LARS 080175

LACIE FIELD MEASUREMENTS

PROJECT PLAN, 1974-75 AND 1975-76

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I. INTRODUCTION

Major advancements in the acquisition, processing, and analysis of remote sensing data have been made during the past decade, particularly with the launch of LANDSAT in 1972. However, as the technology has developed there has been and continues to be a need for fundamental and quantitative studies of the spectral characteristics of vegetation and the factors affecting them. In the past many such studies have been performed in the laboratory because of a lack of instrumentation suitable for field studies. However, the applicability of laboratory studies to field conditions is generally limited. The development in recent years of sensor systems capable of collecting high quality spectral measurements under field conditions now makes it possible to pursue investigations which would not have been possible a few years ago.

With the start of remote sensing applications such as the Large Area Crop Inventory Experiment (LACIE) there are numerous questions needing answers. An example is, what is the optimum time or combination of times to uniquely identify wheat by spectral measurements? Information on this key question will have a direct bearing on the design and operation of LACIE during the next several years. Information is also needed to assist in development of future satellite systems with the objective of improving system performance over that of LANDSAT. An example of such a question is, what are best combination of wavelength bands for identifying crops. In both cases a fully-documented set of spectral, agronomic, and meteorological data is required. The first objective of this experiment is to assemble such a data set for winter and spring wheat. Secondly, it has the objective of obtaining answers to specific questions in support of LACIE, and thirdly providing a data set for research on problems extending beyond LACIE.

This document presents the overall plan for acquiring, processing, and analyzing the data for a field measurements project initiated in the fall of 1974 by NASA, USDA, LARS/Purdue, ERIM, Texas A & M University, and Colorado State University. This document is the fourth iteration of the project plan and incorporates new information and developments since the project was initiated. It is anticipated that the project will continue through the 1976-77 crop years.

II. OBJECTIVES

The overall objectives of the field measurements project are:

1. Obtain a fully annotated and calibrated multitemporal set of spectral measurements over the wavelength range of 0.4 to 1.5 μm and supporting agronomic and meteorological data which will serve as a data base for defining future satellite systems and other research problems.

2. Quantitatively determine the spectral-temporal characteristics of spring and winter wheat canopies, the soil background, and surrounding confusion crops in support of the LACIE.

Specific LACIE research which will be supported by field measurements includes determination of:

1. The spectral separability of wheat and other crops as a function of biological phase and by use of multitemporal spectral data.

2. The effect of crop, soil, and management variables on the spectral properties of wheat and determine their effects on signature extension.

3. The capability for discrimination of harvested from unharvested wheat, including that which will not be harvested due to low yields, hail, or lodging.

4. The effect of sun angle on spectral characteristics of wheat and selected other crops.

5. The characteristics and value of thermal measurements for discrimination of wheat.

6. The relation of wheat grain yield to spectral response.

7. The comparability of Landsat, aircraft, and ground acquired spectral measurements.

III. EXPERIMENTAL APPROACH

Spectral, agronomic, and meteorological measurements for the field measurements project will be made at two LACIE intensive test sites during the 1974-75 crop year. The sites are in Finney County, Kansas, chosen to represent winter wheat production and Williams County, North Dakota, chosen to represent spring wheat growing conditions. A state agricultural experiment station which can be used for controlled experiments is near each site. A third site in Hand County, South Dakota, typical of the transition area between winter and spring wheat production will be added in 1975-76.

The primary sensors to be utilized are the NASA-JSC helicopter-borne field spectrometer (FSS), the NASA airborne 24-channel multispectral scanner (MSDS), the Purdue and NASA-ERL field spectroradiometers, the NASA interferometer (VISS), LANDSAT-1 and -2 multispectral scanner (MSS), and LANDSAT band radiometers.

Helicopter/FSS, A/C scanner, and LANDSAT data will be collected over farmers' fields in a series of flightlines in the LACIE intensive test sites in each county and signature extension flightlines 20 to 30 miles away from the intensive test sites. These data will provide a measure of the natural variation in the temporal-spectral characteristics of wheat and surrounding cover types.

Truck-mounted spectrometers will collect spectra of controlled experimental test plots growing at agricultural research stations at Garden City, Kansas and Williston, North Dakota. These data will enable more complete understanding and interpretation of the spectra collected from farmers' fields. Past experience has shown that there are generally so many interacting variables in farmers' fields that it is difficult to determine exactly what is the cause of observed differences in spectral response. By having data available from test plots where only two to four factors are varied under controlled conditions, it will be possible to better determine and understand the energy-matter interactions occurring in wheat fields.

The spectral measurements will be supported by descriptions of the targets and their condition. These data will include descriptive observations, counts, and measurements of the crop including: maturity, variety, plant height, leaf area, percent ground cover, uniformity, and grain yield. In addition, the measurement conditions such as sensor height and view angle, as well as atmospheric and meteorological conditions at the time of the measurement will be recorded. These data will be supplemented by vertical and oblique photographs of the flight lines and test plots.

A data library of all spectral, agronomic, and meteorological data collected will be established and maintained at LARS. The data will be processed to provide similar data formats and measurement units and provided to experiment participants and other interested researchers.

The initial analysis of the data to accomplish the specific LACIE objectives will be performed by LARS, ERIM, TAMU, and CSU as part of their SR&T Tasks. Additional analyses on other research problems not yet defined may be performed by these and/or other investigators.

Technical coordination and leadership of the project will be provided by LARS and project management will be by JSC/EOD.

IV. TEST SITE DESCRIPTIONS

Each field measurements project test site consists of: (1) a LACIE intensive test site, (2) two signature extension areas 20 to 30 miles from the intensive test site, and (3) an agricultural research farm.

Selection of test sites was based on several criteria: (1) they should include as wide a range of important wheat production areas as possible, (2) both winter and spring wheat should be included, (3) the sites must be in close proximity to agricultural research stations, and (4) personnel to collect required ground truth must be available.

Two areas which meet these requirements are Finney County, Kansas and Williams County, North Dakota. Both counties have agricultural research farms operated by the Agricultural Experiment Stations of the two states. The research farms are located near Garden City, Kansas and Williston, North Dakota. Arrangements have been made to work on these two farms through Kansas State University and North Dakota State University. In addition, ASCS was already collecting ground truth data from previously designated LACIE intensive test sites in each county.

In 1975-76 a third LACIE intensive test site in Hand County, South Dakota will be added to the project and the Finney County, Kansas site will be replaced by a new site in Finney County.

A. Intensive Test Sites

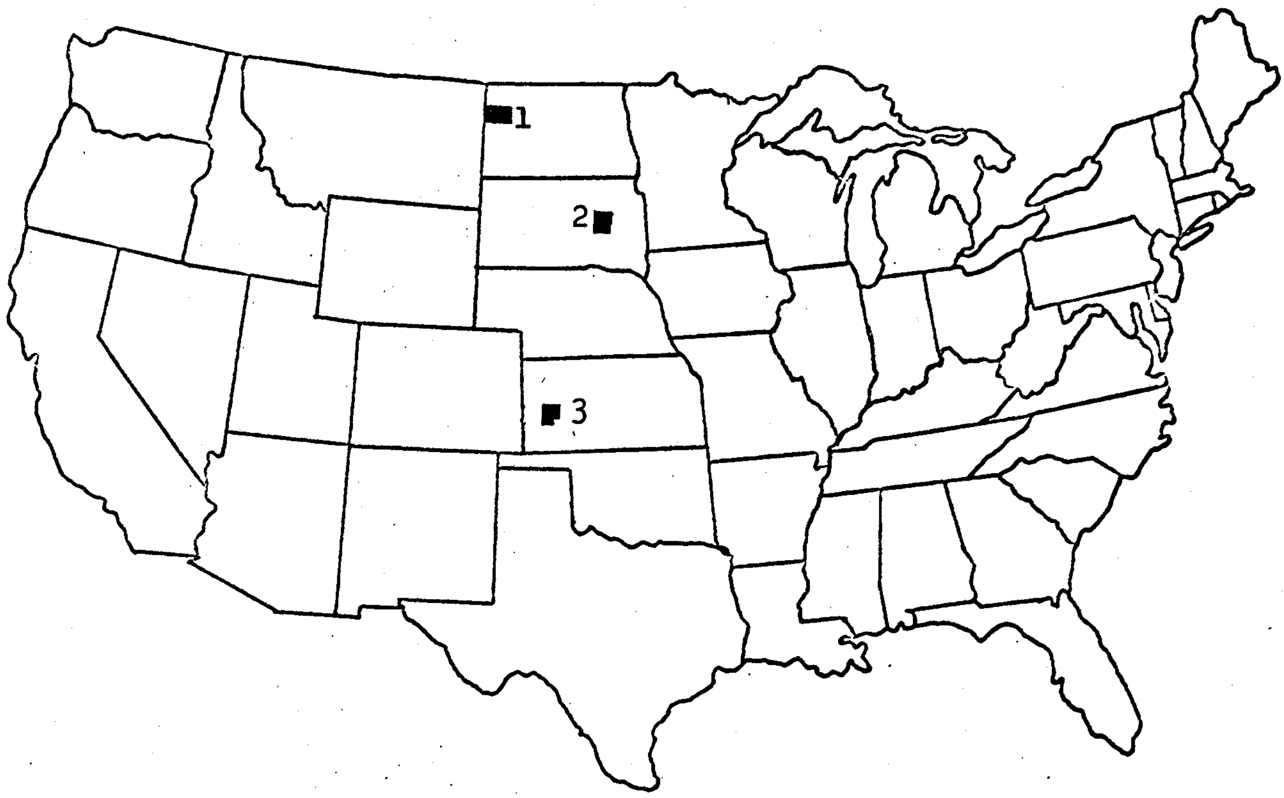
The intensive test sites are 5 x 6 miles in size. Three flightlines, six-miles long are located across each site. In addition, two flightlines three-miles long are located approximately 25 miles away from the primary test sites for signature extension studies.

1. Finney County, Kansas

The test site is located in the High Plains Tableland physiographic area. The altitude of the sites is about 3000 feet. It is overlain by 10 to 30 feet of loess from the early Wisconsin age. The area has a distinct continental type of climate characterized by abundant sunshine and constant wind. Most of the precipitation falls during the warm part of the year with a rapid decline in the probability of receiving adequate rainfall during July and August. Thus, the growth cycle of winter is well-matched to the available moisture supply. Average annual precipitation for Finney County's 19.08 inches with 5.64 inches from March to May, 7.91 inches during June to August, 3.80 inches between September and November, and 1.73 inches from December to February.

The soils of the test site are in the Mollisol order, Ustoll suborder, and Argiustolls great group. Mollisols are soils that have nearly black friable, organic-rich surface horizons high in bases. Ustolls are formed in semiarid regions and are dry for long periods, or have subsurface accumulations of carbonates. The major soil series in the area are Richfield and Ulysses which are deep, fertile, well-drained, nearly level to gently sloping, loamy soils of the upland. They are well-suited to cultivation. Much of the area has been bench leveled for irrigation.

The major crops in Finney County are wheat and grain sorghum which account for about 60 and 20 percent, respectively, of the total cropland over the years. However, in the intensive test site,



Locations of field measurements project test sites.

1. Williams County, North Dakota
2. Hand County, South Dakota
3. Finney County, Kansas

which is extensively irrigated, large amounts of corn and alfalfa are also grown. This site will be moved in 1975-76 to another location having less irrigation and more typical of Kansas winter wheat production

2. Williams County, North Dakota

This test site is located at 48° 19' N latitude and 103° 25' W longitude. It is representative of the cool temperate semiarid areas of the northern Great Plains where annual precipitation averages 14 to 16 inches. The site is located at an altitude of 2300 feet and lies in the glaciated area with a drift mantle and an undulating to steep surface. The site is mantled with glacial drift.

The climate of the area is typically continental with long cold winters, short warm summers, large diurnal ranges in temperture, frequent strong winds, and limited, as well as uncertain and highly variable, precipitation, average amounts of precipitation are 1.40, 3.40, 4.10, and 2.50 inches in the winter, spring, summer, and fall, respectively.

The soils in the site are of the Mollisol order, Boroll suborder or with Williams and Williams-Zahl being the major associations present. Both occur on undulating to rolling landscapes, are well drained to excessively drained. Much of the surface drainage is to depressions. The soils were developed from calcareous, loam glacial till. Soils are suitable for cropland and pasture. The Williams association is a very productive soil.

