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THE USE OF LANDSAT DATA IN A

LARGE AREA CROP INVENTORY EXPERIMENT (LACIE)

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I. ABSTRACT

A Large Area Crop Inventory Experiment (LACIE) has been undertaken jointly by the U.S. Department of Agriculture, the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce and the National Aeronautics and Space Administration (NASA) to prove out an economically important application of remote sensing from space. At the outset LACIE will concentrate on wheat grown in the North American area. The experiment will combine crop area measurements obtained from LANDSAT data and meteorological information from NOAA satellites and from ground stations designed to relate weather conditions to yield assessment and ultimately to production forecasts. The Department of Agriculture will study the utilization of the experimentally derived production estimates in its crop reports. These reports are made public as a routine service to the domestic and international agriculture community. If this activity is successful and the results prove useful the application will be extended to other regions and ultimately to other crops.

II. INTRODUCTION

A series of experimental investigations, utilizing multispectral and meteorological data to identify and measure the areal extent of major crop types and to estimate their yields, has established a base of technology, which if properly expanded, can satisfy the requirements of a major agricultural application objective, i.e., crop production inventories over large areas.

The Large Area Crop Inventory Experiment (LACIE) will expand on this available technology base and assemble an experimental system for demonstrating a crop production inventory in a meaningful "quasi-operational" environment.

The experiment is supported by a parallel research, test and evaluation (RT&E) effort designed to develop solutions in areas where additional technology may be required. The operation and evaluation of the experimental system will be iterated with the RT&E effort to develop a technology which either satisfies the applications objectives or demonstrates that the applications objectives can be satisfied, given that solutions can be developed for specific key problems.

Thus, the expected accomplishments of LACIE will be the development and testing of the technology to produce agricultural crop production inventories on a global scale or, alternatively, the definition of any key problems to be solved prior to the implementation of an operational system.

This paper describes the background of events which shaped the LACIE design, the technical approach being pursued, the details of the implementation of this approach and initial results of the experiment.

The authors wish to acknowledge the many contributions to this experiment, its planning implementation and execution, by their colleagues not only in NASA but more particularly in the U.S. Department of Agriculture (USDA) and in the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce. This is truly a joint venture among the three agencies and many have played important roles in bringing the experiment to its present state.

III. BACKGROUND

To appreciate the particular approach chosen, of the many possible approaches, the general context surrounding the design of LACIE must be understood. The major factors which influenced the design decisions were: (1) the applications objectives and requirements to be satisfied by the technology; (2) the status of the existing remote sensing technology; (3) the time frame imposed to accomplish the stated objectives; (4) the estimated available resources for the experiment and (5) the constraints, both self-imposed and indigenous to the agencies participating in LACIE. Each of these factors will be treated in the following paragraphs.

APPLICATIONS OBJECTIVES AND REQUIREMENTS

A general application objective shaping the overall LACIE design was to develop, test and prove an economically important application of remote sensing from space. The crop inventory application was chosen since it represented an economically important application which could feasibly be accomplished near term with a system built from existing technology. Wheat was chosen as the crop for the experiment because of its importance in human nutrition and international trade.

From this general definition of the objective followed more specific requirements. To prove out this technology, wheat production, area and yield estimates would be necessary on a regional and national level. The system would have to be capable of producing periodic reports from planting through post harvest containing wheat area, yield and production estimates with a quantitative assessment of the confidence and accuracy of these estimates. In addition the reports should identify the wheat growth stage at which the estimate was made and list all source data used to derive the estimate. The accuracy and/or timeliness of this information must improve upon the accuracy and/or timeliness already obtainable by the USDA from areas outside the U.S. and Canada. In addition all information would need to be relatable to geographic coordinates. The experiment would have to be designed to produce experience and information helpful to the design of an eventual operational system. The system design itself was required to conform to existing USDA information security requirements and where feasible, to existing standard specifications to facilitate technology transfer. Finally, the system would have to be designed to provide a basis for a potentially cost effective operational system.

STATUS OF THE AVAILABLE TECHNOLOGY

At the outset of LACIE, a careful review and analysis of the status of the remote sensing technology indicated that wheat production inventories over large areas were feasible. The major task facing LACIE was and is to expand the technology from the relatively local areas for which it had been developed and tested to the large areas over which it would be applied.

For area estimation, the major efforts would have to focus on the development of methodology to obtain training statistics for inaccessible locations and to extend these statistics over large regions; of equal importance, operations procedures would have to be developed to (1) minimize the impact of cloud cover interference on LANDSAT data acquisition and (2) to manage the analysis of the large volumes of data required for the large area application. Historically, a number of key developments contributed to the base technology. These developments are described in the remainder of this section.

In 1966 scientists coupled computerized pattern recognition analysis techniques with remotely-sensed multispectral electromagnetic energy measurements to classify major agricultural crops automatically. (Reference 1). In particular it was learned that mature wheat could be quite accurately recognized in this way.

The first major application of this technology occurred during the Corn Blight Watch Experiment (Reference 2) in 1971. This experiment provided the first demonstration that a single agricultural crop could be identified over large areas using computer-aided analysis of multispectral information. This feasibility demonstration was designed around

a remote sensing technology base developed during more than six years of research into the computer-aided analysis of multispectral data acquired from aircraft.

In addition during this period experiments were conducted from space with remote sensors carried on the Mercury, Gemini and Apollo satellite systems. A most significant investigation conducted on Apollo 9 was the SO-65 experiment. This was a simulation of the future LANDSAT multispectral scanner (MSS). Photographs were acquired by an array of four cameras having film/filter combinations chosen to simulate the then-planned spectral bands of LANDSAT. Scientists digitized these photographs, conducted computer processing and demonstrated that agricultural crops could in fact be automatically recognized with LANDSAT-like measurements acquired from space (Reference 3).

In July 1972 the first Earth Resources Technology Satellite, initially known as ERTS-1 and since renamed LANDSAT 1, was launched and computer-aided analysis of multispectral data from a space platform commenced. The characteristics of the spacecraft acquired MSS data as compared to aircraft-acquired data (narrower scan angles, near simultaneous coverage over larger areas and repetitive coverage) led to the simplification of many of the problems encountered with aircraft platforms and opened the way toward the development of a greatly expanded remote sensing technology base.

A series of critical agricultural feasibility investigations using LANDSAT 1 MSS data acquired for a diverse set of test sites and environmental circumstances (References 4 through 8) generally established that major crops could be identified and measured with reasonable accuracy. The degree to which the feasibility had been established was somewhat limited however, in that these investigations were of limited scope, i.e., results were obtained at a single time over a limited area and were conducted against somewhat simple experimental designs which did not establish the performance indices needed to predict the performance associated with an areal inventory.

These early results were promising enough to convince some within the remote sensing community that a technology base existed which could be expanded to conduct gross inventories of the areal extent of agricultural crops over larger areas.

A follow on effort, the Large Area Project, was proposed by NASA/JSC in mid-1973, which would intensify the LANDSAT 1 feasibility effort and establish classification accuracy and mensuration accuracy to identify major types of wheat grown in selected U.S. test sites. In parallel, the repeatability of the prior LANDSAT 1 investigations for selected row and small grain crops would be verified. At the same time the USDA and Canada entered upon a joint study for spring wheat identification. In addition, a carefully controlled experiment was initiated over test sites in the U.S. to assess the capabilities of the most promising ADP techniques to identify several major food crops. This latter effort, known as the Crop Identification Technology Assessment for Remote Sensing (CITARS) is being concluded and will be documented in the future.

Concommitant to these events, interest was developing within USDA in having a more effective and timely method to inventory the available world food supply. Consequently, in the final quarter of 1973, discussions were begun among personnel of NASA and the USDA centering around the most reasonable approach to the development and demonstration of a major application of available remote sensing technology. It was agreed first that, for several reasons, the gross inventory of a single crop, wheat, would represent an application of considerable value. Wheat was chosen primarily because of the considerable experience which had been acquired in the remote sensing of wheat (identification and area mensuration) and because of its importance as a crop. Wheat exceeds in production and in areal extent any other grain crop in the world. From a technical standpoint, the simplification offered by focusing on the identification and mensuration of a single crop was attractive. In this way, the major problem to be faced, i.e., expanding the technology to a large area application, could be pursued with a minimum of distractions. Subsequently, based on the successful demonstration of this expanded technology, the focus could be shifted to solving problems related to multiple-crop applications.

