

File name - Information and Error Messages
DSRN - PRNTR and TYPEWR
Device type - Printer and Typewriter
Usage - Output
Description - Message numbers are listed below, for text, see User's Manual

MESSAGES

INFORMATIONAL	ERROR
193	591
194	592
	593
	594

File name - Results file printer listing
DSRN - PRNTR
Device type - Printer
Usage - Output
Description - Classification results file information. For examples see User's Manual.

File name - Classification Results File
DSRN - CPYOUT
Device type - Tape
Usage - Output
Description - See LARSYS System Manual for detailed description.

File name - Statistics Deck
DSRN - PNCH
Device type - Cards
Usage - Output
Description - See LARSYS System Manual for detailed description.

5. Supplemental Information

Not Applicable

6. Flowchart

Not Applicable

LARSYS CONTROL CARDS

PRINTRESULTS (WITH PROBABILITY MAP OPTION)

REQ	KEY WORD(COL.1)	CONTROL PARAMETER	FUNCTION	DEFAULT
+	*PRINTRESULTS	(NONE)	SELECT CLASSIFICATION RESULTS PRINTOUT FUNCTION.	(NONE)
+	RESULTS		LOCATION OF RESULTS TO BE DISPLAYED.	(NONE)
		TAPE(XXX)	LOCATED ON TAPE XXX.	(SEE CONTROL CARD)
		FILE(FF)	FILE FF.	(DICTIONARY)
		DISK	USE RESULTS PLACED ON DISK BY CLASSIFYPOINTS IN CURRENT TERMINAL SESSION.	
	PRINT	STATS	PRINT SAVED STATISTICS.	NO STATISTICS PRINTED
		NOLIST	SUPPRESS SAVED FIELD LISTINGS.	SAVED FIELDS PRINTED
		MAPS(N)	PRINT N COPIES OF MAP.	MAPS=1
		OUTLINE(TRAIN)	OUTLINE TRAINING FIELDS.	NO OUTLINE
		OUTLINE(TEST)	OUTLINE TEST FIELDS.	NO OUTLINE
		OUTLINE(TRAIN, TEST)	OUTLINE ALL FIELDS.	NO OUTLINE
		TRAIN(C)	PRINT TRAINING CLASS PERFORMANCE.	
		TRAIN(F)	PRINT TRAINING FIELD PERFORMANCE.	
		TRAIN(F,C)	PRINT TRAINING FIELD AND CLASS PERFORMANCE.	NO TABLES PRINTED
		TEST(F)	PRINT TEST FIELD PERFORMANCE.	
		TEST(C)	PRINT TEST CLASS PERFORMANCE.	
		TEST(P)	PRINT TEST FIELD PERCENTAGES.	
		TEST(F,C,P)	PRINT ALL TEST RESULTS.	
		TABLES(N)	PRINT N COPIES OF ALL REQUESTED TABLES.	N = 1
	SYMBOLS	S1,S2,....	ASSIGN THESE SYMBOLS TO CLASSES. THESE SYMBOLS ARE REQUIRED FOR CLASSIFICATION MAPS	(NONE)
	PROBABILITY	R1,R2,....	ASSIGN EACH POINT TO GIVEN PERCENT PROBABILITY OF CORRECT CLASSFN RANGES. R1,R2,.... ARE THE LOWER BOUNDS ON THE RANGES (E.G. R1 CORRESPONDS TO 100% TO R1)	8 PRESET RANGES (SEE NOTE)
	PSYMBOLS	P1,P2,....	ASSIGN THESE SYMBOLS TO PROBABILITY RANGES	8 PRESET SYMBOLS
	THRESHOLD	T1,T2,....	USE THESE THRESHOLDS FOR CLASSES 1,2,...(SEE NOTE BELOW) THRESHOLDS MUST BE POSITIVE AND ONE VALUE MUST BE SPECIFIED FOR EACH CLASS.	THRESHOLDING NOT USED
	GROUP	NAME(G1/P1,P2/)	GROUP CLASSIFICATION POOLS P1,P2... FOR CALCULATING CORRECT RE-COGNITION. 'NAME' IS THE GROUP NAME AND G1 IS THE GROUP NUMBER.	NO GROUPING