The major crop is wheat which occupies about 70 percent of the grain crop acreage. Both hard red spring and durum wheat are grown. Most of the wheat is grown on summer fallow land. Other crops are oats, barley, alfalfa, flaxseed, and pasture. The cropping calendar for spring and durum wheat begins in late April to early May with seedbed preparation, planting is generally in mid May, heading occurs in late June to mid July, with harvest in mid to late August.

3. Hand County, South Dakota

The test site is in the north-central Great Plains at latitude 44° 30' N and 99° 00' W. It is a transition area with the Corn Belt to the east and the Wheat Belt to the north and south. The topography of the area is flat to slightly rolling. The soils are in the Mollisol order and Ustoll suborder. Average annual precipitation is between 18 and 20 inches. About three-fourths of the precipitation occurs between April and September. Approximately 45 percent of the cultivated acreage is hay, while 32 and 22 percent are in small grains and corn, respectively. The principal small grain crop is winter wheat.

B. Agriculture Experiment Stations

Agronomic experiments with wheat and other crops are available for study on the agriculture experiment stations at Garden City, Kansas and Williston, North Dakota. These research farms are operated by Kansas State University and North Dakota State University.

Typical plot sizes are 12 x 40 feet. The plots are planted and harvested by conventional methods. Advantages of using these plots are: (1) considerable amounts of agronomic data are readily available from the experimenters describing the treatments and their effects on the growth and development of the crop, and (2) sources of differences in spectral response can be more readily explained since only the factors of interest are varied, while other factors are held constant.

1. Garden City, Kansas

The experiments for which measurements will be made in 1974-75 were planned and planted by KSU agronomists. Treatments and plots of most interest to the project were selected from the several available cultural practice experiments on the farm. In subsequent years, experiments specifically for the field measurements project will be planted. The experiments for which measurements will be made are described in the following paragraphs. Observations will be made on two replications of each treatment, with two observations per plot (total, four observations per treatment).

(a) <u>Small Grain Experiment</u>

The objective of this experiment is to determine if small grain species can be discriminated from each other based on their spectral reflectance. The experiment includes two winter wheat treatments (an early and late planting date), plus barley, rye, and triticale.

(b) Irrigation x Fertility Experiment

The objective of this factorial experiment is to determine the effects of time and amount of irrigation and rate of nitrogen fertilizer. The levels of factor 1, irrigation, are:

1. Dry, no irrigation
2. Irrigation at jointing stage of maturity
3. Irrigation at jointing plus boot stages of maturity
4. Irrigation at jointing, boot, and milk stages of maturity

The levels of factor 2, nitrogen fertilizer, are (1) none, and (2) 40 lbs/acre.

(c) Variety x Irrigation Experiment

The objective of this experiment is to determine the effect of variety and its interaction with irrigation. The experiment includes three varieties, Sturdy, Sage, and Centurk, and three irrigation treatments, 3 inches at boot stage, 6 inches at milk stage, and 6 inches at both boot and milk stages of maturity.

(d) Other Crops Experiment

This experiment is to determine the spectral separability of wheat and other crops and cover types. The crops and cover types are: corn, grain sorghum, soybeans, sugar beets, alfalfa, pasture, and bare soil. Plots or fields having planting dates, fertility, seeding rates, etc. typical of the area will be observed periodically during the growing season.

1974-1975 Garden City, Kansas, Agriculture Experiment Station

Remote Sensing Experiments (Site-G1)

Small Grain Experiment

Plots (top)	Crop	Plots (bottom)
111, 112	Triticale	110, 109
113, 114	Wheat (late)	108, 107
115, 116	Barley	106, 105
117, 118	Rye	104, 103
119, 120	Wheat (early)	102, 101

Irrigated Winter Wheat-Fertility Experiment

Plots	Nitrogen	Irrigation
206, 205	N_2	I_1
216, 215	N_2	I_0
214, 213	N_2	I_2
212, 211	N_0	I_2
210, 209	N_o	I_0
204, 203	N_0	I_1
202, 201	N_1	I_1

Nitrogen Fertilization

- N_0 None
- N_1 40 lbs./acre
- N_2 80 lbs./acre

Irrigation Treatment
Pre-irrigation +

- I_0 None
- I_1 Boot
- I_2 Joint + Boot

Sage Variety

Pre-Plant Irrigation - Sept. 26, 1974

Irrigation Winter Wheat-Variety Experiment

Plots	Variety	Irrigation
318, 317	V_1	I_2
316, 315	V_2	I_2
314, 313	V_3	I_2
312, 311	V_2	I_3
310, 309	V_1	I_3
308, 307	V_3	I_3
306, 305	V_3	I_1
304, 303	V_1	I_1
302, 301	V_2	I_1

Winter Wheat Variety

- V_1 Centurk
- V_2 Sage
- V_3 Sturdy

Irrigation Treatment
Pre-irrigation +

- I_1 3" Boot Stage
- I_2 6" Milk Stage
- I_3 3" Boot + 3" Milk Stages

Planting Date - Sept. 30, 1974

Winter Wheat Residue Management Experiment

Plots	Residue	Nitrogen	Seeding
401, 402	M_2	N_1	R_1
403, 404	M_2	N_2	R_1
405, 406	M_1	N_2	R_1
407, 408	M_1	N_1	R_1
409, 410	M_3	N_2	R_1
411, 412	M_3	N_1	R_2
413, 414	M_4	N_1	R_2
415, 416	M_4	N_2	R_2

Residue Management

- M_1 Shredding
- M_2 Complete Removal
- M_3 Heavy Residue
- M_4 Burning

Nitrogen Fertilization

- N_1 50 lbs./acre
- N_2 100 lbs./acre

Seeding Rate

- R_1 Normal
- R_2 Double

Other Crops Experiment

Fallow	Grain Sorghum	Sugar Beets	Soybeans	Alfalfa	Corn

2. Williston, North Dakota

(a) Small Grain Experiment

The objective of this experiment is to determine the spectral separability of various small grain. The experiment includes spring wheat, durum wheat, winter wheat, spring oats, and barley. Seeding rate and planting date will be uniform for the spring seeded crops. Two soil moisture regimes are available for study since the plots will be on both fallow and wheat land from 1974. The fallow land will have the benefit of approximately 60 percent more stored soil moisture compared to the land on which wheat was grown in 1974.

(b) Spring Wheat Experiment

The objective of this factorial experiment is to quantify the major variables affecting wheat growth, development and yield which in turn affect its spectral response. The factors and levels of each factor are:

1. Soil Moisture: (1) Fallow in 1974, (2) Wheat in 1974
2. Planting Date: (1) May 20, (2) May 30
3. Variety: (1) Olaf (semi dwarf), (2) Ellar (standard height)
4. Nitrogen Fertilizer: (1) None, (2) 30 lbs/acre

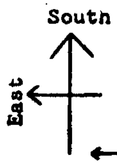
(c) Seeding Rate Experiment

The objective of this experiment is to provide additional information on the interaction of amount of vegetative cover and spectral response. It is a factorial experiment with two replications where the factors are:

1. Soil Moisture: (1) Fallow in 1974, (2) Wheat in 1974
2. Nitrogen Fertilizer: (1) None, (2) 30 lbs/acre
3. Seeding Rate: (1) 30 lbs/acre, (2) 60 lbs/acre, (3) 90 lbs/acre

REMOTE SENSING — WHEAT EXPERIMENTS

Agriculture Experiment Station
Williston, North Dakota



← Wheat in 1974 → (plots 31–45 / 1–15) ← Fallow in 1974 → (plots 46–60 / 16–30)

Rep II (45')

Plot No.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45		46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Date	Kelsey Oats	Crosby Durum	Vandguard Barley	Lark Wheat	D_1	D_1	D_1	D_1	D_2	D_2	D_2	D_2	D_1—V_2—N_1			Border				D_2	D_2	D_2	D_2	D_1	D_1	D_1	D_1	Lark Wheat	Crosby Durum	Vanguard Barley	Kelsey Oats
Nitrogen					N_1	N_1	No	No	No	No	N_1	N_1								No	No	N_1	N_1	N_1	N_1	No	No				
Variety / Rate					V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	R_1	R_2	R_3		R_3	R_2	R_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1				

Rep I (45'; plot width 12')

Plot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Date	Kelsey Oats	Crosby Durum	Vandguard Barley	Lark Wheat	D_1	D_1	D_1	D_1	D_2	D_2	D_2	D_2	D_1—V_2—N_1			Border				D_2	D_2	D_2	D_2	D_1	D_1	D_1	D_1	Lark Wheat	Crosby Durum	Vanguard Barley	Kelsey Oats
Nitrogen					No	No	N_1	N_1	N_1	N_1	No	No								N_1	N_1	No	No	No	No	N_1	N_1				
Variety / Rate					V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	R_1	R_2	R_3		R_3	R_2	R_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1				

Treatment Descriptions

Soil Moisture	Planting Date	Variety	Nitrogen	Seeding Rate
M_1 Wheat in 1974	D_1 May 20	V_1 Olaf (Semi dwarf)	No None	R_1 30 lbs/acre
M_2 Fallow in 1974	D_2 May 30	V_2 Ellar	N_1 30 lbs/acre	R_2 60
				R_3 90

V. SENSOR DESCRIPTIONS

This section describes the characteristics of the various sensors which will be used to acquire spectral data over the intensive test sites and agriculture experiment stations. The sensors to be used in the intensive test sites include: LANDSAT I and II multispectral scanner, 24-channel airborne multispectral scanner, helicopter-borne S-191 spectrometer, and tripod-mounted LANDSAT band radiometer. The sensors which will acquire spectral data on the agriculture experiment stations are: truck-mounted spectroradiometer, truck-mounted interferometer, and precision radiation thermometers.

A. LANDSAT Multispectral Scanner (MSS)

MSS data from both LANDSAT I and II will be requested. This data is acquired at 18 day intervals by each satellite, resulting in repeat coverage of the sites every nine days (beginning in January 1975 with the launch of LANDSAT II). The MSS data has four spectral bands from 0.5 to 1.1μm. The sensor scans crosstrack swaths of 185km (100nm). It has crosstrack field of view of 11.56 degrees. The IFOV is 79 meters.

B. 24-Channel Airborne Multispectral Scanner

The 24-channel MSS is mounted in the NASA C-130 aircraft. The spectral range is 0.34 to 13.0μm. It has an IFOV of 2 milliradians which results in a spot size of 3 feet at 1500 feet above ground altitude and 20 feet at 10,000 feet altitude. The field of view is 80 degrees which gives ground coverage of 2500 and 16,800 feet at 1500 and 10,000 foot altitudes, respectively.

The photographic system consists of two 6-inch focal length cameras with 74 degree field of view covering 15,000 feet at 10,000 feet altitude. Nine and one-half inch color and color infrared photography will be acquired.

C. Field Spectrometer System (FSS)

This is a filter wheel spectrometer instrument which is basically a duplicate of the S-191 sensor used in the SKYLAB EREP experiment. It has been modified by NASA for mounting on a helicopter platform. A team for operating the instrument and providing ground support and surface measurements has been trained. A helicopter (with flight crew) to carry the instrument will be provided by NASA/JSC. The instrument produces data in 14-track digital format which must be converted to CCT's for subsequent reformatting and analysis.

The spectral range of the spectrometer is 0.42-2.50μm and 6.0-16.0μm. The IFOV is 22° which gives a spot size of 78 feet from 200 feet above ground altitude. The helicopter will fly at 50-55 knots. The camera has a 3-inch focal length, a 36° field of view, 130 feet square ground coverage, and will use 70mm color film. A disadvantage of the system is that data is collected over the wavelength range as the helicopter is moving along the flightline; thus, slightly different ground spots are sensed for different wavelength intervals. However, this is not considered a serious limitation as long as the ground scene is relatively homogeneous and is offset by the fact that it can collect continuous spectra over relatively large areas in a short time.

D. ERTS Ground Truth Radiometer

ERTS (LANDSAT) band radiometers, model 100 A, manufactured by Exotech, Inc. will be used to acquire data in selected fields in the intensive test sites. The instrument has four spectral bands which match the wavelengths of the LANDSAT bands. It can be used to measure both incident and reflected radiation. It has 1.0 degree square and 15 degree circular fields of view. The accuracy of measurement is ±5 percent with 0.16 mw/cm^2 sensitivity for reflected radiation. The instruments will be mounted on five-foot tripods. The radiometers have been equipped with special attachments which permit measurements of leaf transmittance in the four spectral bands.