The status of the technology in relation to the identification and mensuration of wheat was still somewhat uncertain so preliminary feasibility investigations for wheat were conducted at the JSC and as a part of CITARS, at the Environmental Research Institute of Michigan (ERIM). These investigations generally indicated that in major wheat-producing regions the identification performance characteristics for wheat was similar to other crop identification performances reported. However, there were indications of difficulties in inventorying marginal wheat-producing areas such as southern Indiana and Illinois.

The JSC investigation utilized LANDSAT 1 data acquired over Hill County, Montana, for three biological phases of wheat (greening, heading and mature) and for two biophases over Burke County, North Dakota (emergence and jointing). These data were processed using only some of the algorithms to be used in LACIE and with much more analyst intervention than planned for LACIE. In addition, multiple LANDSAT passes were spatially registered and processed to evaluate the effect of multitemporal data on crop identification performance. The results of this investigation are shown in Table 1. The single pass results were similar to those reported in a variety of other investigations; as can be seen, the use of multipass data provided a considerable improvement in performance. However, the relationship that these performance numbers would bear to the expected performance for an area inventory were not obvious.

The obscure relationship between the reported performance indices and the area estimation accuracy, which could be expected to result from an application of these techniques, was due primarily to three factors: (1) the relationship between the performance indices of the per pixel classifier and the area estimation accuracy was not completely established and the majority of performance results reported were not in terms of areal estimation accuracy. (2) the unknown degree to which the classifier performance would be degraded over larger areas by factors known to affect signatures such as differences in atmospheric haze and sun angle, soil color, growing seasons, and agricultural practice and (3) the error interactions between the areal estimation model to be used for LACIE and the "per pixel," maximum likelihood classifier to be used were unknown.

The latter two of these three factors would have to be answered by an experiment over larger areas than had previously been examined and thus would have to be addressed by the experimental system in LACIE. The first of these, was partially addressed, both empirically and theoretically in early follow-on feasibility investigations for LACIE.

For the per pixel classifier to be used in LACIE the estimate, P_{ew}, of the areal proportion of wheat in a sample would be the ratio of the number of pixels classified as wheat to the total number of pixels in the sample. Thus in terms of the $P(w/w)$ and $P(w/o)$ in Table I, P_{ew} for a sample would be

$$P_{ew} = P(w/w)P_w + P(w/o)(1-P_w) \tag{1}$$

where $P(w/w)$, $P(w/o)$ are as defined by Table I and P_w, is the actual proportion by area of wheat in the sample. Thus the fractional difference D between the estimate P_{ew} and P_w would be related to $P(w/w)$, $P(w/o)$ and P_w by

$$D = \frac{P_{ew} - P_w}{P_w} = \frac{P(w/w)\ P_w - P(w/o)(1-P_w) - P_w}{P_w} \tag{2}$$

This expression indicates the sources of the difficulties in relating the per pixel probabilities for error to the overall area estimation accuracy. The magnitudes of the terms $P(w/w)$ and $P(w/o)$ depend on the confusion crops present which can vary considerably over regions planted to wheat. In turn, the fractional difference between the estimated and actual proportion as can be seen from equation (2) depends on the relative amount of wheat present in the scene. The values of $P(w/w)$ and $P(w/o)$ reported in the literature however, were for specific confusion crops with specific relative abundancies often unknown or unreported by the investigator.

For these reasons, a study was initiated within JSC to obtain preliminary estimates of D resulting from the per segment areal estimation scheme to be utilized for LACIE. For this study three classification runs were made using LANDSAT 1 data obtained over the Hill County, Montana (for a 2 x 6 mile) test site. Two of the classifications were made using single LANDSAT passes acquired on April 16, 1973, and May 23, 1973, during the green and headed biophases respectively. The third classification utilized twelve channels, a spatially registered combination of these two single passes, plus a pass acquired on June 27, 1973. For this segment within Hill County the areal proportion of wheat P_w is 0.302 as determined from insitu observations. Table II gives the results of this study.

Notice that the values for $P(w/w)$ and P_w/o are somewhat "worse" than the values shown (Table I) for the earlier JSC studies conducted over the same site. These latter values were obtained using processing procedures more representative of the LACIE procedures in that analyst intervention and iterations were greatly reduced. Even with these reported per pixel classification accuracies of from 58.6 percent to 85.1 percent, the proportion estimates for the segment were accurate to within ten percent of the observed

values, ranging from a maximum difference of 8.9 percent to as small as a one percent difference.

These relatively small values of D result from the fact that for these cases the errors of omission, $P(w/w) \cdot P_w$, which lead to underestimates of the amount of wheat, are largely balanced by the errors of comission, $P(w/o) \cdot (1-P_w)$, which lead to overestimates of the amount of wheat.

If this error-cancelling tendency could be maintained operationally for all LACIE segments processed and D tended to fluctuate randomly about zero for these segments, then the classifier tested above would provide large area estimates with accuracies exceeding 90 percent.

For large area inventories, the rms error of the estimate given by equation (1) would also be important since for a given sample unit the total area estimation error would be given by

$$E = (b^2 + v^2)^{1/2} \tag{3}$$

where b is the average bias associated with the estimator and v is the variance component associated with the estimator.

Most investigations prior to LACIE had not been designed to quantify V and it would be important to know the relative magnitudes of b and V in judging the ability of a particular classification scheme to satisfy a particular criteria for area estimation accuracy. A desirable classifier would be one leading to a small or known value for the bias. With such a classifier the area estimation error E, obtainable could then be decreased to an acceptable level by increasing the number of samples examined; or if the bias were known the estimate could be corrected. Without this property, the area estimate over a region would have a residual unknown error, whose magnitude could not be reduced by increasing the amount of data processed.

The CITARS effort initiated prior to LACIE was designed to provide estimates of the performance parameters discussed above. The results from this investigation indicates that certain of the classification procedures tested do not have a negligible bias and that there may be some difficulty in correcting this bias. However, certain other classification procedures, evaluated for performance on corn and soybeans at optimum times for discrimination of these crops, have associated values of bias and variance which would render them acceptable as area estimators of these crops.

A test and evaluation effort similar to the CITARS investigations, has been designed as an integral part of LACIE and will provide estimates of bias and variance specifically for wheat. Preliminary results of this effort will be presented subsequently in this paper.

Since total production estimates are the desired end product of a crop inventory, investigations into available data and literature were begun to determine: (1) to what extent wheat yield (production per unit area) would need to be monitored and (2) the status of the available technology for wheat yield estimation.

An examination of the agricultural statistics reported by various countries indicated that yearly variations in reported yield accounted for as much of the yearly variation in reported production as did yearly variations in reported area. Thus it would be necessary to monitor both area and yield if remote sensing was to provide production estimates which improved upon those estimates obtainable by existing methods.

An examination of the status of the available technology for wheat yield estimation indicated that the key technical issue to be faced in yield estimation was the development and testing of available yield models over regions important to world wheat production. This in turn required a considerable effort devoted to the development of the historic yield and meteorological data base required for yield model development, and a careful evaluation of the effect on the accuracy of the yield predictions of factors not directly accounted for in the available models, such as fertilizer practice and catastrophic events such as insects, disease, etc.

To establish the status of yield estimation technology, personnel from NASA/JSC conferred with investigators in the field and with personnel from the National Oceanic and Atmospheric Administration (NOAA) who were already planning to monitor meteorological conditions for crop condition reports. Of the methods investigated for wheat yield

determination, agro-meteorological (agromet) models appeared to be the most promising approach for wheat yield estimation in a large scale application. The application of multispectral sensing to determine crop condition was (and is) still in the early stages of development. The relationship between spectral data and yield had not been quantified, although multispectral imagery is considered to be one of several sources of information regarding crop condition. Agromet models existed which permitted yield estimates based, upon measured values of key meteorological parameters. The feasibility of these models for yield estimation was indicated by physiological studies which demonstrated that factors such as temperature and moisture played key roles in influencing wheat yield. In addition to these studies, statistical analyses in operational settings (such as described in References 9 through 12) verified the strength of these relationships. Values for the required meteorological variables could also be obtained on a near real time basis from ground stations and the potential existed for supplementing these data with environmental satellite data.

From the investigations described above it appeared that an experimental crop inventory system, utilizing remote sensing technology, could be developed over a two to three year period. This system would demonstrate that remote sensing could upgrade existing information-gathering capabilities and would demonstrate that the crop inventory application requirements could be satisfied given the solutions to certain key problems.