PRINTRESULTS

```
R
E KEY          CONTROL
Q WORD(COL.1)  PARAMETER                    FUNCTION                DEFAULT
- -----------  ------------  ------------------------------  ------------------

  BLOCK                                                      ENTIRE AREA
               RUN(XXXXXXXX)  DISPLAY ONLY RUN XXXXXXXX---I
               LINES(X,Y,Z)   DISPLAY ONLY LINES X TO Y   I
                                 WITH LINE INTERVAL Z     I (NONE)
               COL(X,Y,Z)     DISPLAY ONLY COLUMNS X TO Y I
                                 WITH COLUMN INTERVAL Z----I
               CALC           CALCULATIONS BASED ONLY ON    ENTIRE AREA
                                 AREA DISPLAYED.

  DATA         -----START OF DATA DECK--------------------------------------
               I
               I              FIELD DESCRIPTION CARDS DEFINING TEST FIELDS.
               I              REQUIRED FOR ANY PRINT CARD OPTIONS DEALING
               I              WITH TEST FIELDS.
               I TEST N1
               I FIELD DESCRIPTION CARDS
               I TEST N2
               I FIELD DESCRIPTION CARDS
               I        .
               I        .
               I        .
               I       ETC       (WHERE N1 AND N2 ARE CLASS OR POOLED CLASS
               I                 (NUMBERS FROM CLASSIFYPOINTS OR GROUP NUMBERS
               I                 (DEFINED BY THE GROUP CARDS.
               I
               -------------------------------------------------------------

* END          (NONE)         END OF FUNCTION.              (NONE)


  NOTE.......THRESHOLD VALUES MAY ALSO BE SPECIFIED IN THE FOLLOWING FORMAT...

                              N1*T1,N2*T2,...

             WHERE N1 AND N2 APE INTEGERS WHICH SPECIFY HOW MANY
             CONSECUTIVE TIMES THE CORRESPONDING THRESHOLDS SHOULD
             BE USED AND T1 AND T2 ARE DECIMAL NUMBERS WHICH DESIGNATE
             THE PERCENTAGE OF POINTS THAT ARE EXPECTED TO BE THRESHOLDED

             THUS,          2*7.5, 3*2.9, 1.5
             HAS THE SAME EFFECT AS 7.5,7.5,2.9,2.9,2.9,1.5

   NOTE.......TO GET A PROBABILITY MAP OR TABLES USING THE DEFAULT RANGES,
             USE A 'PROBABILITY' CARD WITH NO RANGES SPECIFIED.

             THE DEFAULT RANGES AND SYMBOLS ARE:
              80 , 60 , 45 , 30 , 20 , 10 , 3 , 0
               M ,  X ,  O ,  I ,  / ,  - , . ,
```


|||

LARS Program Abstract 240

MODULE IDENTIFICATION

Module Name: PRISUP Function Name: PRINTRESULTS

Purpose: Supervisor for PRINTRESULTS

System/Language: CMS/FORTRAN

Author: Date:

Latest Revisor: S.K. Schwingendorf Date: 01/17/79

MODULE ABSTRACT

Supervisor for the Printresults function.

1. Module Usage

PRISUP

CALL PRISUP

There are no arguments to PRISUP. It is called from LARSMN when the PRINTRESULTS function is requested. Control returns to LARSMN upon completion of the function.

2. Internal Description

PRISUP calls the card reader and initiator and then checks to see if probability maps or tables were requested. If so, PRISUP then checks if a normal display routine was also requested. The normal display routine (if requested) is run first. PRISUP goes into a loop of calls to display the results of the different areas on the results file. The loop is composed of calls to three subroutines, DISPY1, DISPLY, and DISPY2. DISPY1 is called to find the next area on the classification tape to be displayed. If there are no more areas to be displayed, DISPY1 will RETURN1 which will cause PRISUP to call DISPY2. If there is another area DISPLY is called to perform the display and performance tally function. Normally, after a call to DISPLY, PRISUP will call DISPY1 again. The exception is if a user issued the 'STOP' command while executing DISPLY in which case a RETURN1 is passed back to PRISUP cuasing DISPY2 to be called. DISPY2 prints up the performance tables and completes the function, if the probability option was not requested. If it was, tapes are rewound and repositioned by entering the initiator at the entry point PRIIN1. This simulates the reading of the proper tapes and positions them for the probability run. Several flags are set appropriately and the display loop is entered and runs until completion.

3. Input Description

Not Applicable

4. Output Description

Standard supervisor information messages (112 and 71).