E. Exotech Model 20C Spectroradiometer

The Exotech Model 20C field spectroradiometer system can acquire spectral data over the wavelength region of 0.4 to 15μm. The instrument features a reflective fore-optical system that permits remote selection of the field of view of the instrument of 3/4 or 15 degrees. Four circular variable filter wheels are used as the dispersion elements in the spectroradiometer and a system of four detectors (silicon, indium antinomide, lead sulfide, mercury cadmium telluride) are used to detect radiation over the wavelengths of interest. The radiation flow from the fore-optic system into the detectors is controlled by two chopper wheels that also serve to expose each detector to appropriate reference sources.

The instrument is equipped with a solar irradiation port and diffuser that provides for solar reference in the reflective wavelength (0.4μm to 2.5μm) region. The instrument consists of two optical heads that allow coverage of the reflective and emissive wavelengths bands separately. The instrument is mounted on a mobile aerial tower that operates with a field instrumentation van which contains the control electronics and data recorder for the system. The data produced by the instrument are recorded on a analog magnetic tape recorder and later converted into digital information by a laboratory analog-to-digital converter. Calibration sources that are designed for field use are used to calibrate the spectroradiometer on site. A data logging system that combines hard-copy field data along with other field observations is used to annotate the magnetic tapes during the analog-to-digital conversion process.

A software system (EXOSYS) especially designed to operate with the field spectroradiometer system is used to process the digital data. The software system has been designed to be user-oriented and allows the user of the field spectral data to prepare the data in a variety of formats. For example, the data can be presented in absolute calibrated form(L_λ _vs._ λ) or in reflectance form (ρ' _vs._ λ).

F. Exotech Model 20D Spectroradiometer

This sensor operated by ERL is similar to the Exotech 20C. However, the long and short wavelength units cannot be operated simultaneously. The instrument will be operated in the short wavelength mode at the Garden City Agriculture Experiment Station beginning in March, 1975.

G. Block Wideband Interferometer (VISS)

This is a unique field instrument that acquires spectral data over the visible and infrared portions of the spectrum.

The instrument scans the spectrum rapidly enough to account for environmental variables and is equipped with a self-contained computer system that yields spectral data from the interferograms produced by the instrument. The instrument control electronics and computer are mounted in an instrument van and the optical head of the instrument is mounted on a mobile aerial tower. The spectral data (wave number) produced by the instrument will be processed by JSC/EOD to provide CCT's of calibrated spectral reflectance factor (wavelength). This system will be a back-up for the ERL and LARS spectroradiometers.

H. Precision Radiation Thermometers

ERL will use a Barnes PRT-6 at Garden City in conjunction with their Exotech. This instrument is a modification of the widely known PRT-5 instrument. It has the option of either a 2° or 20° field of view and eight passband selections in the thermal infrared. The output is analog voltage proportional to irradiance level at the instrument aperture. The operator selects DC offsets, ranges, and filter positions and records output scale changes, electronic offsets, and filter positions. LARS will use the familiar PRT-5 instrument boresighted with the Exotech Model 20C at Williston.

MAJOR SENSOR AND SYSTEM CHARACTERISTICS OF THE TRUCK-MOUNTED SPECTROMETERS

Characteristic	LARS/20C Exotech	ERL/20D Exotech	JSC/Interferometer
Spectral Range (μm)	0.4 - 14	0.4 - 14	0.4 - 2.5; 8 - 14
Spectral Resolution @ 1.0μm	0.025	0.025	0.0064
Scan Time (scans/sec)	1 - 30	1 - 30	10
Field of View (degrees)	15 and 3/4	15 and 3/4	11
Boom Length	25, 25'	22'	40, 34'
Camera			
Focal Length (mm)	55	80	50
Field of View (degrees)	43	37	46
Film Type	35mm color	35 & 70mm color	35mm color

VI. DATA ACQUISITION

This section describes the collection of spectral, agronomic, and meteorological data for the intensive test sites and agriculture experiment stations.

The following comments apply to all forms of data collection: (1) It is critical that there is adequate training and briefing of data acquisition personnel to insure that data are gathered by uniform, accepted procedures and that agronomic, atmospheric, and spectral data can be related to each other, (2) data gathering is coordinated to ensure best use of resources in reacting to weather and other factors affecting the acquisition of useful data, and (3) entering of data into the system is coordinated to ensure proper registration and calibration.

A. Intensive Test Sites

This section discusses spectral data collection procedures, calibration and correlation of sensors, and the measurements and observations of crop, soil, and meteorological parameters in the intensive test sites.

1. Spectral Data Collection

The sensors to be used are the LANDSAT MSS, 24-channel A/C MSS, helicopter-borne FSS, and tripod-mounted radiometers. The data collection procedures and calibration-correlation procedures are described in the following two subsections.

(a) Spectral Data Collection Procedures

Helicopter/FSS

Helicopter/FSS missions are to be flown within a four day "window" of minus one to plus two days of the LANDSAT overpass. Cloud cover must be less than 50 percent and sun angle of zenith plus or minus 30 degrees. If the mission is flown on day 1 and day 2 (LANDSAT overpass) is clear it will be reflown. If either day 1 or 2 is partially cloudy while the mission is being flown, it will be reflown the following day if it is clear.

The nearest town to the Kansas test site is Garden City and the nearest town to the North Dakota test site is Williston. All flights in the test site areas will be staged from the local town. The FSS will be stored in the local area between helicopter flights.

At the test site, six 6-mile long flight lines will be flown by the helicopter. Four additional 2-mile long flight lines, located 20 miles north and south of the prime test site will be flown by the helicopter. Flight lines will be flown at an altitude of 200 feet, 50-55 knot ground speed, and in an east/west direction. Approximately 1 hour of FSS data will be obtained, requiring approximately 5 hours of helicopter flight time in the test site area. Reference panel calibration measurements will be required at 20-minute intervals during overflight of the test sites from a 20 foot altitude. The reference panel consists of a 20 x 40-foot panel centrally located in the test site.

Following is a typical flight sequence for this project:

1. Ferry to location of 2-mile flight line north of test site.
2. Descend to 200-foot altitude and fly two passes over the FL.

3. Ferry to test site area.
4. Descend to 20 foot altitude and hover over calibration panel.
5. Ascend to 200 foot altitude and make two passes over flightline 1 with a 50 to 55 knot ground speed. Second pass should be offset from the first pass by a minimum of 100 feet.
6. Descend to 20 foot altitude and hover over calibration panel.
7. Repeat steps 4, 5, and 6 for flightline 2.
8. Repeat steps 4, 5, and 6 for flightline 3.
9. Ascend to 10,000 foot altitude and acquire aerial photography of test site.
10. Ferry to location of 2-mile flightline south of test site.
11. Descend to 200-foot altitude and fly two passes over the flightline.
12. Fly contingent flight lines as required.
13. Return to point of origin.

Data handling procedure will be as follows:

1. Magnetic tape and systems manager data pack will be turned in DDC. in bldg. 12 at the end of each data flight.
2. Magnetic tape and 70-mm film will be hand-carried back to JSC by system operator. The exposed 70-mm film will be turned into the photo section in bldg. 8 along with proper instructions. PI requests two duplicates of the original film.

3. Sequential 4A tape identification labels will be used during mission.
4. Copies of inflight log, systems managers' report and photo request will be delivered to mission manager and EOD after each data flight.
5. System operator will retain one copy each of all reports and forms generated by each data flight.

C-130/24-Channel MSS

The C-130/24-channel MSS system is to acquire data over the intensive test sites, extended flightlines, and agriculture experiment stations concurrently with the helicopter/FSS beginning in the spring of 1975 (See data collection schedule in section IX). The intensive test sites will be overflown at 10,000 foot altitude and the experiment stations at 1,500 feet. Four gray-scale canvas calibration panels, plus the canvas panel for the helicopter, will be deployed by the ground support team.

Tripod-Mounted Radiometers

An ERTS band radiometer will be used to collect data from one to three fields in each intensive test site. It will be mounted on a five-foot tripod. Three locations within the field will be sampled. The measurements to be made at four times (sun angles) during the day. A barium sulphate standard will be measured between each measurement of the canopy. Spectral measurements include total reflectance, soil reflectance, ratio of diffuse to direct irradiance, and leaf transmittance. Canopy description data includes leaf area index, biomass, number of tillers and leaves, and photographs at 10 degree increments. The data are to be at four growth stages (tillering, jointing, flowering, and mature) at several locations in a typical field.

(b) Sensor Calibration and Correlation

This subsection primarily discusses the procedures to be used in calibrating and correlating the data from the helicopter/FSS. A similar procedure of data reduction could be followed for the A/C MSS data since calibration panels will be overflown by the A/C scanner. The tripod-mounted radiometer will be calibrated by alternately reading the target and a barium sulphate standard.

Barium sulphate panels will be used as the means of routine standardization of instrument response. The panels will be prepared according to procedures described by Shai and Schutt, "Formulation Procedure and Spectral Data for a Highly Reflecting Coating", X-762-71-266 GSFC, Greenbelt, MD. The spectral irradiance standard will be a 1000 watt GE DXW quartz-iodine lamp.

To calibrate data from the helicopter/FSS the following sequence of data collection will be followed:

1 Measure the reflectance factor of the barium sulphate panel with the truck-mounted spectroradiometer.

2. Measure the reflectance factor of the 20 x 40 foot canvas reflectance panel with the truck-mounted spectroradiometer.

3. Measure the response of the canvas panel with the helicopter/FSS. The helicoptor/FSS will be referred to this central standard frequently during each mission.

4. Collect data over the flightlines with helicopter/FSS.

The data processing facility will convert the helicopter/FSS data to reflectance factor based on the measurements made of the barium sulphate standard and canvas panel. The calibration calculation will consist of forming the ratio of the response of the instrument to that of the reflectance standard. Correction for the known reflectance of the standard will be made in the computer. This procedure will produce a reflectance factor for the given sun angle and normal viewing of the subject.

While more elaborate calibration procedures are possible, the interest of the project is in producing data which are directly relatable to satellite data. The radiance received at the satellite includes scene reflected skylight as well as scene reflected direct sunlight. The process of eliminating skylight by subtracting the response of the shadowed scene and shadowed standard has merit in that it produces a quantity related to the reflection distribution function, rho-prime, which is recognized as a quantity of fundamental utility. However, the additional measurements and calculations add uncertainty to each resultant reflectance number. Furthermore, the re-insertion of modeled, computed, or measured skylight to account for the actual scene radiance adds another measure of uncertainty. Therefore, the single comparison method is recommended because, as additional computations accumulate, it is probable that the added uncertainty will be of the same order of magnitude as the skylight itself in the spectral regions of interest.

The calibration procedure to be used in this experiment will deal with limitations imposed by the size and location of the standard by calibrating the instrument at a low altitude (20 feet) and collecting data over the flightlines at 200 feet. This procedure assumes that atmospheric transmittance and path radiance are neglibible for a 200 foot path.

During the calibration observations the instrument will be aimed straight down and the helicopter will hover over a canvas reflectance panel from a distance of 20 feet. The panel will be securely mounted to a stable platform to minimize downdraft effects from the helicopter. Care will be taken to ensure that the standard is not shadowed and that the illumination conditions are as similar to the conditions of the observation of the subject scenes as possible.

The absence of an onboard solar sensor integrated into the instrument makes it desirable that calibrations be performed every 20 minutes. Therefore, the reflectance panels will be centrally located and procedures will be developed to allow calibration on as near to 20 minute intervals as is possible.

Radiance and irradiance callibrations of the field instruments are quite difficult. However, each instrument may be calibrated under laboratory conditions and in the case of the silicon detectors, the calibrations will be valid to within a few percent per year. In the case of the S-191, its internal reference system may be used to monitor the instrument performance. The S-191 will be calibrated in its radiance mode.

Field calibration of instruments which respond to emissive radiation will be accomplished by recording spectral observations of a black body at a temperature below ambient and another black body at a temperature above ambient. The subsequent scans of subject scenes will be converted to spectral radiance using linear interpolation in the digital computer. The frequency of field calibrations will depend on the stability of the instrument and provisions for internal monitoring of system performance.

One of the important features of this project is the production of a uniform data set that can be correlated and compared. Much of this can be accomplished by establishment of the data collection procedures described above. Field calibration procedures described above will provide a measure of correlation, but a necessary step is a side-by-side comparison of the instruments on a common target.

