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Supporting Field Research Project Plan, 1980-82

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SUPPORTING FIELD RESEARCH

PROJECT PLAN, 1980-82

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I. INTRODUCTION

Major advancements have been made in recent years in the capability to acquire, process, and interpret remotely sensed multispectral measurements of the energy reflected and emitted from crops, soils, and other earth surface features. As a result of experiments such as the Large Area Crop Inventory Experiment (LACIE), the technology is moving rapidly toward operational applications (1). There is, however, a continuing need for more quantitative knowledge of the multispectral characteristics of crops and soils if further advancements in the technology are to be made.

Understanding of the relationships between the spectral characteristics and important biological-physical parameters of earth surface features can best be obtained by carefully controlled studies over fields and plots where complete data describing the condition of targets are attainable and where frequent, timely spectral measurements can be obtained. It is these attributes which distinguish field research from other remote sensing research activities.

In 1975, field research activities in support of LACIE were initiated (2). Spectral, agronomic, and meteorological measurements were made at LACIE test sites in Kansas, South Dakota and North Dakota for three years. The remote sensing measurements include data acquired by truck-mounted spectrometers, a helicopter-borne spectrometer, airborne multispectral scanners, and the Landsat multispectral scanners (MSS). There data were supplemented by an extensive set of agronomic and meteorological data acquired during each mission. In 1978-79, a limited amount of data were acquired for corn and soybeans, while continuing the South Dakota site for spring and winter wheat.

The data form one of the most complete and best documented data sets acquired for agricultural remote sensing research. Thus, they are well-suited to serve as a data base for research to: (1) quantitatively determine the relationship of spectral to agronomic characteristics of crops, (2) define future sensor systems, and (3) develop advanced data analysis techniques. The data base, which has become an integral part of the AgRISTARS Supporting Research Project data base, is unique in the comprehensiveness of sensors and missions over the same sites throughout several growing seasons and in the calibration of all multispectral data to a common standard.

Continuing analysis of the field data is providing insight into the spectral properties and spectral identification and assessment of crops. The analyses include determination of the effects of cultural and environmental factors on the spectral reflectance of wheat, corn and soybeans; development of predictive relationships between spectral and agronomic variables related to growth and yield of corn, soybeans and wheat; and comparisons of Landsat MSS and thematic mapper spectral bands for crop identification and assessment.

As we look ahead in the AgRISTARS program to building a capability for new and improved applications utilizing remote sensing techniques (3), it is critical to begin to conduct the field research required to understand the spectral characteristics of crops other than wheat, such as corn, soybeans, rice, sorghum, barley, and cotton. This document describes the objectives and experimental approaches for the Supporting Field Research to be conducted in 1980-82.

A major distinction of the Supporting Field Research and the previous LACIE Field Measurements Project is that the data acquisition is determined by the requirements of specific analysis objectives, whereas LACIE Field Measurements had the overall objective of acquiring and assembling a large general purpose data set and specific analysis objectives were largely defined after the data were collected.

II. OBJECTIVES

The overall objectives of the AgRISTARS Supporting Field Research are:

1. Conduct analyses and develop physical models of the spectral properties of crops and soils in relation to agronomic and other physical characteristics of the scene.

   - Development of relationships and models which predict agronomically important crop canopy characteristics including development stage, leaf area index, percent canopy cover, and canopy vigor or stress from spectral inputs
   - Development of relationships and models which predict spectral response of crops based on cultural factors such as row spacing, planting date and cultivar; soil background conditions; environmental conditions; and atmospheric effects.

2. Provide candidate models, analyst aids and analysis techniques as input to Supporting Research Experiments

   - Crop development stage models
   - Spectral aids (e.g. transformations of T.M.)
   - Crop stress models
   - Image products

3. Assess capability of current, planned and possible future satellite sensor systems to capture available information for identification and

assessment of crops and soils

- Landsat MSS and thematic mapper
- Multispectral Resource Sampler (MRS)
- Optical + radar/microwave measurements.

III. SUMMARY OF EXPERIMENTAL APPROACH

An overview of the experimental approach is shown in Figure 1. At the beginning of the project the technical issues and specific objectives to be addressed with field research data were defined. This led to the definition of the experimental design for data acquisition and processing and the initial definition of data analysis plans and products.

A multistage approach to data acquisition with areal, vertical, and temporal staging is used (Figure 2). Areal sampling is accomplished with test sites in different parts of the Great Plains and Corn Belt. Vertical staging, or collection of data by different sensor systems at different altitudes, ranges from mobile towers to Landsat. Temporally, data are collected at seven to 21-day intervals to sample important crop growth stages, and during several years to obtain a measure of the year-to-year variations in growing conditions and their influence on spectral response.

The test locations are three-five by six mile segments in Cass County, North Dakota, and Webster County, Iowa, and Wharton County, Texas, and two agricultural experiment stations, the Purdue University Agronomy Farm at West Lafayette, Indiana, and the University of Nebraska, Sandhills Agricultural Laboratory near North Platte, Nebraska (Figure 3). The major crops in the test sites are: Cass County, spring wheat, barley and sunflowers; Wharton County, cotton and rice; Webster County, corn and soybeans; Sandhills, irrigated corn; and Purdue, corn, soybeans, and winter wheat.

The primary sensors for data collection are truck-mounted radiometer and spectrometers, a helicopter-borne spectrometer, and aircraft multispectral scanner, and the Landsat-2 and -3 multispectral scanners. Each sensor system has unique capabilities for acquiring spectral data. The

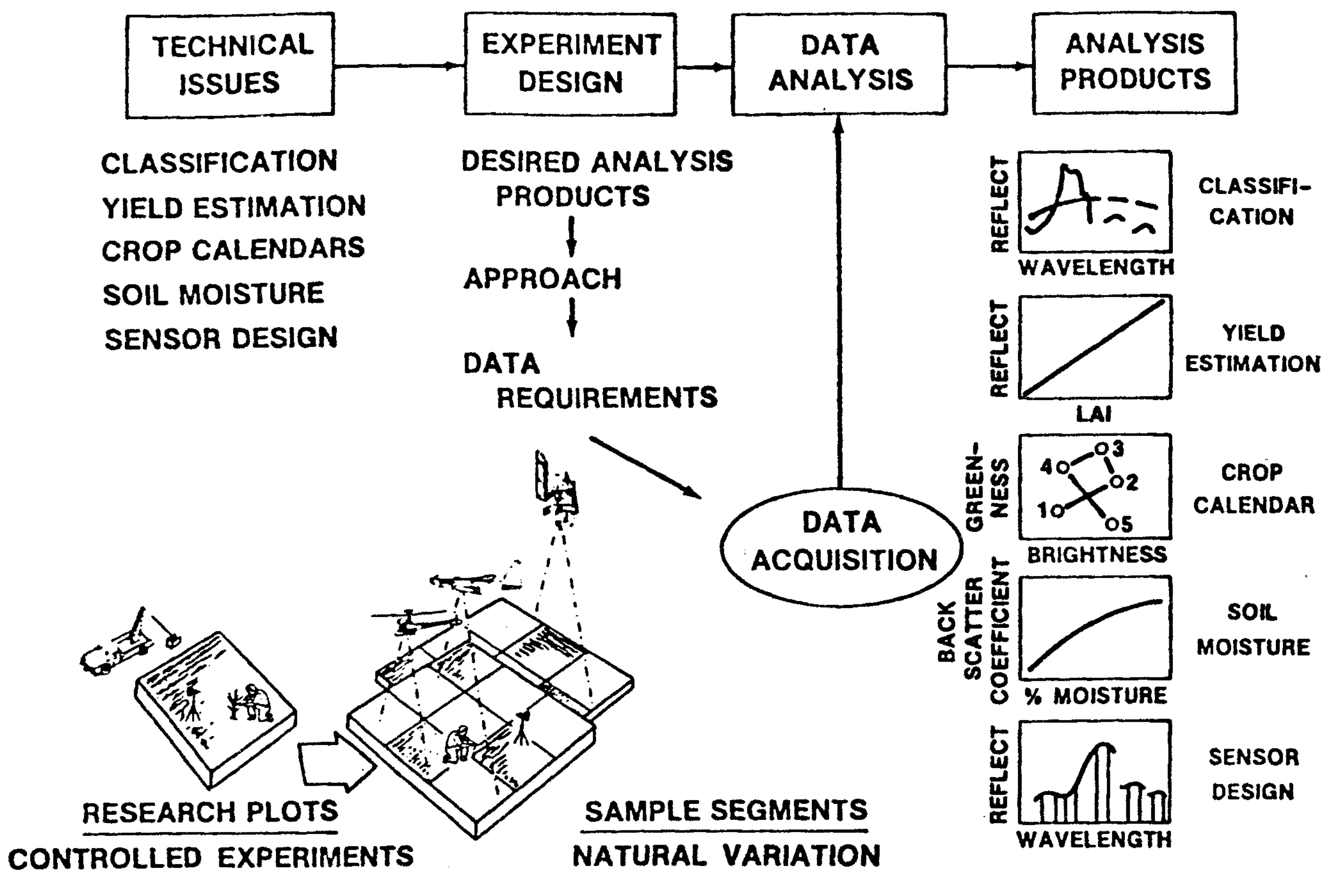


Figure 1. Overview of experimental approach for supporting field research.

