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LACIE-00200
VOLUME VIII

LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

NASA NOAA USDA

Level III Baseline

RESEARCH REQUIREMENTS

NOTICE: THIS IS A BASELINED LEVEL III DOCUMENT CONTROLLED BY THE LACIE LEVEL III CHANGE CONTROL BOARD. ANY PROPOSED CHANGES SHOULD BE DOCUMENTED ON AN RECP FORM AND TRANSMITTED TO R. B. MACDONALD, LACIE MANAGER, NASA-JSC, CODE TF, HOUSTON, TEXAS 77058.

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

DECEMBER 16, 1974

REVISIONS

REV LTR	CHANGE NO.	DESCRIPTION	DATE
		BASELINE ISSUE (Reference CCBD #III-0001, dtd December 16, 1974)*	12-16-74

*The changes required by the following RID's which were approved during the LACIE Project Review conducted December 3 through 5, 1974, have been incorporated into this baseline issue of the LACIE Level III Requirements Documents:

0-2 through 0-13, 0-15 through 0-29, and 0-31 through 0-46
1a-1, 1a-2, 1a-10,, 1a-21, 1a-34, and 1a-36
1b-3 and 1b-6
1c-2, 1c-4, 1c-5, 1c-9, 1c-10, 1c-13, 1c-16, 1c-17, and 1c-20
2-12a, 2-13, 2-17, and 2-27

All other changes required by the remaining RID's approved during the Project Review will be incorporated by transmitting an RECP to the LACIE Level III Change Control Board for approval. Each RECP should be accompanied by the appropriate RID Closeout Form as described during the Project Review.

LIST OF EFFECTIVE PAGES

The current status of all pages in this document is as shown below:

Page No.	Change No.	CCBD No.
i through xii	Original	III-0001
1 through 51	Original	III-0001

FOREWORD

Efficient management of the Large Area Crop Inventory Experiment (LACIE) dictates that effective controls of project activities be established. To provide a basis for effective control, documentation will be prepared, baselines will be established, and changes to the baseline will be subsequently controlled by the proper management levels.

The specific control documents which will be used are defined in the LACIE Project Plan, LAP01. All elements of the LACIE project must adhere to these baselined control documents; and where it is considered that the requirements should be changed, the proper change request, accompanied by a full justification, must be submitted to the proper management level in accordance with established procedures. These documents will be maintained current by change notices and revisions, as required. Each change notice and/or revision will reference the applicable Change Control Board Directive which approved the change.

This document, LACIE-00200, Volume VIII, defines the LACIE research requirements and has been prepared in accordance with the "Instructions for Preparation of LACIE Requirements Documents", LACIE-00100, Revision C, dated November 20, 1974. "Full-Up System", as used in this document, is defined as the system required to accomplish LACIE Phase II. In general the approach used in each section is to first specify the requirements of the Full-Up System and then to specify the requirements of any interim systems by reference to specific paragraphs in the Full-Up System requirements sections of the document. The LACIE project phases are defined in the LACIE Project Plan, LAP01.

The organization responsible for the implementation of each requirement defined in this document is specified on an individual requirement basis. Where the implementation responsibility applies to the complete section, the implementation responsibility is specified after the section title. A "section" for the purpose of designating implementation responsibility is defined as being any numbered paragraph and all subparagraphs. Where different implementation responsibilities apply to different portions of a section, the implementation responsibility is specified on an individual paragraph or sentence basis, as applicable. All implementing organizations designated shall accomplish their implementation activities in accordance with the requirements specified herein.

R. B. MacDonald
Manager, Large Area Crop Inventory Experiment

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GLOSSARY

bpi	bits per inch
CAMS	Classification and Mensuration Subsystem
CAS	Crop Assessment Subsystem
CCT	Computer Compatible Tape
CSU	Colorado State University
DAPTS	Data Acquisition, Preprocessing, and Transmission Subsystem
ERIM	Environmental Research Institute of Michigan
ERL	Earth Resources Laboratory
ERTS	Earth Resources Technology Satellite
FSAS	Field Signature Acquisition System
FSO	Facilities Support Office
FSS	Field Spectrometer System
GSFC	Goddard Space Flight Center
ISRRS	Information Storage, Retrieval, and Reformatting Subsystem
ITS	Improved Technology Satellite
JSC	Lyndon B. Johnson Space Center
KSU	Kansas State University
LACIE	Large Area Crop Inventory Experiment
LAI	Leaf Area Index
LARS	Laboratory for Applications of Remote Sensing
mse	mean square root
MSS	Multispectral Scanner

NASA	National Aeronautics and Space Administration
RTEB	Research, Technology, and Evaluation Branch
S&AD	Science and Applications Directorate
SPE	Systems Performance Evluation
TAMU	Texas A&M University
TBD	To Be Determined
UCB	University of California at Berkeley
UH	University of Houston
USDA	U.S. Department of Agriculture
UTD	University of Texas at Dallas
YES	Yield Estimation Subsystem

1.0 FUNCTIONAL RESPONSIBILITIES

1.1 GENERAL

The research section of the Research, Test and Evaluation Branch (RTEB) will be responsible for conducting a LACIE project support activity directed toward improving the system methodology and performance. Research will conduct a research program aimed at solving anticipated or existing problems of the application systems.

2 SPECIFIC

The accuracy of the results of any experimental program is dependent on the methodology used to arrive at such results. LACIE will rely on existing technology to accomplish its objectives; however, in order to improve the accuracy of the results of the experiment, research must be conducted to refine and improve the technology. Three major categories that can benefit greatly from such technological refinements are the following:

a. Estimation of acreage of wheat grown and harvested.

b. Yield estimation.

c. Production estimation.

The research section has defined several major research objectives within the three categories and has identified them as crucial to the development of technology pertinent to LACIE.

The research includes both short-and long-term efforts, with some elements supporting Phase I of the program, other elements supporting Phase II, and a few supporting possible follow-on crop inventory projects.

The major objectives are as follows:

1.2.1 Crop Acreage Research and Development

Estimation of crop acreage for a given sample can be divided into three phases: definition of training statistics, classification using the training data, and estimation of acreage within the sample from the classification results. Objectives of research in these areas are as follows:

- To develop improved methods of image interpretation for development of classifier training statistics. Both manual and computer-aided techniques will be explored.
- To develop methods for extension of training statistics over large geographical areas. Definition of signature extension strata and development of signature adjustment algorithms will be pursued.
- To investigate methods for improving the accuracy of classification. A number of diverse areas are included, such as determination of the optimum crop development stage for discrimination, feature selection, use of spatial information, etc.
- To develop methods for improving the accuracy of crop estimation for a given sample. A number of diverse areas are included, such as improvement of classification accuracy, corrections for classification bias and percent of unharvested wheat, and acreage estimation without classification.

1.2.2 Crop Yield Research and Development

To adapt existing wheat yield models and yield estimation procedures to the specific yield problems of LACIE.

Yield models and estimation procedures based on historical, meteorological and scanner data will be developed and evaluated.