A more complete correlation should be performed in a laboratory evaluation of the transfer functions of the individual instruments. The correlation could be performed by LARS/Purdue with the calibration facilities used for its instrument system. Each instrument system would be brought to the Purdue facility with operating crews to be furnished by the institution operating the instruments. Ideally this correlation should have taken place immediately before the spring data acquisition. The base line data obtained during this laboratory calibration period would then be related to field calibration data to permit rectification of the experimental data produced by the instruments. Basic instrument changes (i.e., optics or detector changes) could invalidate these procedures; therefore, a careful record of the configuration of each instrument would be maintained throughout the experiment.

2. Agronomic Data Collection

Agronomic measurements, counts, and observations describing the condition of each of the fields for which spectral data are collected will be acquired. These data will describe the condition of each field as fully as possible and will be used to account for differences in the spectral measurements. The data will be recorded on standard forms, keypunched, and transmitted to LARS for inclusion in the data bank.

Data describing the fields in the intensive test sites and flightlines will be collected by USDA/ASCS. The following data will be collected:

1. Inventory at beginning of season of all fields in the test sites
    a. Field number
    b. Acreage
    c. Crop species and variety
    d. Irrigation
    e. Fertilization
    f. Planting date
    g. Other descriptive information
2. Periodic observations at 9 day intervals coinciding with LANDSAT passes
    a. Field number, acreage, crop identification
    b. Growth stage
    c. Percent ground cover
    d. Plant height
    e. Surface moisture condition
    f. Evaluation of stand quality
    g. Quality relative to other fields in site
    h. Field operations
    i. Density of stand
    j. Weed infestation
    k. Growth/yield detractants
    l. Vertical 35 mm photographs
    m. Additional descriptive comments

GROUND TRUTH INVENTORY FORM

TEST SITE #
INVENTORY OBSERVATION

DATA RECORDED BETWEEN - - / - - /75
AND - - / - - /75

LAND USE CROP CODES

100 SPRING WHEAT (GEN)
101 FORTUNA HRS
102 THATCHER
103 DURUM
104 CHRIS SPRING
105 WELLS DURUM
106 LEEDS DURUM
107 JUSTIN SPRING
108 ROLETTE DURUM
109 HERCULES DUMUM
110 LARK SPRING
111 BONANZA SPRING
112 WALDROW SPRING
113 RUSHMORE
114 CRIM
115 EMPIRE
116 MANITOU
117 VALLEY
118 CANTHATCH
119 PITIC
120 1809
121 NEEPEWA
122 GLENDEA
123 SELKIRK
124 ERA
125 WASCANA
126 OLAF
200 BARLEY(GEN)
201 LARKER
202 VANGRARD
203 BONANZA
204 DICKSON
205 PRIMUS
206 SHAWBET
207 PIROLINE
208 BETZES
209 STEPTOE
210 FERGUS
211 PARAGON
212 HERTA
213 CONQUEST
214 WISCONSIN
215 HECTOR
216 HYPANA
217 MORAVIAN
300 OATS(GEN)
301 RUSSELL
302 BASIN
303 KELSEY
304 RODNEY
305 LODI
306 KINSEY
307 HARMON
308 MISSION
400 WINTER WHEAT(GEN) (CODE LIST ATTACHED)
500 GRASSES/PASTURE ETC.
600 OTHER CROPS (GEN)
601 RAPESEED
602 RYE
603 MUSTARD
604 FLAX (GEN)
605 NORALTA FLAX
636 REDWOOD FLAX
607 CORN
610 BUCKWHEAT
611 SUNFLOWERS
612 DRY BEANS
613 LENTILS
614 DRY PEAS
615 SUGUR BEETS
616 GRAIN SORGHUM
617 SOYBEANS
618 COTTON
700 SUMMER FALLOW
800 NON-AGRICULTURE
900 UNKNOWN CROPS

MAP REFERENCE # OF FIELD	ACREAGE	LAND USE CROP CODE	IRRIGATED	FERTILIZED	PLANTING DATE MONTH DAY YEAR	COMMENTS
1	______	__ __ __	Y N	Y N	- - / - - / - -	
2	______	__ __ __	Y N	Y N	- - / - - / - -	
3	______	__ __ __	Y N	Y N	- - / - - / - -	
4	______	__ __ __	Y N	Y N	- - / - - / - -	
5	______	__ __ __	Y N	Y N	- - / - - / - -	
6	______	__ __ __	Y N	Y N	- - / - - / - -	
7	______	__ __ __	Y N	Y N	- - / - - / - -	
8	______	__ __ __	Y N	Y N	- - / - - / - -	
9	______	__ __ __	Y N	Y N	- - / - - / - -	
10	______	__ __ __	Y N	Y N	- - / - - / - -	
11	______	__ __ __	Y N	Y N	- - / - - / - -	
12	______	__ __ __	Y N	Y N	- - / - - / - -	
13	______	__ __ __	Y N	Y N	- - / - - / - -	
14	______	__ __ __	Y N	Y N	- - / - - / - -	
15	______	__ __ __	Y N	Y N	- - / - - / - -	
16	______	__ __ __	Y N	Y N	- - / - - / - -	
17	______	__ __ __	Y N	Y N	- - / - - / - -	
18	______	__ __ __	Y N	Y N	- - / - - / - -	
19	______	__ __ __	Y N	Y N	- - / - - / - -	
20	______	__ __ __	Y N	Y N	- - / - - / - -	
21	______	__ __ __	Y N	Y N	- - / - - / - -	
22	______	__ __ __	Y N	Y N	- - / - - / - -	
23	______	__ __ __	Y N	Y N	- - / - - / - -	
24	______	__ __ __	Y N	Y N	- - / - - / - -	
25	______	__ __ __	Y N	Y N	- - / - - / - -	
26	______	__ __ __	Y N	Y N	- - / - - / - -	
27	______	__ __ __	Y N	Y N	- - / - - / - -	
28	______	__ __ __	Y N	Y N	- - / - - / - -	

GROUND TRUTH PERIODIC OBSERVATION FORM

TEST SITE
) OBSERVATION)

	MONTH	DAY	
ERTS PASS DATE	— —	/ —	/75
OBSERVATION DATE	— —	/ —	/75

RAINFALL SINCE LAST OBSERVATION _____ IN.

PHOTO
Y-YES N-NO
PHOTOGRAPH
STARRED FIELDS

LAND USE CODES
WW-WINTER WHEAT
P -PASTURE
O-OATS C-CORN
SF-FALLOW
GR-GRASSES
B-BARLEY RY-RYE
SW-SPRING WHEAT
R-RAPE F-FLAX

GROWTH STAGES
01-NOT PLANTED
02-PLANTED NO EMERGENCE
03-EMERGENCE
04-TILLERING, PREBOOT, PREBUD
05-BOOTED OR BUDDED
06-BEGINNING TO HEAD OR FLOWER
07-FULLY HEADED OR FLOWERED
08-BEGINNING TO RIPEN
09-RIPE MATURE
10-HARVESTED
11-DOES NOT APPLY

GROUND COVER (%)
1- 0- 19
2-20- 39
3-40- 59
4-60- 79
5-80-100

SURFACE MOISTURE CONDITIONS
1-DRY
2-DAMP
3-WET
4-STANDING WATER

WEED GROWTH
1-NEGLIGIBLE
2-SLIGHT
3-MODERATE
4-HEAVY

FIELD OPERATIONS
01-BARE GROUND
02-BARE DISKED/CULTIVATED
03-BARE PLOWED
04-BARESEEDED
05-STANDING STUBBLE
06-STUBBLE DISKED/CULTIVATED
07-STUBBLE PLOWED
08-STUBBLE SEEDED
09-BURNED
10-GRAZED
11-WINDROWED OR SWATHED
12-MOWED OR COMBINED
13-STACKED OR BALED
14-OTHER

GROWTH/YIELD DETRACTANTS
01-SALINITY
02-INSECTS
03-DISEASE
04-DROUGHT
05-MOISTURE
06-WIND
07-HAIL
08-FROST
09-BIRDS
10-POT HOLES
11-UNEVEN STAND
12-WEEDS
13-WINTERKILL
14-LODGING
15-OTHER

STAND QUALITY
1-POOR
2-BELOW AVERAGE
3-AVERAGE
4-ABOVE AVERAGE
5-EXCELLENT
6-DOES NOT APPLY

FIELD NO.	ACREAGE	LAND USE CODE	PHOTO	GROWTH STAGE (CIRCLE ONE)	GROUND COVER (CIRCLE ONE)	PLANT HEIGHT (INCHES)	SURFACE MOISTURE (CIRCLE ONE)	WEED GROWTH (CIRCLE ONE)	FIELD OPERATIONS (CIRCLE ONE)	GROWTH/YIELD DETRACTANTS (CIRCLE ONE)	STAND QUALITY RATING (CIRCLE ONE)	COMMENTS
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N
_____	_____	_____	Y N	01 02 03 04 05 06 07 08 09 10 11	1 2 3 4 5	[ ][ ][ ]	1 2 3 4	1 2 3 4	01 02 03 04 05 06 07 08 09 10 11 12 13 14	01 02 03 04 05 06 07 08 09 10 11 12	1 2 3 4 5 6	Y N

3. Meteorological Data Collection

The following atmospheric and meteorological measurements will be made in conjunction with S-191 and A/C scanner data collection at the intensive test sites:

(a) Percent cloud cover and type

(b) Wet and dry bulb temperature

(c) Barometric pressure

(d) Sky Brightness

(e) Total irradiance

(f) Visibility (miles)

(g) Wind speed and direction

(h) Optical depth at seven visible and near infrared wavelengths

ASCS personnel will also make measurements of optical depth and airmass at the time of LANDSAT overpasses.

B. Agriculture Experiment Stations

This section describes the collection of spectral, agronomic, and meteorological data at the agriculture experiment stations.

1. Spectral Data Collection

(a) Spectral Data Collection Procedures

The spectral data on the agriculture experiment stations will be collected by ERL at Garden City and LARS at Williston. The primary sensors are the Model 20C and Model 20D Exotech field spectroradiometers. These will be augmented by a PRT-6 at Garden City and a PRT-5 at Williston. The JSC interferometer system (VISS), along with the LARS spectroradiometer system, was used to collect data in October and November, 1974 at Garden City. The interferometer system will be located at College Station, Texas during the summer of 1975 for experiments by TAMU, but will be available as a back-up for the two spectroradiometers if needed. To obtain data which can be readily compared, the two instruments will be operated following similar procedures. These instruments will be operated from their aerial towers at seven meters above the target which minimize the shadowing of skylight and yet ensures that the large field of view of the instrument is filled with the subject scene. Care will be taken to avoid scene shadowing and minimize the reflective interaction due to personnel or vehicles. The routine data taking mode of the instruments will be straight down, reflectance factor.

Data to be recorded at the time of each measurement include: date, time, reference illimination, air temperature, barometric pressure, relative humidity, wind speed and direction, percent cloud cover and type, field of view, latitude, longitude, forward direction, side angle and view angle (see measurements record form).

MEASUREMENT RECORD SHEET

1 Experiment Number
10 Observation No.
18 Run Number
27 Experimenter
44 Operator

1 Year
4 Month
7 Day
10 Hour
13 Minute
16 Reference
21 Illumination
30 Air Temp °C
35 Barometer mm Hg
42 Rel.Humidity %
COMMENTS:
45 Wind Speed mph
49 Wind Direction
54 Visibility miles
56 Cloud Cover %
59 Cloud Types
76 Yes - No Comments

1 Detector 1 Incident Range
6 Detector 2 Incident Range
11 Detector 1 Target Range
16 Detector 2 Target Range
21 Detector 3 Range
26 Detector 4 Range
31 Blackbody Pot Set
36 Scan Rate Scans/Sec
41 Ref. High volts
46 Ref. Low volts
51 Field of View °
57 S.W. EQ'ZN
62 L.W.EQ'ZN
67 Photography B W C O I R

1 Latitude N
10 Longitude W
19 Flightline
UNIT 1: 28 Side Angle ° | 31 Swing Angle ° | 34 Forward Direction ° | 38 Distance To ft. | 41 Focal Distance ft.
UNIT 2: 44 ° | 47 ° | 50 ° | 53 ft. | 56 ft.
60 Parellel or Coincide
69 Target Description ....

A 35mm color photograph of each observation will be taken from the aerial bucket. In addition, an oblique photo of each plot will be taken.

Two measurements of each plot will be made by moving the sensor so that a new scene within the plot fills the field of view.

To minimize the effect of solar elevation changes on the spectral response, measurements will only be made when the sun angle is greater than 45 degrees above the horizon.