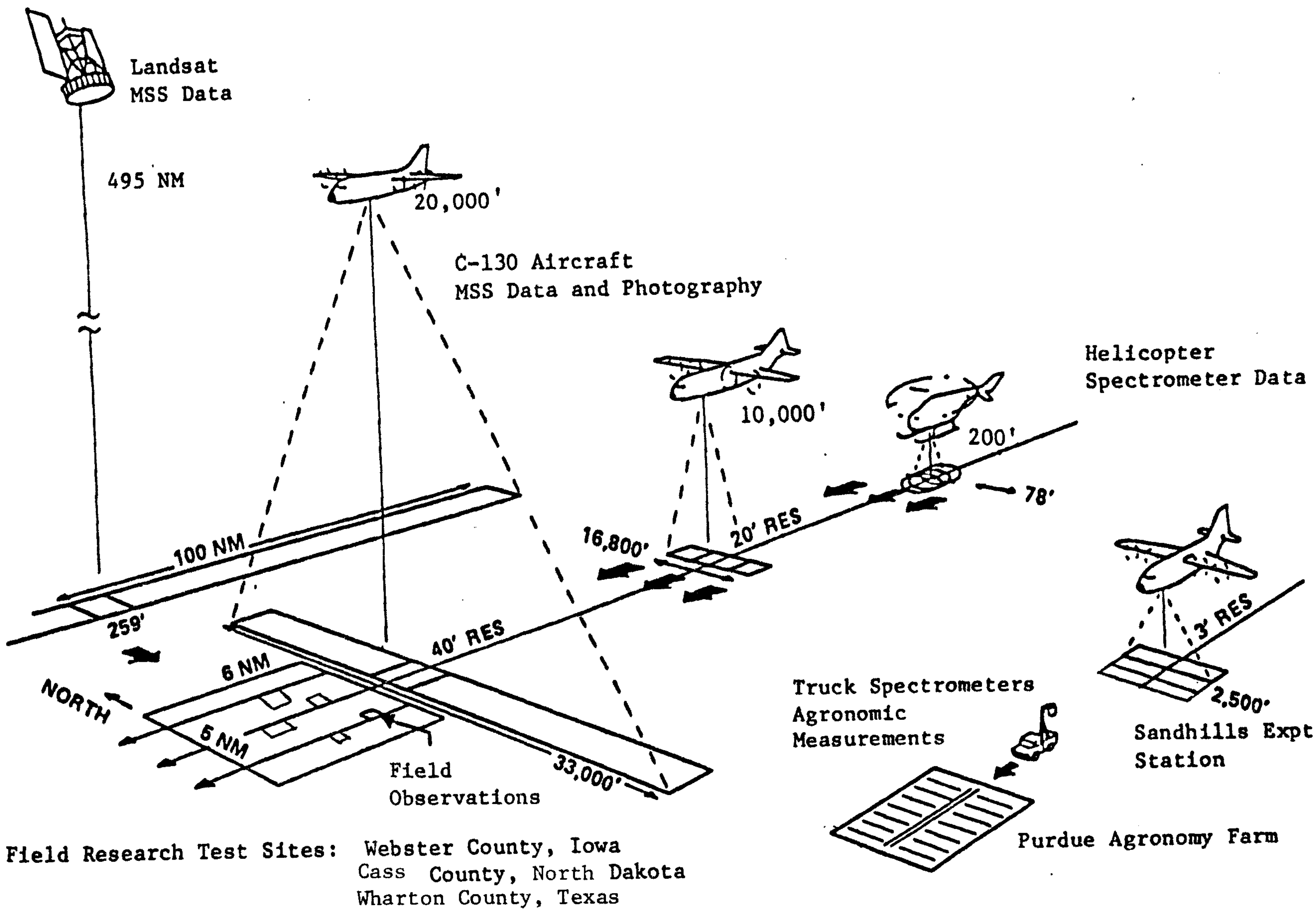
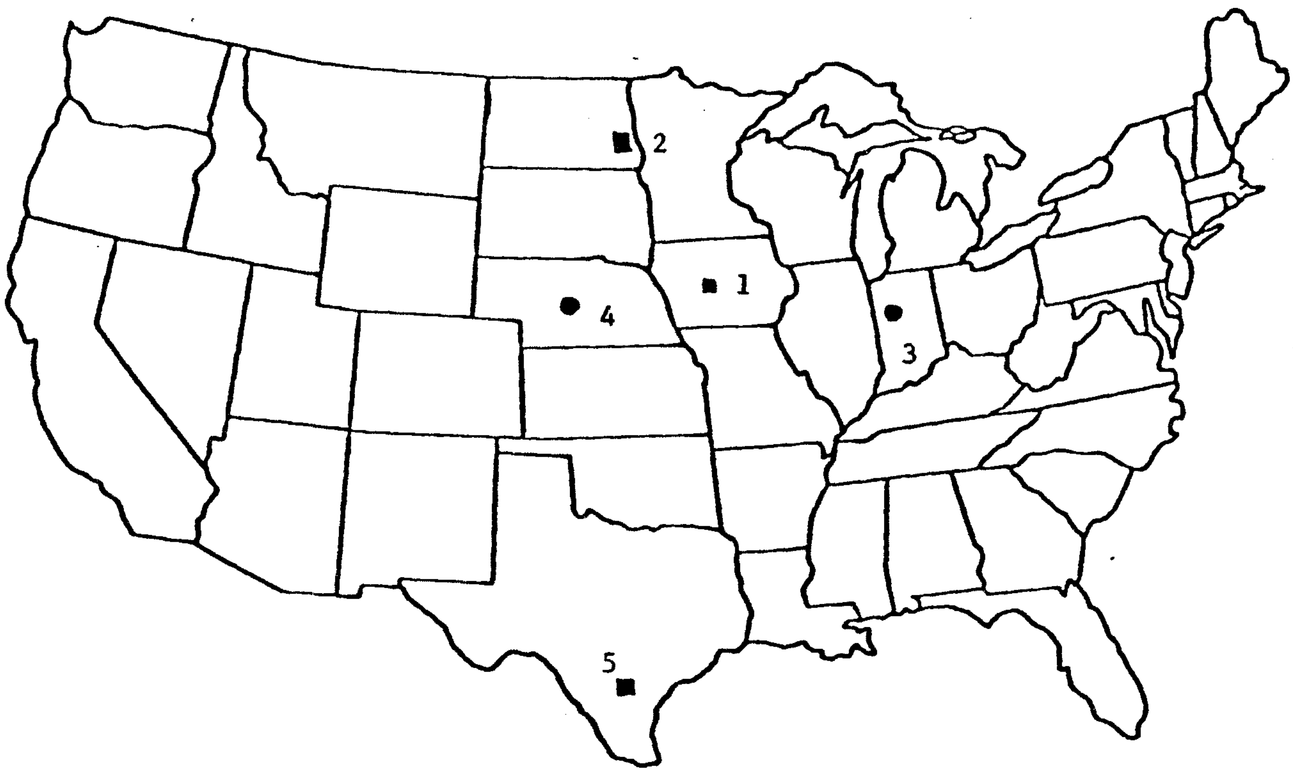


Figure 2. Schematic illustration of multistage approach to multicrop field research data acquisition.



1. Webster County, Iowa
2. Cass County, North Dakota
3. Purdue Agronomy Farm, West Lafayette, Indiana
4. Sandhills Experiment Station, North Platte, Nebraska
5. Wharton County, Texas

Figure 3. Locations of 1980 Supporting Field Research test sites.

spectrometer systems produce the highest quality reflectance measurements, but provide only limited measurements of spatial variability. On the other hand, an aircraft scanner provides spatial sampling of the scene and can obtain data at multiple altitudes, but its spectral coverage, while broader than Landsat MSS, is limited to a fixed set of wavelength bands. The helicopter and aircraft data acquisition systems have the advantage of flexible scheduling and, therefore, provide greater opportunity to obtain cloud-free data at critical crop growth stages than the Landsat system provides. Landsat provides wide-area coverage, but is limited in its spatial resolution and the placement and number of spectral bands.

The staging of data acquisition is summarized in Figure 3. Helicopter-spectrometer and aircraft-scanner data will be collected over commercial fields in a series of flightlines over the sites in Cass and Webster Counties and aircraft scanner data over the Wharton County and Sandhills sites. Landsat MSS data will also be acquired and processed for each Landsat overpass during the season over the sites. These data provide a measure of the natural variation in the temporal-spectral characteristics of wheat, barley corn, soybeans, rice, cotton and other cover types.

The truck-mounted spectrometer and radiometer collect spectra of crops in controlled experimental plots of corn, soybeans, and winter wheat at the Purdue Agronomy Farm. These data, combined with the more detailed and quantitative measurements of crop and soil conditions which can be made on the plots, enable more complete understanding and interpretation of the spectra collected from commercial fields. Past experience has shown that there are generally too many interacting variables in commercial fields to determine exact causes of observed differences in spectral response. With data from plots where only two to four factors are varied under controlled conditions, it is possible to determine more exactly and understand more fully the energy-matter interactions occurring in crops.

The spectral measurements are supported by descriptions of the targets and their conditon. The observations, counts, and measurements of the crop canopy include: maturity stage, plant height, biomass, leaf area index, percent soil cover, and grain yield. Also included are measurement conditions such as sensor altitude and view angle, as well as measurements of the atmospheric and meteorological conditions. The data are supplemented by aerial photography and ground-level vertical and oblique photographs of the fields and test plots.

A key aspect of the spectral data acquisition is the development of the utilization of a multiband radiometer. The radiometer and associated data logger will permit high quality, cabbrated reflectance and thermal measurements to be economically acquired and processed. Acquisition and development of up to twenty instruments are planned in 1981 enabling measurements to be made for much larger set of sites, crops, and experiments than has previously been possible. The radiometer will have the seven thematic mapper spectral bands, plus an additional near-infrared band. A description of the instrument is contained in the appendix (4).

A data library of all spectral, agronomic, meteorological and photographic data collected is maintained at Purdue/LARS. The data will be processed in standard data formats and measurement units and will be made available to NASA/JSC-supported investigators and other interested researchers.

The remainder of this plan describes the background and justification, data analysis objectives and approaches, data requirements and experiment designs, and planned products for each of six research topics:

- Crop growth and development stage determination.
- Estimation of canopy variables from spectral measurements.

- Effects of cultural, soil and environmental factors on spectarl properties of crops.
- Effects of nitrgen nutrition on reflectance and radiant temperatures of corn and wheat canopies.
- Comparison and evaluation of spectral bands for crop identification and condition assessment of corn, soybeans, spring wheat and barley.
- Analysis and model of relationships of percent soil cover, row direction and solar illumination angles to reflectance of soybean canopies.

The appendix to the project plan contains descriptions of the test sites, agronomic data acquisition procedures, sensor descriptions, sensor calibration and correlation procedures, data preprocessing procedures, data evaluation and verification procedures, data library and data distribution, project organization and management, and references.

APPENDICES

Appendix A. TEST SITE DESCRIPTIONS

During 1979 data acquisition for supporting field research experiments will be acquired at test sites in Iowa and North Dakota. The sites were selected to represent important crop-soil-weather situations in the Corn Belt and Great Plains. Data from these sites will be used primarily for investigations of crop identification, crop development stage, and spectral inputs to yield models. The data will provide a measure of the range of variation found within and among crop fields and will be used to test relationships initially developed from controlled experiments. The location, crops, soils and weather at each test site are described below.

A. Webster County, Iowa

Webster County is in the north-central part of Iowa. The test site is located south of Fort Dodge at 42° 25' N latitude and 94° 10' W longitude. Corn, soybeans, oats, hay and pasture are the main crops with about 80 percent of the cropland being used for corn and soybean production.

The soils of the test site are of the Mollisol order and Typic Haplaquolls and Typic Hapudolls subgroups. The primary soils are of the Webster-Clarion-Nicollet association. These soils are nearly level to moderately steep, poorly drained, well-drained and somewhat poorly drained, loamy soils on uplands. These soils were formed under prairie vegetation and are dark-colored and fertile.

The climate of Webster County is subhumid and continental with cold winters and warm summers. Average precipitation is 75 cm per year with about 70 percent of it falling between April and September. The average daily maximum and minimum temperatures in July are 31 and 17°C. The average elevation of the site is 1028 meters.

B. Hand County, South Dakota

Hand County is in east central South Dakota. The test site is north of Miller at latitude 44° 34' N and 99° 00' W. It is a transition area with the Corn Belt to the east, spring wheat producing areas to the north, and winter wheat producing areas to the south. The principal crops of Hand County are winter and spring wheat, pasture and hay, corn, barley, and oats. Most wheat is grown following summer fallow.

The principal soils of the test site are Houdek and Bonila which are in the Mollisol order, Ustoll subgroup. They are dark colored, permeable loams underlain by slowly permeable glacial till, occuring on nearly level to gently undulating topography.

Hand County has a continental climate. Winters are long and cold, and summers are warm. The average annual precipitation is 47 cm; typically 33-36 cm fall between April and September. Winter is the driest season. The county is subject to frequent weather changes and air masses that pass through the area bring a wide variety of temperature and moisture conditions. The seasonal and monthly climate varies widely from year to year.

C. Cass County, North Dakota

Cass County is in east central North Dakota. The test site is about eight miles west of Fargo. The major crops in this area are spring wheat and barley. Some oats are also grown. Most of the small grains are continuously cropped although a small portion is planted after summer fallow. Other crops grown in the county are sunflowers, soybeans, corn, hay, sugar beets, and flaxseed.

The principal soil series of the test site is Fargo, a somewhat poorly to poorly drained Grumusol developed from finely textured glacial lake sediments. Surface textures include silt loam and silty clay loam. Fargo soils are slowly permeable and have a high water - holding capacity. Most Fargo soils are used as cropland.

The average annual precipitation in Cass County is 49.8 cm; typically about 39 cm fall between April and September. The average temperatures range from -14°C in January to about 22°C in July. The frost - free dates are from mid May to late September, averaging about 130 days.

D. Wharton County, Texas

E. Purdue University Agronomy Farm, West Lafayette, Indiana

The Purdue Agronomy Farm is located in Tippecanoe County at 40^{o} 30' N latitude and 87^{o} 00' W longitude. The Agronomy Farm serves the Botany and Plant Pathology, Entomology, and Agronomy Departments as a center for conducting soil and crop research. Over 600 acres are devoted to experiments on corn, soybeans winter wheat, clover and alfalfa. The farm is the site of one of the most complete agricultural weather stations in the U.S. with 12 different microclimate parameters being monitored.

The soils of the farm were developed from glacial till under prarie and forest vegetation. The dark, prairie soils are of the Mollisol order, Typic Hapaquoll subgroup (Chalmers silty clay loam), while the light colored forest soils are of the Alfisol order, Meric Ochraqualf subgroup (Fincastle silt loam). The climate of Tippecanoe County is continental, humid, and temperate. The warm humid summer and moderately cold winter are characterized by frequent changes in temperature. The average temperature in July is 24^{o} C and -3^{o} C in January. The average growing season is 165 days. The average annual precipitation is 97 cm with nearly 60 percent falling from April to September.

F. Sandhills Agricultural Laboratory, North Platte, Nebraska

The Sandhills Agricultural Laboratory is located near North Platte in MacPherson County, Nebraska at 41^{o} 38' N latitude and 41^{o} 36' W longitude. It serves as a research center for crop and livestock production for west central Nebraska. Ranching and farming are the most important enterprises in the area. Corn is the most important crop with increasing amounts being irrigated.