2.3 Crop Assessment Research and Development

To define spatial sampling strategies for both acreage and yield along with methods for aggregating acreages from the individual samples to determine acreage, yield, and productivity for large areas. Sampling and aggregation procedures must take into account the effects of cloud cover on data acquisition. Procedures for using historical, meteorological, and space-borne multispectral scanner (MSS) data to estimate wheat proportions for use in sampling strategy definition will be developed and evaluated for the major wheat-growing areas.

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2.0 APPLICABLE DOCUMENTS

The following documents are applicable to the extent specified here:

1. LACIE-00100 (Rev. C) - Instructions for Preparation of LACIE Requirements Documents (dated November 20, 1974).

2. LACIE Project Plan, LAP01 (dated November 1974).

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3.0 FUNCTIONAL FLOW DIAGRAMS

3.1 DEVELOPMENT

3.1.1 Full-Up System

Since the research section of the RETB is not responsible for the development and operation of a major subsystem of LACIE in the true sense of the word "subsystem", a single functional flow diagram will be used here to define how research will function in its relation to LACIE. This is shown in figure 1. Outputs from the research activity are filtered through the Test and Evaluation Section before any recommendation by the subsystem.

3.1.2 Interim Systems

Not applicable

3.2 OPERATION

3.2.1 Full-Up System

Not applicable

3.2.2 Interim System

Not applicable

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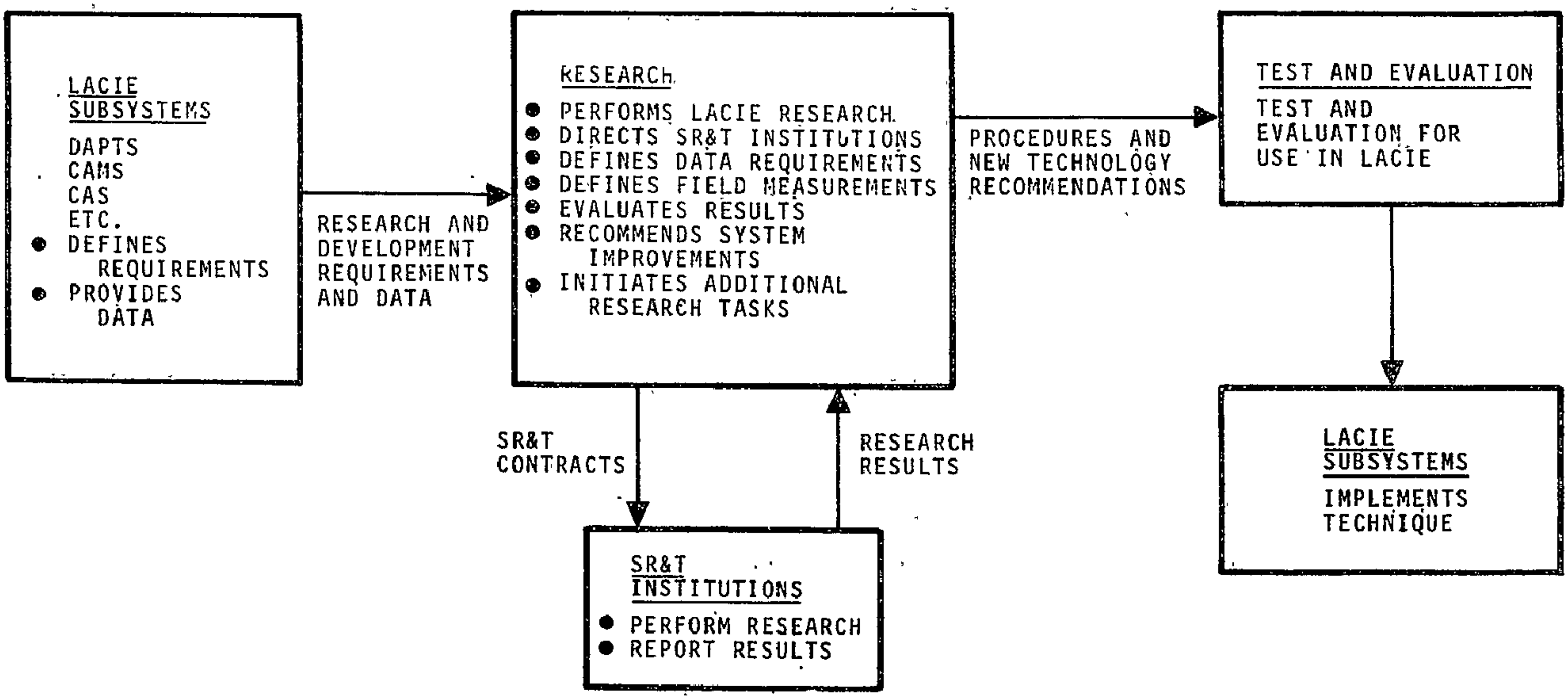

Figure 1.- Research Development Flow Diagram.

4.0 REQUIREMENTS (CONSOLIDATED)

This section will define those tasks needed to be accomplished in attaining the objectives set forth in section 1.2 of this document.

4. FULL-UP SYSTEM

To satisfy the objectives stated in 1.2, the following tasks are to be completed in accordance with the stated task requirements:

4.1.1 Crop Acreage

Estimation of crop acreage for a given sample can be divided into three phases: definition of training statistics, classification using the training statistics, and acreage calculation from the classification results (mensuration). The research activities can be divided into categories which support these three phases.

4.1.1.1 Definition of training statistics.- Training statistics are derived from wheat and non-wheat fields identified by analyst interpretation of Earth Resources Technology Satellite (ERTS) imagery. The process is empirical and requires specialized training and experience on the part of the analyst. Better methods for producing and interpreting the ERTS imagery are sought.

a. Image interpretation (Req'd by CMAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/UCB): Image interpretation techniques for identification of wheat from ERTS data will be developed and evaluated. Procedures are sought that will improve the accuracy of crop identification and will improve accuracy and speed of image interpretation in an operational system. This will include selecting optimum sets of four dates and more (up to the total number of passes from ground preparation through the first pass after wheat harvest) and a quantitative evaluation of AI accuracies expected using each complete set. For the optimum set of 5 dates, evaluate expected AI accuracy for each subset of 4, 3, 2, and 1 dates to demonstrate the penalty resulting from the loss of one or more passes due to cloud cover, other operational problems, or evaluation prior to the end of the data season. The current operational procedure for LACIE AI's will be reviewed in order to better define those materials, equipment and techniques required for consistent AI identification of wheat and efficient interface of the crop identifications into ADP equipment.

b. Image Enhancement (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/LARS): Computer-based techniques (such as best linear combination) will be used to generate enhanced imagery for evaluation by analyst interpreters in task (a).

c. Computer-aided identification of wheat (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/ERIM): Develop methods for selection of training fields without *in situ* ground truth by using clustering techniques.

d. Training field homogeneity (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TBD): Homogeneity tests are required for the following cases: (i) a test to determine whether or not a field or cluster is sufficiently homogeneous to be used as a training sample for a unimodal class, (ii) a test to determine whether a collection of fields or clusters is sufficiently homogeneous to be used as a training sample for a unimodal class, and (iii) an estimate of the likelihood that the class label assigned to each training sample by an image interpreter is correct.

