JSC 09387

CROP IDENTIFICATION TECHNOLOGY ASSESSMENT FOR REMOTE SENSING (CITARS)

VOLUME IV

IMAGE ANALYSIS

PART 1

CROP IDENTIFICATION EXTENSION

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

April 1975

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PART 1

CROP IDENTIFICATION EXTENSION

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13. ABSTRACT

Fields of corn, soybeans, and wheat were identified through the interpretation of aerial photographs acquired over selected sites in Indiana and Illinois periodically through the summer of 1973. Photo-interpreters assigned to the Crop Identification Technology Assessment for Remote Sensing project identified the three crops in more than 140 sections by comparing the spatial and spectral signatures of unknown fields with the signatures of nearby fields identified on the ground by observers of the Agricultural Stabilization and Conservation Service. The proportion of each crop and "other" in each section was calculated after measurement of the area assigned to each crop within the section. Certain ground truth data were withheld from the interpreters to permit an evaluation of the accuracies of their crop identifications. The results of that evaluation are presented elsewhere in the project's final reports published by the National Aeronautics and Space Administration.

14. SUBJECT TERMS

Crop proportion	Ground truth	Training field
Crop identification extension	Known crop data	Unknown field
Crop signature	Temporal analysis	Withheld data

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PREFACE

This volume is submitted as a final summary documentation of the image analysis phase of the Crop Identification Technology Assessment for Remote Sensing project. Procedures, crop interpretation summaries, recommendations, and time requirements to complete major task phases are included in text. All detailed documentation generated during the image analysis phase of the project is included in the appendixes, which have not been reproduced in this volume because of their bulk, but they are available for review through the Earth Observations Division Research Data Facility (Building 17) of the Lyndon B. Johnson Space Center, of the National Aeronautics and Space Administration. A subject listing of the contents of the appendixes, however, is included in this report.

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Acknowledgment is extended to J. W. Disler, T. E. Johnson, and R. W. Payne of Lockheed Electronics Company, Inc., for performing the analyses and completing the main body of this text.

GLOSSARY

ADP – automated data processing; the automated application of mechanical, electrical, or computational procedures by which the data are changed from one form into another.

ASCS – Agricultural Stabilization and Conservation Service.

CITARS – Crop Identification Technology Assessment for Remote Sensing.

Crop identification extension – process of correlating known crop data (collected by ground observers) with corresponding "signature responses" on concurrently acquired aerial photographs and extrapolating these signatures to unknown fields.

Crop proportions – the percentages of corn, soybeans, wheat, or "other" crop within a given section of a test segment.

Crop signatures – the color, tone, brightness, texture, and pattern of a field or a crop within a field; the overall visual characteristics of a crop as it appears on an aerial photograph.

DAS – data analysis station; an instrument for video display of computer-processed digital data with a hard-copy capability.

Digitizer – a multiprogram instrument that measures area in units of 0.001 inch (0.0254 mm) squared.

ERIM – Environmental Research Institute of Michigan (located in Ann Arbor, Michigan).

ERTS-1 – the first Earth Resources Technology Satellite.

Ground truth – crop identifications and crop development data obtained through on-the-ground observations by ASCS personnel.

Ground-truth quarter section – one-fourth of a section (approximately 0.8 km by 0.8 km) in which crop development was observed and recorded at 18-day intervals throughout the experiment period.

Known crop data – the data obtained from ground observations of fields within a test segment.

LARS – Laboratory for Applications of Remote Sensing (located at Purdue University).

NASA – National Aeronautics and Space Administration.

Photographic base map – black-and-white prints of high-altitude color infrared photographs of all test segments. Initially, prints enlarged to scales of 1:30,000 served as the base maps for annotating boundary and field data. Later in the program, the photographs were rectified and enlarged to a

scale of 1:24,000. The final boundary data are keyed to these new photographic base maps.

Photographic printer – a tabletop printer that will produce black-and-white negative or positive paper prints from film negatives or paper originals.

PTD – Photographic Technology Division at NASA.

Section – a basic unit of the land survey system that is in common use throughout much of the western United States. The section is a square tract of land measuring approximately 1.6 kilometers (1.0 mile) in each dimension.

Temporal analysis – the use of photographs acquired on several different dates for adding time-dependent changes to the information that is routinely extracted from a single-date photograph.

Test area segment – a 5- by 20-section tract measuring approximately 8 by 32 kilometers (259 square kilometers) randomly positioned within each of the six CITARS counties.

Test section – one of approximately 144 sections selected within six counties in Indiana and Illinois for the identification of crop types from aerial photographs.

Training field – an area of known crop or land use whose spectral and spatial characteristics are used as a reference for the identification of crop or land use in unknown fields.

Unknown field – an area that exhibits uniform characteristics but in which the type of crop or land use has not been determined.

Withheld data – ground observation data for a field that is available to the project but concealed from the photo-interpreter.

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1.0 INTRODUCTION

1.1 OBJECTIVES AND TASK DESCRIPTION

Sequential aerial photographs acquired during the summer of 1973 over selected areas of Indiana and Illinois were analyzed for extracting agricultural land use data. The basic objective of the image analysis team was to extend crop identifications obtained from ground observations to the identification of nearby farm fields imaged on aerial photographs. The purpose of this extension was to provide an expanded set of known crop data to the automated data processing (ADP) analysts. Test areas were selected and photointerpretation techniques were used for delineating individual field boundaries. Photographic base maps depicting test and ground observation field locations were prepared and disseminated to project users.

Image analysis personnel were provided with detailed crop descriptions (ground truth) for selected farm fields in six study sites designated for analysis. Color infrared aerial photographs acquired over the study sites were utilized for crop signature identification and for extension of these signatures to test fields.

Farm fields were analyzed and crop identifications were recorded along with estimates of the confidence levels for each interpretation. Area measurements for corn, soybean, and wheat fields and the percentages of the three crops in each test section (2.6 square kilometers) were computed.

Complete interpretation and measurement documentation, including photobase graphics, was provided for designated project personnel.

1.2 BACKGROUND

The 8- by 32-kilometer test segments (5 by 20 sections) selected for the Crop Identification Technology Assessment for Remote Sensing (CITARS) analysis are as follows:

Segment 1 – Huntington County, Indiana

Segment 2 – Shelby County, Indiana

Segment 3 – White County, Indiana

Segment 4 – Livingston County, Illinois

Segment 5 – Fayette County, Illinois

Segment 6 – Lee County, Illinois

Three photointerpreters were assigned to the image analysis phase, and each had primary responsibility for two segments.

Within each segment, approximately 24 test sections were randomly selected for interpretation. (See figure 1 for illustration of test segment, test sections, and ground truth quarter sections.) Each photointerpreter was thus responsible for an area of approximately 124 square kilometers.

The Agricultural Stabilization and Conservation Service (ASCS) periodically furnished ground observations on 20 test tracts per segment. Each tract was a quarter section in area, and the interval between ground truth observations

was approximately 18 days. The visits were about coincident with the overflight dates of the Earth Resources Technology Satellite (ERTS-1).

At the outset of the project, the planned task was to extend crop signatures from these quarter-section tracts to the remaining three-quarters of each section containing a ground truth tract. Later the plan was revised to require extension of crop identifications to 24 separate full-section tracts for each of the six county segments. Three or four of the sections included ASCS ground truth quarter-section tracts which were withheld from the interpreter for the purpose of checking interpretation accuracy. The general crop categories identified were corn, soybeans, wheat, and "other." However, when land uses within the "other" category were readily identifiable, they were recorded under specific uses, such as small grain, idle cropland, water, and woods.

Field areas delineated on photographs taken at low altitude were measured with a digitizer to determine the proportions of corn, soybeans, wheat, and "other." The results were recorded in percentage values for each section (e.g., corn, 43.3 percent; soybeans, 32.1 percent; "other," 24.6 percent, for 100 percent of the section area). Tabulations of similar crop percentage values for each section were submitted to the National Aeronautics and Space Administration (NASA) for distribution as each segment was completed. These tabulations are presented in the appendixes of this report [filed at the Lyndon B. Johnson Space Center (JSC) in Building 17].

Table I lists the recording parameters for the mission photographs used in the analysis. Ektachrome infrared film type 2443 was used for all interpretations.

In some cases, photographs from a given mission were acquired over a timespan of several days. The necessary documentation (mission flight logs) showing the exact date that a given segment was photographed was not available. Therefore, the first date listed on the label of the film container was used to represent the approximate date of the photograph.

1.3 SCOPE

The project task section (2.0) describes the procedures used in the performance of the tasks required by Action Document 63-0497-5713.02. The project tasks have been divided into three general groups:

- Preliminary Project Preparation Tasks, section 2.1
- Crop Identification Extension Tasks, section 2.2
- Crop Proportions Task (percentage of crop type), section 2.3

Section 3.0 summarizes the crop interpretations for each county segment selected for analysis. Crop identification and crop signature responses are evaluated for each photographic mission. Corn, soybean, and wheat (where applicable) signature responses on color infrared film are described for each county segment. Variations in crop signature caused by flooding, late planting, or replanting are described when the descriptions are considered relevant. (The photographic

mission frame numbers of all frames used for interpretation of test areas are listed by date for each county segment in the appendixes.)

The Image Analysis Team has reviewed procedures used during this project for areas of potential improvement in efficiency and/or accuracy. Recommended changes are listed in section 4.0 for the consideration of individuals who plan similar tasks.

The summary, section 5.0, includes the time requirements to complete the three major task phases of this project.