The soils of the area, Ustoll order, Typic Ustipsamments subgroup, Valentine series, are deep nearly level to very steep, excessively drained, sandy soils on upland plains. The sandhills consist mainly of stablilized rolling hills and dunes that alternate with nearly level valleys. The climate of the area is continental and is characterized by warm summers and cold winters. Rapid changes in temperature and general weather conditions are common. At North Platte, average annual precipitation is 51 cm and average annual snowfall is 79 cm. The average length of the growing season is 154 days.

During 1979 measurements were initiated at the Sandhills Agriculture Laboratory, MacPherson County, Nebraska, in cooperation with Dr. Blaine Blad of the Center for Agricultural Meteorology and Climatology, University of Nebraska-Lincoln. The experiments are concerned with moisture stress of corn and are part of an on-going research program investigating crop temperature as a means of detecting and assessing moisture stress.

Appendix B. DATA ACQUISITION

This section describes the collection of agronomic, meteorological, and multispectral remote sensing data at the field research test sites and experiment stations.

A. Field Research Test Sites

The following measurements and data will be acquired at the field research test sites in Webster County, Iowa, and Cass County, NOrth Dakota. The schedules for data collection are shown in Figure A-1. Briefly, 12 helicopter missions have been scheduled for each of Webster County and Cass County. Five aircraft missions are scheduled for Webster County and four for Cass County. Two aircraft missions will be flown over McPherson County. Field data collection will proceed even when remote sensing missions are not scheduled or are not possible due to inclement weather conditions.

1. Agronomic Data Collection

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

Data identifying all fields in the field research test sites are collected by USDA/ESCS (4). The following data are collected during spring and fall inventories: field number, acreage, crop species and variety, irrigation, fertilization, planting date, and other descriptive information.

Periodic observations coinciding with Landsat overpasses and aircraft/helicopter missions are made by ESCS to describe the general condition of the fields. The following variables are observed: maturity stage, percent soil cover, plant height, surface moisture condition, field operations, and growth/yield detractants. Information is also obtained describing: planting and emergence dates, row width and orientation, fertilization, harvest date, and grain yield.

In addition to these data, more detailed, quantitative measurements are obtained for a subset of fields. On ten fields each of spring wheat and barley at the Cass County site and corn and soybeans at the Webster County site,

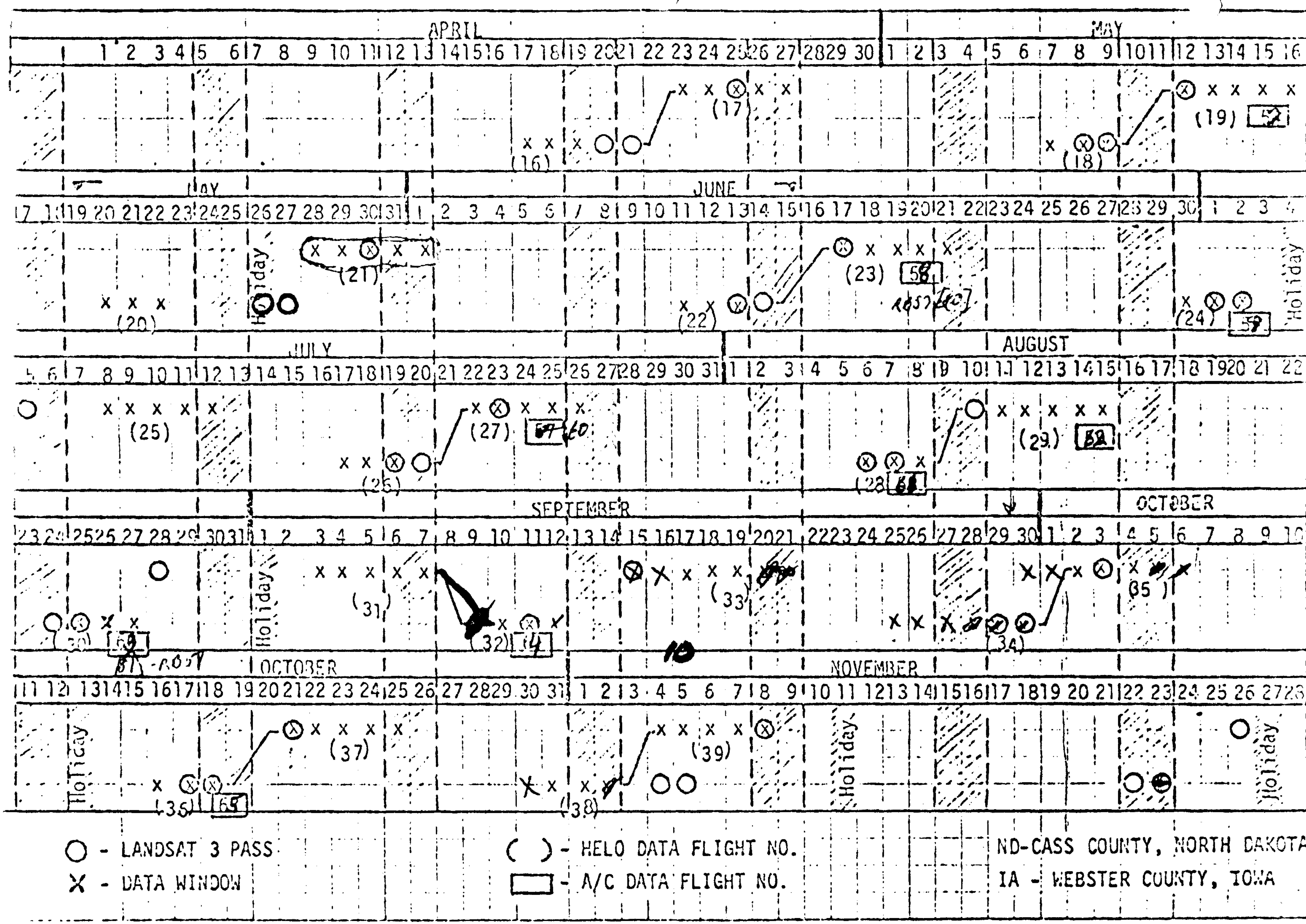


Figure A-1 Schedule of Landsat, aircraft, and helicopter data collection missions.

the following measurements and data are obtained for each helicopter-aircraft mission: plant growth stage, percent soil cover, biomass, leaf area index, and soil moisture. These data are supplemented by photographic views of the fields. These measurements are made in three locations per field.

2. Meteorological Data Collection

The following atmospheric and meteorological measurements are made in conjunction with FSS and aircraft scanner data collection at the intensive test sites: percent and type of cloud cover, wet and dry bulb temperature, barometric pressure, total irradiance, wind speed and direction, and optical depth at seven visible and near infrared wavelengths.

Daily measurement records of temperature, precipitation, relative humidity, soil temperature, and wind will be obtained for the nearest weather station. In addition, rainfall are to be recorded at six to eight locations at each test site.

3. Spectral Data Collection

The spectral data to be collected are: Landsat MSS, helicopter-borne spectrometer, and aircraft scanner. Whenever possible, helicopter and scanner data collection missions have been scheduled to coincide with Landsat-2 or -3 overpasses. However, to increase the probability of obtaining cloud-free data the aircraft and helicopter mission "windows" are three to five days in length.

Helicopter Spectrometer

The helicopter spectrometer (FSS) data are obtained under stable atmospheric conditions with 20 percent or less cloud cover at solar elevation angles greater than 30 degrees. At the Hand County test site, six 9.5 km flightlines are flown by the helicopter in three sets of two lines. At the Webster County site there are five sets of two lines, 4.7 to 9.5 km long. Flightlines flown at an altitude of 60 meters, 100 km per hour ground speed, and in an east/west direction. Reference panel calibration measurements are made from a six meter altitude immediately prior to flying each set of two lines. Correlation of spectra and fields are accomplished using simultaneously acquired 70 mm color photography. Detailed descriptions of the data acquisition procedures are in reference 5.

A total incidence pyranometer is located at the helicopter calibration site to provide a strip chart record of the irradiance conditions on the day of data acquisition (usually beginning one hour before and ending one hour after the data acquisition period). These strip charts provide the data analyst with a visual record of the irradiance conditions at the site during helicopter and multispectral scanner data acquisition.

Airborne Multispectral Scanner

The airborne scanner, either the MMS or NS001, acquires data over the test sites concurrently with data collection by the helicopter spectrometer. The test sites are over-flown at 3,300 and 10,000-meter altitudes and the calibration panels at 500 meters. Collecting data at the two altitudes over the test site flightlines provided different spatial resolutions and different amounts of atmosphere between the scene and sensor. Data collection requirements specify that cloud cover be less than 30 percent and solar elevation greater than 30 degrees. Color infrared photography (23 cm format) are obtained simultaneously with the scanner data.

B. Purdue University Agronomy Farm

The Purdue Agronomy Farm is the location of most of the controlled experiments which will be conducted during 1979. Agronomic, meteorological, and spectral data, as described in this section, will be acquired by Purdue/LARS for the experiments described in section IV.

1. Agronomic Data Collection

The agronomic measurements and observations of the crops provide the foundation supporting many of the analyses planned for the field research data. One of the advantages of the controlled experiments, using relatively small plots, is that more complete and accurate characterizations of the crop canopies and soil background can be obtained than is possible in large commercial fields.

At the beginning of the experiment, information describing the experimental conditions is obtained for all treatments or plots. These data include information on the soil type, fertilization, application of pesticides, planting data, row width and direction, plant population, and cultivar. These data are recorded, keypunched and included in the data record for each plot.

Then, throughout the season, agronomic data describing the condition of the crops and soil are obtained on the same day that spectral measurements are made. These data include the following types of information:

Crop Development Stage

Amount of Vegetation

Plant height
Percent soil cover
Number of plants per square meter
Number of leaves per plant
Leaf area index
Total fresh and dry biomass (g/m^2)
Dry biomass of leaves, stems, and heads, ears or pods (g/m^2)

Crop Condition
Percent leaves green, yellow, and brown
Plant water content (g/m^2)
Presence and severity of stress

Soil Background Condition
Percent moisture
Munsell color
Roughness

Additional data are obtained for particular experiments. For example, for the corn nitrogen fertilization experiment, leaf samples will be collected for determinations of nitrogen concentration and chlorophyll. For the corn leaf blight experiment vertical profiles of the plant with respect to the amount of leaf area infected. Leaf water potentials will be obtained on the corn moisture stress experiment. These data are supplemented by color photographs of each plot, both overhead and ground level views, taken at the time spectral measurements are made. Grain yields will be measured for all plots at the end of the season.

2. Meteorological Data Collection

The following meteorological measurements are recorded on strip charts by Purdue/LARS throughout each day that spectral data are collected:

Total irradiance
Relative humidity
Barometric pressure
Wind speed and direction
Percent cloud cover and type

In addition, hourly records of air temperature, relative humidity, precipitation, pan evaporation, dew, dew point, temperatures at 10 cm depths of bare soil and grass, wind speed, incoming and outgoing solar and infrared radiation, and net radiation are available from microclimatological station located at the Purdue Agronomy Farm.

3. Spectral Data Collection

The spectral measurements of the experiments at Purdue are made by either the Exotech 20C spectroradiometer system or the Exotech 100 radiometer system. Both systems include Barnes PRT-5 sensors and 35 mm cameras, sighted to view the same area as the spectrometers.

To obtain data which can be readily compared, the two instrument systems are operated following similar procedures. These instruments are operated from aerial towers at three to six meters above the target at heights which minimizes the shadowing of skylight and yet ensures that the field of view of the instrument includes only the desired subject. Care is taken to avoid scene shadowing and minimize the reflective interaction due to personnel or vehicles. The routine data taking mode of the instruments is straight down, for determination of bidirectional reflectance factor. Measurements of the $BaSo_4$ painted reference panel are made at 15 minute intervals (the procedures are described in section VII, Sensor Descriptions and Calibration). Two measurements of each plot are typically made by moving the sensor so that a new scene within the plot fills the field of view.

Data recorded at the time of each measurement describing the measurement parameters include: date, time, reference illumination, air temperature, barometric pressure, relative humidity, wind speed and direction, percent cloud cover and type, field of view, latitude, longitude, and zenith and azimuth view angles. A 35-mm color photograph of each observation is taken from the aerial tower.

Periodically, during the day, spectral measurements of skylight are recorded by the Exotech 20C having a solar port. To minimize the effect of solar elevation changes on the spectral response, particularly shadows within the canopy, measurements are only made when the sun angle is greater than 45 degrees above the horizon in the spring and summer and greater than 30 degrees in the fall.

