GEORGE HANUSCHAK'S COPY

AgRISTARS

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

Technical Program Plan

January 15, 1980

TECHNICAL PROGRAM PLAN FOR AgRISTARS

APPROVED BY:

William E. Kibler Date: 1/15/80

William E. Kibler
U. S. Department of Agriculture

Pitt G. Thome Date: 1/15/80

Pitt G. Thome
National Aeronautics and Space Administration

Thomas D. Potter Date: 1/15/80

Thomas D. Potter
U. S. Department of Commerce

Frederick J. Doyle Date: 15 Jan 80

Frederick J. Doyle
U. S. Department of the Interior

TABLE OF CONTENTS

Definition of Acronyms

AA	Accuracy Assessment
AgRISTARS	Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing
AID	Agency for International Development
AIRP	Airborne Instrumentation Research Program
ASCS	Agricultural Stabilization and Conservation Service
CCT	Computer Compatible Tapes
CPF	Commodity Production Forecasting
CRD	Crop Reporting District
EDC	EROS Data Center
ERTS	Earth Resources Technology Satellite
ESCS	Economics, Statistics, and Cooperatives Service
EW/CCA	Early Warning/Crop Condition Assessment
FAS	Foreign Agricultural Service
FCPF	Foreign Commodity Production Forecasting
F&R	Forestry and Range
GSFC	Goddard Space Flight Center
IO	Initial Operations
JAWF	Joint Agricultural Weather Facility
LACIE	Large Area Crop Inventory Experiment
LC	Land Cover
LFC	Large Format Camera
LSAT	Large Scale Application Test
LSD	Landsat D
MSS	Multispectral Scanner

Definition of Acronyms
(Cont'd)

NASA	National Aeronautics and Space Administration
NCIC	National Cartographic Information Center
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
P-2	Procedure 2 - An advanced machine classification procedure
P/C	Pollution/Conservation
P/T	Pilot Test
RBV	Return Beam Vidicon
RCA	Resources Conservation Act
R&D	Research and Development
RD&T	Research, Development and Testing
RPA	Renewable Resources Planning Act
SCS	Soil Conservation Service
SEA-AR	Science and Education Administration-Agricultural Research
SM	Soil Moisture
SR	Supporting Research
T&E	Test and Evaluation
TM	Thematic Mapper
UE	USDA User Evaluation
USDA	United States Department of Agriculture
USDC	United States Department of Commerce
USFS	United States Forest Service

List of Figures

1.0 SUMMARY

This document describes a six-year program of research, development, evaluation, and application of aerospace remote sensing for agricultural resources beginning in Fiscal Year (FY) 1980. The program is a cooperative effort of the USDA, NASA, USDC, USDI, and AID.

The goal of the program is to determine the usefulness, cost, and extent to which aerospace remote sensing data can be integrated into existing or future USDA systems to improve the objectivity, reliability, timeliness, and adequacy of information required to carry out USDA missions. The overall approach is comprised of a balanced program of remote sensing research, development, and testing which addresses domestic resource management, as well as commodity production information needs.

The program specifically addresses the seven information requirements identified in the USDA Secretary's Initiative.[1]

1. Early warning of change affecting production and quality of commodities and renewable resources;
2. commodity production forecasts;
3. land use classification and measurement;
4. renewable resources inventory and assessment;
5. land productivity estimates;
6. conservation practices assessment; and,
7. pollution detection and impact evaluation.

(While all seven are important to the USDA, the first two - early warning and commodity production forecasting - have been given emphasis because of the immediate need for better and more timely information on crop conditions and expected production.)

The Technical Program is structured into eight major projects as follow:

1. Early Warning/Crop Condition Assessment (EW/CCA);
2. Foreign Commodity Production Forecasting (FCPF);
3. Yield Model Development (YMD);

[1] Joint Program of Research and Development of Uses of Aerospace Technology for Agricultural Programs dated February 1978

4. Supporting Research (SR);

5. Soil Moisture (SM);

6. Domestic Crops and Land Cover (DC/LC);

7. Renewable Resources Inventory (RRI); and,

8. Conservation and Pollution (C/P).

These elements are interrelated through research, exploratory experiments, pilot experiments, USDA user evaluations, and large scale application tests.

The EW/CCA research effort is designed to develop and test the basic techniques required to support the operational Crop Condition Assessment Division (CCAD) of the Foreign Agricultural Service in USDA. The EW/CCA addresses 20 crop/region combinations in the U.S. and seven foreign countries (USSR, Argentina, Brazil, Canada, People's Republic of China, Mexico, and Australia) for six major commodities (wheat, barley, corn, soybeans, rice, and cotton).* It is assumed that the techniques utilized for early warning are largely crop dependent and country independent.