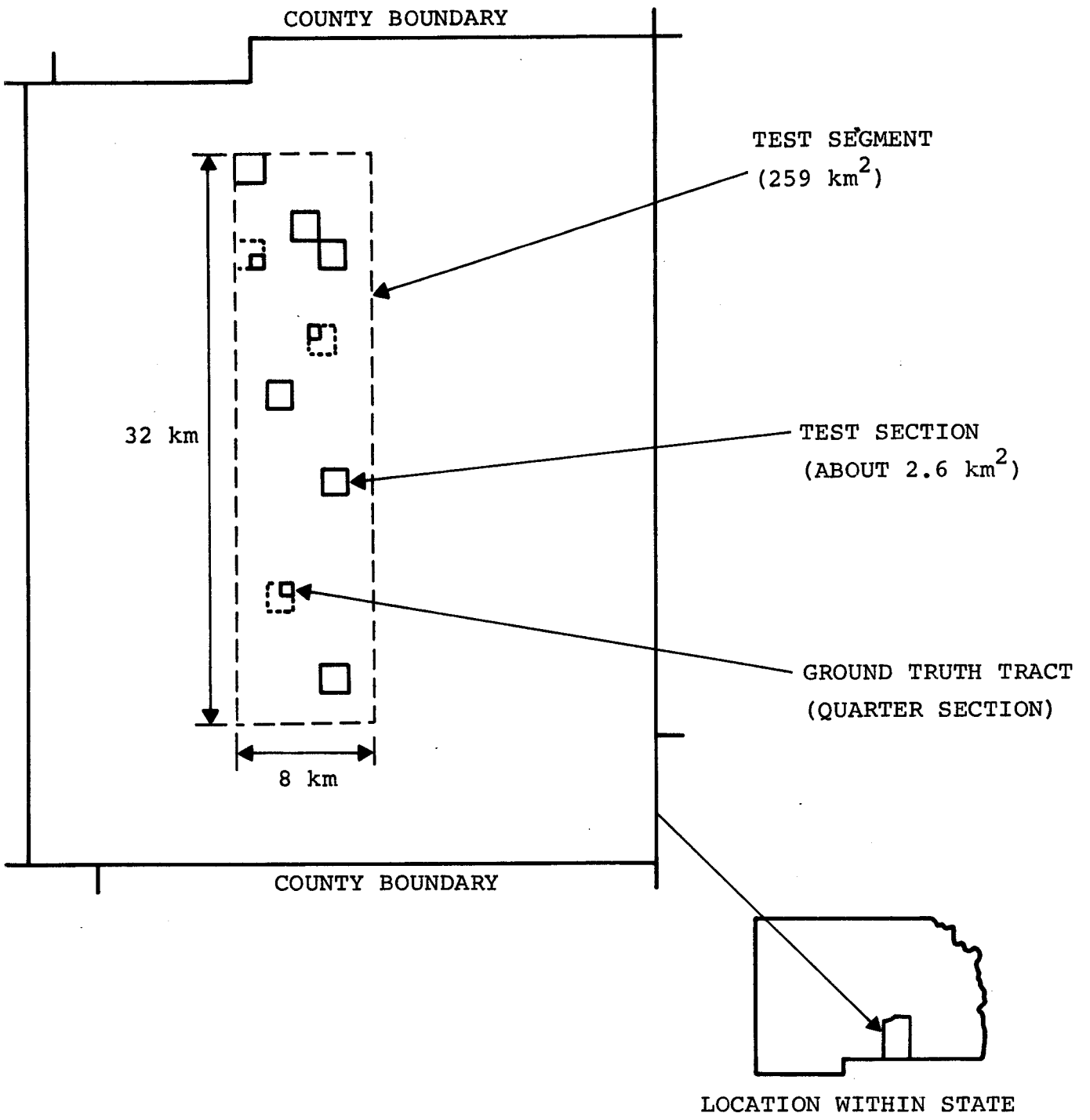

Figure 1.– Relationship of state, county, test segment, section, and ground truth tract boundaries.

TABLE I.— CITARS MISSION PHOTOGRAPHS

Mission number	Roll number	Date	Camera	Focal length, cm	Film	Filter	Approximate altitude, m	Approximate scale
83B[a]	1	6/29-30/73	K-224	15	2443	W-25	4,267	1:28,000
83M[b]	1	7/05-07/73	Zeiss	15	2443	(c)	4,267	1:28,000
83B	2	7/16-18/73	K-224	15	2443	(c)	4,267	1:28,000
83B	3A/3B/3C	8/01-10/73	K-224	15	2443	(c)	4,267	1:28,000
83M	5	8/20-21/73	Zeiss	15	2443	(c)	4,267	1:28,000
83B	4A	8/21/73	K-224	15	2443	(c)	4,267	1:28,000
247[d]	112	8/27/73	RC-8/2	15	2443	510	9,144	1:60,000
	113	8/26-27/73	RC-8/1	15	SO-397	2A+AV		
249[e]	24	8/27/73	RC-8/1	15	2443	Tiffen 15	18,288	1:120,000
	25	8/27/73	RC-8/2	15	SO-397	2A		
83B	5A/5B	9/7,12/73	RC-8	15	2443	15	4,267	1:28,000
83B	6A/6B	9/24/73	K-224	15	2443	15	4,267	1:28,000

[a] Bendix mission.
[b] University of Michigan mission.
[c] Filter not verified.
[d] NASA C-130 mission.
[e] NASA WB-57F mission.

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2.0 PROJECT TASKS

2.1 PRELIMINARY PROJECT PREPARATION TASKS

The activities performed before the crop identification extension phase are described in this section.

2.1.1 Project Planning

Project planning necessitated the following requirements.

2.1.1.1 Interpretation plan.- A draft of the project plan covering the anticipated approach to the assigned tasks was submitted to NASA on August 1, 1973.

2.1.1.2 Map coverage requirements.- Topographic map coverage of the test counties was ordered to support mission planning and operational requirements. U.S. Army Map Services maps with scales of 1:250,000 provided small-scale coverage showing the regional relationships of the test area segments. U.S. Geological Survey maps at the largest scale available (either 1:24,000-scale, 7.5-minute quadrangles or 1:62,500-scale, 15-minute quadrangles) provided detailed coverage within the test area segments.

2.1.1.3 Predicted ERTS-1 coverage determination.- Orbit tracks of the ERTS-1 and boundaries of the anticipated ERTS multispectral scanner coverage were plotted on 1:250,000-scale map sheets which included the test counties.

2.1.1.4 County test segment selection.- Using a selection technique defined by NASA management, the analysts randomly

positioned a 5- by 20-section test area segment within each test county.

2.1.1.5 Test section selection.- Twenty interpretation test sections for each county were randomly selected from the 8- by 32-kilometer test segments, and a quarter of each section was designated for ASCS ground investigation. On August 15, 1973, notification was received from project management that the test sections selected for analysis were not firm. Several days later, a revised list of 23 or 24 sections from each test area segment was delivered. Each section was to be wholly interpreted instead of just the remaining three quarters of each section visited by the ASCS. This change necessitated considerable modifications to the project preparatory data that had already been compiled. The full crew needed 10 working days to make the alterations. The increased section analysis requirements forced milestone revisions in the forthcoming crop identification extension and crop proportions phases of the project.

2.1.1.6 Previous photographic coverage determination.- The ASCS photograph frame numbers covering the test area segment in each county were extracted from the ASCS photograph index map at the request of NASA project management.

2.1.1.7 Ground truth and interpretation section photograph base annotations.- The ASCS ground truth quarter section tracts and the interpretation test sections were annotated on the ASCS photograph index map for the six counties.

2.1.1.8 Preliminary interpreter training.- The photo-interpreters reviewed the available crop calendars and crop signatures on multidate infrared imagery.

2.1.1.9 Base photograph rectification.- High-altitude color infrared transparencies (Mission 249, roll 24, August 27, 1973) were received on September 27, 1973. The frames covering each of the six test area segments were identified, and the segment area in each frame was marked. Black-and-white positive 4-diameter enlargement prints of the segment areas (scale approximately 1:30,000) were ordered from the Photographic Technology Division (PTD).

After receiving the 4-diameter enlargement prints, staff members at the Laboratory for Applications of Remote Sensing (LARS) requested enlargement of the base photographs to a scale of 1:24,000 to simplify comparison with gray maps produced on a line printer from ERTS-1 scanner data. Staff personnel at LARS weighed the time required for rectification versus the observable tilt in the enlargements and requested simple enlargement to the precise scale instead of rectified prints. The CITARS personnel at JSC recomputed scale factors for each frame by standard mensuration techniques and submitted the data through the NASA technical monitor to the PTD.

After receipt of the 1:24,000 prints, LARS personnel found that the distortions inherent in the unrectified enlargements created serious problems in the transfer of data to the line printer gray maps. To correct these distortions, CITARS personnel pulled topographic maps from project files and submitted the maps, photographic data,

and specifications to the personnel of the Mapping Sciences Branch for determination of rectification parameters. Rectifier settings were submitted to PTD with the request for rectified 1:24,000-scale prints of the six CITARS test area segments.

2.1.1.10 Delineation of field boundaries for the crop identification extension phase.- On September 10, 1973, 1:30,000-scale black-and-white unrectified prints were received for the six test area segments. These prints were overlaid with clear acetate, and individual field boundaries for each county test section were interpreted from the prints and annotated on the overlays. This procedure proved to be inefficient and inaccurate. It was inefficient because the scale of the base photographs was changed after the procedure was completed. It was inaccurate because many field boundaries entered as the result of interpreting the single-date black-and-white print required modification during the interpretation of multitemporal color infrared transparencies.

2.1.1.11 Section numbering systems.- The numbering system used to identify the sections in each test area segment was changed during the project. Originally, the township, range, and section numbers of the land survey system were used. This system is currently used by federal and state agencies, but it is inconvenient for computer analysis. The second numbering system assigns the numbers 1 through 100 to the sections in each test area segment. This change was made after the work was in progress; much of the project documentation required modification. Section numbers under the new system are referred to as "CITARS section numbers."

Most of the documentation generated in the image analysis phase of the CITARS project references both systems. Some graphic material, however, depicts only the CITARS section numbering system. Equivalent section numbers for the ground truth and photointerpretation sections are included in the detailed analysis documentation for each county test segment provided in the appendixes.

2.1.2 NASA PTD Film Review

Aerial photographs of the test area segments acquired for this project were reviewed at the NASA PTD after film processing. Individual photographic passes were evaluated for coverage, percentage of cloud cover, film quality, and adequacy of stereoscopic coverage prior to the printing of a working copy of the film from each mission.