C. Sandhills Agriculture Laboratory

In addition to crop temperature measurements obtained by a Barnes PRT-5 and the aircraft MSS data, the following kinds of data will be collected: solar radiation and PAR radiation, net radiation at a few loctions, wind speed, wind direction, humidity and temperature measurements, above and within the plant canopies, leaf temperature with thermocouples at two levels in the upper portion of the canopy, soil temperature, soil moisture measurements, tensiometer measurements, crop phenology, leaf area index in 40-50 cm increments, plant heights, dry matter production, grain yields, leaf water potential, stomatal diffusion resistance, visible and infrared photographs both near the ground and from low level aircraft. The measurement will be made at varying frequencies. Most meteorological data will be hourly, soil moisture readings 2-3 times per week, phenology, LAI, dry matter and height measurements and photographs weekly or as needed. Crop temperature, leaf water potential and stomatal resistance - daily with several days of intensive studies.

Appendix C. SENSOR DESCRIPTIONS

The characteristics of the primary sensors being used to acquire spectral data over the field research test sites and agriculture experiment stations are described in this section. The sensors used in the test sites include: Landsat-2 and -3 MSS, airborne multispectral scanner, and helicopter-borne spectrometer (FSS). The sensor systems acquiring spectral data at the Purdue Agronomy Farm are the truck-mounted spectroradiometer and radiometer systems operated by Purdue/LARS. General descriptions of the sensor systems are discussed below. More detailed descriptions of the sensors are available from other references.

A. Landsat Multispectral Scanners

Landsat-2 and -3 MSS data are acquired at 18 day intervals in four spectral bands from 0.5 to 1.1 μm. The sensor scans crosstrack swaths of 185 km. It has a crosstrack field of view of 11.56 degrees and an IFOV of 79 meters. Computer compatible tape data and color imagery are acquired for each cloud-free overpass of the test sites. Panchromatic RBV imagery with spatial resolution of about 30 meters may also be used.

B. Airborne Multispectral Scanners

During the past three years the Modular Multiband Scanner (MMS) was used (6). The MMS, however, does not have any spectral bands in the middle infrared portion (1.4-2.5 μm) of the spectrum which has been shown to be an important region for vegetation analyses. If operational in 1979 the new Thematic Mapper Simulator (NS001) will be used as the primary scanner system. This scanner has seven spectral bands in the 0.45 to 2.35 μm wavelength region, plus a thermal infrared band, 10.4-12.4 μm (7).

Nine-inch color and color infrared photography are also obtained during the scanner flights to be used as reference data by analysts.

C. Helicopter-borne Field Spectrometer System (FSS)

The FSS is a filter wheel spectrometer instrument which is a modification of the S-191 sensor used in the Skylab EREP experiment (8). It has been modified by NASA for mounting on a helicopter platform (Figure A-2).

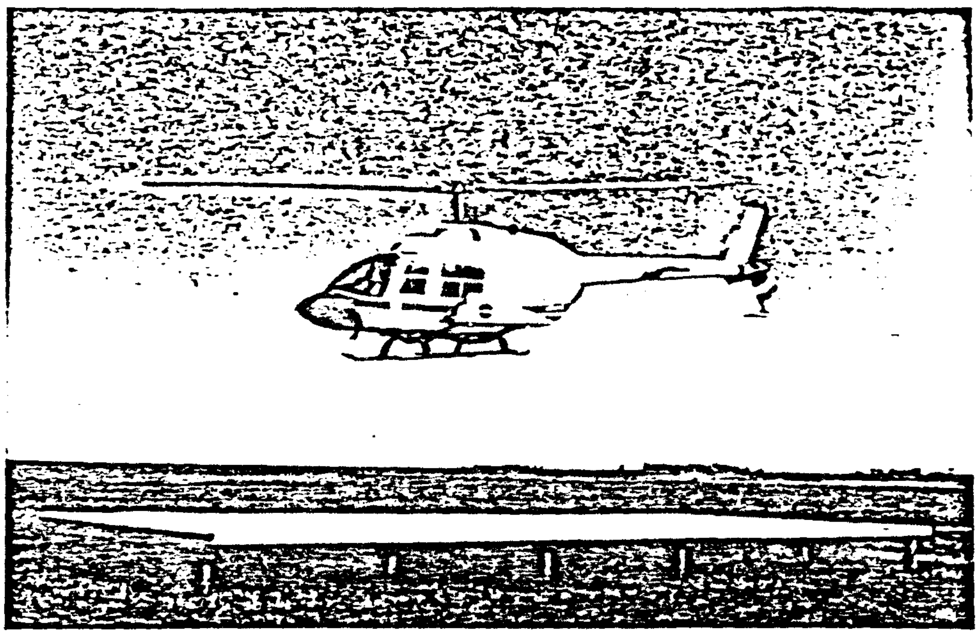


Figure A-2. Helicopter-mounted spectrometer system operated by NASA/Johnson Space Center hovering over canvas calibration panel. The spectrometer is mounted on the left-hand side of the helicopter.

This instrument produces data in 14-track digital format which are converted CCTs for subsequent reformatting and analysis.

The spectral range of the spectrometer is 0.42-2.50μm and 8.0-14.0μm. The field of view is 22 degrees which gives a spot size of 24 meters from 60 meters altitude. The helicopter flies at 100 km per hour. The boresight camera has a 76-mm focal length and a 36-degree field of view, giving 40 meter square ground coverage, and uses 70-mm color film.

D. Truck-mounted Field Spectrometer Systems

The Exotech Model 20C field spectrometer (Figure A-3) operated by Purdue/LARS acquires spectral data over the visible, reflective infrared and thermal infrared wavelength regions (9). The instrument consists of two independently functioning units. The short wavelength unit senses radiation from 0.38 to 2.4 μm, and the long wavelength unit senses radiation from 2.7 to 5.4 and 7.0 to 13.5 μm. The short wavelength unit is equipped with a transluscent diffusing plate which is used to monitor incident spectral irradiance. Each optical head has a reflective fore-optic system that permits remote selection of the field of view (3/4 or 15 degrees).

The instrument is mounted on a mobile aerial tower that operates with an instrumentation van containing the control electronics and data recorder for the system. The data produced by the instrument are recorded on an analog magnetic tape recorder and later converted into digital information by a analog-to-digital converter. Calibration sources designed for field are used to calibrate the spectrometer on site. The system also includes a Barnes PRT-5 thermal infrared sensor and a 35 mm camera for photographing overhead views of plots.

A second spectral data acquisition system, utilizing an Exotech Model 100 radiometer. Barnes PRT-5, and 35 mm camera, is also operated by Purdue/LARS (Figure A-4). This system, mounted on a pick-up truck with an aerial boom, is used to make reflectance measurements in the four Landsat MSS bands, record radiant temperatures, and photograph vertical views of the plots. Although the wavelength coverage and spectral resolution of Landsat-band radiometer are not as great as for the 20C spectroradiometer, the system has the advantage of greater mobility, ease of operating and more economical data processing.

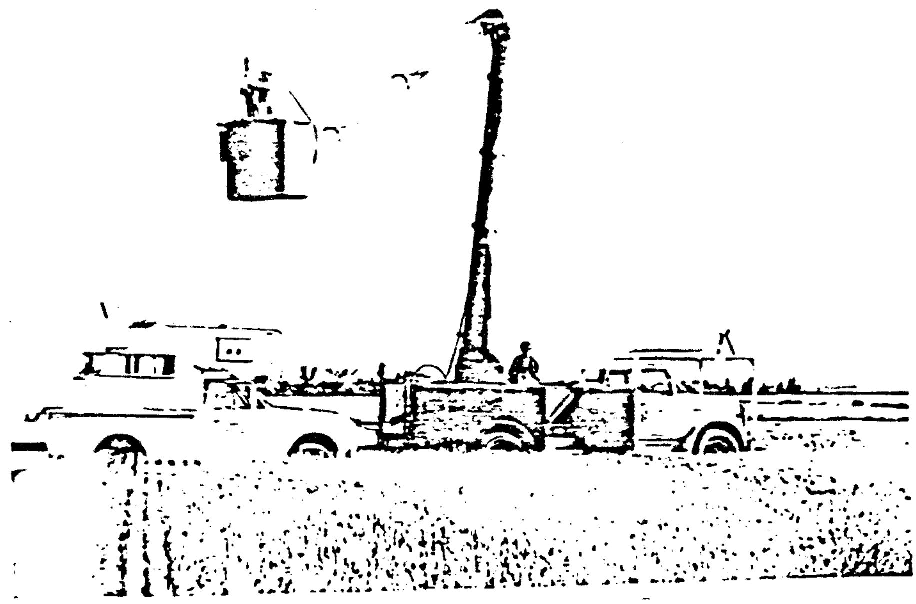


Figure A-3. Field spectroradiometer (Exotech 20C) system operated by Purdue/LARS. The sensors are mounted on the aerial tower and the recording system is the van. The system also includes a Barnes PRT-5 thermometer and 35 mm camera. The calibration standard is mounted over the truck cab.

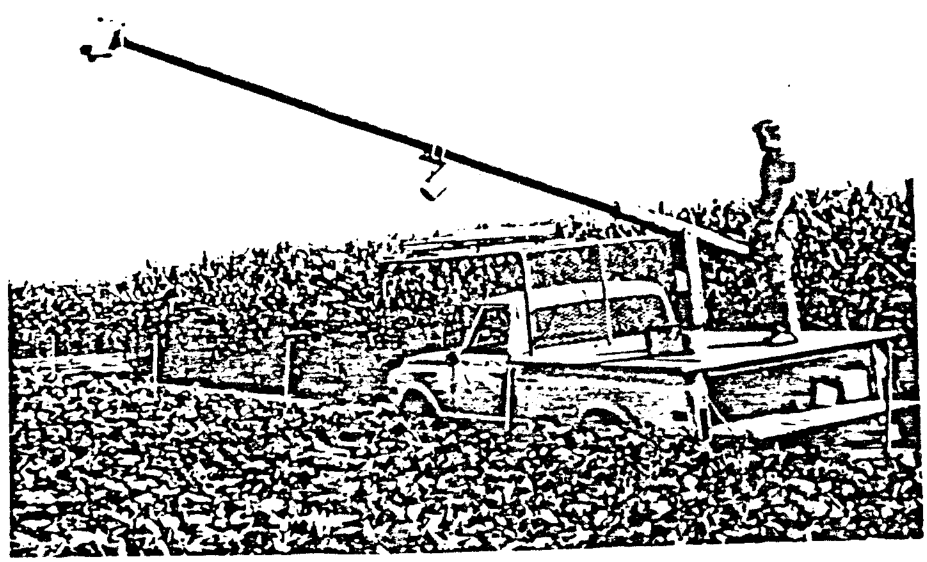


Figure A-4. Multiband radiometer (Exotech 100) system operated by Purdue/LARS. The system includes a data logger, radiant temperature sensor, and camera, as well as the Landsat-band radiometer. A calibration panel is mounted over the pickup cab.

E. Development of Multiband Radiometer System for Field Research

To develop the full potential of multispectral data acquired from satellites, increased knowledge and understanding of the spectral characteristics of specific earth features is required. Knowledge of the relationships between the spectral characteristics and important parameters of earth surface features can best be obtained by carefully controlled studies over areas, fields, or plots where complete data describing the condition of targets is attainable and where frequent, timely spectral measurements can be obtained. The currently available instrumentation systems are either inadequate or too costly to obtain these data. Additionally, there is a critical need for standardized acquisition and calibration procedures to ensure the validity and comparability of data.

A task was initiated in 1978 and is being continued in 1979-80 to develop a multiband radiometer system for agricultural remote sensing field research. The multiband radiometer provides simultaneous multispectral field measurements with a previously unavailable combination of stability, accuracy, and spectral coverage. The standard model includes spectral modules compatible with the Thematic Mapper (Landsat D) spectral channels; however, these modules are field replaceable and interchangeable with any number of custom modules. This built-in versatility makes the instrument ideal for a broad range of multispectral remote sensing applications. The standard channels and ranges for custom modules are given in Table A-1. Figure A-5 shows the distribution of the bands on a typical vegetation spectrum. While the four Landsat MSS bands sample the vegetation spectrum coarsely and over a limited range, the seven Thematic Mapper bands provide complete and rather detailed coverage of the spectrum. The eighth spectral band (1.15-1.30 μm) was selected by LARS agronomists on the basis of spectrometer studies. The instrument will be equipped with three co-aligned fields of view (1°, 15°, and diffuser) which may be exchanged under field conditions.