The thermal data will be acquired as follows: The field system operated by ERL will acquire broad band thernal infrared data with a PRT-6 radiometer boresighted with the Exotech Model 20D spectroradiometer. The instrument will be calibrated using procedures to be established by ERL and LARS. Contact temperature measurements of the targets will not be required.

The field system operated by LARS will acquire spectral-thermal data with the Model 20C spectroradiometer long wavelength unit and the PRT-5 radiometer which will be boresighted with the short wavelength unit. The spectral thermal data will be acquired over the wavelength range of 2.5μm to 14μm. The data will be acquired over wheat plots to be selected on the research farm at Williston, ND. Three of the plots will be equipped with an array of contact and air temperature themistor probes. These data will be collected periodically during a data taking period.

(b) Sensor Calibration and Correlation

Temperature extremes, vibration, dust, and other adverse factors associated with field measurements require that calibration be performed at the site. The procedures chosen reflect the availability of suitable standards and the principal that, in so far as possible, the instrument is exposed to the standard under the same conditions which the measurement is made.

Wavelength calibration of the short wavelength unit is accomplished by irradiating the solar part with sources having known spectral lines. The primary sources are the GE A100/H4T mercury vapor lamp and the helium Pluecker tube. A field wavelength calibrater based on the helium tube was chosen for use because it has at least one strong line in the range of each section of the circular variable filters. Wavelength calibration of the long wavelength unit is based on the absorbtion lines of polystyrene film, carbon dioxide, and methylcyclohexane. A simple field wavelength calibration can be performed by placing a sheet of polystyrene over the opening of the telescope when the instrument is aimed at a uniform view-filling source at 40° to 50° C.

Spectroradiometric calibration of the long wavelength unit involves the measurement of two view-filling blackbodies. The temperature of one blackbody is chosen to be slightly less than the lowest temperature to be encountered in the subject scenes and the temperature of the other blackbody is chosen to be slightly greater than the highest temperature to be encountered. Since, at each wavelength, the spectral radiance of each blackbody is known and since the instrument response voltage varies linearly with spectral radiance, the spectral radiance of the subject is obtained by linear interpolation in the digital computer.

The short wavelength unit may be calibrated for spectral reflectance factor, spectral irradiance, and spectral radiance. A standard based on the highly reflecting properties of barium sulfate is used as a basis for the reflectance factor calibration.

The four foot square standard of barium sulfate paint is used to fill the field of view of the instrument under nearly the same conditions as the measurement to be made. For the simplest calibration, the response to the standard, the full dark response (automatically provided during each spectral scan), and the spectral reflectance/properties of the standard are used to compute the bi-directional reflectance factor with respect to a perfect diffuser. Since it is inconvenient to make this direct comparison for each measurement, the solar part, is frequently used to transfer the reflectance standard.

The calibration calculation consists of forming the ratio of the instrument to the reflectance standard. Correction for the known reflectance of the standard will be made in the computer. This procedure will produce a reflectance factor for the given sun angle and normal viewing of the target.

During the calibration observations the instrument will be aimed straight down at the reflectance standard from a distance of at least six feet. Care will be taken to ensure that the standards are not shadowed and that the illumination conditions are as similar to the conditions of the observation of the subject as possible. Additionally, steps will be taken to minimize the shadowing of skylight and reflective interactions between the instrument support and the reflectance standard. Calibration observations will be performed at a frequency commensurate with the efficient operation of each instrument and the acquisition of meaningful data. This should, however, be at least once every half-hour.

Calibration for spectral irradiance is based on 200 or 1000 watt quartz-iodide lamps which are positioned above the solar port and the response of the instrument is recorded. Of course, accuracy is reduced due to the time interval between calibration and usage. A field irradiance calibrater has been prepared by LARS which will allow insitu irradiance calibration. Spectral radiance may be obtained by computation based on the spectral irradiance and reflectance factor.

It is highly desirable that the instruments be brought together at least once each year for calibration and correlation, including measurement of common targets and reflectance standards, comparison of data collection procedures, and evaluation of instrument performance. This was in fact done in July, 1975 at Williston after it was discovered that data from the ERL system had measured data values significantly greater than the LARS system had for identical standards. It is recommended that resources be made available to accomplish this just prior to the spring-summer, 1976 data collection.

2. Agronomic Data Collection

Crop and soil information for the plots on the research stations will be collected by ERL with assistance from the Agriculture Experiment Station personnel at Garden City and by LARS at Williston. The following data will be collected:

1. Inventory at beginning of season of all plots
    a. Plot number
    b. Size
    c. Species and variety
    d. Irrigation practices

e. Fertilization history

f. Soil type

g. Planting date

h. Other description information

2. Periodic observations at approximately 9 day intervals

a. Field number and crop identification

b. Growth stage

c. Plant height

d. Surface moisture

e. Evaluation of stand quality

f. Field operations such as cultivation or harvesting

g. Stress factors: insect damage, disease, nutrient deficiencies, moisture stress, weeds, or lodging

h. Leaf area index

i. Number of stems, leaves, and heads

j. Dry weight of stems, leaves, heads, and total

k. Soil moisture profile

l. Vertical (for determination of percent ground cover) and oblique 35mm color photographs

3. Other Information

a. LACIE site assessment reports containing detailed information on soils, climate, and crop production practices of the area

b. Daily air temperature, humidity, radiation, wind, precipitation, and soil temperature from nearest weather station

c. Grain yield and test weight

CROPS AND SOILS OBSERVATIONS

Experiment No. | Observation No. | Date | Time

Experiment Name | 18 Investigator

Location: Agronomy Farm Other 32

Field No. 49 | Treatment Level 54 (Factor 1 2 3 4) | Rep. No. 59 | Plot No. 61

Species 1 | Row width 15 cm

Variety 19 | Row Direction 80 (1 = N-S, 2 = E-W, 3 = Other)

Maturity 35 | Ground cover 51 %

Plant Spacing 54 (cm) or 58 plants in 62 . meters of row

Height 68 (cm) | No. Leaves/Plant 72 | Leaf area index 75 .

				Comments
Moisture Stress	yes	1	no	6
Nutrient Deficiency	yes	21	no	26
Weedy	yes	41	no	46
Disease	yes	61	no	66

Hail or Wind Damage	yes	1	no	6
Lodging	yes	21	no	26

Additional Crop Description 41

CROPS AND SOILS OBSERVATIONS

Soil Series 1

Field Texture (circle one) 17: Silt Loam, Silty Clay Loam, Clay Loam, Sandy Clay Loam, Sandy Loam, Loam, Sandy Clay, Silty Clay, Loamy Sand, Sand, Silt, Clay

Lab texture Percent 33 sand | 38 silt | 43 clay

Munsell Color 48 10.0YR/

Moisture 1 Field (dry, moist, wet) | 7 . % Lab

Surface Condition 12 (smooth or rough)

Horizon (A, B, or C) 29

Additional Soil Description 31

Scene Photo Roll No. 1 | Frames 5

General Comments 14

43

Determination of leaf area index (the ratio of leaf area to ground area) is one of the most informative parameters influencing the spectral response of crop canopies. However, it is a very time-consuming and tedious measurement to make for wheat, even with automatic leaf area measurement devices. The following approach, however, can be used to obtain leaf area index (LAI) estimates for a large number of plots with a reasonable level of effort:

1. Harvest a random sample of plants from each major treatment.
2. Measure the length and width of 30 to 50 leaves (depending on their size).
3. Leaf area = length x width x 0.72
4. Dry the sample of measured leaves.
5. Calculate the ratio of leaf area to leaf weight.
6. Harvest a large sample of plants (at least one meter of row) from a known unit of ground area.
7. Separate leaves from stems and heads.
8. Dry and weigh leaves.
9. Let a = area (cm^2) of measured leaves from "small" sample
   w = weight (gms) of measured leaves from "small" sample
   A = area (cm^2) of leaves from "large" sample
   W = weight (gms) of leaves from large sample
   G = ground area (cm^2) of "large" sample
10. $A = a\,W/w$
11. $LAI = A/G$

The method takes advantage of sampling the sources of variability in estimation of leaf area index according to the magnitude of the variability. For example, relatively few measurements are made of the leaf area to weight ratio since it remains nearly constant within a variety and maturity stage, but the major sources of variability (number of plants per unit area and number of leaves per plant) are sampled extensively in the "large" ground area sample. A much better estimate of LAI is therefore available than would be possible by measuring the area of all leaves in what would have to be a much smaller sample of plants or area.

3. Meteorological Data Collection

The following atmospheric and meteorological measurements will be made by ERL and LARS in conjunction with the truck-mounted spectrometer data collection:

a. Percent cloud cover and type

b. Wet and dry bulb temperature (or relative humidity)

c. Barometric pressure

d. Sky brightness

e. Total irradiance

f. Wind speed and direction

g. Soil surface and canopy temperature measurements (selected plots at Williston only)

VII. DATA PROCESSING

Successful accomplishment of the objective statements given above will require data processing support. The data processing includes four basic elements: (1) data bank generation, editing and access, (2) a user analysis capability, (3) a user training program, and (4) availability of the system to other users. Implementation of the system at the LARS computer facility takes advantage of the Exotech Model 20C data processing system currently operational and the availability of remote terminals including dial up. The system can be implemented by expanding the current data processing capability to handle inputs from instrumentation other than the Exotech Model 20C. System expansion involves addition of calibration and reformatting software for data collection equipment other than the Model 20C, modification of the current data bank format for acceptance of other non-20C data, addition of analysis functions to the current user analysis soft ware package (EXOSYS), and development of a training program to augment existing documentation.

A. Data Bank Generation

The data bank will provide a centralized point of data storage and retrieval for spectral data collected for the field research project. Spectral data collected by as many instruments as required by the project will be calibrated and reformatted into a common format for storage in the data bank. Each data collection system (except Model 20C and LANDSAT) entering data into the bank will require new reformatting computer programs for converting data to the common data bank format. The programs may include calibration algorithms as prescribed for the instrument. Data tapes sent to LARS will be 9 or 7 track computer compatible. Nine track tapes will be 800 or 1600 BPI and 7 track 556, or 800 BPI.

The data bank will be the primary access point of field data for analysis during the field research project. Data gathered by instrumentation selected for the project will be calibrated to common units of reflectance factor and reformatted into a standard format for storage in the data bank. The ground truth, instrument parameters, meteorological data and observer commentary associated with spectra will be stored in the data bank.

Spectra will be stored in the data bank in three tape record blocks. The first block is 300 words of identification and descriptor information, the second block is 206 reflectance factor data values in the range 0.35 to 2.4 micrometers with interval and bandwidth .01 micrometers, and the third block is 227 radiance data values in the range 2.7 to 14.0 micrometers with interval and bandwidth .05 micrometers.

1. Ground Truth Data

Test site inventory, periodic observations of crops, and meteorological data verification and editing tasks will be shared by LARS, ERL, and JSC. Ground truth collected for the Kansas test plots will be verified by ERL, for the North Dakota test plots by LARS, and for intensive test site fields by JSC. Following verification and editing, forms will be keypunched at LARS for entry into the data bank.

2. Exotech Model 20C Data

Reformatting of Model 20C data into the common data bank format will be completed in three steps: 1) analog-to-digital conversion, 2) ancillary and ground truth data preparation, and 3) data calibration and formatting. Model 20C data are recorded on 7-track one-half inch instrumentation tape during field operations. The tapes are reproduced at LARS and converted to 10-bit digital form. The raw digital spectra are merged with keypunched ground truth and ancillary data during computer reformatting. The reformatting process calibrates the spectra into units of reflectance factor and writes the spectra and ground truth data into the data bank.

3. Helicopter/FSS Data

During field operations, helicopter/FSS data is digitized and PCM recorded on 14-track one-inch magnetic tape. The PCM recorded tape will be reproduced at JSC, converted to reflectance factor units, formatted and written onto computer compatible tape (CCT) for transmittal to LARS. JSC has developed new software for processing the data to broad-band reflectance. There will be 61 visible and reflective infrared bands and 12 thermal bands. Boresighted 70-mm imagery taken in time synchronization with the S-191 spectra will be processed and edited at NASA. The editing procedure will include qualitative data evaluation, field designation, and time intervals. The film editor will log for each test site field; field number, coverage start time, coverage stop time, and comments. Comments will be indicative of helicopter altitude excursions causing the instrument field of view to exceed test field boundaries and other observations as deemed helpful by the film editor.