2.1.3 Establishment of Project Storage and Retrieval System

2.1.3.1 Imagery.- On receipt of the working copy film from each mission, coverage plots were prepared and keyed to the ASCS county index sheets and 1:250,000-scale map sheets. (Detailed coverage plots were not prepared for the last three missions.) The roll film was then cut and filed by county. Next, a detailed screening of the film was performed, noting the frames covering the interpretation test sections in each county. These frames were then appropriately labeled, cut, and stored in the project files.

2.1.3.2 Ground truth.- Ground observation data from tracts available to the photointerpreters were reviewed, inventoried, and filed in loose-leaf notebooks.

2.1.4 Preliminary CITARS Project Data Dissemination

The preliminary dissemination of CITARS data entailed the following.

2.1.4.1 Dissemination of ground observation tract boundary plots.- No high-altitude photographs suitable for use as base maps were available when LARS and the Environmental Research Institute of Michigan (ERIM) required location data for the ground-observation fields. The best available 1973 photographic coverage was the color infrared imagery from Mission 83M (July 5-7, 1973) which provided nearly complete coverage of all segments at a scale near 1:28,000. Although several frames would be required to transmit the ground investigation data for each test area segment, the decision was made to transmit the field boundaries on contact black-and-white prints from Mission 83M. Coverage from other sources was used only where cloud cover or other problems rendered the primary source unsuitable.

Several steps were required to prepare each frame for distribution. Because time was critical and judged more important than quality of the base photograph, the photographic steps were processed in a tabletop photoprinter that operated in an illuminated room. The procedure for preparing one frame follows: (1) select color infrared frame, (2) print paper negative, (3) print paper positive, (4) annotate in ink the boundaries of quarter-section ground

investigation tracts, field boundaries, and field identifications on the paper positive, (5) print paper negative of annotated print, and (6) print multiple (four or five) positive copies for distribution. This stop-gap procedure was costly (in terms of diverted interpreter manpower resources) and not entirely satisfactory.

When the 1:30,000-scale base photographs prepared from Mission 249 imagery were received, boundaries of the ground-truth quarter sections (but not the individual fields within the ground investigation tracts) and boundaries of the sections selected for photointerpretation were annotated on the base photographs. Four copies of each segment were submitted to NASA project management for dissemination.

2.1.4.2 Initial ground truth dissemination.- The ASCS personnel submitted crop identifications and other ground investigation data to the CITARS personnel at JSC. For the initial distribution of ground truth data, the forms submitted by ASCS personnel were mechanically duplicated for transmission with the photographic prints annotated with field boundaries.

2.1.4.3 Preliminary wheat interpretation.- A special requirement for providing wheat field data in Fayette County by September 11, 1973, was assigned by NASA project management during the assembly of the CITARS project ground truth data packages. The request specified that the crop classification of 10 sections in the Fayette and Shelby County test segments of at least 8 hectares of wheat should be determined through temporal image analysis.

All wheat fields identified in this interpretation were annotated on black-and-white photographic prints and submitted per the request.

This special assignment impacted efforts on the scheduled project data dissemination tasks by approximately 1 man-week.

The confidence levels for these preliminary wheat interpretations are low. At that time, the interpreters were unfamiliar with the test area segments. Harvesting was in progress at the date of the earliest available imagery, and most of the fields had been harvested before the second photographic pass. Complete photographic coverage was not available on the western portion of the test segments, and cloud cover was a constraining factor.

2.1.5 ADP Support

When requested, assistance was provided to ADP personnel in identifying crops on data analysis station (DAS) imagery by comparative analysis to the temporal CITARS photographs. This support was minimal and was integrated into the project planning and the crop identification and proportions phases with no significant impact on other scheduled milestones.

2.2 CROP IDENTIFICATION EXTENSION TASKS

This section discusses the procedures utilized for crop identification extension that were common to the six test area segments.

2.2.1 Preparation of Recording Forms

The initial forms provided for documentation of the crop interpretation results were not adequate for recording temporal signature data. A modified form devised for recording multidate photographic observations was constructed and reproduced. The modified form shortened the time required to record crop signature responses, thereby increasing the overall interpretation rate for each section.

2.2.2 Field Boundary Overlay

The field boundaries annotated on overlays keyed to Mission 249, 1:30,000-scale photographic base (section 2.1.1.10) were checked during the study of temporal changes. In many instances, the field boundaries delineated on the base photographs did not accurately portray the field areas that could be identified during other times of the growing year and had to be modified.

2.2.3 Interpretation

2.2.3.1 Procedures.- The identification/extension process began on October 2, 1973, after receipt of the ninth photographic mission data (acquired during flights on September 7 and 12, 1973).

Drawing from the cut, multidate, color transparencies in the project data files, the image analyst selected a frame from each of the photographic missions that covered the section to be interpreted along with the nearby ground truth quarter sections. The signature responses for ground truth

fields were analyzed to establish the various crop responses on different photographic dates.

A total of 10 photographic missions was conducted over the six CITARS test segments. Normally, only five or six of these were used in the interpretation process. Incomplete coverage of some segments and marginal image quality precluded the use of photographs from all dates for many of the test sections.

Overlays were keyed to the selected cut transparencies so that field boundaries within the section selected for interpretation could be annotated. The field numbers were assigned, starting in the northwest corner and ending in the southeast quarter of each section. Variations to this numbering scheme occurred when the original field boundaries had to be modified. Some fields were subdivided into smaller fields; in other instances, small fields were combined.

The temporal photographs were laid out on a light table. The large surface of the light table allowed the interpreter to have all of the ground truth data, recording forms, and photographs within reach. A table was placed adjacent to each light table for the storage of forms, photographs, and the large-scale photographic base maps.

The information available to the photointerpreter included the ASCS ground truth observations collected at approximately 18-day intervals in each test area segment and the weekly weather and crop bulletins for Indiana and for Illinois. The weekly weather and crop bulletins for

each state, covering the months of July, August, and September, presented generalized data. Crop calendar and crop rotation information for each of the six test area segments was obtained from the ASCS ground truth.

The photointerpreter trained for each segment by comparing the temporal photographs to the ASCS ground observations. The ASCS ground observations (summarized in the appendixes) included data on crop height, stage of maturity, row direction and width, percentage of crop canopy cover, moisture data, stress factors, crop cycle, and homogeneity.

The photointerpreter was requested to delineate all fields within the sections and to identify the crop (wheat, corn, or soybeans). Wheat identification was later deemphasized because most of the wheat had already been harvested at the time of the first photographic mission.

All available photographs were used in the analysis of each field, the crop response and/or field condition for each date of photograph were noted, and field anomalies were recorded by means of diagrams.

The field responses for the date of each photograph were recorded for several entries or until the photointerpreter was familiar with the normal crop signature sequence. This procedure was repeated for each county that was interpreted.

When the analyst had examined a field on each photograph, the crop type was determined and recorded. After the crop type was determined, a percentage of confidence was

recorded based on the analyst's subjective opinion (ranging from 50 to 100 percent) of the accuracy of the identification. A comparative edit between the overlay keyed to the large-scale photographic base and the overlay keyed to a cut, color temporal transparency was performed. Variations in field boundaries and field identification numbers were changed on the photographic base overlay to match the updated temporal overlay. The primary temporal photograph overlay was usually keyed to the transparency taken on Mission 83M (August 20, 1973).

The photographs from the tenth and last mission (September 24 and 27, 1973) were received on October 19, 1973. If the analysis of a county was complete, the interpreter verified the crop interpretations against the photographs; if not, the photographs were incorporated into the normal procedure.

2.2.3.2 Color balance.- The color balance of the infrared film varied drastically from mission to mission, and in several instances, within a single mission. For example, vegetation responses representing live, healthy vegetation appeared red on the photographs of one mission but purple on the photographs of another. Mature corn appeared green in the imagery of one segment but black in another. Some of these color variations were probably due to ground conditions (moisture, canopy cover), and others caused by camera/film conditions. Whether caused by ground, atmospheric, flight, or film response variations, a highly variable color response characterized the crop signatures. The interpreter overcame most of the difficulties caused by variation in color hue through the separate study of crop responses for each date and locality.

2.2.3.3 Temporal evaluation.- The June and early July photographs were valuable for identifying pastures, small grains, and fields for noncrop land uses.

Pastures and small grains were generally live, healthy vegetation (red/pink) compared to the bare soil in recently seeded fields (white, green, and black). Wheat fields (green or red) were mature, and many had been mowed.

On the mid-July photographs, corn and soybean canopies (shades of pink and red) were partially developed, with the corn canopy usually fuller than the soybean canopy. However, corn and soybeans might still resemble bare soil. Small grains may have turned some shade of green indicating maturity or harvest. Often, patterns produced by a mower were visible. Pastures remained a shade of red or pink.

By early August, the corn and soybeans had emerged (except for late planted fields). The corn was usually an olive green shade, and the soybeans were a thin dark red. Small grains were shades of green before harvest; mowing patterns during harvest were common. Some fields were plowed after harvest, producing a bare soil reflectance. Pastures were still red, but a much duller shade than earlier in the season.

The photographs dated August 20 to 27, 1973, provided the greatest separation between corn and soybeans. The corn had matured and was dark green, brown, or black. Soybeans were usually bright red. Row patterns could be detected readily.

On late September photographs, both corn and soybean fields were green (mature). However, the texture of the corn was much coarser than the soybeans, making the two easily distinguishable. The coarse appearance of the corn was probably caused by its height, which caused a shadow mix in the signature return. Pastures and small grains generally appeared bright red, similar to the June imagery.

2.2.3.4 Interpretation edit.- The final interpretation task of the imagery analysis phase was an edit of the crop identifications and field boundaries by the same individual who performed the segment analysis.

2.3 CROP PROPORTIONS TASK

The area of each full-section tract and of each corn, soybean, and wheat field was measured with a digitizer scaled to read area in units of 0.001 inch squared. The percentage of corn and soybeans was calculated for each section. Every section and field was measured three times and the average calculated. Washout areas were measured and subtracted from the average field area. The field and section measurements and the crop percentages for each section were recorded on a summary sheet. (These measurements are available in the appendixes.) All calculations were edited for errors.