TIME CONSTRAINING FACTORS

The time frame and schedules imposed on LACIE resulted from several considerations. Of these the major ones were: (1) the remote sensing community had a technical requirement to maintain continuity in the development and use of satellite MSS data for practical applications which in view of the anticipated lifetime of the LANDSAT 1 sensors, dictated a LANDSAT 2 launch in early 1975, with a possible LANDSAT 3 launch in 1977. (2) the time anticipated to extend the technology and develop an inventory system and (3) the particular timing for the wheat crop cycles over the LACIE regions of interest. Considering all this, a phased approach was chosen which consisted of 3 phases spanning approximately three and one half years. Phase I concentrated on (1) a test of the capability of an area estimation system built from existing technology to determine wheat area within regions of the U.S. and to classify wheat in other areas and (2) development and testing of yield and production estimation models over regions in the U.S. Phases II and III would test LACIE capabilities to determine wheat area, yield and production in the U.S. and other wheat-producing regions.

RESOURCE AVAILABILITY

The three major determinants of resources required to execute LACIE were: (1) the design and construction of the experimental inventory system from available technology; (2) the provision of people and computers to analyze the large volumes of data required to support the application objectives and (3) the funding for the research, test and evaluation required to evaluate and fill gaps in the available technology.

The agencies involved placed a high priority on accomplishing the stated objectives of LACIE as soon as feasible, and resources were made available to pursue the LACIE objectives vigorously with a goal of delivering, at the culmination of LACIE, proven technology plus a definition of the key problems to be solved prior to the implementation of an operational inventory system.

OTHER CONSTRAINING FACTORS

Last but not least in the consideration of the LACIE design were self-imposed constraints and certain organizational and institutional factors peculiar to the agencies participating in LACIE.

Certain constraints were self-imposed by the project designers to simulate the structure of the anticipated operational situation. The two most important constraints arising from this philosophy were: (1) the use of insitu acquired ground observations for the current year would be restricted, (2) the experiment would be conducted in a quasi-operational manner with analysis done in real-time (14 days from data acquisition to completion of processing) with reporting geared to current crop reporting schedules.

Constraint (1) above restricted the acquisition of insitu crop type identifications to limited areas in the U.S. and further limited the use of this data to the evaluation of LACIE and to the development of classifier training statistics for regions outside the U.S. This restriction required that two new elements of technology be developed

(1) analyst procedures for manual analysis of LANDSAT imagery for crop type identification over a small fraction of the data (2 percent of the LANDSAT data processed) and (2) signature extension procedures for extension of the spectral signatures to the remaining 98 percent of the LANDSAT data.

Since the LACIE effort required a joint application of NASA, USDA and NOAA resources, constraints were imposed upon the LACIE design which reflected the existing programs, capabilities, facilities, policies and goals of each agency.

The structure within NASA which shaped the design of LACIE in a major way was the nature of the existing implementation for ADP analysis of multispectral data, and the extent to which this implementation could be modified or augmented given the projected resources and schedule. The Earth Resources Interactive Processing System (ERIPS) contained a majority of the implemented data processing technology readily available to LACIE. ERIPS was resident on IBM 360/75 machines in the Houston Real Time Computer Complex (Mission Control Center).

To meet the schedules imposed upon LACIE, a decision was made to develop the LACIE experimental system around ERIPS, changing or augmenting it only where necessary. The influence of this decision is strongly reflected in the current LACIE subsystem for processing LANDSAT data to provide area estimations.

Another set of factors which strongly influenced the LACIE design was the decision to utilize multitemporal data, the associated state of the art in registration technology and the projected available resources for registering the LACIE MSS data. A reasonable upper limit on registration accuracy required for multitemporal recognition processing was estimated at one pixel rms. The registration technology which could readily be implemented for use by LACIE would permit a "one-job" registration (to the required accuracy) of roughly one-one hundredth of a LANDSAT frame, or less than about a 10 x 10 mile square on the ground. The number of one-job registrations possible with the projected available resources, precluded an optimally efficient sampling strategy with units of smaller size scattered throughout each LANDSAT frame; that is, the quantity of 10 x 10 mile portions required to cover the geographic area under consideration could not be registered within the projected available resources. Within these constraints a sample unit of 5 x 6 nautical miles (nm) was chosen as adequate.

The major factors within the USDA which influenced the design of LACIE were: (1) the level of resources available to acquire the ground observations and measurements required to support critical development and evaluation tasks within LACIE and (2) the USDA desire to facilitate the transferability from NASA to USDA, of technology validated by LACIE. USDA projected sufficient resources to obtain observations and measurements within about 28 intensive test sites totaling about 286,000 acres. In addition, data published in USDA crop reports would be available. Although the resources are considerable to obtain even this amount of ground data, considerable ingenuity was required to develop an experimental design which could use this data set to evaluate properly new developments and to quantify the performance of the experimental system.

In early 1974 project planning and certain key developments were begun to initiate the Large Area Crop Inventory Experiment. The year was spent developing the management approach, designing the experiment, designing and building the system to support the experiment and working out the necessary interagency agreements for joint USDA, NOAA and NASA participation. This work culminated in late 1974 in a joint Project Plan, which was reviewed by persons representing the leading technical expertise within the remote sensing community.

In November 1974, initial operations began with a preliminary data system for classification and mensuration of wheat using LANDSAT 1 data acquired over selected segments in Kansas.

IV. DESCRIPTION OF THE LACIE

The description of the experiment will be treated in two parts. The first section will describe the technical approach, i.e., the basic design of the experiment including the approach to area, yield and production estimation, the experimental data system design, the flow of the data through the system, the evaluation of the system output products and details of the research test and evaluation effort supporting LACIE. The second section will describe the functional approach, i.e., the functions required to support the development, test, operation and evaluation of the LACIE data system, the organization

developed to execute these functions and the phases and schedules for implementing the basic approach.

TECHNICAL APPROACH

The crop identification and mensuration is carried out with LANDSAT multispectral scanner (MSS) data and the inventory is being performed on a sampling rather than an exhaustive coverage basis. Data is being acquired through the normal Goddard Space Flight Center (GSFC) processes over the geographic areas under study.

A stratified random sampling strategy has been developed employing 5 x 6 nautical mile segments randomly allocated to strata according to the 1969 agricultural census data specifying areas planted to wheat in the U.S. A total of 637 sample segments were allocated to the U.S. to obtain a sample error of approximately 2 percent. This criteria is to some degree arbitrary since the precision and accuracy of the production estimates are the final concern in accuracy. However, at this stage of development not enough is known regarding the overall error interactions between the LACIE system components to design a sample strategy against a specific set of performance criteria. Preliminary analysis of the U.S. strategy indicates that the associated sample error (precision) is less than 2 percent at a 2σ confidence level. As will be discussed in section V a preliminary performance assessment of LACIE area estimates in Kansas provides no reason to alter the sample strategy design. In the RT&E effort alternate sample strategies are being investigated to minimize the cloud cover interference problems.

The LACIE sample strategy for the U.S. allocates the total of 637 segments to counties such that each county receives sample units in proportion to the product of the total area of the county times the estimate of the standard deviation of wheat areal density in the county. The estimate of the standard deviation is derived from the 1969 agricultural census estimate of the wheat areal density for the county by assuming the wheat density to be binomially distributed within the county. This strategy usually gives from 0 to 5 segments to a county and for each stratum (crop reporting district (CRD) for the U.S.) a maximum of about 15. Figure 1 is a facsimile of segment locations within a CRD. Area estimates for counties receiving no segments will be ratio estimates to counties which do contain segments. Data for these 5 x 6 nm segments (containing 117 lines of 196 pixels each) will be extracted from the full scenes by GSFC and transmitted to JSC.

Roughly 20 percent of the segments will be "training" segments. In the LANDSAT imagery acquired from these segments, training "fields" will be manually located to train the classification algorithm to identify wheat in the "training" and "ordinary" segments. An "ordinary" segment is one for which no training fields are selected. Training segment data is acquired at every opportunity to maximize the probability of acquiring acceptable data. Acceptable is defined to GSFC in terms of minimally tolerable interference from cloud cover (< 30 percent of segment area obscured).

GSFC will similarly preprocess ordinary segments which will be transmitted only 4 times during the growing season, once for each of the biological phases of crop establishment, green, heading and mature. The first data taken in each phase which meets quality criteria will be used. For each segment the first take of the season will become a reference set and subsequent data takes will be registered to the reference set to form a multitemporal set of up to 16 channels.