The film editing results and the CCT copy of the S-191 data will be sent to LARS. At LARS the CCT data will be merged with associated ground truth, and stored in the data bank. The spectra will be stored in spectra sets, where a set consists of all spectral scans (which do not contain a field boundary) collected over one test field during one time interval.

4. Interferometer (VISS) Data

Data collected by the interferometer instrument will be calibrated and processed into units of reflectance factor at NASA. The data will be sent to LARS in CCT form. At LARS, the CCT data will be merged with ground truth data and written into the data bank in the standard format.

5. Exotech Model 20D Data

Data collected by the Exotech Model 20D will be calibrated into units of reflectance factor, formatted, and sent to LARS on computer compatible tape. At LARS, the CCT data will be merged with ground truth data and written into the common data bank.

6. LANDSAT Band Radiometer Data

Because of their limited scope these data will be handled manually rather than thru the computer system. A fully annotated data set will, however, be available to CSU and other interested users.

7. Multispectral Scanner Data

LANDSAT MSS data tapes will be sent to LARS for inclusion in the data bank and will be available in LARSYS Version 3 format. Twenty-four channel MSS data will be processed by NASA to provide CCT form data to LARS for the data bank.

8. PRT-5 and PRT-6 Data

These data will be keypunched and included with the spectral data collected by the Exotech spectroradiometers.

B. Analysis Software

The analysis software package will provide primary access to the data bank and data analysis functions pertinent to completion of the project objectives. Implementation of the package will be through expansion and adaptation of the currently operational Model 20C data analysis software, EXOSYS. EXOSYS is highly user-oriented and currently includes three analysis functions:

(1) Lists identification information describing Exotech data storage tape runs.

(2) Prints data and graphical displays.

(3) Punches cards or writes data on tape for use in other statistical analysis programs.

Example products of EXOSYS are shown in the following figures. The software system and its use has been documented.

Statistical analysis functions have not been implemented to date because detailed specifications of such functions have not been completed. In support of the field research project, such specifications would be of primary importance to allow installation of needed analysis functions. The system is currently designed for use on terminal sites equipped with typewriter, card read-punch and line printer, however, it could be modified for operation on simple terminals consisting of a typewriter only.

```
EXCSYS                LABORATORY FOR APPLICATIONS OF REMOTE SENSING          AUG  16,1974
VERSION 1.1                        PURDUE UNIVERSITY                          2 47 23 PM
```

```
RUN SEQUENCER .................... 1          RUN NUMBER ..................... 72003100
EXPERIMENT NUMBER .............72100201       OBSERVATION NUMBER ............      70601
TIME DATA COLLECTED .............. 1721       EXPERIMENT NAME .......        GROUND COVER
PRINCIPAL INVESTIGATOR     BAUER, MARVIN      LOCATION .............         AGRONOMY FARM
AIR TEMPERATURE ................... 19.3      CLOUD COVER ........................... 10
VISIBILITY ........................ 4.00      REFORMATTING DATE .......             3/ 8/73
REFORMATTING CALIBRATION CODE ....... 3       SIDE ANGLE ............................ 00
SWING ANGLE ........................ 00       FORWARD DIRECTION ..................... 135
DISTANCE TO GROUND ............... 30.00     FIELD OF VIEW ....................... 15.00
LOCATION LATITUDE ............. 384536N      LOCATION LONGITUDE ............    873441W
NUMBER OF SAMPLE GROUPS ............. 3      TREATMENT CODE 1 ......................  1
TREATMENT CODE 2 .................... 2      FIELD NUMBER ..........................  62
REPLICATION NUMBER .................. 1      PLOT NUMBER ...........................   1
SPECIES ...............            CORN      VARIETY ..............            P10 3369A
MATURITY ..............  10 LEAF STAGE      HEIGHT ............................... 84.40
ROW WIDTH ......................... 7.60      LEAVES PER PLANT .......................  9
LEAF AREA INDEX ................... 0.53      LATEST ID UPDATE DONE ...            5/31/73
SERIES NAME ...........        CHALMERS      TEXTURE ..............     SILTY CLAY LOAM
MUNSELL COLOR .........        10YR 3/2      MOISTURE (FIELD) CONTENT               MOIST
SURFACE CONDITION .....      SMOOTH-DRY      HORIZON ...........................     A
INSTRUMENT NAME ....... EXOTECH MOD 20C      SCAN RATE ........................... 0.25
IRRADIANCE CALIBRATION RUN .... 72032100      HIGH SQUARE WAVE LEVEL ........... 5.000
LOW SQUARE WAVE LEVEL ........... 0.001
  SOLAR CR CANOPY+SOIL                  CLOUDS ON HORIZON
```

DETECTOR NAME	DETECTOR RANGE	DETECTOR EQUILIZATION	NUMBER OF SAMPLES	WAVE BAND COEFFICIENTS A	B	C	D	SAMPLE GROUP
SI	0.300	0.25	465	0.374	0.001	0.0	0.0	1
PB S	0.300	0.25	450	0.747	0.001	0.0	0.0	2
PB S	0.300	0.25	443	1.289	0.003	0.0	0.0	3

```
RUN SEQUENCER .................... 2          RUN NUMBER ..................... 72003200
EXPERIMENT NUMBER .............72100201       OBSERVATION NUMBER ............      70602
TIME DATA COLLECTED .............. 1726       EXPERIMENT NAME .......        GROUND COVER
PRINCIPAL INVESTIGATOR     BAUER, MARVIN      LOCATION .............         AGRONOMY FARM
AIR TEMPERATURE ................... 19.3      CLOUD COVER ........................... 10
VISIBILITY ........................ 4.00      REFORMATTING DATE .......             3/ 8/73
REFORMATTING CALIBRATION CODE ....... 3       SIDE ANGLE ............................ 00
SWING ANGLE ........................ 00       FORWARD DIRECTION ..................... 180
DISTANCE TO GROUND ............... 30.00     FIELD OF VIEW ....................... 15.00
NUMBER OF SAMPLE GROUPS ............. 3      TREATMENT CODE 1 ......................  1
TREATMENT CODE 2 .................... 3      FIELD NUMBER ..........................  62
REPLICATION NUMBER .................. 1      PLOT NUMBER ...........................   2
SPECIES ...............            CORN      VARIETY ..............            P10 3369A
MATURITY ..............  10 LEAF STAGE      HEIGHT ............................... 81.80
ROW WIDTH ......................... 7.60      LEAVES PER PLANT .......................  7
LEAF AREA INDEX ................... 1.83      MOISTURE STRESS ...       YES VERY SLIGHT
LATEST ID UPDATE DONE ...        5/31/73      SERIES NAME ........... CHALMERS          N
TEXTURE ..............   SILTY CLAY LOAM      MOISTURE (FIELD) CONTENT               MOIST
SURFACE CONDITION .....      SMOOTH-DRY      HORIZON ...........................     A
INSTRUMENT NAME ....... EXOTECH MOD 20C      SCAN RATE ........................... 0.25
IRRADIANCE CALIBRATION RUN .... 72032100      HIGH SQUARE WAVE LEVEL ........... 5.000
LOW SQUARE WAVE LEVEL ........... 0.001
  SOLAR CR CANOPY+SOIL                  MOVED FOV LFT SOUTH
```

DETECTOR NAME	DETECTOR RANGE	DETECTOR EQUILIZATION	NUMBER OF SAMPLES	WAVE BAND COEFFICIENTS A	B	C	D	SAMPLE GROUP
SI	0.300	0.25	465	0.374	0.001	0.0	0.0	1
PB S	0.100	0.25	450	0.747	0.001	0.0	0.0	2
PB S	0.100	0.25	443	1.289	0.003	0.0	0.0	3

```
RUN SEQUENCER .................... 3          RUN NUMBER ..................... 72003300
EXPERIMENT NUMBER .............72100201       OBSERVATION NUMBER ............      70603
TIME DATA COLLECTED .............. 1734       EXPERIMENT NAME .......        GROUND COVER
PRINCIPAL INVESTIGATOR     BAUER, MARVIN      LOCATION .............         AGRONOMY FARM
AIR TEMPERATURE ................... 19.3      CLOUD COVER ........................... 10
VISIBILITY ........................ 4.00      REFORMATTING DATE .......             3/ 8/73
REFORMATTING CALIBRATION CODE ....... 3       SIDE ANGLE ............................ 00
SWING ANGLE ........................ 00       FORWARD DIRECTION ..................... 180
DISTANCE TO GROUND ............... 30.00     FIELD OF VIEW ....................... 15.00
NUMBER OF SAMPLE GROUPS ............. 3      FIELD NUMBER ..........................  62
PLOT NUMBER ......................... 2      SPECIES ...............                CORN
VARIETY ...............       P10 3369A      MATURITY ..............       10 LEAF STAGE
HEIGHT ............................ 81.80     ROW WIDTH ............................ 7.60
LEAVES PER PLANT .................... 7      LEAF AREA INDEX ...................... 1.83
LATEST ID UPDATE DONE ...        5/31/73      INSTRUMENT NAME .......     EXOTECH MOD 20C
SCAN RATE ......................... 0.25      IRRADIANCE CALIBRATION RUN .... 72032100
HIGH SQUARE WAVE LEVEL ........... 5.000     LOW SQUARE WAVE LEVEL ............. 0.001
  SOLAR CR CANOPY+SOIL                  MOVED FOV LFT SOUTH
```

DETECTOR NAME	DETECTOR RANGE	DETECTOR EQUILIZATION	NUMBER OF SAMPLES	WAVE BAND COEFFICIENTS A	B	C	D	SAMPLE GROUP
SI	0.300	0.25	465	0.374	0.001	0.0	0.0	1
PB S	0.100	0.25	450	0.747	0.001	0.0	0.0	2
PB S	0.100	0.25	443	1.289	0.003	0.0	0.0	3

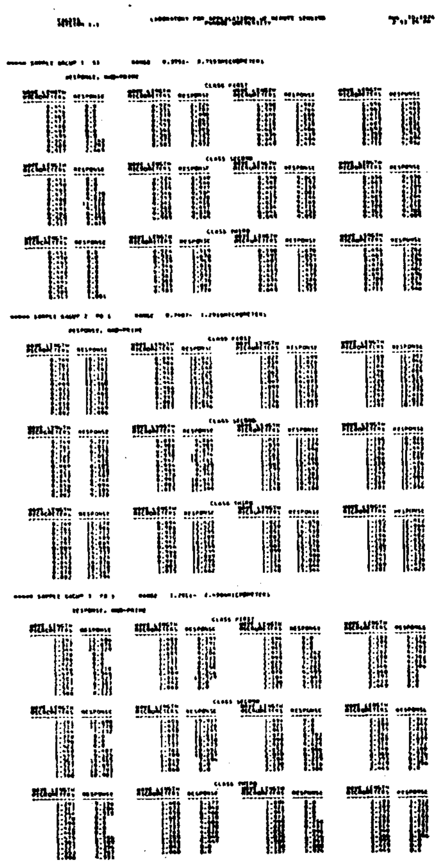
Example computer output from the IDLIST processor.