5. Supplemental Information

Refer to the LARSYS System Manual for supervisor requirements.

6. Flowchart

Not Applicable

LARS Program Abstract 246

MODULE IDENTIFICATION

Module Name: PRICOM Function Name: PRINTRESULTS

Purpose: Block Data for PRICOM

System/Language: CMS/FORTRAN

Author: Date:

Latest Revisor: S. K. Schwingendorf Date: 01/17/79

MODULE ABSTRACT

This is the BLOCK DATA subroutine for the PRINTRESULTS common block PRICOM.

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Revised January, 1979

LARS Program Abstract 247

MODULE IDENTIFICATION

Module Name: PRIINT Function Name: PRINTRESULTS

Purpose: PRINTRESULTS initiator

System/Language: CMS/FORTRAN

Author: Date:

Latest Revisor: S.K. Schwingendorf Date: 01/17/79

MODULE ABSTRACT

PRIINT reads the first part of the results file, checks grouping and symbols and allocates array space. It also reads the test fields.

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119

1. Module Usage

PRIINT

CALL PRIINT (FLDBAS,TSTST,TRNST,TSTBAS,UNUSED,DISTOP)

Output Arguments:

FLDBAS - I*4, returned with the base address in ARRAY of TRNFLD (see DISPLY)

TSTST - I*4, returned with base address in ARRAY of the array containing test field calucaltions (TSTTAB in DISPLY).

TRNST - I*4, returned with base address in ARRAY of array containing training field calculation (TRNTAB in DISPLY).

TSTBAS - I*4, returned with base address in ARRAY of the array containing test field coordinates (TSTFLD in DISPLY).

UNUSED - I*4, returned with the base address in ARRAY of the array to be used for the buffer for reading the results file.

DISTOP - I*4, returned with the number of bytes remaining unused in ARRAY.

PRIINT performs the initiation function for the PRINTRESULTS load module.

2. Internal Description

The first two records of the results tape are read. The sixth word of the first record is checked for a flag indicating a results tape produced by the modified *CLASSIFYPOINTS processor. If the flag=1, the weights are read from record 2 of the tape. Otherwise, no weights are included in the READ statement, and the weights are set to zero. The only other information used off record type 1 is the serial number. The users threshold or range values are coded into the same coding scheme used on the results file. Grouping is checked and a check is made for sufficient symbols. If insufficient symbols are available, more are requested. The training fields are read from the results file (record type 3) via RDTRN. The test field data cards are read via RDFLDS. Then the remainder of the array base addresses are computed and a check made for sufficient space in ARRAY. Record type 4 is read from the results file via STATS. During a probability option run the initiator may be re-entered (if run with normal display option) at PRIIN1. Upon entry an entryflag, ENTFG, is set. Records 1 and 2 are read from MAPTAP and then a jump is made to a loop that advances the results file to an 'EOS'. STATKY is set equal to 0 and storage allocation continues until completion. A jump is now made to the STATS call. Upon returning, TRNTAB and TSTTAB are initialized, and the routine returns to the supervisor. This entry is necessary only if a standard display run is used with the probability option. Entering the initiator at PRIIN1 repositions the tapes and reallocates storage area for the probability run.

3. Input Description

The first four records of the results file have been read by the end of PRIINT (1 and 2 are read in PRIINT and 3 and 4 via calls to other subroutines). If required, an additional symbols card is read from the typewriter. The flags and switches in PRICOM which were set in PRIRDR are used extensively in PRIINT.

4. Output Description

Information messages that are issued are I0034 and I0081.

A list of supervisor options is printed including the serial number of the results, the number of maps and copies of tables requested and the number of training and test fields stored in memory. If a printout of statistics was requested, they will be printed in STATS which is called by PRIINT. Disk file TRNTEST FIELDS is created in the call to RDTRN and RDFLDS.

5. Supplemental Information

Not Applicable

6. Flowchart

Not Applicable

MODULE IDENTIFICATION

Module Name: PRIRDR Function Name: PRINTRESULTS

Purpose: Interprets the PRINTRESULTS control cards.

System/Language: CMS/FORTRAN

Author: Date:

Latest Revisor: S.K. Schwingendorf Date: 01/17/79

MODULE ABSTRACT

PRIRDR interprets all function control cards for PRINTRESULTS. Checks are made for complete and valid specifications.