2.4 POSTANALYSIS WHEAT PROPORTIONS TASK

After the final compilation of crop identifications and measurements for corn, soybean, and "other" categories, a wheat proportions task for the Shelby and Fayette County test

segments was requested. The ASCS collected wheat ground truth in the original test sections for these two county segments and for 18 additional sections in the Fayette County test segment.

Proportion of wheat was compiled for each section containing an ASCS-identified wheat field. The same compilation techniques were used as for the previous crop proportions task. The wheat proportions task required 80 hours for completion. The wheat proportions tabulations for the two county test segments were delivered to NASA management upon completion. (A tabulation of the wheat and "other" category proportions is included in appendixes B and E.)

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3.0 COUNTY TEST SEGMENT SUMMARIES

Individual interpretations for each of the six county test segments are discussed separately in this section. A comparison of the summary data for these segments shows some broad similarities as well as some differences.

Heavy spring rains were reported for the Indiana/Illinois region of the Corn Belt in 1973. Therefore, the crop observations for a given date and test segment may not be necessarily typical of "normal" years.

3.1 HUNTINGTON COUNTY CROP INTERPRETATION SUMMARY

Photographic coverage, interpretation observations, and average daily interpretation and measurement rates for the Huntington County test segment are discussed in this section. Table II lists the mission photographs used in the interpretation of this segment. (Photographic coverage gaps are also noted.)

Five of eight photographic missions used in the interpretation lacked coverage of one or more test sections. The flight of August 2, 1973, failed to provide data for 14 sections (58 percent of the test segment). This photographic date is normally valuable in the identification of corn. Incomplete coverage is due to both cloud cover and insufficient data acquisition.

Crop interpretations included corn, soybeans, and wheat. Table III gives typical signature responses observed for each crop type on color infrared imagery for individual mission dates.

Temporal responses noted in the Huntington County test segment were for the most part typical and were consistent throughout the growing season. Heavy rains did, on occasion, contribute to localized anomalies largely attributable to the resultant excessively moist soil. Other variations to a lesser extent are attributed to replanting or to the planting of companion crops resulting in atypical responses.

Typical responses for mature crops on key identifying dates are as follows:

Corn (August 20, 1973) - dull, medium red

Soybeans (August 20, 1973) - very bright red

Wheat (July 5, 1973) - green, green and red, or green and brown

Confidence levels for the identification of each crop type varied, largely attributable to the very nature of characteristic responses. Soybeans, for example, exhibit a very bright red, which is almost unique to August 20, 1973, photographs. This being the situation, confidence levels of 95 percent are typical for this crop; and only absolutely certain identification of woods, lakes, and "other" rated higher (100 percent). Corn generally rated 90 percent of less, since under some circumstances it was found to exhibit signatures similar to other crops or signatures not typical of other cornfields. However, this was exceptional; and a high level of confidence in the identification of corn is assured. Wheat ranked lower in confidence, principally because of strong similarities between its signature and those of other small grain varieties.

In addition, emphasis on the identification of wheat has been relatively weak in comparison to the emphasis on corn and soybeans. As a result, there is a lack of previous interpretation work on which to train. Low confidence levels for wheat can be improved considerably with further attention to data acquisition during the early months of the wheat-growing season.

No major problems existed in the interpretation phase, and an average of 1.8 sections per working day was analyzed. The measurements and computations of crop proportions were accomplished at a rate of approximately 3.1 sections per day.

3.2 SHELBY COUNTY CROP INTERPRETATION SUMMARY

Photographic coverage, interpretation observations, and average daily interpretation and measurement rates for the Shelby County test segment are discussed in this section. Table IV lists the mission photographs used in the interpretation of this segment. (Photographic coverage gaps are also noted.)

Only the mission of September 24, 1973, had coverage over all test sections. The mission of July 5, 1973, lacked coverage over 13 sections (54 percent of the test segment). This photographic date is normally valuable in the identification of wheat. Incomplete coverage is due to both cloud cover and insufficient data acquisition.

Crop interpretations included corn, soybeans, and wheat. Table V provides typical signature responses observed for each crop type on color infrared imagery for individual mission dates.

Relatively few signature variations were noted in the analysis, each crop maintaining consistent characteristic temporal responses during the growing season. Minor anomalies and a few major inconsistencies are largely attributable to wet soil caused by heavy rainfall and, in a few cases, to the possibility of replanting.

Typical responses for mature crops on key identifying dates are as follows:

Corn (August 20, 1973, photographs) - dull, medium red

Soybeans (August 20, 1973, photographs) - very bright red

Wheat (July 5, 1973, photographs) - green, green and red, or green and brown

Because of the characteristic responses of each crop type, confidence levels varied accordingly. Highest confidence was for soybeans, resulting from an almost unique signature on August 20, 1973, imagery. It was felt that chances of an interpretation error were lowest for this crop, resulting in a typical confidence level of 95 percent. Only absolutely certain identification of houses, lakes, woods, and other nonfarm categories rated higher (100-percent confidence levels). Typical cornfields generally ranked 90 percent or less since, under certain conditions, corn was found to exhibit signatures similar to other crops, or a signature not typical of other cornfields. However, these incidences were exceptional;

and a high level of confidence in corn identification is assured. Wheat ranked lower overall in confidence because of a lack of photographic coverage available for interpretation during the wheat-growing season. Table IV clearly shows the absence of June 29, 1973, and July 5, 1973, imagery, the key identification dates for wheat. A second reason for low confidence in the identification of wheat is the strong similarity between its typical signature and those of other small grain varieties. Perhaps most important, training on identification of wheat has not been emphasized to the extent that corn and soybeans have, resulting in an on-the-job-training mode for this crop. It is felt that the confidence levels of 50 to 80 percent could be improved considerably early in the growing season with the aid of quality imagery.

No major problems in accomplishing the interpretation task were encountered, and an average rate of one section per working day was analyzed. The crop proportions task was accomplished at a rate of approximately 3.2 sections per day, including measurements and computations.

3.3 WHITE COUNTY CROP INTERPRETATION SUMMARY

Photographic coverage, interpretation observations, and average daily interpretation and measurement rates for the White County test segment are discussed in this section. Table VI lists the mission photographs used in the interpretation of this segment. (Photographic coverage gaps are also noted.)

Photographs from Missions 83B (August 21, 1973) and 247 (August 27, 1973) were not used in the interpretation task because the crop responses from them were similar to those on Mission 83M (August 20, 1973). Mission 249 photographs (August 27, 1973) were used primarily for locating the test sections and for identifying the ASCS ground observation fields. Cloud coverage on Mission 83B photographs (August 1, 1973) precluded the use of this mission's photographs for interpretation in some test sections.

Corn and soybeans were easily differentiated from the other field crops. Corn responded with a red signature on all mission photographs until Mission 83M (August 20, 1973), when the signature changed to a rust brown. On Mission 83B photographs (September 12, 1973) the signature was a red and green mix. The best photographic date for identifying corn and for separating corn from other crops was August 20, 1973 (Mission 83M). Ground truth quarter section 46 had two cornfields which had a normal response on all of the multidate photographs.

Soybeans were easily separated from corn and small grains because the soybeans had a characteristic bright red signature on Missions 83M (August 20, 1973) and 83B (September 12, 1973), which was different from the other field crops. On the last mission, 83B (September 24, 1973), the soybeans were predominantly green but with some red. Prebloom soybeans planted late in the season had a signature and pattern similar to a plowed field containing weeds. When the soybeans reached the blooming stage, they were identifiable. Ground truth quarter section 60 had four soybean fields with a normal soybean response.

Wheat was identified with photographs from Missions 83B (June 29, 1973) and 83M (July 5, 1973). The wheat signature before harvest was aqua green or a red-green mix. Wheat identifications were incomplete because the majority of the wheat was harvested before the first photographic mission (83B) on June 29, 1973. CITARS section 14, field 22, is a ground truth example of wheat.

Small grains and legumes were easily differentiated from corn and soybeans. The only exception to this was late-planted soybean fields in the prebloom stage, which had a pattern and signature similar to plowed, weedy fields.

Permanent pastures and woods were easily identified. When the pastures were mowed and baled, the fields were classified as hayfields. The signature for woods and the permanent pastures varied from light red to bright red.

Urban land use areas and farmsteads were identified without difficulty.

Table VII gives a summary of the normal signatures of corn, soybeans, and wheat for each date of photographs interpreted. The signature response and the corresponding ASCS ground observations are listed for each mission used in the crop interpretation task. It should be noted that wide variations occur in the crop maturity stages, crop height, and canopy cover. These wide variations increased the difficulty of the photointerpretation task.

The White County test segment photographs could be used in future image interpretation training programs. This segment is considered good for training for several reasons.

The responses for corn, soybeans, pastures, woods, and urban land uses are easy to identify and are uniform throughout a single mission. The photographic coverage is complete on six of the missions, except for test section 35 on the August 20, 1973, photographs. The quality of the photographs is generally very good, and the scale for all missions does not vary significantly. The fields are quite large, and boundaries between them are easily distinguished. The crop calendar was uniform and did not vary within the test segment.

The interpretation of White County required 10 working days, and the average number of sections interpreted each day was 2.3. The crop proportions task required 8 working days for an average of 2.9 sections measured each day.

3.4 LIVINGSTON COUNTY CROP INTERPRETATION SUMMARY

Photographic coverage, interpretation observations, and average daily interpretation and measurement rates for the Livingston County test segment are discussed in this section. Table VIII lists the mission photographs used in the interpretation of this segment. (Photographic coverage gaps are also noted.)

Four of the eight photographic missions used in the interpretation lacked coverage of six or more test sections.

Photographic gaps for all but two of the test sections listed were caused by inadequate coverage on the western side of the test segment. CITARS sections 61 and 82 were obscured by cumulus clouds on the June 29, 1973, imagery.