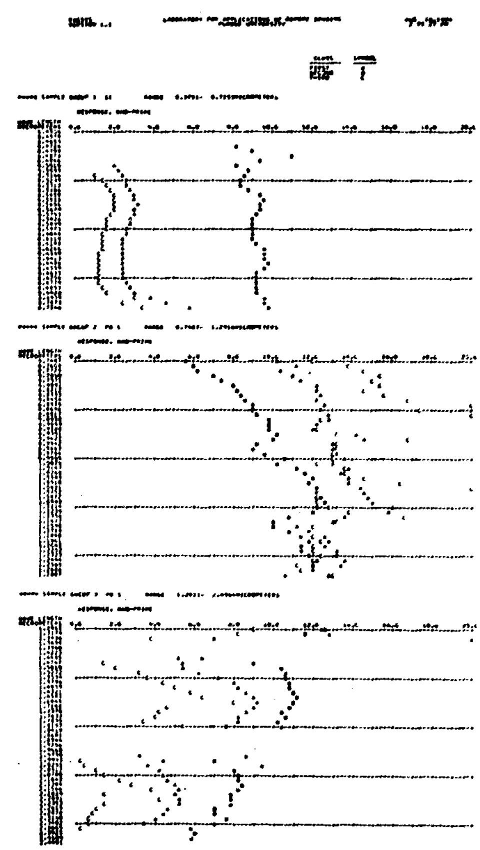
```
EXOSYS                LABORATORY FOR APPLICATIONS OF REMOTE SENSING            AUG 16,1974
VERSION 1.1                        PURDUE UNIVERSITY                           2 54 29 PM

RUN NUMBER ..................... 72017300      RUN SEQUENCER ...................      55
EXPERIMENT NUMBER ...............72100202      TIME DATA COLLECTED ............... 1640
EXPERIMENT NAME .......       CORN BLIGHT      DATE DATA COLLECTED .....         8/ 9/72
OBSERVATION NUMBER ...............  80901      REFORMATTING DATE .......         5/31/73
CLASS NAME ....................SET A

RUN NUMBER ..................... 72017400      RUN SEQUENCER ...................      56
EXPERIMENT NUMBER ...............72100202      TIME DATA COLLECTED ............... 1644
EXPERIMENT NAME .......       CORN BLIGHT      DATE DATA COLLECTED .....         8/ 9/72
OBSERVATION NUMBER ...............  80902      REFORMATTING DATE .......         5/31/73
CLASS NAME ....................SET A

RUN NUMBER ..................... 72017500      RUN SEQUENCER ...................      57
EXPERIMENT NUMBER ...............72100202      TIME DATA COLLECTED ............... 1650
EXPERIMENT NAME .......       CORN BLIGHT      DATE DATA COLLECTED .....         8/ 9/72
OBSERVATION NUMBER ...............  80903      REFORMATTING DATE .......         5/31/73
CLASS NAME ....................SET A

RUN NUMBER ..................... 72017600      RUN SEQUENCER ...................      58
EXPERIMENT NUMBER ...............72100202      TIME DATA COLLECTED ............... 1651
EXPERIMENT NAME .......       CORN BLIGHT      DATE DATA COLLECTED .....         8/ 9/72
OBSERVATION NUMBER ...............  80904      REFORMATTING DATE .......         5/31/73
CLASS NAME ....................SET A

RUN NUMBER ..................... 72017700      RUN SEQUENCER ...................      59
EXPERIMENT NUMBER ...............72100202      TIME DATA COLLECTED ............... 1659
EXPERIMENT NAME .......       CORN BLIGHT      DATE DATA COLLECTED .....         8/ 9/72
OBSERVATION NUMBER ...............  80905      REFORMATTING DATE .......         5/31/73
CLASS NAME ....................SET B

RUN NUMBER ..................... 72017800      RUN SEQUENCER ...................      60
EXPERIMENT NUMBER ...............72100202      TIME DATA COLLECTED ............... 1701
EXPERIMENT NAME .......       CORN BLIGHT      DATE DATA COLLECTED .....         8/ 9/72
OBSERVATION NUMBER ...............  80906      REFORMATTING DATE .......         5/31/73
CLASS NAME ....................SET B

RUN NUMBER ..................... 72017900      RUN SEQUENCER ...................      61
EXPERIMENT NUMBER ...............72100202      TIME DATA COLLECTED ............... 1703
EXPERIMENT NAME .......       CORN BLIGHT      DATE DATA COLLECTED .....         8/ 9/72
OBSERVATION NUMBER ...............  80907      REFORMATTING DATE .......         5/31/73
CLASS NAME ....................SET B

RUN NUMBER ..................... 72018000      RUN SEQUENCER ...................      62
EXPERIMENT NUMBER ...............72100202      TIME DATA COLLECTED ............... 1705
EXPERIMENT NAME .......       CORN BLIGHT      DATE DATA COLLECTED .....         8/ 9/72
OBSERVATION NUMBER ...............  80908      REFORMATTING DATE .......         5/31/73
CLASS NAME ....................SET B
```

```
EXOSYS                LABORATORY FOR APPLICATIONS OF REMOTE SENSING            AUG 16,1974
VERSION 1.1                        PURDUE UNIVERSITY                           2 55 02 PM
```

	BAND LIMITS	0.400 0.500	0.600 0.650	0.800 0.900	12.000 13.000
	NO SAM	138	69	84	71
CLASS SET A	RUN 72017300	0.0	1.59	11.43	826.70
CLASS SET A	RUN 72017400	0.02	1.64	10.29	842.34
CLASS SET A	RUN 72017500	0.0	1.60	11.14	834.35
CLASS SET A	RUN 72017600	0.0	1.44	12.03	810.96
CLASS SET B	RUN 72017700	0.07	2.19	8.20	834.72
CLASS SET B	RUN 72017800	0.07	1.53	9.90	836.79
CLASS SET B	RUN 72017900	0.03	2.28	8.62	850.53
CLASS SET B	RUN 72018000	0.02	1.71	11.28	820.89

Example computer output from the DATA SELECT processor.





Example computer output from the GRAPH processor.

C. System and Data Availability

The key element to providing a centralized data processing system to several institutions in support of a coordinated project is system availability. Hardware currently installed at the LARS computer facility enables linkage of remote terminals via common carrier communications lines. To date, remote high speed reader-printer-punch and low speed typewriter terminal systems have been installed. The task of providing access at remote sites, therefore, reduces to procurement of remote site terminal equipment and adaptation of the software to various terminal output requirements.

Alternatively, if analysts at other institutions choose not to utilize the data handling and analysis software developed at and available thru LARS, only the data and its documentation will be provided.

D. Training Program

Analysis results will be significantly improved by an effective training program or educational procedure directed toward timely orientation of user analysts to the available facilities. The program will consist primarily of tutorial classroom type presentations of system documentation with on-line computer session demonstrations.

E. Data Processing Subtasks

The following is a list of major subtasks which support the data processing task of the field measurements research project:

(1) Study and evaluate instrumentation selected for the field research project. Data characteristics, applications and delivered format will be reviewed to determine its impact on data bank format, user analysis software (EXOSYS) and to determine programming resources required to convert the data to a common format. This study is essential to defining an adequately encompassing data bank format.

(2) Determine user requirements not satisfied by the current Model 20C data bank. This task includes one or more meetings with user groups to discuss the existing system's operations and capabilities to determine what modifications will be required for the project.

(3) Modify the existing system data bank format. Following determination of what data collection instrumentation will be providing inputs to the data bank, the base system data bank format will require modification in order to accomodate instrumentation other than the Model 20C for which it was specifically designed.

(4) Specify data collection, calibration and reformatting procedures. For each instrument selected for providing input to the system, a specific procedure for collecting and entering the data into the data bank will be required. This procedure must be well planned in order to achieve minimum data transmission time from the field to the data bank. This task will be completed for each type of instrument used and in conjunction with the measurements team of the project.

(5) Modify the Model 20C calibration and reformatting

software and generate new reformatting software. Depending on the final data bank format specification, current Model 20C reformatting software will require alteration.

(6) Develop 24-Channel data reformatting software. Programs to reformat 24-Channel MSS to LARSYS format must be written.

(7) Develop S-191 reformatting software. Programs must be written to S-191 data and merge JSC and ASCS growth truth data for entry into the data bank.

(8) Develop Interferometer software. A reformatting program will be required to reformat calibrated interferometer data for entry in the data bank.

(9) Develop Model 20D reformatting software. Programs must be written to merge ground truth and reformat calibrated Model 20D data for entry into the data bank.

(10) Adapt EXOSYS to the project requirements. EXOSYS will require program modifications dependent on uset requirements (subtask 2 above), data bank format changes, and remote terminals installed.

(11) Write a user manual. The user manual will consist of a user-oriented description of the analysis software with detailed discussion on how to use the system.

(12) Classroom presentation. A tutorial presentation will be prepared for presentation to new users of the software. This presentation will include a terminal session demonstration in the use of the software.

(13) Provide assistance in implementation of remote system access to participating institution. This subtask includes

consulting with remote users advising them of remote access methods supported by the LARS computer facility, and assistance in implementation of remote terminal equipment.

(14) Prepare data users guide and index. An index to all agronomic, meteorological, and spectral data collected for the project will be prepared and published to assist data users in selecting the data required for their particular research.

(15) Disseminate data to users. Data will be routinely disseminated to users identified in the data analysis section and to other users upon request.

VIII. DATA ANALYSIS

Analysis of the spectral, agronomic, and meteorological data collected will be performed by LARS, ERIM, TAMU, and CSU. Analysis tasks have been divided among these institutions by objective, e.i., each institution is responsible for analyzing the data required to meet specific objectives. Most of the data analysis will be performed as part of other SR&T research tasks; however, the analysis objectives are briefly described here. The analysis plans will be further developed prior to the start of data analysis.

A. LARS

LARS will analyze the spectral (Exotech, S-191, A/C and LANDSAT MSS), agronomic and meteorological data to:

(1) Determine the effect of crops, soil, and management variables on the spectra of wheat and determine their effects on signature extension. Comparisons of wheat at various stages of maturity with other confusion crops will be made.

(2) Determine the relationship of wheat grain yield to spectral response.

The analysis procedures will utilize univariate and multivariate analysis of variance and multiple regression to determine relationships among agronomic and meteorological variables and spectral response. Variability of spectral response and the factors accounting for it will be determined.

Variation in the S-191 and A/C and LANDSAT MSS data within and among fields will be determined to obtain a measure of the degree of variation in the natural scene (fields in the intensive test site) while the Exotech data will be analyzed to determine the effects of individual factors which could not be quantified in the intensive test site fields.

(3) Determine the characteristics of thermal measurements for discrimination of wheat.

The thermal data will be analyzed as follows:

a. Determine the physical parameters of crop canopies that cause thermal differences among different canopies.

b. Determine the thermal interaction between the canopy and the environment and investigate the energy transfer and storage mechanisms within wheat canopies.

c. Determine to what extent the canopy is a Lambertian emitter and reflecter and identify source of non-Lambertianess.

d. Quantitatively determine the relation of canopy geometry to emission.

B. ERIM

ERIM will perform the following data analysis tasks:

(1) Determine preferred time(s) for discriminating wheat through analysis of the measurement and model data and recognition processing of LANDSAT data.

(2) Determine if multitemporal signatures of wheat permit its remote identification without ground truth.

(3) Identify the major factors affecting signature

extendability and study means for overcoming deleterious effects on recognition of wheat.

The analyses will include analysis of variance and regression to characterize magnitudes and sources of variability of wheat reflectance and to determine the significance of the various factors considered. In addition, comparisons of measurements with calculations made with Suit's vegetation canopy reflectance model will be made. And, LANDSAT data collected over the test areas will be correlated with the field measurement data.

C. Texas A & M University (TAMU)

TAMU will have responsibility for analyzing the field measurements data set, including LANDSAT data, to:

(1) Determine the optimum biological phases for spring and winter wheat discrimination.

(2) Determine the degree of discriminability between unharvested and harvested wheat, including wheat which has not or will not be harvested due to poor yield (e.g., crop abandonment).

(3) Verify the correlation between LANDSAT, S-191, and field spectrometer data.

In preparation for analyzing data from Kansas and North Dakota, TAMU will analyze the 1973 LANDSAT, S-191, and ground truth data from Bushland, Texas.

D. Colorado State University (CSU)

CSU will perform analyses required to define a simple signature extension algorithm to account for variations in sun angle at various stages of crop development based on wheat canopy modeling.

E. Other Investigators

It is understood that other investigators may want to analyze parts of the data. As additional investigators and their objectives are identified data from the data library will be supplied to them. The following investigators planning to use field measurements data have been identified:

1. Goddard Institute of Space Science--Conduct simulation studies on the accuracy of terrain classification as a function of instrument parameters.
2. ERL--determine typical subsets of spectral and spatial resolution required for earth resources applications.
3. LARS--derive an analytical procedure capable of predicting optimal or achievable classification accuracy for a given program and scanner design.

IX. SCHEDULE

The August-December, 1974 period was spent in preparation for and planning the project, although certain modifications and additions to the plan have subsequently been made, e.g., addition of A/C MSS data collection.

Data collection began at Garden City, Kansas in mid-October and early November with the LARS Exotech and S-191. Data collection was re-initiated in Kansas in March with the ERL Exotech and S-191 and in early April the 24-Channel MSS began collecting data. Data collection in Kansas will continue with all three systems thru harvest in early July.

Data collection in North Dakota began in May with the 24-Channel MSS and early June with the S-191 and LARS Exotech and will continue thru harvest in late August or early September.

Data processing and entering the data into the data library will occur during May-October, 1975. Data from the early missions should be processed, entered in the data library, and ready for analysis by August 1, 1975 (although this is dependent upon timely receipt of the data from ERL and JSC at LARS). All data should be ready for analysis by November 1, 1975.