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1. Module Usage

PRIRDR

PRIRDR has no calling parameters. Various flags in PRICOM reflect the control cards interpreted. These are:

Control Card	Action
RESULTS	RESULT will be set to the correct DSRN for tape or disk as requested. If tape is requested, MMTAPE is called to mount the tape and position it.
PRINT	STATS STATKY = 1 NOLIST LISTKY = 1 MAPS NOMAPS is set to the number of maps OUTLINE OTRKEY and OTSKEY are set to 1 accordingly. TRAIN and TEST TRFLD, TRCLS, TSFLD and/or TSCLS are set to = 1 accordingly. TABLES COPIES is set to the number of copies requested.
SYMBOLS	The symbols are stored in SYMMTX.
PROBABILITY	User defined ranges are stored in PRBRNG.
PSYMBOLS	These symbols are stored in PSYMTX and are used for the probability map.
THRESHOLD	The threshold values are stored in THRES.
GROUP	GRPNAM and GRPSTK are computed by a call to GRPSCN.
BLOCK	The first 6 words of BLOCK are used to contain this field boundary definition and the run number is in RUNNUM.

2. Internal Description

Internals are standard for card readers. A check is made to be certain that a results specification was made. If display maps were requested, a check is made that symbols were given. If either is missing, the user is asked to type in the needed card. If a probability card is read with no ranges given, then the reader automatically defaults to 8 preset ranges.

If the last range is not zero another symbol and range (zero) is added. A check is made to be sure that enough probability symbols were given. The user is given a list of ranges and is asked for more symbols if necessary. If no probability symbols were given and there are fewer than nine ranges, then the reader will default to preset symbols. If results are on disk, a read is made of the disk file to be certain the file exists. If results are on tape, MMTAPE is called with mode 0 indicating the tape is read only.

3. Input Description

The control cards are read via call to CTLWRD. If results are on disk, the first record is read to be certain the file exists.

4. Output Description

Information messages 72, 73, and 74 are typed. Error message 441-457 and 459 are written via ERPRNT. A list of options selected is printed.

5. Supplemental Information

See the LARSYS Systems Manual for card reader requirements.

6. Flowchart

Not Applicable

LARS Program Abstract 243

MODULE IDENTIFICATION

Module Name: DISPY2 Function Name: PRINTRESULTS

Purpose: Controls printing of performance tables.

System/Language: CMS/FORTRAN

Author: Date:

Latest Revisor: S.K. Schwingendorf Date: 01/17/79

MODULE ABSTRACT

DISPY2 controls the printing of all performance tables including printing multiple copies. It is called after all areas to be displayed have been processed.

1. Module Usage

DISPY2

CALL DISPY2 (TRNFLD,TSTFLD,TRNTAB,TSTTAB)

Input Arguments:

TRNFLD - I*4, the array of training field definitions dimensioned (10,NOFLD) where NOFLD is the number of training fields. The format is the same as the array FLDARY in REFLDS (which creates TRNFLD).

TSTFLD - I*4, the array of test field definitions dimensioned (10,NOTST) where NOTST is the number of test fields. The format is the same as TRNFLD.

TRNTAB - I*4, table of training field performance. Used only to pass on to subroutine PRTPCT.

TSTTAB - I*4, table of test field performance used only to pass on to subroutine PRTPCT.

Note that TRNFLD and TSTFLD are modified in DISPY2. This modification of rows 4 and 7 is used by subroutine PRTPCT when it is passed TRNFLD and TSTFLD but the modification is not considered an output back to the caller.

The list of training test fields and all performance and percentage tables have been printed when DISPY2 has completed execution.

2. Internal Description

DISPY2 first moves group names into a vector for printing. If the probability option is being run, the vector is reloaded with generated range names so that the probability performance tables will be labelled correctly. If LITSKY is 1, the list of training and test fields is printed, otherwise this code is skipped. Then all tables are printed by calls to PRTPCT. Before a table is printed by calling PRTPCT, a branch is made to an internal subroutine which calls TSTREQ to check for the STOP command and prints the header via a call to PRTHED.

If several copies of tables were requested, PRTPCT is passed the DSRN of the file PRESULT SCRATCH rather than the DSRN of the printer. Then in the case of multiple copies, the file PRESULT SCRATCH is rewound and read and printed the desired number of times.

3. Input Description

The training and test field definitions are read from file TRNTEST FIELDS (DSRN TTFLDX). See Data Organization. The file PRESULT SCRATCH may be read. If so, it was created by DISPY2.