4.1.1.2 Classification - Research supporting classification has the general objective of increased classification accuracy. This covers a wide range of topics, including the optimum crop development stage for discrimination, registration of multitemporal imagery (for use of multitemporal data to improve accuracy), specialized classification techniques, signature extension, and a field measurements activity to provide data needed by the research program.

a. Temporal Sampling Strategy:

(1) Determine the optimum crop development stages for discrimination of spring and

winter wheat (Req'd. by CAMS; Cat. 2; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

(2) Determine the optimum spectral bands for discrimination of spring and winter wheat (Req'd by CAMS; Cat. 4; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

(3) Develop improved temporal sampling strategy using crop calendars adjustable from meteorological data (Req'd by CAMS; Cat. 1; Impl. Resp.: Research/NASA-S&AD-RTEB).

(4) Investigate the applicability of the previously developed procedure for selecting the single linear combination of the available measurements such that the probability of misclassification is minimized to the selection of those times of year when wheat can best be discriminated from non-wheat and the generation of enhanced gray level imagery for use in identifying training fields by photointerpretation (Req'd by CAMS; Cat. 1; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

b. Registration:

(1) Current algorithms for image registration of low contrast ERTS images will be evaluated and improvements recommended (Req'd by CAMS/DAPTS; Cat. 2; Impl. Resp.: Research/NASA-S&AD-RTEB/LARS).

(2) Multitemporal ERTS imagery will be registered by two procedures: standard Goddard Space Flight Center (GSFC) "nearest-neighbor" and interpolation. Both full-frame and LACIE sample segments will be registered. Root-mean-square misregistration errors will be evaluated for all products (Req'd by Research; Cat. 2: Impl. Resp. Research/NASA-S&AD-RTEB/TBD).

c. Feature selection: Features used in classifying remote sensing data should be selected so that the probability of misclassification is minimized.

(1) Computational improvements (Req'd by Research; Cat. 1; Impl. Resp.: Research/NASA-S&AD-RTEB/UH). Improve, in terms of accuracy and efficiency, the previously developed procedure for selecting, as features for use or discriminating among m classes, k linear combinations of n available measurements such that the probability of misclassification is minimized.

(2) Linear features extraction This task has two separate subtasks as follows:

a) Develop a procedure for generating the "initial guess" that is needed when the Davidon-Fletcher-Powell iterative optimization procedure is used to find the single linear combination of all the available measurements that minimize the probability of misclassification (Req'd by Research; Cat. 1; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

(b) Generalize the previously developed procedure for finding the single linear combination of the available measurements such that the probability of misclassification is minimized to the case of non-normal probability density functions (Req'd by Research; Cat. 1; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

(3) Optimum number of features - Develop an accurate and efficient algorithm for finding the smallest number (K) of linear combinations of n available measurements that must be used as features for classification in order that the decrease in the probability of correct classification not exceed a user specified (Req'd by CAMS; Cat. 1; Impl. Resp.: Research/NASA-S&AD-RTEB/UH).

d. Multitemporal classification techniques:

(1) Consider the case of a LACIE sample segment that is observed on two passes and the data from these two passes is registered. Suppose that there were scattered clouds (or scanline drop-outs) on one pass; then the measurement vectors for those pixels that were obscured are incomplete in the sense that the components for the obscured pass have large errors. If the training field for a class includes such obscured pixels, the class statistics estimated from the training data will be in error; likewise the classification of any obscured pixel will be in error. Such obscured pixels can be deleted from the data set if they can be recognized. However, this reduces the number of pixels available for training, classification, and subsequent crop acreage estimation even though the deleted pixels were correctly observed on one of the two passes. The objective of this task is to develop procedures for estimating class statistics, selecting features for use in classification, and classifying and estimating acreage that use both the complete and the incomplete measurements vectors for the sample segment.

(2) Single-pass classifier - Investigate the feasibility of a classifier that utilizes training data gathered from different sites on different dates. One potential approach to be considered is a sequential or layered classifier which, for each successive pass, eliminates the non-wheat from among those pixels considered to be potentially wheat on the previous pass (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TBD).

(3) Classification errors produced by misregistration of multitemporal ERTS data sets will be evaluated (Req'd by CAMS: Cat. 2; Impl. resp. Research/NASA-S&AD-RTEB/ERIM).

e. Signature extension: Techniques for extending spectral signatures of wheat over large areas are required. The following tasks must be performed:

(1) Define signature extension strata by image interpretation supported by clustering techniques (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/UCB).

(2) Define signature extension strata using primarily clustering techniques (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/LARS).

(3) Define the physical factors which control signature extension and determine whether these and other ancillary data (climate, soil conditions, elevation differences, etc.) can be used to define signature extension areas which are geographically separated (analog areas) (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/LARS/UCB).

(4) Develop a model of class spectral signature variability that is computationally useful for extending signatures from one sample segment to geographically nearby sample segments (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/UH).

(5) Define a simple signature extension algorithm to account for variations in sun angle at various stages of crop development (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/CSU).

4.1.1.3 Mensuration.- Two problem areas exist; one is concerned with estimation of acreage of wheat grown; the other with determination of the percentage of wheat grown that is actually harvested. Specific tasks are as follows:

Estimation of planted acreage in sample segment: Several statistical procedures for estimating what proportion of a sample segment of known area is in wheat will be investigated. These procedures divide into two categories: those that require the use of a classifier and those that do not.

(1) Proportion estimation by classification -

(a) Develop a procedure for making unbiased, positive, proportion estimates using the

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classification results from a supervised classifier applied to an unlabeled sample and the confusion matrix; i.e., the matrix of probabilities of correct and misclassification for that classifier (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/UTD).

(b) Develop a recursive procedure for making an unbiased proportion estimate; i.e., for updating the estimate of the true proportions after each additional pixel is classified so that the variance of the final estimate is minimized (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/Rice Univ).

(c) Develop a recursive procedure for finding the linear transformation from n dimensions to 1 such that when an unlabeled sample is classified using this transformation the proportions produced by the classifier are an unbiased, minimum variance estimate of the true proportions. This is an extension of a previously developed feature selection procedure which transformed the observations to minimize the probability of error (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

(2) Proportion estimation without classification via mixture models -

(a) Apply the Environmental Research Institute of Michigan (ERIM) "proportion of unresolved objects" rule to the acreage estimation problem using (1) first moments only and (2) first and second moments in conjunction with a rule for eliminating excess classes (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/ERIM).