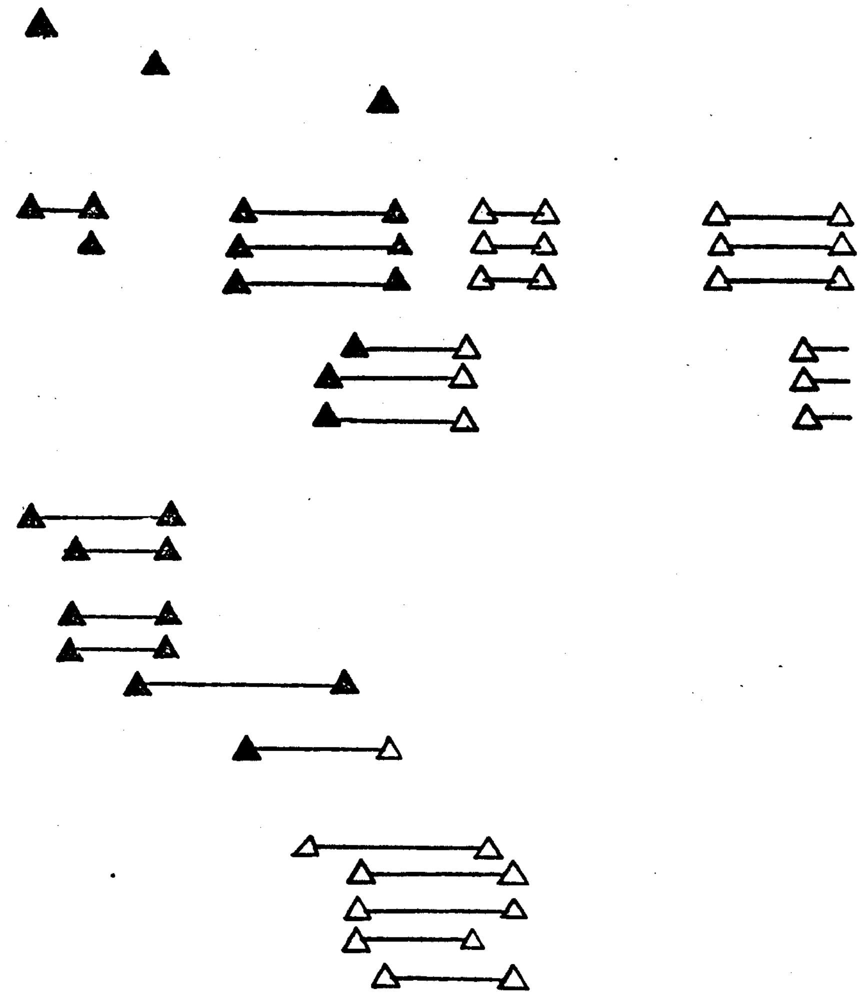
Data analysis will be carried-out during the August, 1975 to April, 1976 time period. Results of the first year's investigations are to be completed by May 30, 1976.

Data collection for the 75-76 crop will start in Kansas and South Dakota in mid-September and in April in North Dakota.

A schedule of tasks follows:

Field Measurements Research Schedule

Task	1974 A S O N D	1975 J F M A M J J A S O N D	1976 J F M A M J



Project Definition and Planning

- Project Plan - I
- Project Plan - II
- Project Plan - III

Data Collection

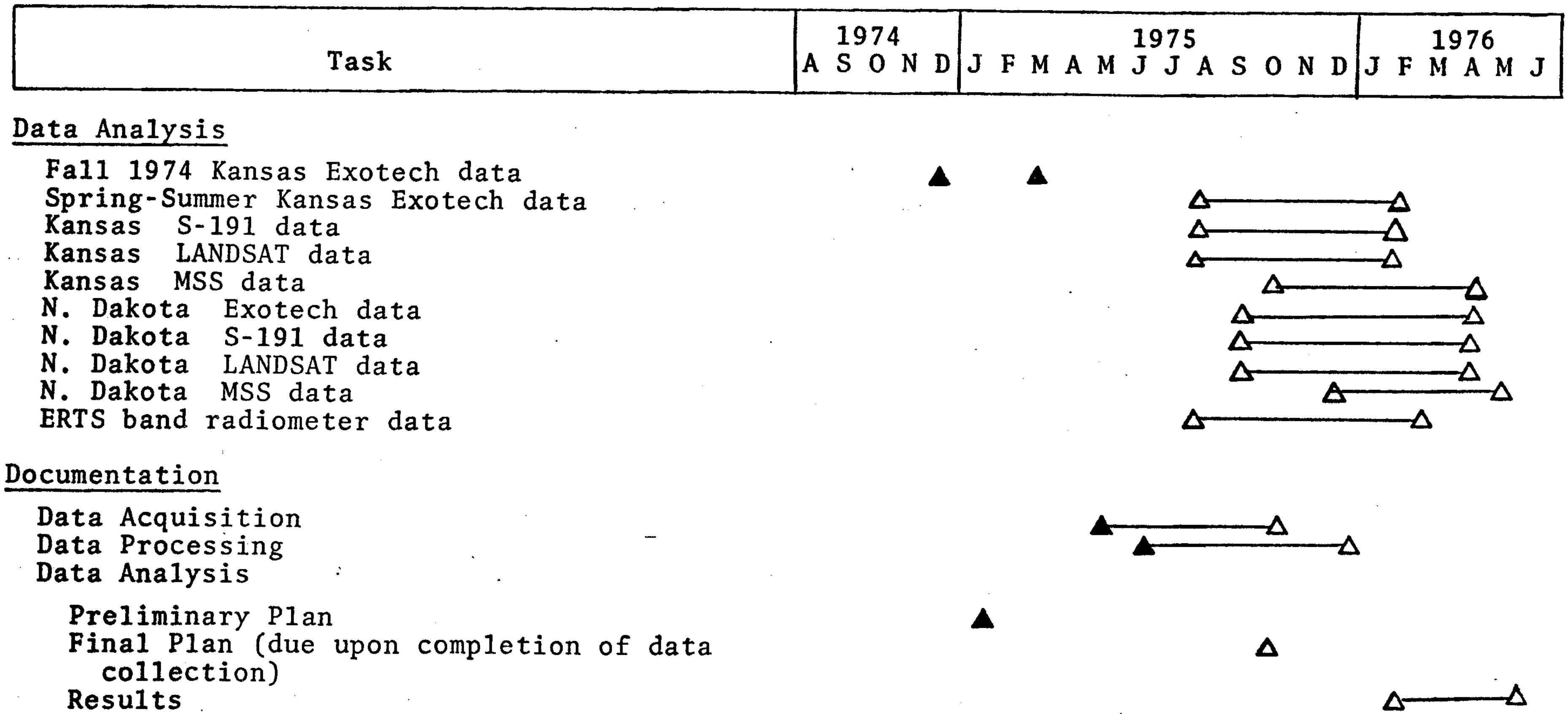
Kansas - Exotech
- S-191
- MSS

N. Dakota - Exotech
- S-191
- MSS

Data Processing Tasks

- Develop S-191 processing software (JSC)
- Programming to convert VISS data to reflectance (JSC)
- Develop specifications for reformatting (LARS)
- Develop specifications for data library (LARS)
- Modify calibration and reformatting software for S-191, 20D, and VISS (LARS)
- Modify EXOSYS software for other sensor data (LARS)
- Operational data processing
  - S-191 (JSC)
  - S-191 (LARS)
  - MSS (JSC)
  - Exotech - Model 20D (ERL & LARS)
  - Exotech - Model 20C (LARS)

Field Measurements Research Schedule (Cont.)



Field Measurements Data Collection Calendar, 1974-1975

Kansas					
Date	LANDSAT-1	LANDSAT-2	S-191	A/C MSS	Exotech
1974					
October 18	X				X
November 5	X		X		X
1975					
March 20		X	X	X	X
April 7		X	X	X	X
April 25		X	X	X	X
May 13		X	X	X	X
May 22	X		X	X	X
May 31		X	X	X	X
June 9	X		X	X	X
June 18		X	X	X	X
June 27	X		X	X	X
July 6		X	X	X	X

Mid-September, begin 75-76 data collection

North Dakota					
Date	LANDSAT-1	LANDSAT-2	S-191	A/C MSS	Exotech
May 17		X		X	
May 26	X			X	
June 4		X	X	X	X
June 13	X			X	
June 22		X	X	X	X
July 1	X			X	
July 10		X	X	X	X
July 19	X		X	X	X
July 28		X	X	X	X
August 6	X		X	X	
August 15		X	X	X	X
August 24	X		X	X	X
September 2		X	X	X	

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* Data collection "window" for S-191 and A/C MSS data is minus one to plus two of the LANDSAT pass.

+ The "window" for Exotech data collection lasts until all data is collected.

Tentative Field Measurements Data Collection Calendar, 1975-1976

Kansas					South Dakota				North Dakota				
Date	LANDSAT-2	A/C MSS	Helicopter FSS	Truck Spectrometer	Date	LANDSAT-2	A/C MSS	Helicopter FSS	Date	LANDSAT-2	A/C MSS	Helicopter FSS	Truck Spectrometer
Sept. 15	X				Sept. 16	X	X	X	Sept. 20	X			
Oct. 3	X	X	X	X	Oct. 4	X			Oct. 8	X			
Oct. 21	X			X	Oct. 22	X	X	X	Oct. 26	X			
Nov. 8	X	X	X	X	Nov. 11	X			Nov. 13	X			
March 14	X	X	X	X	March 15	X			March 19	X			
April 1	X	X	X	X	April 2	X			April 6	X			
April 19	X	X	X	X	April 20	X			April 24	X			
May 7	X	X	X	X	May 8	X	X	X	May 12	X	X	X	X
May 25	X	X	X	X	May 26	X			May 30	X	X	X	X
June 12	X	X	X	X	June 4		X	X	June 17	X	X	X	X
June 30	X	X	X	X	June 13	X			July 15	X	X	X	X
July 18	X	X	X	X	June 20		X	X	July 23	X	X	X	X
					July 1	X			Aug. 10	X	X	X	X
					July 10		X	X	Aug. 28	X	X	X	X
					July 19	X			Sept. 15	X	X	X	
					Aug. 1		X	X					

X. ORGANIZATION AND MANAGEMENT

The following institutions will be participating in the project: NASA/JSC and ERL, USDA/ASCS, LARS/Purdue, ERIM, Texas A & M University and Colorado State University. The Agriculture Experiment Stations of Kansas and North Dakota will also be participants.

Overall technical coordination of the project is to be provided by LARS. NASA/EOD will provide project management. A technical management committee with representatives from each institution has been established. The representatives are as follows:

Marvin Bauer, LARS, Technical Manager
Michael McEwen, NASA/EOD, NASA Project Manager
Clark Ison, USDA/ASCS
William Malila, ERIM
Cliff Harlan, TAMU
Leroy Silva, LARS
James Smith, CSU
R. H. Griffin, ERL

The major tasks for which each institution is responsible are as follows:

LARS/Purdue

1. Technical leadership and coordination.
2. Exotech spectroradiometer data collection and supporting ground truth at Williston, ND.
3. Reformatting, storage, screening, and retrieval of all sensor data and associated ground truth.

4. Development of analysis software and training of analysts in its use.
5. Data analysis for signature extension, yield, and thermal data objectives.

NASA/JSC

1. Data collection with S-191 and 24-Channel MSS.
2. Preprocessing of 24-Channel MSS data, provide CCT's.
3. Conversion of S-191 data to reflectance, provide CCT's.
4. Conversion of interferometer data to reflectance, provide CCT's.
5. Annotation of helicopter photography and S-191 data and MSS data.
6. Optical depth and visibility measurements at time of flights.
7. Editing of ground truth collected by ASCS.
8. Determination of ground cover and soil color from 35 mm photos.
9. Provide interferometer system as back-up.

NASA/ERL

Data collection with Exotech Model 20D, PRT-6, and supporting ground truth at Garden City.

Texas A & M University

1. Data analysis for biological phases and harvested-unharvested wheat objectives.
2. Collection of ERTS band radiometer and supporting data at Garden City.

Colorado State University

Data analysis for sun angle effects objective.

ERIM

Data analysis for optimum time, multitemporal signature, and signature extension objectives.

USDA/ASCS

Ground observation data collection for intensive test site fields in Finney County, Kansas; Williams County, North Dakota; and Hand County, South Dakota.

Kansas State University and North Dakota State University

Provide experimental plots of wheat and other crops.