The analysis of the MSS data is being intentionally carried out without the use of current ground data. Ground observations will, of course, be used for evaluation purposes but the only data used operationally will be that typically available in real time over large areas from existing sources. This self-imposed constraint makes it necessary to train the classifier using LANDSAT data itself together with crop calendar information. To enhance the chances for success, "seasonally adjusted" crop calendars, developed from "normal year" calendars modulated by current year weather data are being used.

The initial crop calendar update model implemented for LACIE (operated at Washington by NOAA) is based on the Robertson bio-time model (Reference 13). This model, based on real time measurements of maximum and minimum daily temperature and USDA estimates of planting start dates, will be used to provide bi-weekly updated estimates of the actual times for occurrence of the LACIE biophases for each of 60 crop reporting districts in the U.S. In addition to use in training field identifications the outputs of this model will be used to specify LANDSAT data acquisition windows to GSFC for each LACIE biophase.

Following receipt in Houston, LANDSAT digital data is converted to film image form and analyst interpreters select from training segments 40 to 50 training fields for wheat

and other agricultural categories and provide a definition of the boundary of such fields to the ADP analyst for the classification. This represents manual analysis of about 2 percent of all LANDSAT data acquired.

In these segments the analyst interpreter (AI) will rely mainly on interpretative keys which distinguish wheat from nonwheat based on tonal appearance and change over the growing season and spatial information such as texture and shape. In addition the AI will be provided with historical cropping practice data for each segment. In regions where wheat has a crop calendar distinctly different from other crops, the AI should be able to accurately distinguish wheat from other, provided he has an accurate knowledge of the current year's cropping calendars for the various crops.

The AI will be provided with weather summary data (from NOAA) each week summarizing meteorological events known to affect crop appearance. Snowfall, heavy precipitation or drought and temperature extremes will be the key variables of interest.

While the AI procedures described above will be the backbone of the initial LACIE effort, the concept of extending signatures between regions known to be "analogous" to each other is being investigated in the RT&E activity.

Image analysis will also be used for another purpose. Previously, difficulty has been experienced in classifying accurately such non-cropland areas as forests, and towns. Frequently, such areas are highly heterogeneous at the LANDSAT resolution, and poor classification has resulted. Therefore, major non-cropland areas will be identified by image analysis and will be manually excluded. Similarly, areas in which data quality is poor due to such factors as clouds and noise can be identified and manually excluded.

Major wheat-growing regions will be partitioned into smaller areas over which signature extension is expected to be successful. This partitioning will be accomplished based upon such ancillary data as crop calendars, meteorology, and soil color, as well as on the basis of trial classifications. Each signature extension region will contain one or more training segments. If cloud cover or other operational problems prevent acquisition of the training segment for a given signature extension region, signature extension will be attempted from a neighboring region. This "neighbor region" approach is expected to provide reduced classification accuracies in the region without a training segment. It is anticipated that signature extension regions will be typically about the size of a LANDSAT scene.

The classification subsystem design is based upon the judgment that wheat can be separated adequately from other crops by analysis of up to four acquisitions of LANDSAT data during the biological development of wheat. The biophases chosen are:

    a. Crop establishment: planting to booting
        (with a gap during dormancy for winter wheat)

    b. Green: booting to heading

    c. Heading: heading to soft dough

    d. Mature: soft dough to harvest

Signatures obtained on one calendar date within a biophase are not necessarily expected to be valid for other acquisition dates within the same phase; however, training field boundaries generated for one date will usually be valid on other acquisition dates within the same biophase. Therefore, by acquiring the training segments on each LANDSAT pass and using training field boundaries located on one acquisition date for that biophase statistics appropriate to a different acquisition date can be computed without expending additional image analysis effort. It is planned to conduct major image analyses only upon training segments and only once per biophase.

Procedures for the classification were based in part on the CITARS procedures described in another Section (Background). Basically, the training data are clustered to aid in selecting suitable training classes, sun angle and mean level adjustments are made if required, a feature selection process can be employed to reduce the number of channels using the Bhattacharyya distance as a separability measure. The segment is classified with a maximum likelihood classifier into wheat and nonwheat classes. The details of this procedure are covered in another paper (Trichel, et al). A high degree of analyst interaction will be possible but the intent of the system is eventually to automate the classification as completely as possible. The fraction of each segment's area classified as

wheat will be determined by ratioing wheat pixel count to total pixel count.

The key RT&E issues being addressed in the classification of LANDSAT data are methods for developing training signatures,methods for extending the developed signatures over large areas and improved methods for estimating wheat proportions within the sample segments.

The technology required for LACIE represents to some extent a departure from the existing technology base in that insitu ground observations have been traditionally used to "train" the classifier. The LACIE RT&E effort in this regard is focused on improving analyst interpreter techniques and the development of the "analog" area concept discussed earlier.

Signature extension is key to LACIE in that the manpower expended per segment decreases drastically with increasing ability to apply training statistics over larger areas. Signature extension RT&E is focused on: (1) definition of methods to determine signature strata, i.e., geographic regions for which multispectral signatures are sufficiently homogeneous so as to not significantly degrade classification performance. Such strata will most probably be uniform in soil spectral characteristics, crop biophase and in the agricultural practices employed. (2) development of algorithms which permit signature extension between areas with different environmental conditions i.e., atmospheric conditions or sun angles.

Finally, improved proportion estimation schemes are key to developing unbiased estimations of wheat proportions within segments. The importance of this is pointed out in the background section of this paper.

Yield projections will be made from models which involve weather data, typically, precipitation and temperature. Such data will be obtained from current (ground) networks. The development of the yield models is being carried out by NOAA at their center of Climatic and Environmental Assessment at Columbia, Missouri. The initial models which will be statistical in nature, i.e., expressions for yield as a function of key meteorological parameters will be derived from regression analyses using historical yield and weather data over each of a number of yield strata. For the U.S. in Phase I, a stratum will be a Crop Reporting District. Within any one stratum the same set of coefficients in the model will apply, however, varying weather conditions at various locations within the stratum will result in different projected yields. The operation of this model will take place at NOAA facilities in Washington, D.C. and the results will be supplied to JSC. Basic meteorological parameters currently available on the World Meteorological Organization (WMO) network will provide the input data to the models.

The later phases of LACIE may employ yield models of a more sophisticated type, such as the Baier model, in which plant growth phenomena are taken into account explicitly. Also, observations from environmental satellites may be utilized to extend and interpolate the meteorological data from the WMO network.

The area and yield determinations per stratum provide the basic inputs to a production estimate. The LACIE system will produce monthly yield estimates, area estimates and production estimates for each major wheat-producing Crop Reporting District, state and region in the U.S.

For each crop reporting district the area estimate will be computed by the relationship

$$A_j = A_{1j} + A_{2j} + A_{3j} \tag{4}$$

where A_{1j} is the estimate of the area in the counties within the jth CRD which had no segments allocated, A_{2j} is the estimate for those counties which were allocated fractions of segments PPS (probability proportional to size without replacement) and A_{3j} is the estimate for counties allocated one or more segments.

For counties falling into the first class the area estimate is

$$A_{1j} = (A_{2j} + A_{3j}) \frac{x_j}{w_j} \tag{5}$$

where x_j is the agricultural census wheat area for counties in group 1 and w_j is the agricultural census area for the CRD.

For counties with total area A_2 falling into class 2 containing m_j sample segments

$$A_{2j} = A_2 \frac{p_j}{m_j} \sum_{k=1}^{m_j} \frac{\hat{p}_{jk}}{p_{jk}} \tag{6}$$

where $\hat{p}_{jk}$ is the LACIE wheat proportion estimate within the kth county p_{jk} is the agricultural census wheat proportion estimate in that county and p_j is the census estimate for the jth CRD.

For the m_j counties falling into class 3, A_{3j} is simply the product of the average areal proportion of wheat in each county as estimated from the sample segments multiplied by the area of the counties containing the segments i.e.,

$$A_{3j} = \frac{A_3}{m_j} \sum_{k=1}^{m_j} \hat{p}_k \tag{7}$$

where $\hat{p}_k$ is the wheat areal proportion in the kth county.

Methods for wheat yield aggregation are still being investigated as a part of the LACIE research test and evaluation effort as is production aggregation.