The data acquisition system will record data from the multiband radiometer, a precision radiation thermometer, and ancillary sources. The radiometer and data handling systems will be adaptable to helicopter, truck, or tripod platforms. The system will also be suitable for portable

Table A-1. Standard channels for the multiband radiometer and possible spectral ranges for custom modules.

	STANDARD	POSSIBLE SPECTRAL RANGE	(1) L* (WATTS. M^{-2} .SR^{-1})
1	0.43 - 0.54μm	0.4 - 1.1μm	31
2	0.50 - 0.62	0.4 - 1.1μm	27
3	0.62 - 0.70	0.4 - 1.1μm	25
4	0.73 - 0.93	0.4 - 1.1μm	45
5	1.50 - 1.80	1.0 - 2.7μm	16
6	2.00 - 2.40	1.0 - 2.7μm	6
7	10.4 - 12.5	8.0 - 15.0μm	8-32
8	1.15 - 1.30	1.0 - 2.7μm	21

(1) L* is the nominal in-band radiance of a perfectly diffusing reflector normal to the irradiance at sea level on a clear day (m=1). L* is factory preset to produce a response of 3 volts in 0.5V output range of the instrument for a gain setting of one. For channel 7, L* corresponds to -20°C and +70°C which are the minimum and maximum radiance temperature measured by the instrument.

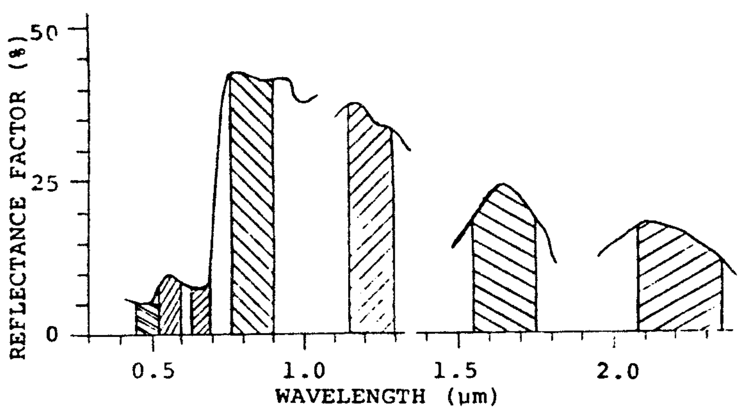


Figure A-5. Spectral distribution of passbands superimposed on a typical vegetation spectrum.

hand-held operation. Power can be obtained from the lightweight belt-mounted rechargeable power pack provided, or from any twelve volt automotive-type battery. With the recharger accessory provided, the power pack can operate the radiometer for six hours continuously on a six-hour charge. The instrument is dust-tight, rain-resistant, and weighs less than eight pounds.

The general characteristics of the system are that it will be: (1) comparatively inexpensive to acquire, maintain, and operate; (2) simple to operate and calibrate; (3) complete with the data handling hardware and software and (4) well-documented for use by researchers. The instrument system will be a prototype of an economical system which can be utilized by many researchers to obtain large numbers of accurate, calibrated spectral measurements. As such, it is a key element in improving and advancing the capability for field research in remote sensing. Production units for use in the AgRISTARS Supporting Field Research are to be obtained for use beginning in 1981.

Appendix D. VII. Sensor Calibration and Correlation Procedures

A key objective of the Field Research Program is the acquisition of calibrated multispectral data. Calibrated data are required in order to: (1) facilitate comparisons of data from different sensors and (2) compare and relate spectral measurements made at one time and/or location to those made at other times and locations.

In order to have comparable data, scene reflectance was chosen as the measured property rather than scene radiance. Scene reflectance is a property of only the scene, whereas scene radiance is also a property of the illumination. Calibration largely removes the effects of varying illumination and measurement conditions due to changing sun angle, atmospheric conditions, and sensor. The bidirectional reflectance distribution function gives the most complete description of the reflectance characteristics of a surface. But, since this property is difficult to measure, more common use is made of the reflectance factor.

Reflectance factor is defined as the ratio of incident radiant flux reflected by a sample surface to that which would be reflected into the same reflected beam geometry by a perfectly diffuse (Lambertian) standard surface identically irradiated and viewed (10). Since the principal component of the irradiance is direct solar irradiance and the measurement is made in a relatively small cone angle (15 to 20 degrees), the bidirectional reflectance factor is used to describe the measurement. One of the directions is specified by the solar zenith and azimuth angles; the other is specified by the zenith and azimuth viewing angles.

Since no perfectly reflecting diffuser is available, painted barium sulfate reference surfaces which are highly diffuse are used as a reference standard (11). The spectral bidirectional reflectance factor of these surfaces was measured in both the laboratory and field by processes which are traceable to the reflectance of pressed barium sulfate (Figure A-6). A correction using the published reflectance of the pressed barium sulfate enables the computation of an approximation to the bidirectional reflectance factor.

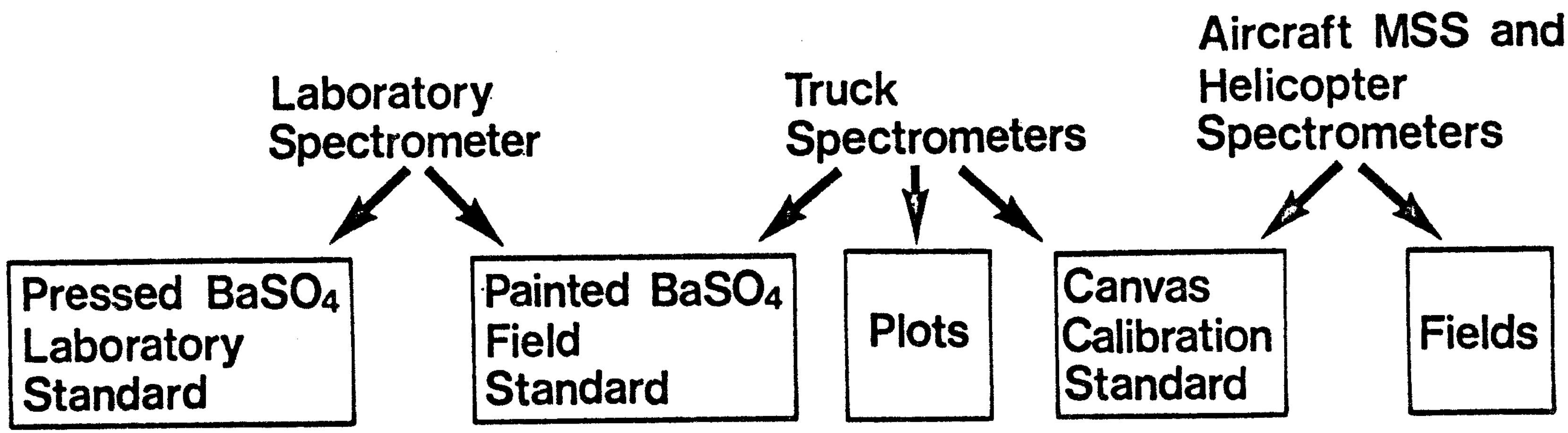


Figure A-6. Schematic diagram of the basic procedures used for reflectance calibration of field research data.

Due to the presence of skylight, the measurement is not strictly bidirectional. The process of eliminating skylight by subtracting the spectral response of the shadowed scene and shadowed standard has merit in that it could remove the effects of the skylight. However, the additional measurements and calculations add uncertainty to each computed reflectance. This uncertainty is greater than the effect itself (12). Furthermore, since the interest of the project is in producing data directly relatable to satellite data which includes the effects of the skylight, the single comparison method was used. Since the dominant effects are due to the directional nature of the irradiance, the term bidirectional reflectance factor has been chosen to describe the measurements.

A. Calibration of Truck-mounted Spectrometer Systems

Temperature variations, dust, vibration, and other adverse factors associated with field measurements require that calibration be performed at the field site. The procedures chosen reflect the availability of suitable standards and the principal that the calibration measurements be obtained under the same conditions as the target measurements.

The painted barium sulfate field standard is used to fill the field of view of the instrument under nearly the same conditions as the measurement of plots. For the simplest calibration, the response to the standard, the response to the scene, the full dark response (automatically provided during each spectral scan), and the spectral reflectance properties of the standard are used to compute the bidirectional reflectance factor. Since it is inconvenient to make this direct comparison for each measurement, the solar port is frequently used to transfer the reflectance standard for the Purdue/LARS Exotech 20C system.

The calibration calculation consists of forming the ratio of the instrument response for the target to that for the reflectance standard and correcting for the known reflectance of the standard. This procedure produces a reflectance factor for the given sun angle and normal viewing of the target.

During the calibration observations the instrument is aimed straight down at the reflectance standard from a distance of 2.4 meters. Care is taken to ensure that the standards were not shadowed and that the illumination conditions are as similar as possible to the conditions of the observation of the subject. Calibration observations are performed at approximately 15 minute intervals.

Wavelength calibration of the reflective wavelength unit is accomplished by irradiating the solar port with sources having known spectral lines. (13). The primary sources are the GE A100.H4T mercury vapor lamp and the helium Pluecker tube. A field wavelength calibrator 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.

B. Calibration of Helicopter-borne Field Spectrometer System

The helicopter-borne spectrometer is calibrated using a 60 percent reflectance canvas panel and the measurements made by the truck-mounted spectrometer of the canvas panel. These in turn are related to the measurements of the barium sulphate painted panels and pressed barium sulphate standard.

The calibration procedure used deals with limitations imposed by the size and location of the standard by calibrating the instrument at a low altitude (6 meters) and collecting data over the flightlines at 60 meters. This procedure assumes that atmospheric absorption and path radiance are negligible for a 60 meter path.

The absence of an onboard solar sensor integrated into the instrument makes it desirable that calibrations be performed as frequently as possible. Therefore, the reflectance panels are centrally located and procedures followed which allow calibration within 15 minutes of any data acquisition (beginning of each flightline of data collection).

The data processing facility converts the FSS data to bidirectional reflectance factor based on the measurements made of the barium sulfate standard and the canvas panel. The calibration calculation consists of forming the ratio of the FSS response for the target to that of the canvas standard and correcting for the measured reflectance of the canvas standard. This procedure produces a reflectance factor for the given solar illumination angle and normal viewing of the subject.

Field calibration of the FSS with respect to thermal/infrared radiation is accomplished by recording spectral observations of a blackbody at a temperature below ambient and another blackbody at a temperature above ambient. The subsequent scans of subject scenes are converted to spectral radiance using linear interpolation.

C. Calibration of Airborne Multispectral Scanner Data

The reflective data from the airborne multispectral scanner can be calibrated to reflectance using the five gray canvas panels located at the site and the spectral bidirectional reflectance factor measurements collected by the truck-mounted spectrometers over the canvas panels. The nominal reflectances of the panels are 6, 12, 18, 30 and 60 percent.

The gray panel reflectance factor and multispectral scanner response data collected 500 meters above the panels can be related through linear regression. The regression equation can then be used to transform the low-altitude airborne multispectral scanner data to scene bidirectional reflectance factor. The higher altitude multispectral scanner data can be calibrated to bidirectional reflectance factor using agricultural fields common to data collected as calibration targets at both altitudes and with these define another regression equation. The error in the reflectance factor calibration increases, however, with each transfer.

Alternatively, the airborne multispectral scanner can also be calibrated using the calibrated helicopter-borne field spectrometer system data collected over the fields common in the FOV of both data collection systems. The reflectance factor of the fields as measured by the FSS and the multispectral scanner response data over the same areas (fields) can be related through a regression analyses.

The emissive multispectral scanner data can be calibrated by means of the two blackbodies at known temperatures located in the scanner and which were viewed with each scan of the scene.

D. Sensor Correlation Procedures

The three major sensor systems, the truck-mounted spectrometer and radiometer, the helicopter-borne spectrometer, and the aircraft multispectral scanner, can be correlated using the spectral data collected by each system over common targets, i.e., five 6 x 12 meter gray canvas panels. The aircraft scanner collected data over the panels during each mission. The helicopter and truck spectrometer systems measure the reflectance of the four darker gray panels during correlation experiments performed during each crop year. The calibration measurements made of the brightest canvas calibration panel by the helicopter and truck spectrometer systems are also used in correlating the sensors.

Appendix E. Data Preprocessing

This section describes the data preprocessing and reformatting operations which are performed on the field research data in order to put them in the required formats.