(b) Develop a procedure for proportion estimation based on a model where the moments of the sample are approximated by a constrained convex combination of the moments of the classes (Req'd by CAMS; Cat. 2; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

(c) Develop a procedure for proportion estimation based on the method of maximum likelihood and a model in which the probability density function of the sample is approximated by a constrained convex combination of the class density functions (Req'd by CAMS; Cat. 2; Impl. Resp.: Research/NASA-S&AD-RTEB/UTD).

(d) Develop a recursive procedure for making unbiased, minimum variance proportion estimates based on a model in which the probability density function of the sample is a convex combination of the class density functions (Req'd by CAMS; Cat. 2; Impl. Resp.: Research/NASA-S&AD-RTEB/Rice Univ.).

(e) Develop a procedure for making a proportion estimate based on a model in which each of the marginal distribution functions for the sample is approximated by a convex combination of the corresponding class marginal distribution functions (Req'd by CAMS; Cat. 2; Impl. Resp.: Research/NASA-S&AD-RTEB/UTD).

(3) Variance of Proportion Estimators

(a) Develop a method for estimating the variance of a wheat proportion estimate for a sample segment when ground truth not available. Such a variance estimator is needed for the naive proportion estimator that is currently used in LACIE plus those candidate replacements that test best (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RT&E/UTD).

b. Correction for unharvested wheat:

(1) Develop a method for discrimination of harvested from unharvested wheat in ERTS data (Req'd by CAMS; Cat. 3; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

(2) Develop crop calendars, which provide harvest start and harvest end dates for any location in

the United States using meteorological data inputs (Req'd by CAMS; Cat. 3; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

(3) Develop a technique for estimating the harvested wheat acreage from combination of the percent harvested wheat on a given date from ERTS data with the harvest start and stop dates (Req'd by CAS; Cat. 3; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

4.1.1.4 Acreage estimation (aggregation of sample segments).

a. All LACIE countries: Develop a standard aggregation scheme for all LACIE countries (based on task 4.1.3.1a) (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

b. Variable confidence aggregation schemes: Devise an aggregation scheme which preferentially incorporates sample segments of higher confidence in wheat acreage estimates. The wheat acreage estimate for a given substratum (i.e., county) will, in general, be a weighted average of the historical (ratio) and the current (ERTS) estimates. If all segments in a county are lost due to clouds, then the weights would be 0 (zero) for "ERTS" and 1 (one) for "ratio." Conversely, if all data are good, the weights might be 0 (zero) for "ratio" and 1 α for "ERTS", where α is TBD (possibly 0). If some data are available but not all, an optimal system of weight determination must be developed (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

c. Cloud cover effects: Determine a model for the inclusion of cloud cover in the sampling area. Cloud cover statistics will be combined with the aggregation scheme defined above to provide estimates of sampling errors introduced by cloud cover data loss (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU/TBD).

4.1.1.5 Field measurements. Several of the research tasks outlined above require data currently unavailable. These tasks include temporal sampling strategy, definition of physical factors which control signature extension, and definition of sun angle effects. A field measurements program has been initiated to provide the required data.

Truck- and helicopter-mounted spectrometers will be used to measure reflectance and emittance spectra of wheat and other crops at the agricultural experiment stations in Garden City, Kansas; and Williston, North Dakota; and in the nearby intensive test sites and other sites as required. Extensive support data will be collected, processed, and included in the analysis of the spectral data. Specific tasks to be performed are as follows:

a. S-191H helicopter-mounted spectrometer: The S-191H helicopter-mounted Field Spectrometer System (FSS) will acquire reflective and thermal spectra of winter wheat, spring wheat, and confusion crops during the 1974-75 crop year. Specific sites and schedules are as follows (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/FSO):

    (1) Garden City, Kansas - A single helicopter flight will be performed in the fall of 1974. Flights will be resumed in spring, beginning on or about March 1, 1975. One flight will be required every 18 days until wheat heading begins (approximately May 1, 1975), after which flights will be required every 9 days through wheat harvesting (approximately June 15, 1975). Estimated total of Kansas flights is 11.

    (2) Williston, North Dakota - Helicopter flights will begin on or about June 15, 1975. Flights will be required every 18 days until heading occurs and every 9 days from heading through wheat harvesting (approximately October 1, 1975). Estimated total of North Dakota flights is eight.

b. Truck-mounted spectrometer: Truck-mounted field spectrometers will acquire reflective and thermal spectra as a function of sun angle and biological phase for wheat varieties and confusion crops in Garden City, Kansas; Williston, North Dakota; and other sites as required (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU/LARS/ERL/FSO).

c. Agricultural data collection: Agricultural data will be collected in support of the field measurements program for wheat varieties and confusion crops in Garden City, Kansas; Williston, North Dakota; and other sites as required (Req'd by Research; Cat. 1; Impl. Resp.: Research/NASA-S&AD-RTEB/USDA/TAMU/LARS/ERL/FSO).

d. Meteorological data collection: Meteorological data will be collected in support of the field measurements program for wheat varieties and confusion crops in Garden City, Kansas; Williston, North Dakota; and other sites as required (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU/LARS/ERL/FSO).

e. Simplified software program: A new simplified software program (from Skylab S-191 program) will be developed for processing S-191H data. This program will reformat digital raw data to a Computer Compatible Tape (CCT) with an output of segmental reflectance and thermal spectra (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/FSO).

f. Estimation of percent ground cover: Estimation of percent ground coverage of crops within the intensive test sites by studying 70-millimeter photographs obtained during S-191H flights over test sites (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/FSO).

g. Leaf Area Index and related measurements: Measurements of Leaf Area Index, Soil Moisture, and biological mass dry weight of plant matter for wheat at Garden City, Kansas; Williston, North Dakota; and other sites as required. (Req'd by: Research; Cat. 1; Imp. resp.: Research/NASA-S&AD-RTEB/USDA/NOAA).

4.1.2 Crop Yield

Research and development in this area are directed into two areas: one is the development of improved meteorological models for yield prediction, and the other is research on the possibility of yield prediction from analysis of scanner imagery. Tasks to be performed are the following:

4.1.2.1 <u>Meteorological models</u>.- Meteorological models include the following:

a. Baier model: Adapt the Baier yield model for winter wheat and apply to foreign countries (Req'd by YES: Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/KSU).

b. Haun model: Adapt the Haun yield model for spring wheat and apply to foreign countries (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/Clemson).