The final step in each phase of LACIE is an evaluation of the output products of the LACIE system. This evaluation begins with an assessment of the "accuracy" of the output estimates of area, yield and production. These "accuracy" figures, are included with the area, yield and production estimates and transmitted in a report to an "Information Evaluation (IE) Group" within the USDA in Washington. The IE group will compare the LACIE estimates to conventional estimates and note differences in these. In addition the LACIE reports will be assessed for their value to the normal operations of USDA. The IE group will provide feedback to LACIE personnel in Houston. Any discrepancies between the LACIE estimates and conventional estimates will be investigated by USDA analysts at Houston to determine if differences are due to faults in the LACIE approach (data, techniques, etc.)

For area "accuracy" three main quantifiers are proposed: (1) the percent difference between conventional estimates and the LACIE estimates i.e., percent bias, (2) the precision of the area estimate $P = [Var(\hat{p})]^{1/2}/\hat{p}$ where $\hat{p}$ is the LACIE wheat areal density estimate for a given strata, region or country, (3) the confidence level α that the LACIE estimate $\hat{A}$ is within ten percent of the conventional estimate A.

Over a large area, such quantifiers are more easily defined than obtained. In the U.S. the only information available for comparison to the LACIE estimates are: (1) crop identification data obtained by the USDA from the 28 Intensive Test Sites (ITS), ranging from 5 x 6 n. miles to 3 x 3 miles in extent, and located in major wheat growing regions, (2) SRS estimates of area at the county, crop reporting district, state, regional and national level, (3) historic area data compiled by the SRS at these levels, (4) insitu information from the SRS sample segments (approximately 1 mile square).

If, as was the case in LACIE development testing, retrospective data for prior crop years is being analyzed, the accuracy of the LACIE estimates may be assessed by comparing them to the SRS data. It is generally believed that while the SRS data is not one hundred percent accurate, its accuracy is sufficient to use as a standard against which to evaluate how well the LACIE accuracy is meeting its goals.

Real time however, estimates of the percent bias of the LACIE estimates will need to be inferentially determined without reference to the SRS data since it will not be available to the LACIE system. Such methods are being developed within LACIE which will utilize intensive test site and other data.

The precision of the LACIE estimates can be determined from an examination of real time LACIE area estimates and historic SRS area data. The variance of p, Var(p) is given for an area composed of K strata by:

$$Var(p) = \sum_{k=1}^{K} C_k^2 \ Var(p_k) \qquad (8)$$

where $Var(p_k)$ is the variance of the estimate of the wheat areal proportion in the kth stratum and C_k^2 are areal density weighting functions for the strata within the area. Within a given stratum (assuming all counties are class 3 counties in the particular example) $Var(p_k)$ is given by:

$$Var(p_k) = \sum_{j=1} D_{kj}^2 \ Var(\hat{p}_{kj}) \qquad (9)$$

where $Var(\hat{p}_{kj})$ is the variance of the estimate of the wheat areal proportion contained in the jth county within the kth crop reporting district and D_{kj}^2 are areal density weighting functions for the counties.

Estimating the variance $Var(p_{kj})$ is not straightforward in LACIE since many counties contain only one sample segment. A good estimate of this quantity is critical since it will determine to what degree the "accuracy" of the LACIE estimates can be determined. The figures quoted previously for the sample error associated with the LACIE sample strategy were based on the assumption that the wheat proportion distribution relative to the 5 x 6 nm sample segment would be binomial so that $Var(p_{kj}) = p_{kj} (1-P_{kj})$. This estimate will be somewhat conservative (i.e., will create overestimates of the precision) since LACIE sample segments will be considerably larger than the average wheat field and the wheat fields tend to be distributed somewhat uniformly throughout a county as opposed to being conglomerated in just one portion of the county.

Latest estimates of the variance of the LACIE area estimates (see Section V) are based on the use of historic area data and real time LACIE proportion estimates to determine the within-county variance. For a stratum, historic SRS area figures are used to determine the between-county variance of p within the stratum. This figure is subtracted from the estimate of the variance of the LACIE proportion estimates over the stratum to obtain an estimate of the LACIE within-county variance. Other methods to estimate this variance are being investigated in the RT&E effort.

Given an estimate of the bias and precision, an estimate of the confidence level can be obtained. For LACIE α will be defined for a stratum, state, etc. as

$$\alpha = P (|\hat{A} - A| < 0.1A) \qquad (10)$$

where $\hat{A}$ is the LACIE estimate of the area and A is the conventional SRS estimate.

As a performance objective of the LACIE experimental system, an α of 0.9 at a national level has been chosen. Such a choice requires that the LACIE area estimate be, with a ninety percent confidence, within ten percent of the conventional estimate. This criteria has been referred to as the "90/90" criteria.

By assuming the LACIE estimate to be normally distributed about its mean value, the estimate of the bias and the Var(p) can be used to determine α.

Methods for similarly quantifying the performance of the yield and production estimates are being developed in the RT&E effort. The focus in this area is to develop an error simulation/propogation model which describes the contribution of yield and area errors to the production estimation error.

IMPLEMENTATION APPROACH

To understand the implementation approach taken for LACIE it must be realized that the experiment calls for simultaneous execution of activities which, given a more leisurely schedule, would normally be undertaken sequentially. Specifically, the application of the base technology had to proceed in full recognition of the fact that many components of this Application Evaluation System (AES) had not been fully developed and thoroughly tested. At the same time, research test and evaluation had to proceed to strengthen the suspect areas and to conduct thorough tests of new system components prior to their

introduction into the mainstream AES. The way these project elements relate is depicted graphically in figure 2. As this figure makes clear the role of LACIE is, for one important agricultural application, to bridge the gap between the multitude of feasibility tests and exploratory studies and the eventual operational systems.

The functional organization for LACIE involves numerous elements of the three participating agencies. Each agency maintains, of course, its own administrative control over those resources allocated to LACIE. However, at the project level the technical staff is fully integrated (figure 3).

A number of implementing organizations may be in collaboration for a particular subsystem. For example in the case of the DAPTS (Data Acquisition, Preprocessing and Transmission Subsystem) NASA Goddard, USDA field staff (Agricultural Stabilization and Conservation Service) and NOAA (Environmental Data Service, National Weather Service and National Environmental Satellite Service) all acquire and preprocess portions of the data for LACIE in response to requirements specified by the subsystem manager.

In other cases a single implementing organization such as the NASA Data Systems and Analysis Directorate will implement hardware and software that supports the functional requirements of several subsystems. For example, the portion of the LACIE data system which was derived from the ERIPS referred to earlier, supports the functional requirements of the electronic part of the ISRRS (Information Storage, Retrieval and Reformatting Subsystem) and the CAMS (Classification and Mensuration Subsystem).

To as great an extent as possible the personnel assigned to LACIE have no other duties. In each case the responsibility for a particular area is made in consonance with the respective agency roles. For example, the CAS manager is from USDA, the YES manager from NOAA. To the extent possible some personnel from USDA are assigned to each functional area since USDA will eventually wish to operate an operational follow-on system. NOAA participation is limited (by resource availability) to YES, DAPTS, and project management activity.

The great majority of LACIE effort and resources is allocated to the AES (Application Evaluation System). This system provides the actual mechanisms, including ADP equipment, software, personnel, procedures and facilities with which LACIE data is processed to produce wheat inventory reports and evaluations by the user of the utility of those reports. A simplified schematic of the AES is given in figure 4. A full treatment of the functioning of this system is beyond the scope of this paper. It should be noted; however, that as complex a system as the AES requires the exercise of careful control over requirements, configuration and operation. The implementation of the system is, accordingly, carried out in response to formally documented detailed requirements. Interfaces between collaborating organizations are rigorously defined by interface control documentation and formal change control procedures are in force to eliminate uncoordinated change.

The research test and evaluation effort, while modest in comparison with the AES effort, is fully as important in reaching the overall goal of a successful application of remote sensing technology.

Research of a highly focused and applied nature is initiated pursuant to requirements developed by the AES personnel, who perceive the technological gaps, in conjunction with research personnel who are in touch with the most current developments in the remote sensing community. This research is carried on under contract by academic and research institutions long experienced in the field. A tabulation of the major task areas and the institutions working on each is given in Table 3. In each case a task team monitors the contract and assures its congruity with LACIE needs. Both research and AES personnel participate.