A. Landsat MSS Data

Landsat imagery and CCTs are received at Purdue/LARS via standing orders placed with NASA/GSFC. The data are screened for cloud cover and if the frame is 50 percent or more cloud-free over the test site, it is reformatted to LARSYS Version 3 format and stored in the Field Research data library at LARS. Any Landsat segment data over the test sites processed at NASA/GSFC for NASA/JSC are also included as part of the Field Research Library along with the associated imagery (PFC, Product-1).

B. Aircraft Multispectral Scanner Data

Eleven-channel M^2S scanner data or eight channel NS001 scanner data are recorded on 14-track digital tape on board the aircraft. The aircraft tapes are reproduced to generate visicorder imagery at JSC. Visicorder imagery is a 13 cm wide, medium contrast paper strip record of the tape contents. The imagery is reviewed to determine the start and stop time of each flightline recorded on a particular aircraft tape. The aircraft tapes are reproduced a second time selecting data from the flightline time intervals only. These data are written onto computer compatible tapes (CCT) in LARSYS Version 3.0 format. In addition to the tapes, quality control printouts are generated for evaluation.

The CCTs are sent to LARS where a LARS run number is assigned and the data stored in the LARS/Field Research library. The library tapes are then available for analysis by users of the Purdue/LARS computational facility or may be copied for distribution to users outside LARS. Note that MSS data are simply reformatted and that scene relative radiance values are not altered or calibrated in any way during transmittal from the aircraft tape to the Purdue/LARS library. If calibrated (reflectance) data, rather than relative response, is required for particular analyses, calibration can be performed utilizing measurements made by the aircraft MSS of the grey level calibration panels, along with those made by the helicopter and truck spectrometers.

C. Field Spectrometer System (FSS) Data

FSS data are digitized to 10-bit accuracy and recorded on 14-track, one-inch instrumentation tape in digital form on board the helicopter. Current inventory, periodic observation, meteorological data and optical depth corresponding to each field are later added to form a full complement of FSS associated data. With the exception of photographic images and flight log information this complement of data is computer processed and stored in the Field Research data library for subsequent analysis. Data processing flow for the FSS is shown in Figure A-7.

1. Initial Processing:

Airborne recorded 14-track digital tapes are reproduced at NASA/JSC and converted to computer compatible tape format. In addition, strip charts are generated and other outputs used for data quality evaluation. The strip charts are later edited to delineate scans collected directly over the calibration panel for use in calibrating the field data into reflectance units. This edit is very critical since the helicopter can not always hover directly over the calibration panel for extended time periods. For each calibration run the contiguous set of panel scans having the highest uniform response on the strip chart is selected. A unique calibration data set is collected and edited for each flightline. During computer processing at JSC instrument reflective response values are averaged into 52 reflective bands, in 0.02 μm intervals from 0.40 to 1.10 μm and 0.05 μm intervals from 1.10 to 2.40 μm. The 0.68-0.70 μm band is processed as two .01 μm bands. Spectral reflectance factors are computed as follows:

$$R = \frac{V_t - b_1}{V_p - b_2} \quad R_p k$$

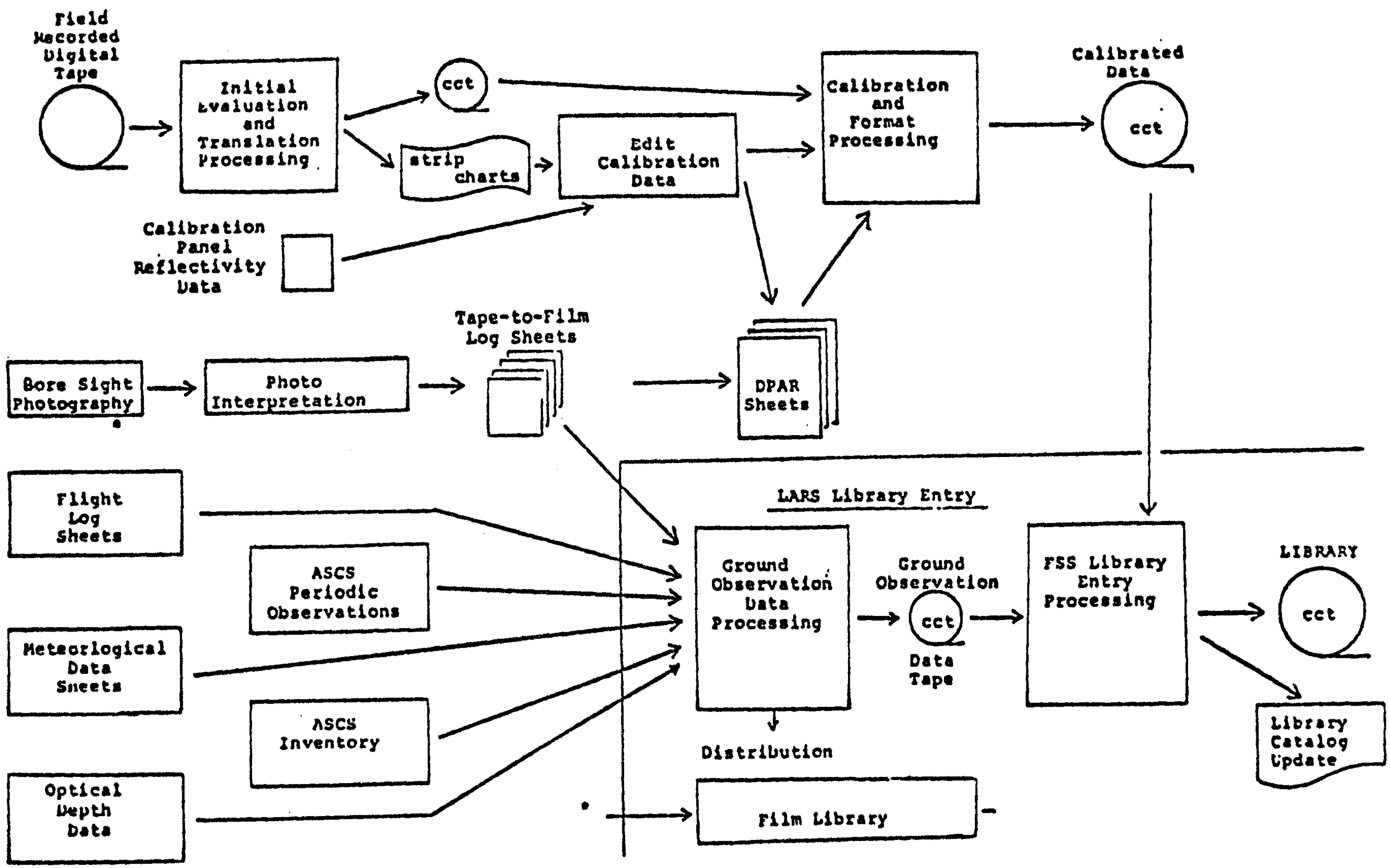


Figure A-7. FSS Data Processing Steps.

Where: R - bidirectional reflectance factor

V_t - instrument response over the target

V_p - instrument response over the calibration panel

b - detector bias values

R_p - bidirectional reflectance factor of the canvas panel

k - field of view conversion constant

Basically the reflectance factor is computed as the ratio of the instrument response over the target to the response over the reflectance standard. To compensate for the standard being less than a perfect reflector (reflectance factor less than 1.0), R_p is used. The constant k is used to compensate for the change in instrument field of view for the target calibration panel data. The above calculation is performed for each of 62 wavelength band values.

Emmisive data (8 to 14 μm) are averaged into 12 wavelength bands, each 0.5 μm in width. Instrument response values are converted to radiance units by referencing instrument responses to internal calibration sources. Reference 14 provides additional details on FSS software operations at JSC.

Boresite photography collected coincident with spectrometer data is used by photo-interpreters to generate "tape-to-film" data sheets showing the time interval corresponding to the helicopter overpass of each ground scene field or object. The time is read from a precision clock mounted within the camera and viewed in each photograph. The clock is synchronized with the spectrometer time code generator with an error not greater than two seconds. The tape-to-film sheets are transcribed to data processing action request (DPAR) sheets with modifications as dictated by data quality evaluations and other inputs. DPAR sheets are subsequently keypunched and input to the calibration/formatting processor. Available calibration panel reflectivity data are supplied from the Purdue/LARS Exotech 20C Field System.

Each FSS spectral scan is calibrated to bidirectional reflectance factor by referencing the data to the most current (previous) calibration panel scan and the panel reflectivity table. Processing results are recorded on computer compatible tapes. Copies of the CCTs, DPAR sheets, flight logs, meteorological data, optical depth data, tape-to-film logs, and photographs are sent to LARS for further processing.

2. Final Processing

At LARS, tape-to-film, meteorological, optical depth, and ASCS data sheets are keypunched and processed by the "ground observation data processor" to produce a ground observation tape data record for each time interval or field for which FSS data were processed at JSC. This record contains all the information about a given field which can be found on the several data sheets.

Finally, the JSC spectral data and ground observation data tapes are combined with program control data to produce the FSS field research library tape. This data are processed into two formats- field average and single scan. The scans of each field (and times) are averaged to form a single scan of spectra. Statistical analysis algorithms are used to omit atypical scans during the averaging process. Each scan of data is also processed separately. Also during this step, the data may be recalibrated if updated calibration panel reflectivity values become available. Recalibration is performed as follows:

$$R_u = R \frac{R_n}{R_o} \text{ for each wavelength}$$

where: R_u - updated bidirectional reflectance factor (in percent)

R - bidirectional reflectance factor from JSC processed data tape

R_n - updated bidirectional reflectance factor for the canvas panel

R_o - bidirectional reflectance factor for canvas panel used during JSC processing

D. Exotech Model 20C Spectroradiometer Data

Field spectroradiometer data acquired by Purdue/LARS are collected by the Exotech Model 20C and PRT-5 field instrumentation systems. Procedures for handling and processing data collected by these systems are outlined in this section. The general flow of data through the processing system is shown in Figure A-8.

Instrument parameters are recorded during field operations on measurement record sheets and later edited in the laboratory. The edited forms are keypunched and used in the processing steps discussed below. Spectral data from the 20C spectroradiometer are recorded on 7-track analog magnetic tape. At LARS, the field recorded tapes are reproduced and digitized to 10-bit precision. The digital data are stored on computer compatible tapes.

Agronomic and soils ground observation data collected in the field are recorded on LARS field observation sheets. In the laboratory, the sheets are completed under supervision of a project agronomist. Information not available at the time of field data collection is later added to the sheets.

The completed forms are then keypunched for computer input. In the calibration and data processing step, field data from the first CCT, calibration in structuring instrument data, and ground observation data are combined to produce the spectrometer data library tape. This processing step also produces data quality tabulations which are evaluated and may result in subsequent reprocessing of parts of the data. The spectrometer library tape contains the full-resolution form of the Exotech 20C data and must subsequently be postprocessed into the specialized storage format for the field research spectrometer data. In this step, wavelength bandwidths are standardized to 0.01 micrometers for reflective bands and 0.05 micrometers for emissive bands. The resultant CCT is stored in the field research tape library and is distributed to analysts.