Topographically, the CITARS segment in Livingston County is a low-relief plain developed on Pleistocene glacial till. The terrain appears mottled in many areas; undulations may be viewed stereoscopically. Drowned spots in the farm fields were frequently observed in the lower areas.

Table IX provides the typical corn and soybean signature responses on color infrared imagery for each mission date. Variations in crop signatures from those described in table IX, in most instances, resulted from drowned fields and replanting. The most exceptional appearance is for replanted soybeans on September 12, 1973, infrared imagery in which normal plant date soybeans are light green or purple and the replanted soybeans are bright red. Soybean replants were sometimes noted in previously drowned areas of cornfields. For example, CITARS section 66 contained fields that were relatively difficult to interpret because of drowned spots and thin canopies. Field 20, interpreted as corn, and field 24, interpreted as soybeans, were assigned only 70 percent confidence values. An example of a drowned area extending across a corn and soybean field occurred in CITARS section 82. In this instance, the complete drowned area was replanted with soybeans resulting in normal plant date soybeans and late plant date soybeans. The late plant soybeans included several hectares of the original cornfield acreage (field 20). Drowned spots presented a problem in the crop proportions task because these areas had to be subtracted from the total crop area for obtaining accurate percentage values.

There was no requirement for the interpretation of wheat fields in Livingston County.

The crop identification extension phase for this segment required 12 working days at an interpretation rate of two test sections per day. Detailed signature response recordings were made for anomalous fields only; therefore, the interpretation rate was relatively high.

The crop proportions task required 7 work days, an average of 3.43 sections measured, including the necessary computations, per work day.

3.5 FAYETTE COUNTY CROP INTERPRETATION SUMMARY

Photographic coverage, interpretation observations, and average daily interpretation and measurement rates for the Fayette County test segment are discussed in this section. Table X lists the mission photographs used in the interpretation of this segment. (Photographic coverage gaps are also noted.)

Mission 83B (June 29, 1973) covered only the eastern portion of the test segment. As a result, the first photographic coverage for the 15 test sections in the western portion was Mission 83M (July 5, 1973). Mission 83B (August 1, 1973) had approximately 50-percent cloud cover, and photographs from this mission could be used for only a few of the sections selected for crop identification.

Missions 83B (August 21, 1973) and 249 (August 27, 1973) were not used in the interpretation process because the crop signatures were almost identical to those on Mission 83M (August 20, 1973). In addition, part of Mission 83B was out of focus, rendering that portion unusable for interpretation.

Mission 247, which was flown on August 27, 1973, was used in the analysis of several sections although the signatures from this imagery were similar to Mission 83M (August 20, 1973). It was used because the identification of several fields was uncertain and because the examination of additional imagery became necessary. Corn, soybeans, and wheat (when standing) were easily identified by the temporal interpretation method. When the field size was greater than 2 hectares, no confusion occurred between the small grains or legumes and the three major crops (corn, soybeans, and wheat). Very small fields were difficult to interpret, and the confidence level was generally lower on these fields.

The identification of wheat was accomplished with the photographs obtained during Missions 83B (June 29, 1973) and 83M (July 5, 1973). Before harvest, wheat responded on both of these missions as red, bright green, or aqua green. The reason for the differences in color responses is not known.

The initial crop proportions task for this test segment included corn, soybeans, and the "other" categories. The wheat proportions measurements were not computed at this time because NASA project management decided that the photointerpreter did not have sufficient multidate photographs to identify wheat fields accurately. On January 31, 1974, a special task was assigned to provide wheat proportion values on wheat fields identified by ASCS ground observers. Only two categories are in this second proportions task: wheat and "other."

The percentage values for these two tasks must be used separately, and the values should not be combined because some wheat fields, after being harvested, were sown to soybeans or to "other" crops. Consequently, some fields were measured twice; once as a wheat field and then as a soybean field or some "other" field crop. The result of combining the percentage values from the first and second proportions tasks may be a percentage total in excess of 100 percent.

The wheat identifications were incomplete in Fayette County because of the lateness of the first photographic mission. This photographic mission occurred on June 29, 1973, and by this date the majority of the wheat had been harvested. All wheat fields may have been identified if sequential photographs had been acquired over a period of several weeks before the harvesting period.

Corn was easily differentiated from the other field crops because the field signature was red on all missions except on Missions 83B (September 12, 1973) and 83B (September 24, 1973), in which the field signatures were green. The color response on Mission 83M (August 20, 1973) was rust red, and this provided the most differentiation between corn and the other crops.

Soybeans, like corn, were readily identified; and the key mission for identification was Mission 83M (August 20, 1973). The color response on this imagery was a bright red.

Small grains (oats and rye) and the legumes (alfalfa and clover) were identified as being either hays or small grains. No attempt was made to differentiate between the two crop types.

Permanent pastures and woods were easily identified because of their unique appearance (texture, color, and pattern). Pastures which were mowed and baled were classified as hayfields.

Urban land uses and farmsteads were accurately identified in all of the test sections.

The crop calendar within Fayette County varied by 1 to 2 weeks because the fields were flooded in June and early July. In five of the inundated test sections, the soybean seeding was approximately 2 weeks late, and the cornfields were either a week late in maturing or washouts occurred in the field. Both of these conditions occurred in some fields.

Table XI gives a summary of the normal signatures for corn, soybeans, and wheat on each mission used for interpretation. The corresponding ground truth for these missions is listed along with the normal crop signatures. The wide variances in the crop maturity stages, crop heights, and canopy covers increased the difficulty of the photointerpretation task.

The interpretation of Fayette County required 22.5 working days, or an average of 1.1 sections were interpreted each working day. The crop proportions task required 7 working days for an average of 3.5 sections measured each day.

3.6 LEE COUNTY CROP INTERPRETATION SUMMARY

Photographic coverage, interpretation observations, and average daily interpretation and measurement rates for the

Lee County test segment are discussed in this section. Table XII lists the mission photographs used in the interpretation of this segment. (Photographic coverage gaps are also noted.)

Three of eight photographic missions used in the interpretation lacked coverage of one or more test sections. Photographic coverage gaps for sections located along the western side of the test segment were caused by operational flight parameters. CITARS sections 6, 11, 30, 50, 51, and 53 were obscured by clouds on the July 16, 1973, photographs. Section 38 was cloud covered on the June 29, 1973, imagery.

Table XIII provides the typical corn and soybean signature responses on color infrared imagery for each mission date. Variations in crop signatures from those described in the table may be the result of late planting, drowned areas, or insect infestation. Lee County ASCS ground truth reports for August 22, 1973, commented on insect damage to some of the corn and soybean fields. Certain fields within nine of the CITARS sections in Lee County were difficult to interpret. These sections include the following:

1. CITARS section 18 — Fields 4, 5, 7B, 7C, 7E, 9, 10, and 31 were identified as idle or pasture (other) but are possible soybean failures. Section 18 is located in the head water drainage of the Green River and may have received excessive amounts of water. Insect damage and hail damage are also possible confusion factors.

2. CITARS sections 30, 50, 51, and 91 — A military storage area occupies portions of these sections. Crops had

been planted within the perimeter of the storage area, usually between what appeared to be bunkers. Many of these fields had irregular shapes, were relatively small, and had incomplete canopy cover, making crop interpretation difficult.

3. CITARS section 38 – This section is adjacent to section 18; and fields 4, 5, and 26 are similar to those fields previously described under the CITARS section 18 comments.

4. CITARS section 41 – A loop of the Rock River and Chamberlain Creek transgresses CITARS section 41, indicating that a relatively large amount of moisture or surface water may have been present during crop development. All of the fields in this section were interpreted with a high confidence level, but only after all of the temporal photographs had been thoroughly examined under optimum magnification.

5. CITARS section 76 – Several fields within this section had unusual signature response, resulting in a lower interpretation confidence. Fields 2B, 6, 8, 17, and 18 were identified as idle but may have been soybean failures. Similarly, fields 7 and 20 were identified as soybeans (60 to 70 percent confidence) but were conceivably volunteer beans or weeds.

6. CITARS section 83 – This section lies between, and in very close proximity to, Franklin and Chamberlain Creeks. Fields 1A, 1C, 15, 16B, and 18 were interpreted as "other", but with only a 70-percent confidence level.

Fields 23A, 23B, 24B, 27, and 28 were interpreted as being soybeans with an 80-percent confidence level. Unusual signature responses may have been caused by an influence of the two creeks.

The interpretation of wheat fields in Lee County was not required.

The identification extension phase for Lee County required 19 work days, an interpretation rate of 1.26 test sections per day. The crop proportions task required 11 work days, an average of 2.18 sections measured, including the necessary computations, per work day.