In each research effort specific goals are spelled out with deliverable products scheduled at appropriate times. Generally such a product would be an alternate algorithm or procedure for some part of the LACIE system. During the development of such a product some testing will, of course, have been done. If the results appear promising then further more rigorous testing will be done either by the developing institution according to an approved test plan or by the test and evaluation personnel in the project. Implementation of the new procedure in the AES will take place in parallel with the testing or following it depending upon the urgency of incorporating the new procedure and implementation resources available. It should also be noted that RT&E effort can contribute in an important way to eventual follow-on systems by providing solutions for key problems that may be identified but not resolved during the lifetime of LACIE.

The development of the LACIE system and its operation is being conducted in three phases, each tied to the wheat-growing cycle and expanding in scope as capability increases. The first phase covers the 1974-75 crop year (in the U.S.) and addresses area estimates for nine wheat-growing states in the Great Plains. In a smaller area or areas, likely one or two states, yield models will be tested and production estimates made. Classification tests will be conducted on representative segments in other wheat-growing regions and the 28 intensive test sites in North America will be analyzed to provide one basis for performance assessment.

The second phase from the fall of 1975 to the spring of 1977 will include area, yield and production estimates for a large area, likely the entire U.S., a continuation of tests on representative sites elsewhere and intensive test sites and will cover a longer crop cycle to include both northern and southern hemisphere wheat crops.

The third phase from the fall of 1976 to the spring of 1978, will provide area, yield and production estimates over one or more large area regions and will incorporate those refinements to the technology developed during the RT&E efforts of the earlier phases.

The schedule for LACIE is clearly very success-oriented. This was considered necessary; however, to exploit fully the LANDSAT 2 capability and to demonstrate a large-scale application of space remote sensing at the earliest possible time.

V. SUMMARY OF INITIAL PERFORMANCE ASSESSMENT

At the writing of this paper an initial assessment of the performance of the initial LACIE/CAMS system had been performed by conducting analyses of the results of processing LANDSAT 1 data acquired during 1973 and 1974 over 33 segments in Kansas. For this study, the LACIE sample segments were moved within each county to encompass either an intensive test site or an SRS sample unit. Of these 33 segments, 5 were LACIE intensive test site segments for which "wall to wall" insitu observations of crop type were available and the remaining 28 each contained a 1 x 1 mile section of crops observed for crop types by the Statistical Reporting Service of USDA.

For three of the five ITS segments, LANDSAT data was available for all biological phases. For the other two, cloud cover resulted in the data for two biological phases not being acquired. For this 1973-74 data set, biophase 4 is postharvest. For the 28 remaining segments, 22 were acquired during biophase 1, 4 acquired during biophase 2, and 2 acquired during biophase 3.

The analyst interpreter (AI) performance was evaluated on the intensive test sites by comparing their identifications of wheat and nonwheat to ground observations. The AIs picked approximately 15 wheat and 15 nonwheat fields for classifier training. The figures in Table 4 are percent correct identifications of these fields when compared to the ground observed identifications.

The classification performance for wheat obtained by using the analyst-interpreter provided fields as training data was determined. The classification performance varied considerably from biophase to biophase and from segment to segment (see Table 5). These performances are for single pass data only. Multidate analyses in the intensive test sites resulted in a considerable performance improvement.

Estimates for the three parameters used in LACIE to quantify the area estimation accuracy were computed for the 28 segments analyzed.

Two estimates of the bias were obtained for 12* of the 28 segments. The wheat areal proportion estimates obtained by LACIE were compared to the proportions as determined from the SRS sample units (1 x 1 mile) within the 5 x 6 nm segments. The results, shown in Table 6, indicate the difference of -.0035 to result in a negative "bias" (underestimate) in the LACIE estimate of -1.02%, of the SRS mean value. In Table 7, an aggregation of the LACIE results over the 6 crop reporting districts containing the LACIE segments agree to -3% with the 1973-74 SRS estimate over the same CRD's.

The accuracy of the LACIE area estimate was also estimated in two ways. Returning to Table 6 the standard error associated with the difference between the LACIE and SRS estimates in the 12* sample segments is about 12% of the SRS mean value over these segments.

*This is an arbitrary subset of the 28.

Projected to the area consisting of 6 CRD the associated standard error would be roughly 8%. In Table 8, the precision of the LACIE estimate is computed based on all 28 segments processed for each of the 6 CRD's examined and is computed for the aggregate of these. These are the precisions associated with the LACIE area estimation discussed in Section IV. Notice that the precisions fluctuate with the CRD. This is a result of the fact that each CRD had a different number of acceptable sample segments and that the error of the ratio estimators discussed earlier enters into these calculations. The precision of the LACIE estimate for the 6 CRD's is 8.3%.

Based on these preliminary results, an _estimate_ can be made of the performance to be expected at a state level in Kansas. Assuming the bias of -3% to remain about the same at the state level and (based on sample theory) assuming the precision will decrease in proportion to the square root of the ratio of the number of samples to be acquired cloud free at the state level in Kansas (~50) to the number examined here (28), a rough estimate of the precision at the state level would be

$$\sqrt{\frac{Var(\hat{p})}{\hat{p}}} = \sqrt{\frac{28}{50}} \times 8.3 = 6.2\% \tag{11}$$

For the bias figure of 3%, the confidence that the LACIE Kansas estimate will be to within 10% of the SRS state estimate would be approximately 85%.

Projecting this estimate beyond Kansas to the national level is probably not too meaningful at this time since: (1) the Kansas results were obtained using only local signatures (i.e., signatures developed for each segment without employing signature extension), (2) conditions in other states will vary considerably, (3) of the 28 segments examined, data for 22 was acquired in biophase 1 (bare soil). However, the very preliminary evidence examined indicates that the confidence at a national level could increase considerably as a result of increased sampling.

It is concluded that this preliminary assessment shows every indication that the "90/90" criteria nationally is a reasonable goal to be achieved by the LACIE system and one which will productively stimulate the development of the LACIE technology.

VI. REFERENCES

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Table 1. Probabilities for Correct Classification and
Probabilities for Comission Error

Hill County, Montana

	Single Pass			Multidate		
	t_1	t_2	t_3	(t_1,t_2)	(t_1,t_3)	(t_1,t_2,t_3)
P(w/w)	0.70	0.90	0.80	0.90	0.90	0.95
P(w/o)	0.20	0.15	0.05	0.05	0.05	0.00

t_1 = greening $\qquad$ t_2 = heading $\qquad$ t_3 = mature

Burke County North Dakota

	t_1	t_2	(t_1,t_2)
P(w/w)	0.75	0.85	0.90
P(w/o)	0.10	0.10	0.05

t_1 - emergence $\qquad$ t_2 = jointing

P(w/w) = Probability with which wheat test pixels are classified as wheat

P(w/o) = Probability for classifying non-wheat test pixel as wheat (comission error)

Table 2. Area Estimation Accuracy Results for
Hill County Study

	Single Pass		Multidate
	Greening	Heading	Three Passes
P(w/w)	0.586	0.698	0.851
P(w/o)	0.141	0.155	0.060
Bias Error D	-0.089	0.056	-0.01

Table 3. Major Task Areas in LACIE Research, Test and
Evaluation and Performing Organization

Task Area   Performer

o Area

   o Definition of Training Statistics   UCB (U. of Calif. Berkeley,) LARS (Laboratory for
                                                                   Application of Remote Sensing), ERIM (Environmental
                                                                   Research Institute of Michigan)

   o Registration   LARS
   o Classification
      o Temporal Sampling Strategy   TAMU (Texas A&M Univ.)
      o Multitemporal Classification   UTD (U. of Texas, Dallas)
      o Proportion Estimation   ERIM, UTD, TAMU, Rice Univ.
      o Feature Selection   UH (U. of Houston), TAMU
   o Signature Extension   UCB, LARS, ERIM, Colo. (Colorado State)
   o Estimation of Unharvested Wheat   TAMU
   o Sampling and Aggregation   UCB, TAMU
   o Field Measurements*   LARS, TAMU, ERL (Earth Resources Laboratory, FOD
                                                                     (Flight Operations Directorate)

o Yield

   o Yield Models   KSU (Kansas State Univ.), TAMU, ERIM, Clemson

o Production

   o Error Model   TRW

* Supports Classification, Estimation Unharvested Wheat, Signature Extension

Table 4. Intensive Study Site Summary of AI Performance
Percent of Fields Correctly Identified