4.1.2.2 Models using scanner data.- Models using scanner data include the following:

a. Leaf area index (LAI): The variation of LAI during the growing season is known to be a partial indicator of wheat yield. LAI will be predicted using ERTS data and correlated with wheat yield on a field-by-field basis and on an overall area basis (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/KSU).

b. Plant physiology: A deterministic yield model based on known plant physiology will be developed to relate yield to leaf area development, canopy structure, and environmental parameters (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/ERIM).

c. Classification techniques: Perform automatic pattern recognition analysis of wheat fields and determine the degree of correlation existing among spectral clusters, wheat yield/yield indicators, and Haun wheat growth index using data collected over Bushland, Texas (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

4.1.2.3 Yield estimation.- TBD

4.1.3 Crop Assessment

Crop assessment is concerned with the aggregation of acreages and yields for individual samples into acreage, yield, and production for major areas. The primary focus of research in this area is on sampling strategy and aggregation schemes for acreage. A sampling strategy and aggregation scheme for the United States has been defined for LACIE Phase 1, using historical wheat acreage data as a basis. Extension to other LACIE countries is required, using available historical data. Recognizing that such data are often sparse or inaccurate, techniques for development of sampling strategies without historical data are required. In addition, improved aggregation procedures are needed, and it is essential that the effects of data loss due to cloud cover be taken into account. Future developments may make available full-frame registered ERTS data. The potential value of these data for improved sampling requires exploration. Specific research tasks are as follows:

4.1.3.1 <u>Sampling</u>.-

a. Plans for all LACIE countries: Develop a standard sampling strategy for all LACIE countries, taking into account the unique characteristic of each country (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

b. Variable sampling strategy: Develop variable sampling techniques for acreage estimation. A study is to be made of the feasibility of using image interpretation data for the purpose of allocating sample segments (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/UCB).

c. Full-frame registration sampling: Define improvement of sampling strategy produced by full-frame registered data as follows:

    (1) Develop a model for the variance of an acreage estimate based on optimal allocations of samples without regard to present restrictions (i.e., 5 x 6 miles size and "ERTS constraints"). Such a model should include not only a sampling variance, but also a component of degradation due to signature extension errors. Some provision for training areas should also be made (Req'd by CAS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

    (2) Attempt to quantify the above by obtaining estimates of variances from work done by CAMS on the intensive sites as well as historical data for the last 10 years of

wheat acreages by county over the intensive test site areas (Req'd by CAS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

d. Reduction in sample error: Evaluate reduction in sample error due to "cluster sampling;" provide means to balance increased sample error versus reduced classification error when classification error dependence upon signature extension is known; and perform such balancing (Req'd by CAS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

4.1.3.2 <u>Production estimation</u>.- TBD

4.2 INTERIM SYSTEMS

Not applicable.

5.0 RESEARCH INPUT REQUIREMENTS

Inputs required by research from the other LACIE functional elements are defined in the following subparagraphs:

5.1 FULL-UP SYSTEM

5.1.1 Data Acquisition, Preprocessing, and Transmission Subsystem (DAPTS)

DAPTS will provide research with the following data:

5.1.1.1 ERTS data requirements.

a. Seven 9-track CCT's, 800 bits per inch (bpi), standard format; require full frames covering all intensive test sites each pass for which cloud cover <30% for the 1973-74 growing season. These data will be used for tasks 4.1.1.1a; 4.1.1.2b(2); 4.1.1.2f(1); 4.1.1.2f(2); 4.1.1.2f(3); 4.1.1.3a(1a), (1b), and (1c); 4.1.1.3a(2a), (2b), (2c), (2d), and (2e); 4.1.1.4b; and 4.1.1.4c (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

b. Five 9-track CCT's, 800 bpi, standard format; require full frames adjacent to Garden City and Williston sites. These data will be used for tasks 4.1.1.1c; 4.1.1.2f(1); 4.1.1.2f(2); 4.1.1.2f(3); and 4.1.1.3b(1) (Req'd by Research; Cat. 2; Impl. resp.: DAPTS).

c. One 9-track CCT, 800 bpi, standard format; require full frame adjacent to Garden City and Williston sites (September 1974 through September 1975) for all passes with <30% cloud cover and no snow cover. These data will be used for task 4.1.1.2f(5) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

d. Five 9-track CCT's 800 bpi, standard format; require full frames which include Garden City, Kansas, and Williston, North Dakota, test sites from September 1974 through September 1975 for all passes with <30% cloud cover and no snow cover. These data will be used for tasks 4.1.1.2a(1), 4.1.1.2a(2), 4.1.1.1c, 4.1.1.2f(1), f(2) and f(5) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

e. One 9-track CCT, 800 bpi, standard format, for Ellsworth and Riley Counties, Kansas, for all good ERTS passes (30% cloud cover or less, no snow cover) from September 1973 through September 1975. These data will be used for task 4.1.2.2a (Req'd by Reserach; Cat. 1; Impl. resp.: DAPTS).

f. Two 9-track CCT's, 800 bpi, standard format of all acceptable cloud-free full-frame ERTS data covering the 1973-74 growing season for the five intensive test sites in Kansas and the three in Texas. This includes successive day coverage at the same site and multitemporal registered data for both Kansas and Texas for the 5 × 6 sample segments at the intensive sites. The data will be used for tasks 4.1.1.1c and 4.1.2.2c (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

g. Two CCT's, 9-track 800 bpi, standard format of the "November operation;" i.e., four passes for each intensive test site plus one pass for each of 31 sample segments in Kansas. The three additional passes for each of the 31 sample segments that are to be obtained after the NASA Data Processing Facility at GSFC is modified will be needed. If data are in registered form, the angle of rotation is required (this is not necessary for the reference pass over each site). The data are needed for tasks 4.1.1.2c(1) and 4.1.1.2d(3) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

h. One 9-track CCT, 800 bpi, standard format for the sample segments in Finney or Morton Counties, Kansas, that will be used for the November operation. The data are needed for task 4.1.1.2e(1) (Req'd by Reserach; Cat. 1; Impl. resp.: DAPTS).

i. One set of ERTS black-and-white transparencies (9.5 inches and 75 millimeters) over all the intensive test sites for the 1973-74 growing season for which cloud cover <30%. These data will be used for task 4.1.1.1a (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

j. One set of 9-track CCT's, 800 bpi, standard format, full-frame coverage for at least four or more ERTS "cycles" with less than 30% cloud cover during the 1973-74 growing season for three LACIE intensive test sites distributed to exhibit varied conditions preferably distributed as follows:

One Improved Technology Satellite (ITS) from Kansas
One ITS from Washington
One ITS from Canada

These data are to be used for task 4.1.1.2b(1) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

k. One 9-track CCT, 800 bpi, standard format; require full frame covering some intensive test sites (sites selected at random) with >30% cloud cover at different times during the year to attain a variety of sun angles on the scene. These data are to be used for task 4.1.1.2c(2) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

l. Five 9-track CCT's, 800 bpi, standard format, full frame for all sample segments plus the Kansas intensive test sites for those passes that are used in the November operation. Part of the intensive test site plus the photointerpretation training fields and the training segments must be cloud covered on at least one pass. These data are to be used for tasks 4.1.1.2e(1) and 4.1.1.2e(2) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

m. TBD number of ERTS full frame data sets. These data are to be used for task 4.1.1.2e(3) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

n. One set of controlled mosaics made from band 5, ERTS-1 MSS data acquired during the "green phase" over each LACIE country. These data to be used for task 4.1.1.1a (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

5.1.1.2 <u>Field data requirements</u>.

a. Six sets of ground truth, field measurements, and country analysts' reports or equivalent data in support of the ERTS data of Garden City, Kansas, and Williston, North Dakota, test sites from September 1974 through September 1975. These data shall consist of the following:

(1) Field identification maps and photographs
(2) Cropping practises
(3) Crop calendars
(4) Soil types
(5) Crop quality indicators
(6) Yield measurements from selected fields
(7) Weekly and monthly weather summaries including maximum and minimum temperatures, precipitation, wind speed, sunshine duration, sky cover, unusual weather, and degree days.
(8) Crop identifications distinguishing harvested from non-harvested wheat.