1. Processing algorithms

Reflectance factor calibration is achieved as follows (for each wavelength):

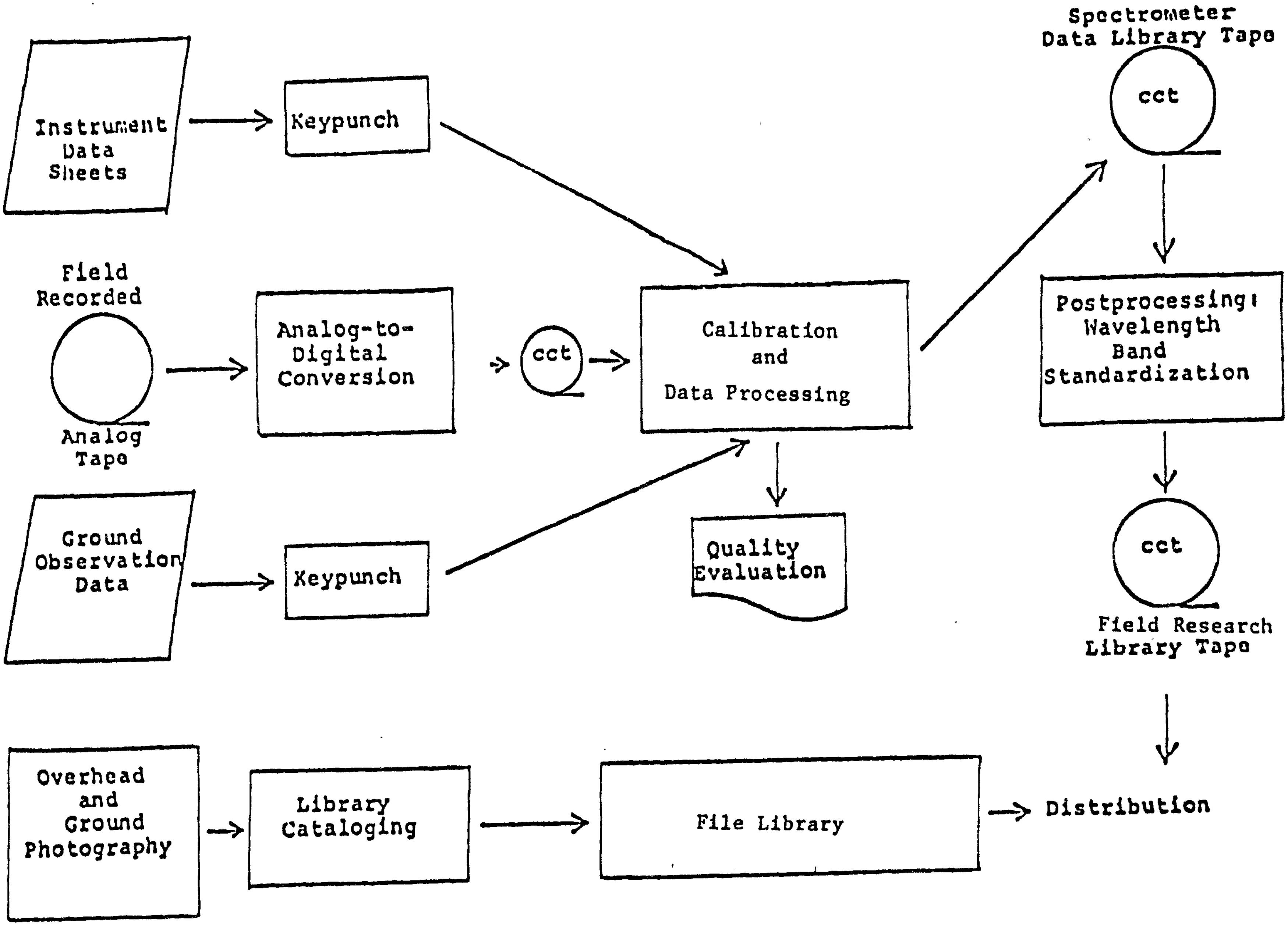


Figure A-8. LARS Field Spectroradiometer Data Processing Steps.

$$R_s = \frac{V_s}{V_b} R_b \text{ (measured in laboratory)}$$

$$R_t = \frac{V_t}{V_i} \frac{V'_i}{V'_s} R_s \text{(measured in field)}$$

Where:

R_s - bidirectional reflectance factor of field calibration standard

V_s - instrument response for field standard

V_b - instrument response for pressed $BaSo_4$ reflectance reference

R_b - bidirectional reflectance factor of pressed $BaSo_4$ (published table)

R_t - bidirectional reflectance factor of scene

V_t - instrument response for scene

V_i - instrument response to solar port at time V_t measured

V'_i - instrument response to solar port at time V_s measured

Appendix F. Data Evaluation and Verification

An important requirement in the field research program is that the quality of data be monitored and documented in a timely fashion. The purpose of this is two fold: First, the data verification can be used to note inadequate procedures or poor sensor performance which can then be corrected for subsequent missions. Second, the data evaluation documents and results can be used by data analysts to determine which data meet their research requirements and to assist them in interpreting the results of their data analysis.

To adequately verify data, information needs to be collected on three major phases: (1) field procedures, including instrument comparisons and system tests: (2) instrument checks, including prefield, field and post-field checks; and (3) data evaluation. A summary of key steps in the data evaluation and verification include:

<u>Landsat MSS Data</u>

- Estimate cloud cover over test site
- Estimate could cover over entire frame

<u>Aircraft Photographic and MSS Data</u>

- Monitor scanner system performance and total irradiance charts during data acquisition
- Review MSS imagery
- Review MSS histograms
- Review photography

<u>Helicopter and Truck-Mounted Spectrometer Data</u>

- Test preseason spectrometer performance
- Monitor system performance during mission
- Review spectrometer strip charts for each mission
- Review and annotate film
- Study processing quality control reports
- Review total irradiance charts collected during data acquisition
- Review data acquisition procedures periodically
- Review processed data (spectral, agronomic, and meteorological)
- Study calibration panel data
- Study correlation of spectrometers using gray panel and color panel data

Solar Radiometer (Optical Depth) Data

- Calibrate instruments to international standards (independent institution)
- Review data for each mission carefully
- Test sensor periodically including filter bandpasses
- Compare data from channel to channel, day to day

A. Landsat Data

The Landsat data is reviewed to verify that the test site is included. Also the cloud cover for both the test site and the frame are noted. Only the frames having 50% or more cloud free coverage over the test site are processed into LARSYS Version 3.0 format for use by researchers. Channels with poor data quality are noted in the Field Research Data Library Catalog.

B. Aircraft Multispectral Scanner and Photographic Data

Variability in illumination of the flightline during data collection caused by clouds over or even near the flightline seriously reduces the relative accuracy of the data and analyses of data are greatly complicated since variations in the data may be caused by illumination differences in addition to the differences in the ground scene. Data are to be collected only when conditions have been stable for at least 15 minutes. To determine wheather conditions are suitable for data collection, a strip chart recording of total incidence pyranometer data is acquired during data acquisition periods at the calibration site. The strip chart is used after the mission by data analysts to determine actual conditions under which data were collected (Figure A-9). This procedure was implemented early in 1976.

After the mission both qualitative and quantitative checks of data quality are made. The qualitative checks include examination of the total incidence pyranometer data and examination of imagery and histograms of each spectral band. Examination of the imagery can be used to verify that the flightline was properly flown, detect clouds and/or cloud shadows, and detect gross problems in sensor performance such as banding. These checks are performed at JSC; any abnormalities are noted in a data quality report for each mission.

C. Helicopter and Truck-mounted Spectrometer Data

Major factors contibuting to the uncertainty in the helicopter and truck-mounted spectrometer data are, in order of importance, clouds,

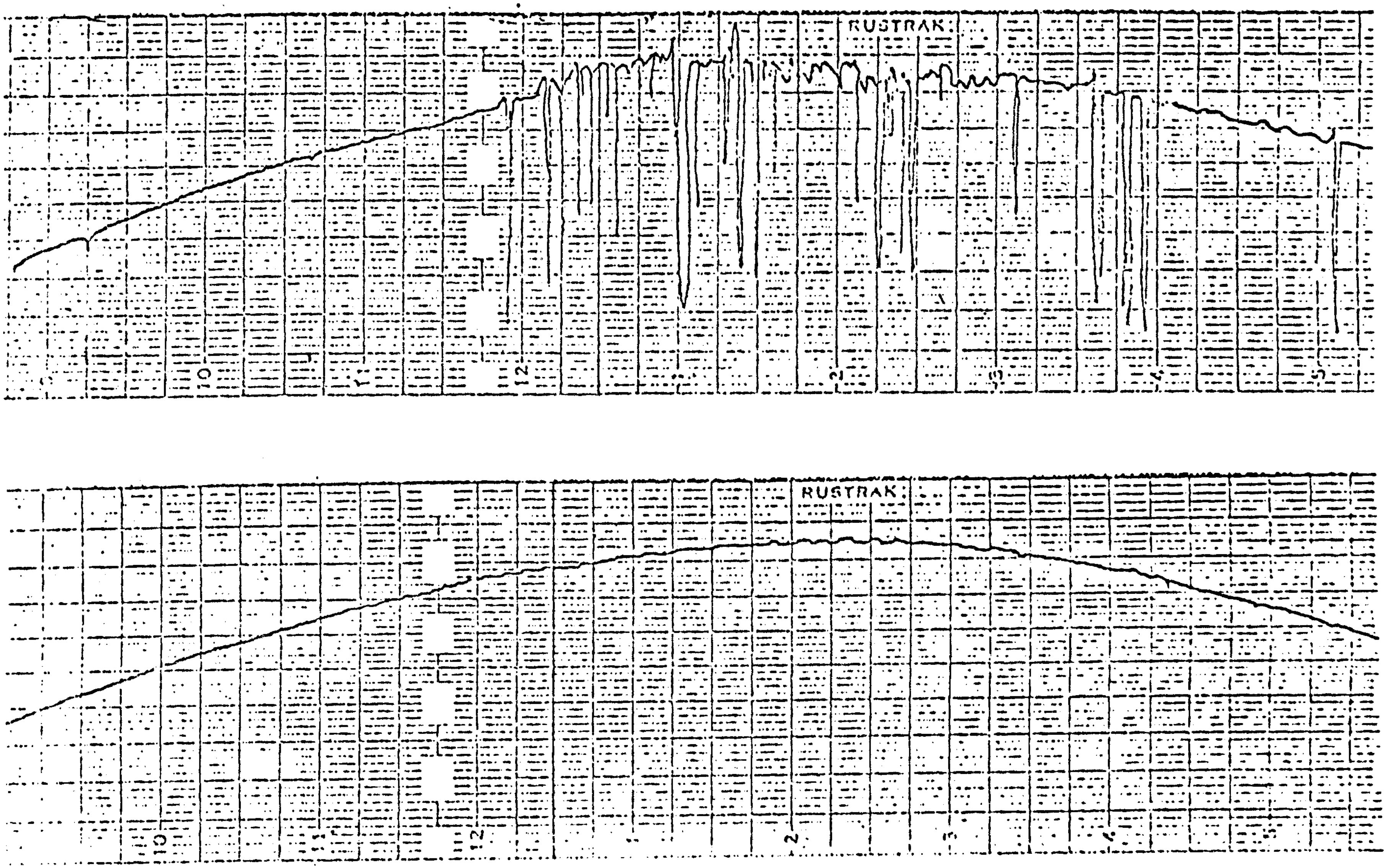


Figure A-9. Example of pyronometer data of total solar irradiance recorded during spectral data collection missions.

calibration procedures, atmospheric conditions, instrument performance, and data processing system performance. The requirement for sensor performance evaluation has long been recognized and quick-look, as well as more extensive instrument tests, are currently performed. Preseason tests are performed for each instrument by the respective institutions which operate them. The preseason tests include wavelength calibration, field of view alignment, and instrument linearity studies.

As with the multispectral scanner data the strip chart pyranometer recording is used to determine the suitability of cloud/atmospheric conditions after the mission. Criteria for evaluating conditions for data collection have developed and were used in the field in 1976. Following these procedures for determining whether conditions were satisfactory for data collection is believed to have considerable improved the helicopter data collected in 1976 over that collected in 1975.

On a clear day the most critical factor in system uncertainty is the instrument alignment during the calibration process. It is most important that the field of view of the instrument be filled by the calibration panel. Alignment of the fields of view of the FSS and Exotech should be checked regularly. A procedure for assessing system uncertainty which also provides an indication of alignment has been developed and is used by Purdue/LARS. It consists of applying a cosine correction for solar zenith angle changes to the calibration panel measurements. All calibration spectra should be approximately the same following cosine correction. If significant deviations are noted, attempts are made to determine their cause.

System performance at various spectral reflectance levels are studied. This information is used to evaluate the performance of the circular variable filter wheel. Periodically the helicopter and truck systems take data over the gray panels used to calibrate the aircraft system. The processed spectra is examined for repeatability from mission to mission and the smoothness of the transition from one filter to the next. Malfunctions of the instrument are evidenced by gross changes from mission to mission of the gray panel spectra. Any systematic offset in the spectra at the transition from filter section to another indicates an instrument malfunction. Also, the data collected by each instrument over the gray panels and color panels are used to study the correlation of the spectrometer systems.

Appendix G. Data Library and distribution

The LACIE Field Research Project, under the sponsorship of the Earth Observations Division, NASA/JSC, was initiated in the Fall of 1974 to acquire, process, and make available to researchers agricultural remote sensing data. As a result, one of the most comprehensive remote sensing research data sets has been assembled. The Field Research data library facility is located at the Laboratory for Applications of Remote Sensing, Purdue University. The general organization of the data library is illustrated in Figure A-10.