Biological Stage	Morton		Finney		Ellis		Saline		Rice	
	W	NW	W	NW	W	NW	W	NW	W	NW
IA	27%	100%								
IB	100%	100%	100%	80%	100%	66%				
II	89%	100%	100%	100%	100%	80%	100%	100%		
III			100%	100%	100%	80%			100%	100%
IV	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 5. Classification Performance on 5 Kansas
Intensive Test Sites

| Segment | 1034 | | 1042 | | 1106 | | 1111 | | 1114 | |
Phase \ Crop type	W	NW	W	NW	W	NW	W	NW	W	NW
1A			75.72	89.64						
1B	54.09	76.35	72.46	94.61	21.60	85.00				
2	86.80	61.20	75.35	78.88	66.05	31.30			77.46	81.68
3	68.80	88.90			80.27	18.54				
4	38.30	84.70	37.50	54.80			85.13	48.00	78.10 78.00	67.50 65.00

Number	Biophase	Segment Number	County
1A	Fall Seedbed Preparation	1034	Finney
1B	Spring Reemergence	1042	Morton
2	Booting through Heading	1106	Ellis
3	Soft Dough to Harvest (Mature)	1111	Rice
4	Post Harvest	1114	Saline

Table 6. Comparisons of SRS and LACIE Estimates

| | | | Wheat Proportion | |
Segment	County	Phase	ERTS (Y)	SRS (X)
1040	Kearny	2	.322	.337
1109	Marion	1	.254	.222
1036	Grant	1	.520	.321
1118	Reno	2	.180	.434
1018	Graham	2	.127	.182
1029	Scott	1	.400	.411
1037	Gray	1	.290	.266
1045	Stevens	2	.249	.209
1065	Haskell	1	.300	.321
1104	Barton	3	.380	.605
1106	Ellis	2	.607	.404
1110	McPherson	2	.526	.401
		Mean:	.34625	.34275

Difference in means = .0035
Associated Standard Error = .0407

Table 7. A Map Comparison of USDA and LACIE Wheat Proportion
Estimates for Six Kansas Crop Reporting Districts

Kansas CRD Number	Wheat Proportion		Relative Difference Percent
	USDA (1973-74)	LACIE	
1	.244	.189	-2
2	.228	.230	5
4	.255	.214	16
5	.307	.390	27
7	.267	.321	20
8	.385	.282	-27
All 6 CRD's	.286	.278	-3

Table 8. Precision of LACIE Area Estimations

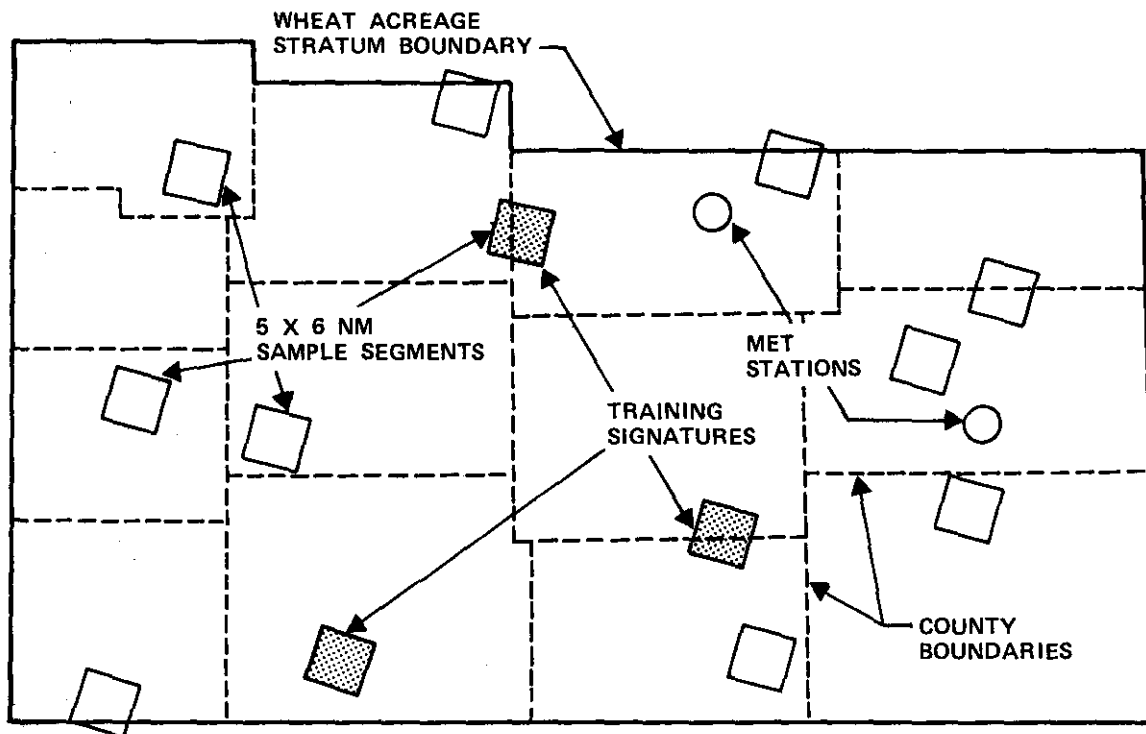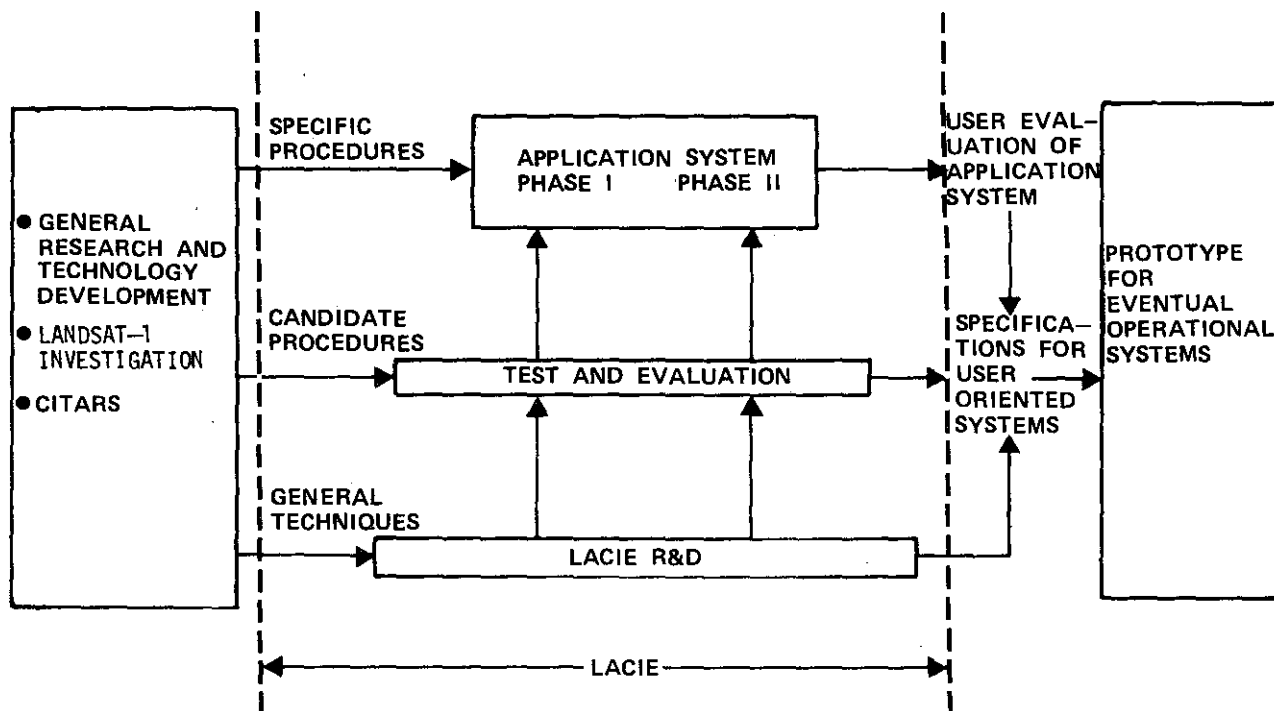| Kansas CRD Number	No. of Segments		Precision
	Allocated	Classified	
1	8	1	60%
2	11	3	21.2%
4	9	2	26%
5	11	8	8.7%
7	14	10	10%
8	14	4	16%
Aggregated	67	28	8.3%