These data will be used for the following tasks: 4.1.1.1c, 4.1.1.2a(1), 4.1.1.2a(2), 4.1.1.2a(3), 4.1.1.2f(1), 4.1.1.2f(2), 4.1.1.2f(3), 4.1.1.2f(5), 4.1.1.3b(1), 4.1.1.3b(2), 4.1.2.2a, 4.1.2.2b, and 4.1.2.2c (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

b. One set of S-191H data from the 1973-74 Bushland, Texas, field measurement project processed into reflectivities and radiances. These data will be used for tasks 4.1.1.2a(1), 4.1.1.2a(2), and 4.1.2.2c (Req'd by Research; Cat. 1; Impl. resp.: FSO).

c. Four tapes of S-191H and field spectrometer data for Garden City and Williston sites, tapes to contain reflectivities and radiances in TBD format. Tapes required within 1 month of each acquisition from November 1974 through September 1975. These tapes will be used for tasks 4.1.1.1c, 4.1.1.2a(1), 4.1.1.2a(2), 4.1.1.2f(2), 4.1.1.2f(5), and 4.1.2.2c (Req'd by Research; Cat. 1; Impl. resp.: FSO).

d One set of measurements of LAI, leaf slope distributions, and hemispherical reflectances and transmittances of wheat elements and soil for the crops for which sun angle data were collected. These data will be used for task 4.1.1.2f(5) (Req'd by Research; Cat. 3; Impl. resp.: FSO).

e. Measurements of atmospheric optical depth at Garden City and Williston sites at time of ERTS data acquisitions. These data will be used for task 4.1.2.2c (Req'd by Research; Cat. 1; Impl. resp.: FSO).

f. 70-millimeter photographs of the S-191H intensive test sites (from helicopter). These data will be used for task 4.1.1.5f (Req'd by Research; Cat. 1; resp.: FSO).

g. Atmospheric optical depth measurements are required at each LACIE intensive test site. A solar radiometer or equivalent shall be used to obtain said measurements during and for each ERTS pass. Measurements shall be taken as close to the exact time of the ERTS pass over the test sites as possible and when cloud conditions are favourable. These data are to be used in several research tasks (Req'd by Research; Cat. 1; Impl. resp.: DAPTS/FSO).

h. High-altitude aircraft photography of intensive test sites (colour infrared if available). Field boundary overlays registered to above photography. Field crop identification of fields shown in such overlays. These data are to be used for task 4.1.1.1a (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

i. TBD sets of standard data products as available to Image Analysts for all countries, all regions covering agricultural practices. These data will be used for task 4.1.1.1a (Req'd by Research; Cat. 1; Impl. Resp.: DAPTS).

j. Three sets of ground truth; i.e., crop identification marked on a map of aerial photograph (or overlay to one of these) for each field in each intensive test site in Kansas for each pass that was obtained for the "November operation." These data are needed for task 4.1.1.2d(3), 4.1.1.2e(1) and (2) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

k. Four sets of ground truth, field measurements, and country analysts' assessment reports or equivalent data in support of the ERTS data of Garden City, Kansas, and Williston, North Dakota, test sites from September 1974 through September 1975. These data shall consist of the following:

(1) Field identification maps and photographs.

(2) Crop identification distinguishing harvested from non-harvested wheat. These data are to be used for tasks 4.1.1.3a(1a), (1b), and (1c); 4.1.1.3a(2a), (2b), (2c), (2d), and (2e); 4.1.1.3b(3); and 4.1.1.4b (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

1. TBD sets of measurements of Leaf Area Index, Soil Moisture, and wheat biological mass dry weight at Garden City and Williston test sites. These data are required by NOAA/USDA for testing of physiological yield models (approved by PMT) and will be used for task 4.1.2.2.a, 4.1.2.2.b, and 4.1.2.2.c. (Req'd by: Research; Cat. 3; Impl. resp.: DAPTS/FSO).

5.1.1.3 <u>Historical agricultural data requirements</u>.

a. One set historical acreage of wheat by county over the last 10 years. These data to be used for tasks: 4.1.3.1b(1) and b(2) (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

b. One set of crop calendars and other support data currently provided to operational LACIE analyst interpreters. These data are to be used for task 4.1.1.1a (Req'd by Research: Cat. 1: Impl. resp.: DAPTS).

c. Two sets of historical agricultural statistics for wheat acreage over the last 15 years in the smallest political units for all LACIE countries. These data are to be used for tasks 4.1.1.4a, 4.1.3.1a, 4.1.3.1b, 4.1.3.1c(1), 4.1.3.1c(2), and 4.1.3.1d (Req'd by Research; Cat. 1; Impl. resp.: DAPTS).

5.1.1.4 <u>Real-time meteorological data requirements</u>.

TBD.

5.1.1.5 <u>Historical meteorological data requirements</u>.

TBD.

5.1.2 CAMS

CAMS will provide research with the following:

a. Analysis of signature extension errors: This will be used for tasks 4.1.3.1c(1), 4.1.3.1c(2), and 4.1.3.1d (Req'd by Research; Cat. 1; Impl. resp.: CAMS).

b. Image interpreter labeled training fields for each training segment adjacent to some TBD intensive test sites on each pass that is acquired. This data to be used for tasks: 4.1.1.2e(1) and 4.1.1.2e(2) (Req'd by Research; Cat. 1; Impl. resp.: CAMS).

5.1.3 YES

No requirements

5.1.4 CAS

CAS will provide research with the following:

a. Computation of cloud cover over intensive test sites: This computation will be used for task 4.1.1.4c (Req'd by Research; Cat. 1; Impl. resp.: CAS).

5.1.5 Information Storage, Retrieval, and Reformatting Subsystem (ISRRS)

No requirements

5.1.6 Systems Performance Evaluation (SPE)

No requirements

5.1.7 Information Evaluatio

No requirements

5.1.8 Research

Research will provide the following:

a. A project plan for the 1974-75 LACIE field measurement program. The plan will specify data collection, processing and analysis methods and procedures, schedules, and milestones for usage of S-191H and the Field Signature Acquisition System (FSAS) as well as test site locations and all supporting ground truth requirements. This plan will be used for tasks 4.1.1.5a, b, c, and d (Req'd by Research; Cat. 1; Imp. resp.: Research/LARS/FSO).

b. A program for converting S-191H digital data to CCT's usable by LARS: This program will be used for task 4.1.1.5e (Req'd by Research; Cat. 1; Impl. resp.: Research/FSO).