4. Output Description

Information message I0023 indicating the user used the STOP command. If multiple copies of tables were requested, the tables are written onto the file PRESULT SCRATCH (DSRN PRESUX). Note that the file is rewound at the beginning of DISPY2 so that any earlier information is overwritten.

The list of training and test fields is printed and all copies of performance and training tables are printed. If only one copy of tables is requested, it is printed by subroutine PRTPCT. If multiple copies were requested, DISPY2 prints them (see Section 2 above).

5. Supplemental Information

Not Applicable

6. Flowchart

Not Applicable

MODULE IDENTIFICATION

Module Name: PRTHED Function Name: PRINTRESULTS

Purpose: Prints headers

System/Language: CMS/FORTRAN

Author: Date:

Latest Revisor: S.K. Schwingendorf Date: 01/17/79

MODULE ABSTRACT

Prints the headers for PRINTRESULTS containing run identification and channels and classes information or ranges information.

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Revised January, 1979

1. Module Usage

PRTHED

CALL PRTHED (RUNKEY,CHNKEY,CLSKEY,UNIT)

Input Arguments:

RUNKEY - I*4, flag for writing run identification. RUNKEY = 0 means do not write run identification and RUNKEY = 1 means do write it.

CHNKEY - I*4, flag for writing channel (and calibration) information. CHNKEY = 0 means do not write and = 1 means do write.

CLSKEY - I*4, flag for writing classes information. CLSKEY = 0 means do not write any classes information. CLSKEY = 1 means list class name, group name (if any), threshold percent (if any), and symbol for printing. CLSKEY = 2 means the same as = 1 excpet that symbols are not written. During a probability run, CLSKEY = 1 means list symbol for printing and range interval. CLSKEY = 2 means the same as CLSKEY = 1 except the symbols are not written.

UNIT - I*4, DSRN to write header on.

PRTHED is used to write headers for PRINTRESULTS. The unit number is variable because in the call, the write will be to a scratch data set of several copies are to be printed.

2. Internal Description

The writing of channel and calibration information is done with a variable format statement depending upon the calibration codes. The writing of classes information is done using the FORTRAN carriage control character '+' in order to print the group name and threshold percent only if they exist and to write the heading for symbol group name, threshold percent, and weights only if they are to be written. Note that in CMS the '+' is executed as no space after print rather than no space before print (which is specified in FORTRAN language specifications).

PRTHED is programmed such that the output will have data items aligned correctly independent of whether the '+' control is executed as no space after or before print. The only difference will be the number of spaced between the heading and the data items.

3. Input Description

Not Applicable

4. Output Description

The following outputs are written to unit UNIT:

The standard LARSYS header.

A line giving the classification serial number and date of classification.

Run identification if requested.

Channel and calibration information if required.

Class and weight information if requested.

Probability symbols and range intervals if a probability run.

5. Supplemental Information

Not Applicable

6. Flowchart

Not Applicable

MODULE IDENTIFICATION

Module Name: DISPLY Function Name: PRINTRESULTS

Purpose: Creates the display map

System/Language: CMS/FORTRAN

Author: Date:

Latest Revisor: S.K. Schwingendorf Date: 01/17/79

MODULE ABSTRACT

DISPLY creates the display map and/or the probability map for one area of the results file. Thus DISPLY is called once for each area of the results file displayed and once more for each area displayed as a probability map.

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1. Module Usage

DISPLY

CALL DISPLY (TRNFLD,TSTFLD,TRNTAB,TSTTAB,IR,IVR,IPTS, *)

Input Arguments:

TRNFLD - I*4, An array of training field definitions dimensioned (10, NOFLD) where NOFLD is the number of training fields. The format is that of the array FLDARY in subroutine RDFLDS (which creates the array).

TSTFLD - I*4, An array of test field definitions dimensioned (10, NOTST) where NOTST is the number of test fields. The format is the same as TRNFLD.

IR - I*2, A buffer area used to read in a line of the classification file. It is dimensioned the number of points in a classified line. After unpacking, IR contains either class numbers as valid halfword integers or the coded discriminant value if the probability option is being used.

IVR - I*2, A buffer area used to place the coded discriminant value into when it is unpacked from IR. IVR is dimensioned the same as IR.