Figure 1. Segment Locations Within a Crop Reporting District
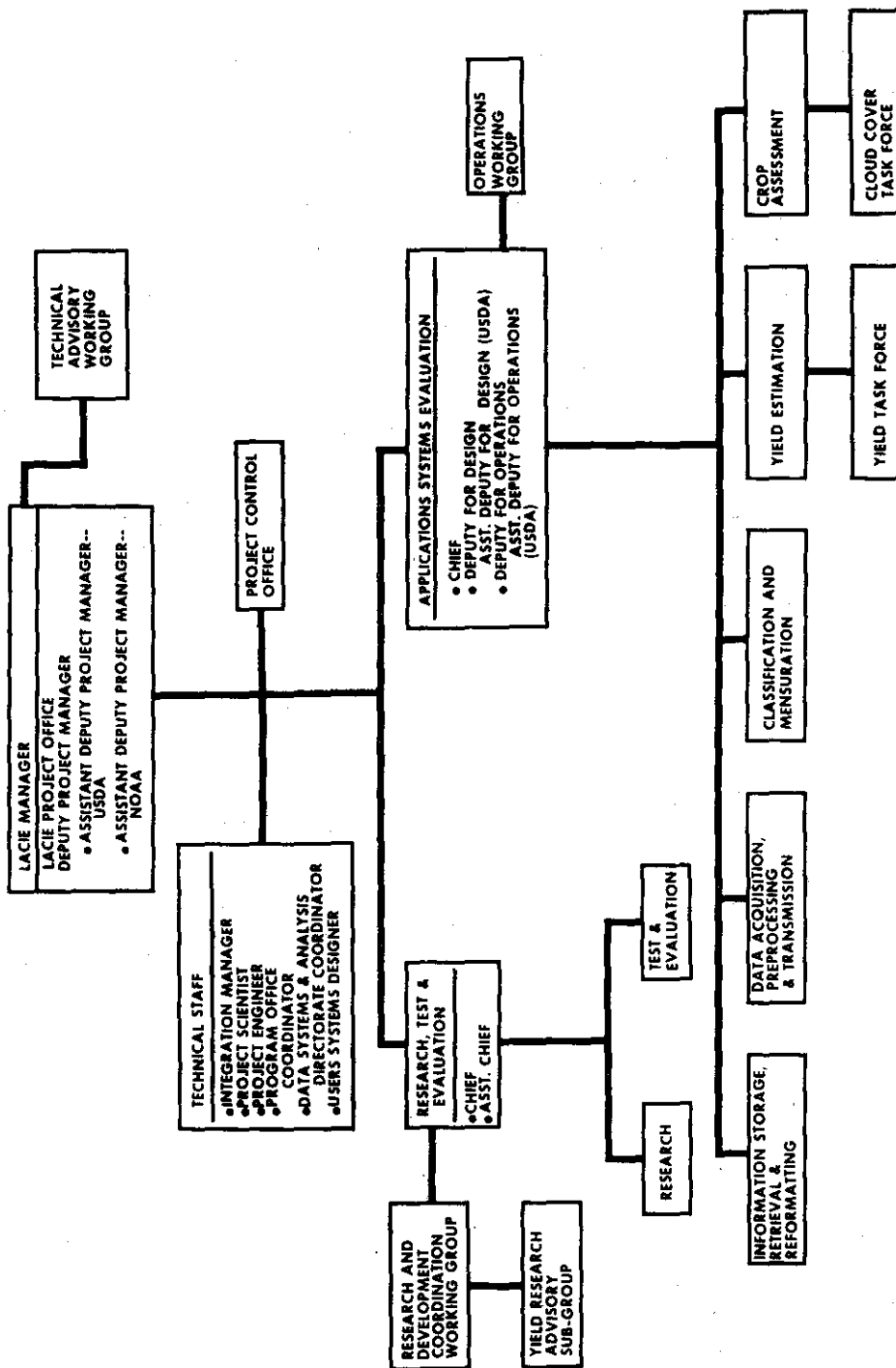

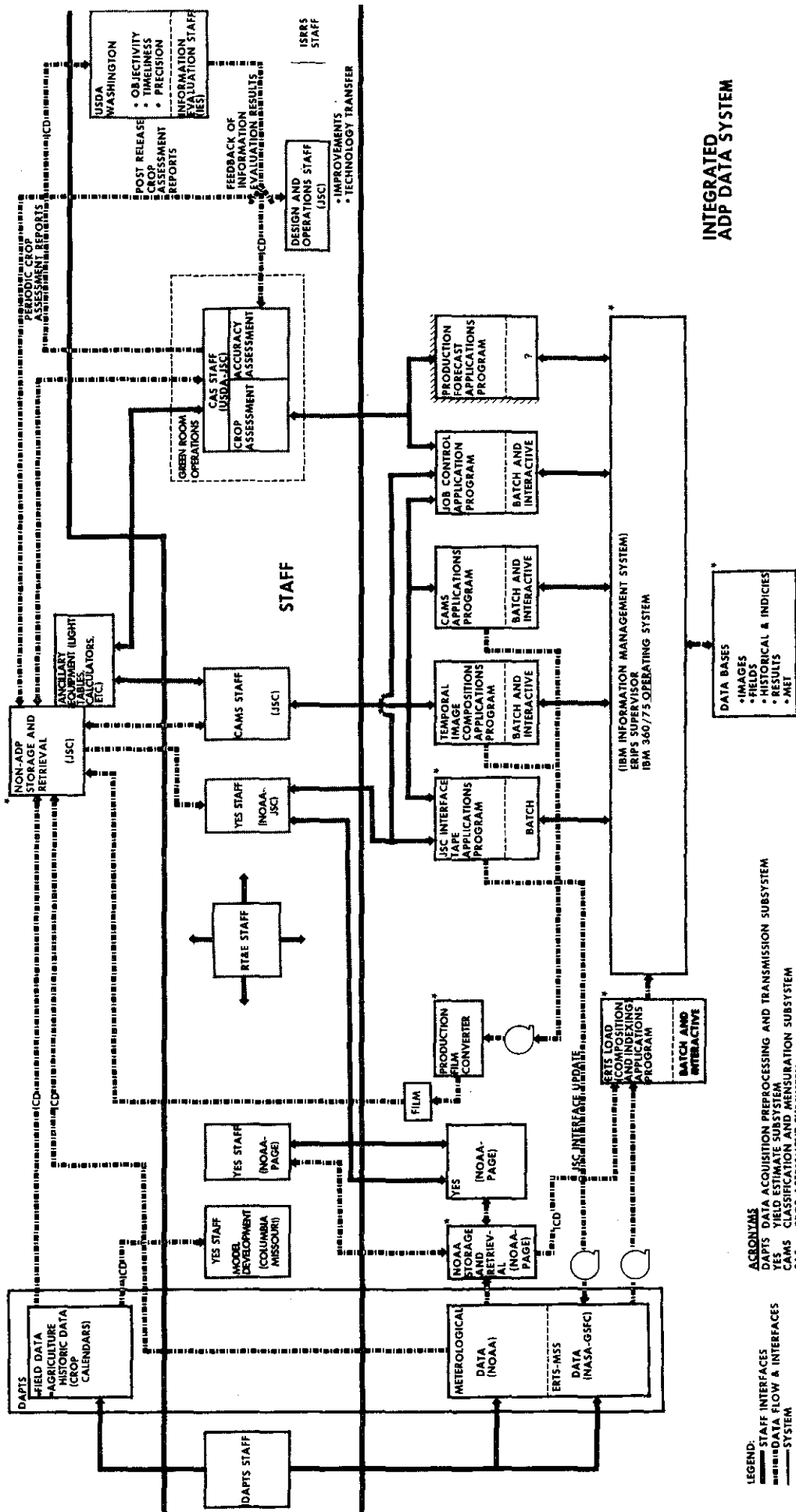Figure 2. LACIE Project Elements

Figure 3. LACIE Project Organization

Figure 4. LACIE INTEGRATED APPLICATIONS EVALUATION SYSTEM

LEGEND:
▬▬▬ STAFF INTERFACES
▪▪▪▪ DATA FLOW & INTERFACES
───── SYSTEM

ACRONYMS
DAPTS DATA ACQUISITION PREPROCESSING AND TRANSMISSION SUBSYSTEM
YES   YIELD ESTIMATE SUBSYSTEM
CAMS   CLASSIFICATION AND MENSURATION SUBSYSTEM
CAS   CROP ASSESSMENT SUBSYSTEM
ERTS   EARTH RESOURCES TECHNOLOGY SATELLITE
IES   INFORMATION EVALUATION SUBSYSTEM
ICD   INTERFACE CONTROL DOCUMENT
*ISRRS INFORMATION STORAGE, RETRIEVAL, AND REFORMATING SUBSYSTEM

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