TABLE II.— PHOTOGRAPHIC MISSIONS USED IN THE INTERPRETATION OF CROP SIGNATURES OF HUNTINGTON COUNTY, INDIANA

Mission	Date	Sections with partial or no photographic coverage
83B	6/29/73	16, 40, 59
83M	7/05/73	27
83B	7/16/73	2, 27, 88
83B	8/02, 16/73	2, 14, 15, 16, 27, 29, 40, 42, 47, 59, 63, 64, 67, 86
83M	8/20/73	
249	8/27/73	
83B	9/12/73	47
83B	9/24/73	

TABLE III.— HUNTINGTON COUNTY TEST SEGMENT CROP RESPONSES ON COLOR INFRARED PHOTOGRAPHS WITH CORRESPONDING GROUND TRUTH

Mission/ ground truth	Date	Corn	Soybeans	Wheat
ASCS	6/08-09/73	Pretasseled 5 to 20 cm high 0% to 20% cover	Newly seeded to prebloom 5 to 30 cm high Bare soil or freshly cultivated	Headed 91 cm high 100% cover
83B	6/29/73	Thin light red or bare soil	Bare soil	Green, red with green, or brown with green
83M	7/05/73	Light red to red	Bare soil or very thin red	Green, red with green, or brown with green
ASCS	6/26-28/73	Pretasseled 56 to 183 cm high 40% to 80% cover	Prebloom to bloom 5 to 46 cm high 10% to 40% cover	Turning yellow or harvested Stubble to 91 cm 0% to 100% cover
83B	7/16/73	Thin red to bright red	Bare soil to thin red	Bare soil to brown or gray
ASCS	7/15-16/73	Pretasseled 91 to 213 cm high 70% to 100% cover	Prebloom to bloom 30 to 61 cm high 50% to 80% cover	Bare soil or stubble
83B	8/02-16/73	Green or green with red	Red to bright red	Bare soil to brown or gray
ASCS	8/02-03/73	Pretasseled to tasseled 183 to 244 cm high 100% cover	Blooming to early pod set 41 to 91 cm high 90% to 100% cover	Bare soil or stubble
83M	8/20/73	Dull red to red	Very bright red	Bare soil to brown or gray
ASCS	8/20-22/73	Tasseled 213 to 244 cm high 100% cover	Blooming to late pod set 76 to 91 cm high 100% cover	Bare soil, stubble, or other crops
249	8/27/73	Dull red	Bright red	Bare soil to gray
ASCS	None	Tasseled or mature	Majority in late pod set	Idle or other crops
83B	9/12/73	Dull red to gray	Bare soil to bright red	Bare soil to gray
ASCS	9/08/73	Tasseled or mature 213 to 244 cm high 100% cover	Pod set to mature 76 to 102 cm high 0% to 100% cover	Idle or other crops

TABLE IV.— PHOTOGRAPHIC MISSIONS USED IN THE INTERPRETATION OF CROP SIGNATURES OF SHELBY COUNTY, INDIANA

Mission	Date	Sections with partial or no photographic coverage
83B	6/29/73	38, 47, 62, 66, 68, 73, 77, 80, 84, 92, 96
83M	7/05/73	4, 13, 20, 23, 24, 25, 27, 28, 34, 35, 38, 40, 92
83B	7/16/73	4, 13, 68
83B	8/02, 16/73	4, 25, 84
83M	8/20/73	28, 47
249	8/27/73	73
83B	9/12/73	84
83B	9/24/73	

TABLE V.— SHELBY COUNTY TEST SEGMENT CROP RESPONSES ON COLOR INFRARED PHOTOGRAPHS WITH CORRESPONDING GROUND TRUTH

Mission/ ground truth	Date	Corn	Soybeans	Wheat
ASCS	6/09/73	Pretasseled 15 to 30 cm high 5% to 20% cover	Newly seeded to prebloom 5 to 10 cm high 0% to 5% cover	Headed 76 to 91 cm high 80% to 100% cover
83B	6/29/73	Bare soil to thin red	Bare soil or very thin pink	Green or red with green
83M	7/05/73	Bare soil to light red	Bare soil to thin red	Green, red with green, or brown with green
ASCS	6/26/73	Pretasseled 61 to 122 cm high 5% to 20% cover	Prebloom 8 to 30 cm high 0% to 5% cover	Mature 91 cm high 80% to 100% cover
83B	7/16/73	Light red to red	Thin red to red	Bare soil or gray
ASCS	7/14-16/73	Pretasseled to tasseled 61 to 213 cm high 50% to 100% cover	Prebloom to bloom 5 to 51 cm high 5% to 80% cover	Harvested, stubble, or other crops
83B	8/02-16/73	Green or green with red	Red to bright red	Bare soil or gray
ASCS	8/01-02/73	Tasseled 91 to 274 cm high 50% to 100% cover	Prebloom to early pod set 15 to 91 cm high 5% to 100% cover	Bare soil, stubble, or other crops
83M	8/20/73	Dull red to red	Very bright red	Bare soil or gray
ASCS	8/20-21/73	Tasseled 91 to 274 cm high 50% to 100% cover	Prebloom to late pod set 20 to 91 cm high 5% to 100% cover	Bare soil, stubble, or other crops
249	8/27/73	Dull red to gray	Bright red	Mostly gray
ASCS	None	Tasseled or mature	Pod set to late pod set	Bare soil, stubble, or other crops
83B	9/12/73	Dull red to gray	Bare soil to bright red	Gray
ASCS	9/06-07/73	Tasseled 122 to 274 cm high 80% to 100% cover	Pod set to mature 46 to 91 cm high 80% to 100% cover	Bare soil, stubble, or other crops

TABLE VI.— PHOTOGRAPHIC MISSIONS USED IN THE INTERPRETATION OF CROP SIGNATURES OF WHITE COUNTY, INDIANA

Mission	Date	Sections with partial or no photographic coverage
83B	6/29/73	
83M	7/05/73	
83B	7/16/73	1, 9, 19, 24, 30, 33, 35, 46, 50, 53, 73, 75, 91, 94, 95, 96, 99
83B	8/01/73	1, 9, 19, 21, 24, 30, 33, 35, 46, 50, 53, 73, 75, 87, 88, 91, 94, 95, 96, 99
83M	8/20/73	35
249	8/27/73	
83B	9/12/73	
83B	9/24/73	

TABLE VII.— WHITE COUNTY TEST SEGMENT CROP RESPONSES ON COLOR INFRARED PHOTOGRAPHS WITH CORRESPONDING GROUND TRUTH

Mission/ ground truth	Date	Corn	Soybeans	Wheat
83B	6/29/73	Red or light red	White	Aqua green or red-green mixture
ASCS	6/27-28/73	Pretasseled 15 to 91 cm high 0% to 100% cover Moist	Bare soil or prebloom 0 to 30 cm high 0% to 80% cover Moist	Mature or harvested 91 cm high 80% to 100% cover
83M	7/05/73	Red or light red	White or blue with red tint	Bright green, white, or light red
ASCS	7/05/73	Pretasseled or tasseled (no ground truth)	Prebloom 15 to 30 cm high 0% to 50% cover	Mature or harvested
83B	7/16/73	Red or purple	White with red or purple tint	
ASCS	7/15-16/73	Pretasseled or tasseled 30 to 244 cm high 50% to 100% cover	Prebloom or blooming 30 to 46 cm high 20% to 100% cover	Harvested
83B	8/01/73	Red	Red	
ASCS	8/02-03/73	Pretasseled or tasseled 91 to 274 cm high 80% to 100% cover Moist	Prebloom or early pod set 30 to 91 cm high 20% to 100% cover Moist to wet	Clover or grass normally follow the harvest
83M	8/20/73	Rust red	Bright red	
ASCS	8/20-21/73	Tasseled 213 to 274 cm high 80% to 100% cover	Early to late pod set 61 to 107 cm high 50% to 100% cover	Not applicable
249	8/27/73	Red	Red	
ASCS	None	Tasseled or mature	Late pod set	Not applicable
83B	9/12/73	Red and/or green	Bright red	
ASCS	9/07/73	Mature 229 to 274 cm high 80% to 100% cover	Late pod set and turning yellow, leaves dropping 91 to 107 cm high 80% to 100% cover	Not applicable
83B	9/24/73	Green	Predominantly green with some red	
ASCS	9/25/73	Mature 229 to 274 cm high 80% to 100% cover	Mature, turning yellow with leaves dropping, or harvested 91 to 107 cm high 80% to 100% cover	Not applicable

TABLE VIII.— PHOTOGRAPHIC MISSIONS USED IN THE INTERPRETATION OF CROP SIGNATURES OF LIVINGSTON COUNTY, ILLINOIS

Mission	Date	Sections with partial or no photographic coverage
83B	6/29/73	1, 5, 6, 9, 11, 12, 13, 16, 17, 19, 23, 61, 82
83M	7/05/73	5, 6, 9, 16, 17, 19
83B	7/16/73	1, 5, 9, 11, 12, 13, 16, 17, 19
83B	8/01/73	1, 5, 6, 9, 11, 13, 16, 17, 19
83M	8/20/73	
249	8/27/73	
83B	9/12/73	
83B	9/24/73	

TABLE IX.— LIVINGSTON COUNTY TEST SEGMENT CROP RESPONSES ON COLOR INFRARED PHOTOGRAPHS WITH CORRESPONDING GROUND TRUTH

Mission/ ground truth	Date	Corn	Soybeans
83B	6/29/73	Blue with white to thin red	Bare soil to thin pink
ASCS	6/29/73	Pretasseled 30 to 86 cm high 5% to 50% cover Moist	Prebloom 0 to 30 cm high 0% to 5% cover Moist
83M	7/05/73	Thin red to red	Light green to thin pink
None		Pretasseled or tasseled	Soil response to prebloom
83B	7/16/73	Thin purple to purple	Light blue to thin purple
ASCS	7/17/73	Pretasseled or tasseled 102 to 203 cm high 80% to 100% cover Dry	Prebloom or blooming 5 to 61 cm high 0% to 5% cover Dry
83B	8/01/73	Olive green	Light green to thin red
ASCS	8/06/73	Tasseled 203 cm high 80% to 100% cover Moist	Blooming or early pod set 20 to 61 cm high 5% to 100% cover Moist
83M	8/20/73	Dark red to gray	Red
None		Tasseled	Early pod set
249	8/27/73	Black and red	Bright red
ASCS	8/29/73	Tasseled or mature 203 to 229 cm high 80% to 100% cover Dry	Early pod set to late pod set 51 to 91 cm high 20% to 100% cover Dry
83B	9/12/73	Blue to green	Light green to red
ASCS	9/09/73	Tasseled or mature 203 to 229 cm high 80% to 100% cover Moist	Late pod set or turning yellow, leaves dropping 51 to 91 cm high 50% to 100% cover Moist
83B	9/24/73	Green	Green
ASCS	9/27/73	Mature or harvested 203 to 229 cm high 80% to 100% cover Moist	Mature 51 to 91 cm high 50% to 100% cover Moist, harvest started

TABLE X.- PHOTOGRAPHIC MISSIONS USED IN THE INTERPRETATION OF CROP SIGNATURES OF FAYETTE COUNTY, ILLINOIS

Mission	Date	Section with partial or no photographic coverage
83B	6/29/73	2, 10, 11, 15, 16, 17, 19, 20, 26, 29, 33, 34, 35, 36, 39, 44
83M	7/05/73	69
83B	7/16/73	2, 10, 11, 15, 16, 17, 19, 20
83B	8/01/73	2, 10, 11, 15, 16, 19, 33, 34, 35, 36
83M	8/20/73	
247	8/27/73	
83B	9/07/73	
83B	9/24/73	