IPTS - I*4, The number of points in a line. This is equal in value to PTS but is I*4 rather than I*2. This is required because IPTS is used as a dummy dimension for IR and IVR and dummy dimensions must be I*4.

Output Arguments:

TRNTAB - I*4, An array of performance tallies for training fields. It is dimensioned (NOCLS5, NOFLD). TRNTAB(I,J) = the number of points in training field J classified into class I.

TSTTAB - I*4, The same as TRNTAB except for test fields.

Revised January, 1979

Non-standard Return:

RETURN1 - If DISPLY has terminated because the user has issued a STOP System Support Command, RETURN1 is executed.

DISPLY is called after DISPY1 has located an area to be displayed.

DISPLY does the creation of the display map and tallying of performance statistics for the area.

2. Internal Description

See flowchart

3. Input Description

Record type 6's are read from the results file until a record type 7 is read. The file PRESULT SCRATCH (DSRN PRESUX) is read if more than one copy of the map is requested. In that case the file has been created earlier in DISPLY and in DISPY1. See Data Organization.

4. Output Description

The file PRESULT SCRATCH is completed. The display map is printed.

Error 483 (end of file on results file) is written via ERPRNT. Information Messages I0078 (bad line on results file, line ignored), I0079 (typed after each 100 lines displayed), I0080 (indicating which copy of the map is being printed) and I0023 (when STOP command is issued).

5. Supplemental Information

Not Applicable

6. Flowchart

(Page numbers refer to the pages of the flowchart.)

LARSYS CONTROL CARDS

CHANGEDETECTION

```
R
E KEY           CONTROL
Q WORD(COL.1)  PARAMETER                    FUNCTION                    DEFAULT
- ------------ ----------- ------------------------------------------- -----------------

* *CHANGEDETECT (NONE)          SELECT CHANGE DETECTION            (NONE)
                                   FUNCTION

* BASERESULTS                   LOCATION OF RESULTS FROM           (NONE)
                                  FIRST DATE.
               TAPE(XXX)        LOCATED ON TAPE XXX.               (SEE CONTROL CARD
               FILE(FF)         FILE FF.                           (    DICTIONARY
               DISK             USE RESULTS PLACED ON DISK
                                  IN CURRENT TERMINAL SESSION.

* COMPARERESULTS                LOCATION OF RESULTS FROM           (NONE)
                                   SECOND DATE.
               TAPE(XXX)        LOCATED ON TAPE XXX.
               FILE(FF)          FILE FF.
               DISK             USE RESULTS PLACED ON DISK
                                IN CURRENT TERMINAL SESSION.

* NEWRESULTS                    LOCATION OF CHANGE (OUTPUT)        (NONE)
                                   RESULTS FILE.
               TAPE(XXX)        WRITE ON TAPE XXX.
               FILE(FF)         FILE FF.
               INIT             INITIALIZE TAPE AND WRITE
                                  RESULTS IN FILE 1
               DISK             PLACE RESULTS ON DISK

* BLOCK
               RUN(XXXXXXXX)    RUN NUMBER  IS    XXXXXXXX---I
               LINES(X,Y,Z)     DISPLAY  LINES     X  TO  Y   I
                                  WITH LINE INTERVAL Z        I  (NONE)
               COL(X,Y,Z)       DISPLAY   COLUMNS  X TO Y     I
                                  WITH COLUMN INTERVAL Z----I

* DATA         -----START OF DATA DECK-------------------------------------------
               I
               I       DEFINE CHANGE CLASSES OF INTEREST BY NAMING THE CLASS
               I         ON A 'CLASS' CARD, AND INDICATING WHICH CLASSES
               I         FROM THE FIRST CLASSIFICATION (ON 'BASE' CARD) AND
               I         WHICH CLASSES FROM THE SECOND CLASSIFICATION (ON
               I         'COMP' CARD) ARE PERMITTED FOR A POINT TO BELONG
               I         TO THIS CLASS.
               I
               I CLASS NAME1
               I BASE N1, N2, N3, ....
               I COMP M1, M2, M3, ...
               I CLASS NAME2
               I        .
               I        .
               I        .
               I       ETC        (WHERE M1,M2,... AND N1,N2,... ARE CLASS OR
               I                  (POOL NUMBERS FROM CLASSIFYPOINTS.
               I
               ------------------------------------------------------------------

* END          (NONE)           END OF FUNCTION.                   (NONE)
```