5.1.9 Test and Evaluation

No requirements

5.2 INTERIM SYSTEM

Not applicable

6.0 RESEARCH OUTPUT REQUIREMENTS

Outputs from research which will be provided to the other LACIE functional elements are defined in the following subparagraphs:

6.1 FULL-UP SYSTEM

6.1.1 Crop Acreage

This section shall define the output products resulting from the tasks described in section 4.1.1 of this document.

6.1.1.1 Definition of training statistics.-

a. Image interpretation: The following image interpretation procedure will be supplied to the subsystems as indicated: A procedure to improve reliability of crop identification by analyst interpreters (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/UCB).

b. Image enhancement: Resolution-corrected imagery for interpretation by analysts and techniques for processing imagery to enhance image interpretation accuracies (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/LARS)

c. Computer-aided identification: Reports and algorithms specifying means of selecting training fields without ground truth using clustering techniques (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/ERIM).

d. Training field homogeneity: An algorithm for carrying out the homogeneity test outlined in section 4.1.1.1d (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TBD).

6.1.1.2 Classification.-

a. Temporal sampling strategy: The following products will be supplied to the subsystems as indicated.

   (1) A report specifying optimum biological stages for discriminating spring and winter wheat (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

   (2) A report defining optimum spectral bands for discriminating spring and winter wheat (Req'd by CAMS; Cat. 4; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

   (3) Crop calendars for wheat, adjustable by geographic location and meteorological data, combined with paragraphs a and b above to yield a complete temporal sampling strategy (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB).

   (4) The best one, two, three, and four dates for discriminating wheat from non-wheat, a gray level image of the test data set generated using the feature extraction will be recommended (Req'd by Research; Cat. 1; Impl. resp.: Research-NASA-S&AD-RTEB/TAMU).

b. Registration:

   (1) An improved algorithm for registering low-contrast ERTS imagery. Evaluation of GSFC registration capability (Req'd by Research; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/LARS).

   (2) Registered multitemporal ERTS imagery, TBD number of full frames, and TBD number of sample segments. Each data set to be registered by "nearest-neighbor" and by interpolation. Registration errors for each data set (Req'd by Research; Cat. 2; Impl. resp.: Research-NASA-S&AD-RTEB/TBD).

c. Preprocessing:

(1) Scan line dropout detector - An estimate of the frequency with which scan line dropout occurs and a documented algorithm for its detection will be provided (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB).

(2) Cloud and shadow detector - Procedure for automatically detecting and flagging all pixels in a sample segment that were obscured by clouds (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD/RTEB/Research).

d. Feature selection: The following feature selection techniques will be supplied to the subsystems as indicated:

(1) A more accurate, efficient, and documented feature selection algorithm, a FORTRAN program implementing it, and test results (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/UH)

(2) Linear feature extraction using the probability of misclassification will generate the following (Req'd by CAMS; Cat. 1; Impl. Resp.: Research/NASA-S&AD-RTEB/TAMU).

(i) A documented algorithm for generating the required initial guess and a FORTRAN program to implement it.

(ii) An algorithm for finding a linear combination of all the available measurements and a FORTRAN program to implement it.

(3) A documented algorithm for automatically extracting the number of linear combinations required to maintain the class separability in the original measurement space, a FORTRAN program implementing this algorithm and test results (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/UH).

e. Multitemporal classification:

(1) Incomplete data - The output of this task will be a set of documented algorithms for (a) estimating class statistics from an incomplete labeled sample for each class, (b) estimating crop acreage for a sample segment from an incomplete data set, and (c) combining acreage estimates for several sample segments into an estimate for a stratum where not all segments were observed on the same set of passes (Req'd by Research; Cat. 3; Impl. resp.: Research/NASA-S&AD-RTEB/UTD).

(2) Single-pass classifier - A classification/acreage estimation procedure that user training data gathered from different sites on different dates; a FORTRAN program implementing this algorithm plus test results (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TBD).

(3) A quantitative statement as to the classification errors introduced by "nearest-neighbor" registration and the degree of improvement produced by interpolative registration (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-Research).

f. Signature extension: The following signature extension outputs will be supplied to the subsystems as indicated:

(1) Signature extension strata for North America defined using photointerpretation techniques (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/UCB).

(2) Reports and computer programs defining algorithms for specifying signature strata by clustering techniques. Signature extension strata initially in Kansas and North Dakota, then for North America (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/LARS).

(3) Reports which define the value of ancillary data (climate, soil conditions, elevation differences, etc.) for definition of signature extension strata and provide examples of use of such data to define geographically separated strata (analog areas) (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/LARS/UCB).

(4) A mathematical model and an algorithm for using this model for extending signatures from one sample segment to geographically nearby sample segments (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/UH).

(5) Reports and computer programs defining algorithms to specify the behavior of the ERTS spectral signature with sun angle at various crop development stages (Req'd by CAMS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/CSU).

6.1.1.3 Mensuration.

a. Estimation of planted acreage in sample segment: For each of the eight approaches outlined in section 4.1.1.3, the output will be a documented algorithm for estimating what proportion of a sample segment is in wheat given an ERTS pass over the segment, a computer program implementing the algorithm, test results or several common data sets for which the true proportions are known and a documented comparison of these test results in terms of bias and mean square error (mse). Where the problem is mathematically tractable, the mse will be obtained from an analytical model; otherwise, it will be estimated by simulation. One or more of the procedures that seem most promising will be selected for extensive test and evaluation (Req'd by CAMS; Cat. 3; Impl. resp.: Research/NASA-S&AD-RTEB/UTD/RICE Univ./TAMU/ERIM.

b. Correction for unharvested wheat:

(1) A technique for determination of the percent of wheat harvested by classification of ERTS imagery collected during harvest (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

(2) Crop calendars which permit estimation of start and stop dates of harvest in North America (Req'd by CAMS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

(3) A report describing and evaluating the combination of ERTS classification with harvest start and stop dates to find the percent harvested wheat at conclusion of harvest (Req'd by CAS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

6.1.1.4 <u>Acreage estimation (aggregation of sample segments)</u>.–

a. All LACIE countries: An aggregation plan suitable for each LACIE country, based on the sampling strategy defined in 6.1.3.1a (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

b. Variable confidence aggregation schemes: An aggregation plan which includes a system of weighting factors (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

c. Cloud cover effects: A complete model for the sampling error including cloud cover. The model will be quantified by using cloud cover statistics computed by CAS (Req'd by CAS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU/TBD).

6.1.1.5 <u>Field measurements</u>.– Specific data output products to be provided by the field measurements program should be as follows:

a. S-191H helicopter-mounted spectrometer (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/FSO): S-191H helicopter-mounted spectrometer data consisting of

(i) CCT's of segmental reflective and thermal spectra

(ii) 70-millimeter color positive transparencies and color infrared

(iii) Inflight log and system manager's report of mission

b. Truck-mounted spectrometer (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU/LARS/ERL/FSO): Truck-mounted spectrometer data consisting of

(i) Reflected and thermal emitted energy from test plots and reference targets at incremental wavelengths.