TABLE XI.— FAYETTE COUNTY TEST SEGMENT CROP RESPONSES ON COLOR INFRARED PHOTOGRAPHS WITH CORRESPONDING GROUND TRUTH

Mission/ ground truth	Date	Corn	Soybeans	Wheat
83B	6/29/73	Light red (mottled appearance)	White	Green with some pink or red
ASCS	6/28-29/73	Pretasseled 10 to 127 cm high 0% to 100% cover Wet	Prebloom 0 to 30 cm high 0% to 5% cover Wet	Mature or harvested Stubble to 91 cm high 80% to 100% cover Wet
83M	7/05/73	Red (slightly mottled appearance)	White	Green and red mixture
ASCS	None	Pretasseled or tasseled	Soil response to prebloom	Mature or harvested (stubble)
83B	7/16/73	Red or purple	White with red or purple tint	Red and blue
ASCS	7/16-17/73	Pretasseled or tasseled 61 to 213 cm high 20% to 100% cover Dry	Prebloom or blooming 8 to 61 cm high 0% to 100% cover Dry	Harvested, then wheat stubble, clover (blooming), planted to beans or grass and weeds
83B	8/01/73	Rust brown, red, or purple	Light red to bright red	
ASCS	8/03-04/73	Pretasseled or tasseled 122 to 274 cm high 50% to 100% cover Moist, some water damage	Prebloom to early pod set 15 to 91 cm high 0% to 100% cover Moist and wet, drowned spots	Not applicable
83M	8/20/73	Rust brown or red	Bright red, red, or light red	Not applicable
ASCS	8/21/73	Tasseled 152 to 274 cm high 50% to 100% cover Dry	Prebloom to late pod set 15 to 122 cm high 20% to 100% cover Dry	
247	8/27/73	Light red to red	Light red to red	
ASCS	None	Tasseled or mature	Majority in early pod set	Not applicable
83B	9/12/73	Red and green	Red and green	
ASCS	9/07-08/73	Tasseled or mature 168 to 274 cm high 80% to 100% cover Dry	Early pod set or turning yellow, leaves dropping 46 to 102 cm high 50% to 100% cover Dry and moist	Not applicable
83B	9/24/73	Green Mature	Green Mature or harvested	Not applicable

TABLE XII.— PHOTOGRAPHIC MISSIONS USED IN THE INTERPRETATION OF CROP SIGNATURES OF LEE COUNTY, ILLINOIS

Mission	Date	Sections with partial or no photographic coverage
83B	6/29/73	5, 6, 11, 18, 23, 36, 38, 39, 41, 45, 46, 76
83M	7/05/73	18
83B	7/16/73	6, 11, 30, 50, 51, 53
83B	8/01/73	
83M	8/20/73	
249	8/27/73	
83B	9/12/73	
83B	9/24/73	

TABLE XIII.— LEE COUNTY TEST SEGMENT CROP RESPONSES ON COLOR INFRARED PHOTOGRAPHS WITH CORRESPONDING GROUND TRUTH

Mission/ ground truth	Date	Corn	Soybeans
83B	6/29/73	Bare soil to blue, thin pink	Bare soil to blue
ASCS	6/29/73	Pretasseled 15 to 76 cm high 0% to 50% cover	Prebloom 3 to 15 cm high 0% to 50% cover
83M	7/05/73	Green, thin red, red	Green, thin red
None		Pretasseled	Prebloom
83B	7/16/73	Thin purple on blue, purple	Blue to thin purple
ASCS	7/18/73	Pretasseled 61 to 198 cm high 20% to 100% cover	Prebloom 15 to 46 cm high 0% to 20% cover
83M	8/20/73	Red with black	Thin red to bright red
ASCS	8/22/73	Tasseled 229 to 259 cm high 80% to 100% cover	Late pod set 30 to 107 cm high 5% to 100% cover Some insect damage
249	8/27/73	Black with red, gray	Thin red to bright red
None			Late pod set
83B	9/12/73	Gray green	Pink, red
ASCS	9/10/73	Mature 229 to 259 cm high 90% to 100% cover	Late pod set turning yellow 30 to 91 cm high 20% to 100% cover
83B	9/24/73	Green	Green
ASCS	9/28/73	Mature 229 to 259 cm high 90% to 100% cover Some corn being chopped for silage	Turning yellow, leaves dropping 91 to 107 cm high 20% to 100% cover

4.0 RECOMMENDATIONS

4.1 PROJECT PLANNING PHASE

Photographic coverage should be acquired commencing in early March rather than in late June at general latitude ranges and climatic conditions similar to those that existed for the CITARS test areas.

If at all possible, existing high-altitude photographs should be rectified and enlarged for use as photographic base maps. This would eliminate delays early in the program caused by the requirement for current imagery (for printing of individual black-and-white frames utilizing the photographic printing equipment) for timely dissemination of data requiring a photographic base.

It is generally felt that imagery of a higher quality than that typical of the K-224 camera system is desirable. Imagery from the Zeiss camera system used in the project met all requirements of quality for the crop analysis task. Vignetting and underexposure were consistent problems with K-224 data; and while these did not make the imagery unusable, they did change typical crop signatures sufficiently to be inconvenient to the interpreter. Partially as a result of the overall superiority of the imagery, the missions flying the Zeiss camera system became key mission dates for crop identification.

Utilization of color prints might be considered as an alternative to the use of transparencies. Several advantages to this approach, taken together, may offer a considerable

savings in time and a reduction in the inconvenience inherent in the handling of cut film.

Because absolute resolution is not a major factor in crop analysis, the traditional advantages of transparencies in this respect are of little consequence to the total result. It is felt that minimal degradation would be acceptable in exchange for the great advantages offered by color prints in data handling. Some specific disadvantages of using cut film that became apparent during the course of the project are the following:

1. Equipment such as light tables, reels, optics, and gloves is needed for viewing the data.

2. Cut film is difficult to handle, label, reidentify, and store.

3. Data retrieval systems are complicated by special handling needs, and upright filling is impractical.

4. Data being analyzed had to be taped to prevent curling.

5. Unnecessary eye fatigue and general inconvenience are associated with the paraphernalia required to identify, index, view, and analyze data because of dictated working conditions.

6. Excessive amounts of time were required to set up and dismantle the sections under analysis using cut film.

Provision for adequate working space, equipment, and storage facilities should be made before a project is begun. A major move to a new work area should not be necessary after a project commences.

4.2 CROP IDENTIFICATION EXTENSION PHASE

Complete crop calendar data should be provided for the major crop types occurring in the region of interest. ASCS personnel might provide a synoptic briefing of the anticipated agricultural activities by county or region directed to the photointerpreter's perspective. This briefing should include color slides and aerial photographs and should be designed to impart a comprehensive understanding of the conditions and anomalies that may be encountered in areas to be analyzed.

On future projects, duplicate imagery should be put into open file for the use of interested parties other than the Image Analysis Team. This would preserve the interpreter's indexed copies for exclusive use in the photographic analysis task and should reduce the incidence of misplaced or lost imagery. These occurrences created a minor problem in the course of the initial project.

Stereoscopic techniques did not significantly aid in crop identification of individual fields at the photographic scales utilized. Stereoanalysis is not recommended for extensive crop interpretations similar to those in this effort.

Field boundaries should not be delineated, and field identification numbers should not be assigned before the temporal interpretations have been initiated. Field boundary determinations derived from single-date photographs were not reliable.

A field boundary overlay with field number assignments should be prepared for a representative frame of the temporal photograph set for each test section. This overlay should be considered the master when transferring boundary delineations to other project photographic base materials.

The crop response for each date of photography should be recorded for a typical soybean field, a typical cornfield, and "other" per test section. It is considered unnecessarily time consuming to describe every field for every photographic date in a given section, since much of the data recorded are repetitious. Typical responses should be recorded for only one field to establish trends. Of course, anomalous responses should always be documented.

Establishment of a standard set of abbreviations, symbols, and acronyms to be used for documentation of photographically derived data is recommended.

4.3 CROP PROPORTIONS PHASE

It is recommended that washout areas should not be subtracted from field measurements and that the entire crop proportions task should be assigned to technician-level personnel. If washout areas should be included, establishment of a brief training session for technicians on the criteria for washout classification would be necessary.

5.0 SUMMARY

Figure 2 shows the approximate completion milestones for the project preparation, crop interpretation, and crop proportions tasks.

Table XIV provides a more detailed listing of project milestones.