The Field Research Data Library Catalog provides information on data available from the library. Its purpose is to provide information to researchers describing by location, date, and sensor the data contained in the library.

The catalog is divided into separate volumes, one for each crop year during which data were collected:

1974-75 Volume I
1975-76 Volume II
1976-77 Volume III
1977-78 Volume IV
1978-79 Volume V

Each volume of the data catalog consists of four levels with each level including an increasing amount of specificity describing individual items of data. The first level is the Summary, the second level is the Record, the third is the Index, and the fourth level is the Listing.

The Summary lists the data collected by the major sensor types for the missions over each of the test sites.

The Record lists the dates that data were collected over the test site and provides a record of which data has been processed to the point that it is available for users. This section is organized according to test site and location (field research test site or experiment station) of data collection.

The Index lists the data collected by sensor type, i.e. Landsat, aircraft, FSS, Exotech 20C, Exotech 20D, and Exotech 100. The Landsat data is listed by site and date; the aircraft data by site, date, and flightline; and FSS data by site date and field number; the truck-mounted spectrometer data is listed by site, date and plot number and the tripod-mounted radiometer data is listed by site, date and plot number.

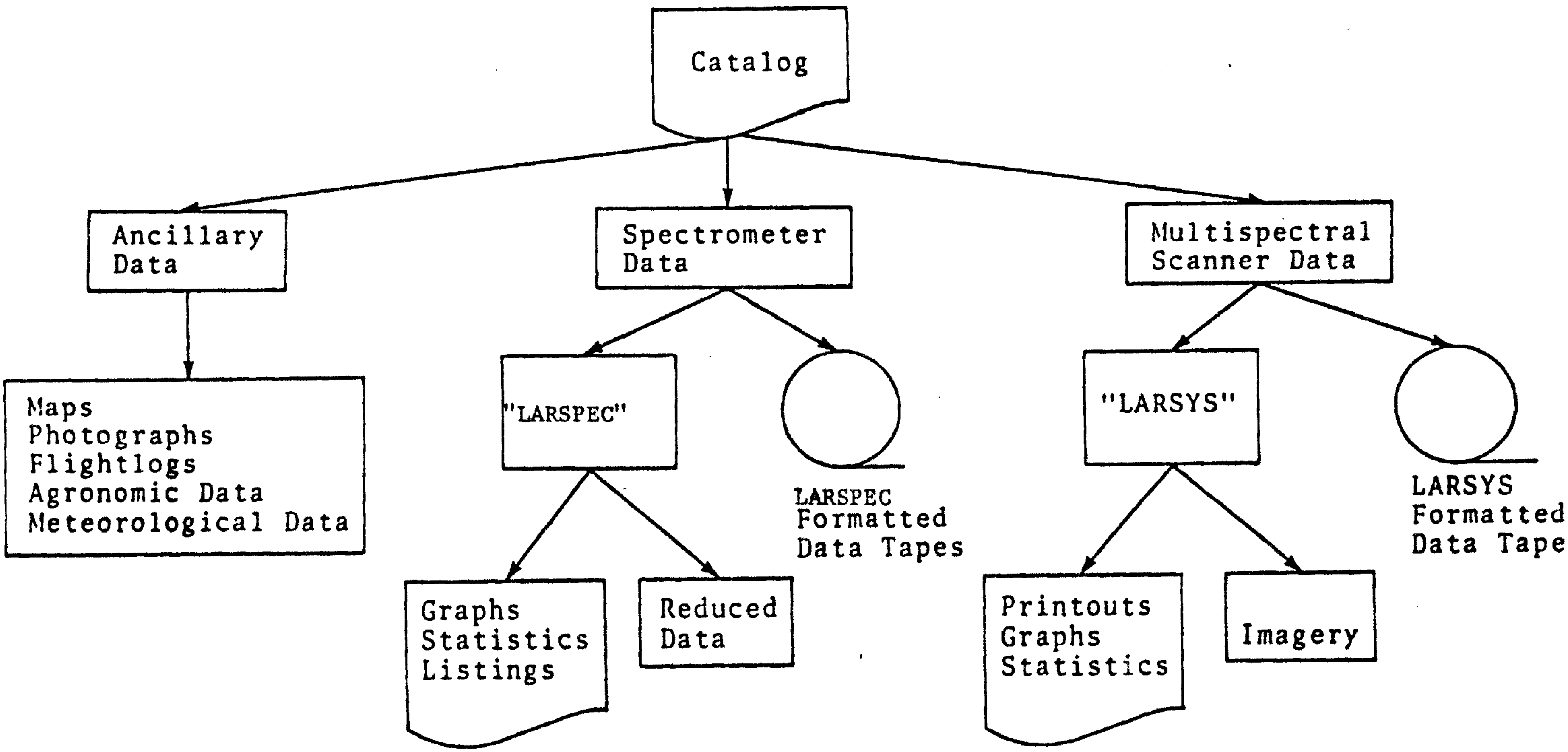


Figure A-10. Organization of Field Research Data Library. LARSPEC and LARSYS are Purdue/LARS software systems to analyze spectrometer and multispectral scanner data.

The fourth level of the data catalog, a computer printout, is a listing of the information (i.e. observation number, location, date, time, scene type, instrument) required to access individual spectra. It is not included in the catalog itself, but is available upon request from Purdue/LARS.

Appendix I of the catalog contains information pertaining to the location of the test sites and flightlines. Appendix II describes the treatments (plots) for which data were acquired on the agriculture experiment stations. Appendix III briefly describes the supporting agronomic, meteorological, and atmospheric measurements. Appendix IV gives a summary of the sensor specifications and operational characteristics.

The formats of the data are either imagery, hard copy outputs (tables), or 9-track computer compatible tapes (CCT). The CCTs for the Landsat and aircraft multispectral scanner data are in LARSYS Version 3.0 format. These data are approximately linearly related to the scene radiance, i.e. the data have not been altered from the initial processing performed at the respective institutions which operated the sensors. The CCTs containing the spectrometer or interferometer data (FSS, FSAS, Exotech 20C and Exotech 20D) are in LARSPEC format. These data are calibrated as bidirectional reflectance factor. Also, each observation on the LARSPEC-CCT has a header record which contains the supporting agronomic, meteorological, and atmospheric observations.

Following processing and logging into the library, the data is routinely sent to investigators requiring the data for their NASA/JSC funded SR&T analysis tasks. A mechanism to provide data to interested resea-chers from other NASA centers, as well as other research organizations, has been defined by the NASA/JSC Earth Observations Division. Information on procedures for obtaining data may be obtained from the NASA/JSC field research project manager.

Appendix H. Project Organization and Management

Supporting Field Research is one of several research elements within the AgRISTARS Supporting Research Project (Figure A-11). Within the Supporting Research Project, Supporting Field Research is one of six areas of responsibility of the Vegetation and Soils Characteristics Research leader. The NASA/JSC task manager for Supporting Field Research is D.E. Pitts; the Purdue/LARS technical manager is M.E. Bauer. The task managers supply administrative and technical leadership and are responsible for the conduct of all tasks done under Supporting Field Research. The task managers supports the level 3 project manager in planning technical task, develops overall technical approach, schedules, and procedures to be used, assures technical validity and coordinate this project element with other project elements, and prepares reports on a periodic basis and as requested by management.

To assure continuing responsiveness to technical requirements of AgRISTARS an advisory team has been formed. The membership is as follows:

D.E. Pitts, (JSC) Task manager (Co-chairman)
M.E. Bauer (Purdue) Technical manager (Co-chairman)
D.R. Thompson (JSC), Crops research
K.E. Henderson (JSC), Soils research
M.C. Trichel, (JSC) Area estimation research
W.A. Malila (ERIM), Analysis and modeling
B.F. Robinson (Purdue), Instrumentation
L.L. Biehl (Purdue), Data acquisition and preprocessing
V.C. Vanderbilt (Purdue), Analysis and modeling
F.G. Hall(JSC), EOD Chief Scientist
R.B. MacDonald (JSC), Directorate Chief Scientist

The primary responsibilities for task implementation are as follows:

NASA/Johnson Space Center

Task management
Acquisition and preprocessing of Landsat MSS, FSS, and aircraft MSS data
Coordination of USDA field data collection

Purdue/LARS

Technical coordination
Data acquisition and preprocessing of Purdue acquired data
Data base management and data distribution
Data evaluation and verification
Data analysis and modeling

SUPPORTING RESEARCH FUNCTION FLOW

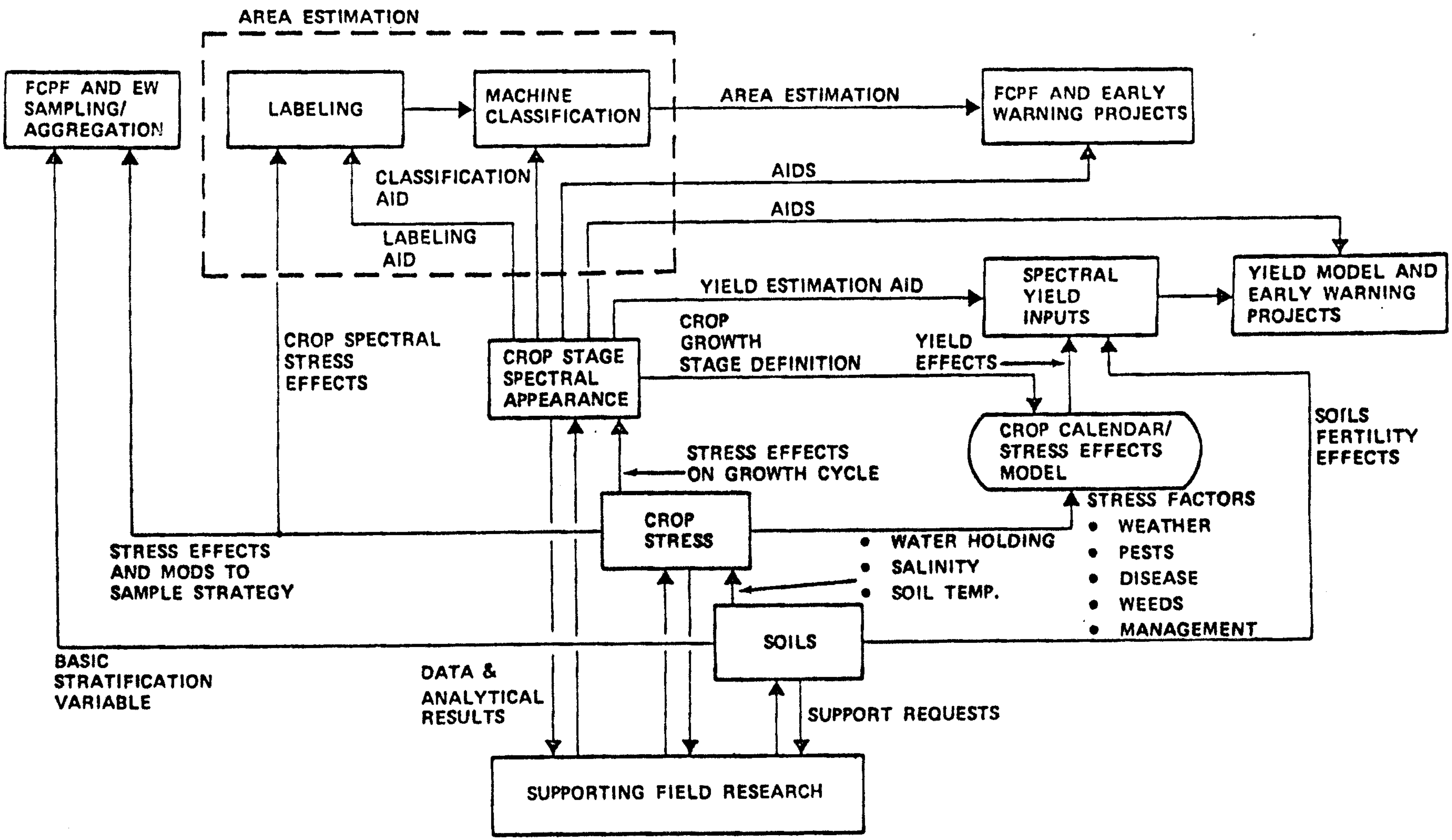


Figure A-11. Interrelationship of Supporting Field Research and other Supporting Research project elements.

USDA/ESCS

Collection of general gronomic data at test sites

ERIM

Data analysis and modeling

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