(ii) Log, including time of spectral measurements, field locations, crop variety, etc., distance from spectrometer to ground.

(iii) Color infrared and positive transparencies from camera boresited on spot. Orientation and scale reference of photograph will be documented.

c. Agricultural data collection (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU/LARS/ERL/USDA/FSO): Agricultural data from Garden City and Williston test sites and the agricultural station test sites consisting of

(a) Field identification

(b) Crop species

(c) Crop variety

(d) Crop maturity

(e) Plant spacing

(f) Plant height and number of leaves

(g) Row width and direction

(h) Percent ground cover

(i) LAI

(j) Agronomic properties of plant; i.e., moisture stress, nutrient deficiency, weedy, disease

(k) Hail or wind damage

(l) Lodging

(m) Soil properties; i.e., clay, loam, silt, moisture, surface condition

(n) 35-millimeter photography

(o) Crop yield

(p) Furrow depth and shape

(q) Crop treatments; i.e., planting date, fertilization and irrigation amounts and times, etc.

d. Meteorological data collection (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU/LARS/ERL/FSO): Meteorological data from Garden City and Williston test sites and the agricultural stations test sites consisting of

(a) Daily maximum and minimum air temperatures

(b) Incident solar energy at seven wavelengths in the visible and near-infrared at the time of ERTS pass

(c) Solar elevation and azimuth angle, instrument observation angle and azimuth and instrument altitude at time of radiometric measurements during ERTS pass and the time of each spectral measurement both by S-191H and FSS

(d) Cloud cover

(e) Wet and dry bulb temperature

(f) Barometric pressure

(g) Surface temperature measurements to support thermal band data

(h) Sky brightness

(i) Wind speed and direction

e. Simplified software program: A simplified software program for reformatting raw digital S-191H data to CCT (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU/LARS/FSO).

f. Estimation of percent ground cover: Percent ground coverage of intensive test sites that have been surveyed by S-191H helicopter-mounted field spectrometer (Req'd by Research; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/FSO).

6.1.2 Crop Yield

The following crop yield research products will be supplied to the subsystems as indicated:

6.1.2.1 Meteorological models.-

a. Baier model: Coefficients and parameters for the Baier yield model adapted to Kansas and other Great Plains States (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/KSU).

b. Haun model: Reports and computer programs for advanced Haun yield models for both spring and winter wheat (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/Clemson).

6.1.2.2 Models using scanner data.-

a. LAI: Reports defining the correlation of ERTS spectra with LAI for wheat, and hence with yield (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/KSU).

b. Plant physiology: Reports defining plant growth response as a function of environmental parameters. Test results will be compared with real data (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/ERIM).

c. Classification techniques: Reports defining the correlation of ERTS data to wheat yield or yield indicators (Req'd by YES; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

6.1.2.3 Yield estimation.- TBD

6.1.3 Crop Assessment

This section shall define the output products resulting from the tasks described in section 4.1.3 of this document.

6.1.3.1 Sampling.- The following products will be supplied to the subsystem as indicated:

a. Plans for all LACIE countries: The following will be determined for each LACIE county:

(1) Definition of "agricultural area," "counties," "crop-reporting districts," "pseudo-counties."

(2) A set of criteria for the determination of a "county" being in Group I, II, or III (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

b. Variable sampling strategy: Feasibility study results consisting of the following (Req'd by CAS; Cat. 1; Impl. resp.: Research/NASA-S&AD-RTEB/UCB):

(1) A comparison of photointerpretative versus historical data.

(2) A comparison of photointerpretative versus last year's results based on random sampling in arbitrary "counties."

(3) An estimate of manpower required for adequate photointerpretation.

(4) A correlation between crude estimate and actual acreage.

(5) A calculation of sampling variance.

c. Full Frame Registration Sampling:

(1) A model for variance of acreage estimation using full-frame registration (Req'd by CAS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

(2) An evaluation of variances for the intensive test site areas (Req'd by CAS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

d. Reduction in sample error: Recommend procedure to reduce sample error due to "cluster sampling" and to balance increased sample error versus reduced classification error (Req'd by CAS; Cat. 2; Impl. resp.: Research/NASA-S&AD-RTEB/TAMU).

6.1.3.2 Production estimation.- TBD

6.2 INTERIM SYSTEMS

Not applicable

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7.0 INTERFACE REQUIREMENTS

Each implementing organization shall comply with the interface requirements specified in the following documents:

a. Earth Resources Data Format Control Book, Document PHO 543, July 1973.

b. GSFC/JSC Interface Control Document for LACIE, April 1974.

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8.0 OPERATIONAL REQUIREMENTS AFFECTING SUBSYSTEM DESIGN

8.1 THROUGHPUT REQUIREMENTS

Not applicable

8.2 RESPONSE REQUIREMENTS

Not applicable

8.3 RELIABILITY REQUIREMENTS

Not applicable

8.4 SECURITY REQUIREMENTS

Not applicable

8.5 DELIVERY REQUIREMENTS

Reports, programs, and other products must be delivered by October 1975 for the 1974-75 year's research in order to be incorporated in Phase II of LACIE. Reports, etc., from the 1975-76 year's research must be delivered by October 1976 to permit evaluation of their utility in follow-on crop inventory programs.

8.6 QUALITY ASSURANCE REQUIREMENTS

Not applicable

8.7 OTHER OPERATIONAL REQUIREMENTS

None at this time

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9.0 SUBSYSTEM VERIFICATION REQUIREMENTS

Not applicable

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0.0 RESEARCH REQUIREMENTS

As outlined in section 4.0 of this document

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11.0 TEST AND EVALUATION REQUIREMENTS

TBD

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LACIE PROJECT OFFICE
NASA, L. B. Johnson Space Center
Houston, Texas 77058

Project Control Office
LACIE Change Notice
Distribution List
October 18, 1976

The attached is a LACIE Change Notice to the *Research Requirements* document, LACIE-00200, Vol. VIII. The changes to this document were authorized by CCBD 6M0037, dated 9/22/76. In order to update your document, replace the following pages with those of the same number attached: List of Effective Pages, v & vi, 27 through 30.

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W. Chase
J. Mager
FS5/R. Coblentz
J. Hall
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J. Ferry
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J. Quirein
D. Saile
C. Scott (2)
F. Solomon
B. Stonestreet
P. Swanzy
R. Tokerud
P. Walsh
B10/J. Vaccaro
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NASA Hdqtrs.
J. Powers

GSFC
902/L. Gonzales (5)
563/W. Anonsen (5)
V. Thomas (5)

LIST OF EFFECTIVE PAGES

The current status of all pages in this document is as shown below:

Page No.	LACIE Change Date	Authorizing CCBD No.
i thru iv	Baseline 12/16/74	III-0001
v & vi	9/22/76	6M0037
vii thru xii	Baseline 12/16/74	III-0001
1 thru 26	Baseline 12/16/74	III-0001
27 thru 30	9/22/76	6M0037
31 thru 51	Baseline 12/16/74	III-0001