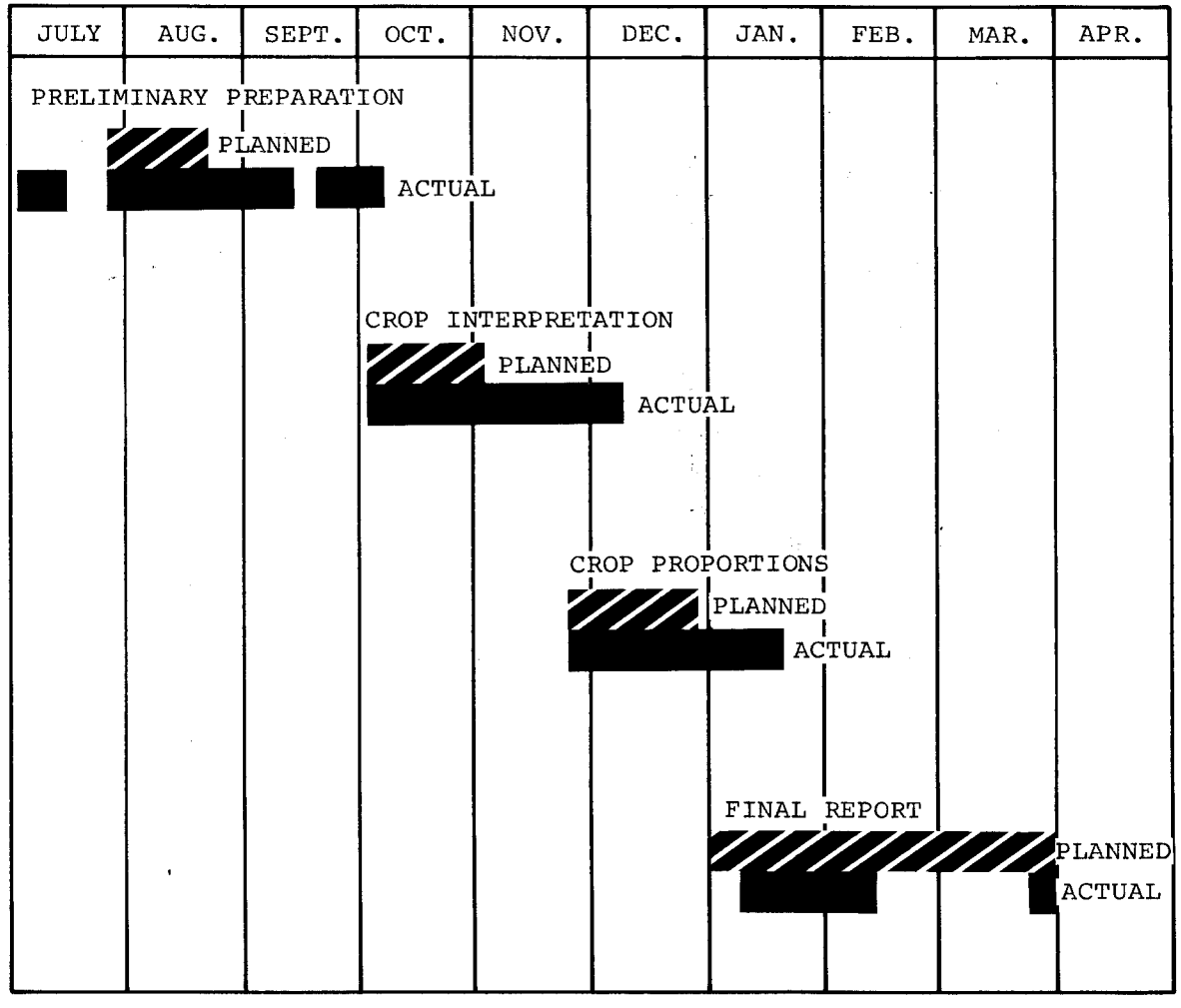

Figure 2.— Scheduled and actual major timelines of the image analysis phase of the CITARS project.

TABLE XIV.— MILESTONES OF THE IMAGE ANALYSIS PHASE OF THE CITARS PROJECT, 1973-1974

Date	Milestone
7/26/73	Completed test segment and test section selection
7/27/73	Began project planning phase on full-time basis
8/01/73	Submitted rough draft of interpretation plan
8/06/73	Received Mission 83B, roll 1 imagery
8/07/73	Received Mission 83M 7/05/73 imagery
8/10/73	Received ASCS ground-truth books
8/14/73	Received reprinted "good" copy of Mission 83M on 7/05/73
8/15/73	Notified of test section change
8/20/73	Received Mission 83B, roll 2 on 7/16/73
8/30/73	Received Mission 83B, roll 4A on 8/21/73
9/06/73	Received Mission 83B, roll 3 on 8/21/73
9/06/73	Began special wheat interpretation task
9/10/73	Received RB-57 prints for each county
9/10/73	Submitted Fayette County wheat interpretations
9/11/73	Received new section numbering system
9/11/73	Exchanged personnel (one man)
9/21/73	Submitted test section and ground-truth packages for dissemination
9/26/73	Began intermittent down time for Skylab
9/27/73	Received Mission 83M, roll 5 on 8/20/73
9/27/73	Received Mission 249, roll 24 on 8/27/73
9/27/73	Received Mission 249, roll 25 on 8/27/73
10/01/73	Submitted memorandum on revised milestones caused by impacts
10/02/73	Started identification extension phase
10/04/73	Submitted special request - scale factor computations for Mission 249 photographic bases
10/04/73	Prepared new form for recording interpretation results
10/16/73	Moved to new working area
10/24/73	Received procedures in order to increase interpretation rate; decided to discontinue detailed description and acreage estimate
10/30/73	Completed Lee County interpretation
11/05/73	Completed Fayette County interpretation
11/07/73	Completed Shelby County interpretation
11/19/73	Received Mission 83B, rolls 6a and 6b on 9/24/73
11/26/73	Completed Livingston and White County interpretations
11/27/73	Started crop proportions task
11/27/73	Completed Huntington County interpretation
12/05/73	Completed Fayette County crop proportions
12/13/73	Completed Shelby County crop proportions
12/14/73	Submitted four copies of all interpretation data for six counties
12/18/73	Completed Livingston County crop proportions

TABLE XIV.— MILESTONES OF THE IMAGE ANALYSIS PHASE OF THE CITARS PROJECT, 1973-1974 - Concluded

Date	Milestone
1/02/74	Completed Lee County crop proportions
1/06/74	Commenced final report documentation
1/09/74	Submitted four copies of crop proportions data for five counties
1/18/74	Completed Huntington County crop proportions
1/21/74	Submitted four copies of crop proportions data for Huntington County
1/29/74	Submitted rough draft of final report for review by NASA monitor
1/30/74	Submitted Shelby County segment wheat overlay to photographic support for reproduction
1/30/74	Submitted updated Shelby County wheat summary sheets to NASA monitor
1/31/74	Commenced work on request for the transfer of all wheat ground truth from 1:30,000 photographic base to the 1:24,000 rectified photographic base for Fayette County segment; edited ground-truth wheat fields against photointerpretation results
2/02/74	Submitted Fayette County segment wheat overlay (pencil copy) to cartographics
2/05/74	Submitted Shelby County segment section/frame correlation to NASA monitor
2/08/74	Project accounting number changed from 75-235.01 to 75-713.02
2/11/74	Submitted Lee and Livingston County segment summaries to NASA monitor; also Lee, Livingston, and Huntington section/frame correlations
2/11/74	Began intermittent down time for Skylab
2/13/74	Received rough draft of final report from NASA monitor with edit comments
2/15/74	Submitted detailed interpretation forms for Fayette County segment to NASA monitor; also submitted four copies of Fayette County segment wheat proportions data
2/19/74	Stopped work on project; started Skylab on a full-time basis
4/01/74	Submitted final report

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APPENDIX A

TEST SEGMENT 1 – HUNTINGTON COUNTY, INDIANA

APPENDIX A

TEST SEGMENT 1 – HUNTINGTON COUNTY, INDIANA

Appendix A contains the following data, which are stored in the reference file at the Project Support Facility in Building 17.

1. Segment schematic
2. Section number correlation
3. Field boundary schematics
4. List of photographs used in interpretation
5. Interpretation summary forms
6. Segment 1 crop proportions summary for corn and soybeans
7. Summary of digitizer measurements for corn and soybeans
8. ASCS ground observations

APPENDIX B

TEST SEGMENT 2 – SHELBY COUNTY, INDIANA

APPENDIX B

TEST SEGMENT 2 – SHELBY COUNTY, INDIANA

Appendix B contains the following data, which are stored in the reference file at the Project Support Facility in Building 17.

1. Segment schematic
2. Section number correlation
3. Field boundary schematics
4. List of photographs used in interpretation
5. Interpretation summary forms
6. Segment 2 crop proportions summary for corn and soybeans
7. Summary of digitizer measurements for corn and soybeans
8. Segment 2 crop proportions summary for wheat
9. Summary of digitizer measurements for wheat
10. ASCS ground observations

APPENDIX C

TEST SEGMENT 3 – WHITE COUNTY, INDIANA

APPENDIX C

TEST SEGMENT 3 – WHITE COUNTY, INDIANA

Appendix C contains the following data, which are stored in the reference file at the Project Support Facility in Building 17.

1. Segment schematic
2. Section number correlation
3. Field boundary schematics
4. List of photographs used in interpretation
5. Interpretation summary forms
6. Segment 3 crop proportions summary for corn and soybeans
7. Summary of digitizer measurements for corn and soybeans
8. ASCS ground observations

APPENDIX D

TEST SEGMENT 4 – LIVINGSTON COUNTY, ILLINOIS

APPENDIX D

TEST SEGMENT 4 – LIVINGSTON COUNTY, ILLINOIS

Appendix D contains the following data, which are stored in the reference file at the Project Support Facility in Building 17.

1. Segment schematic
2. Section number correlation
3. Field boundary schematics
4. List of photographs used in interpretation
5. Interpretation summary forms
6. Segment 4 crop proportions summary for corn and soybeans
7. Summary of digitizer measurements for corn and soybeans
8. ASCS ground observations

APPENDIX E

TEST SEGMENT 5 – FAYETTE COUNTY, ILLINOIS

APPENDIX E

TEST SEGMENT 5 – FAYETTE COUNTY, ILLINOIS

Appendix E contains the following data, which are stored in the reference file at the Project Support Facility in Building 17.

1. Segment schematic
2. Section number correlation
3. Field boundary schematics
4. List of photographs used in interpretation
5. Interpretation summary forms
6. Segment 5 crop proportions summary for corn and soybeans
7. Summary of digitizer measurements for corn and soybeans
8. Segment 5 crop proportions summary for wheat
9. Summary of digitizer measurements for wheat
10. ASCS ground observations

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APPENDIX F

TEST SEGMENT 6 – LEE COUNTY, ILLINOIS

APPENDIX F

TEST SEGMENT 6 – LEE COUNTY, ILLINOIS

Appendix F contains the following data, which are stored in the reference file at the Project Support Facility in Building 17.

1. Segment schematic
2. Section number correlation
3. Field boundary schematics
4. List of photographs used in interpretation
5. Interpretation summary forms
6. Segment 6 crop proportions summary for corn and soybeans
7. Summary of digitizer measurements for corn and soybeans
8. ASCS ground observations