The Foreign Commodity Production Forecasting (FCPF) activity addresses 12 crop/region combinations on the U.S. and six foreign countries (USSR, India, Argentina, Brazil, Canada, and Australia) for five major commodities (wheat, barley, corn, soybeans, and rice). This project will develop and test procedures for using aerospace remote sensing technology to provide more objective, timely, and reliable crop production forecasts several times during the growing season and improved preharvest estimates for the crop/regions of interest. The FCPF activity builds upon the existing remote sensing technology base and extends this technology to additional crops and regions. Large Scale Applications Testing (LSAT) of candidate technology for making estimates or production in foreign countries will be conducted by USDA.

The Yield Model Development (YMD) will support USDA crop production forecasting and estimation by (1) testing, evaluating and selecting crop yield models for application testing; (2) identifying areas of feasible research for improvement of model usefulness; and (3) conducting research to modify existing models and to develop new crop yield assessment methods.

The Supporting Research (SR)project covers research, development, and testing of new and/or improved remote sensing technology. Research will be conducted in the following areas, as related to applications of remote sensing technology: area estimation, crop development stage estimation, spectral crop appearance in yield estimation, crop stress, and soils.

*These crops and regions may change in response to USDA information needs.

Soil Moisture (SM) research is directed toward development of the measurement of soil moisture (in-situ and remotely) for potential use in other applications, such as early warning uses, crop yield estimation, watershed runoff, and vegetative stress assessments.

Domestic Crops and Land Cover (DCLC) objectives are directed at automatic classification and estimation of land cover with emphasis on major crops. Landsat and advanced sensor data will be used in conjunction with ground data to improve the precision of estimation and classification procedures at the substate level and to investigate change monitoring techniques.

The Renewable Resources Inventory (RRI) Project involves requirements in seven major problem areas: Regional and Large Area Inventories; Current Technology Assessment; New Technology Development; Detection, Classification and Measurement of Disturbances; Classification, Modeling and Measurement of Renewable Resources; Determination of Site Suitability and Land Management Planning; and Analytical and Cartographic Support to the Resource Information Display System.

The Conservation Assessment portion of the Conservation and Pollution (C/P) Project addresses applications in three areas: inventory of conservation practices; estimation of water runoff using hydrologic models; and determination of physical characteristics of snowpacks.

The Pollution portion of the C/P Project will provide an assessment of conservation practices through use of remote sensing techniques to quantitatively assess sediment runoff, to detect gaseous and particulate air pollutants, and to assess their impacts on agricultural and forestry resources.

The primary roles of each department/agency are indicated in Figure 1-1. Additional information on responsibilities are included in the individual project implementation plans.

1.1 Milestones for Anticipated Accomplishments

These milestones and anticipated accomplishments are subject to modification as a result of detailed planning and resource availability

1.1.1 Early Warning/Crop Condition Assessment

1. FY 80

o Collect data and conduct analysis for soybeans, corn, and small grains.

o Initiate data collection for rice and cotton.

o Conduct research on selected EW alarms for wheat (soil moisture, winterkill, untimely freeze, hot-dry winds).

o Initiate research into relationship between spectra and plant condition for small grains.

FIGURE 1-1

DEPARTMENT/AGENCY ROLES

USDA

- DEFINE USDA INFORMATION REQUIREMENTS
- YIELD MODEL RD&T AND APPLICATIONS
- RD&T-APPLICATIONS ANALYSIS FOR AREA, YIELD, AND PRODUCTION ESTIMATION
- AGRONOMIC/ANCILLARY DATA BASE
- USER EVALUATION
- GROUND DATA COLLECTION
- RD&T AND APPLICATIONS CROP/ WEATHER ASSESSMENTS[1]
- RD&T AND APPLICATION FOR EARLY WARNING
- RD&T AND APPLICATIONS FOR RENEWABLE RESOURCES ANALYSIS
- RD&T AND APPLICATIONS FOR LAND USE, PRODUCTIVITY, CONSERVATION, AND POLLUTION ANALYSIS
- RD&T FOR SOIL MOISTURE MEASURING TECHNIQUES
- LARGE SCALE APPLICATIONS TESTS

NASA

- RD&T FOR FOREIGN CROP AREA ESTIMATION
- RD&T FOR COMBINING AREA AND YIELD ESTIMATES FOR FOREIGN CROP PRODUCTION
- FIELD RESEARCH
- LANDSAT DATA ACQUISITION
- RD&T-SPECTRAL INPUTS TO YIELD MODELS
- RD&T-SPECTRAL INPUTS TO QUANTITATIVE EARLY WARNING AND CROP CONDITION ASSESSMENT
- RD&T FOR SPECTRAL ANALYSIS RELATED TO INVENTORY AND CONDITION ASSESSMENT TECHNIQUES FOR RENEWABLE RESOURCES
- RD&T INVENTORY AND MONITORING TECHNIQUES FOR LAND USE, CONSERVATION, AND POLLUTION
- RD&T FOR REMOTELY SENSED SOIL MOISTURE MEASURING TECHNIQUES
- DEFINITION OF REQUIREMENTS FOR FUTURE SENSORS (INCLUDING IN-SITU)

USDC

- METEOROLOGICAL DATA BASE
- RD&T AND APPLICATIONS OF ENVIRONMENTAL SATELLITE DATA
- RD&T METEOROLOGICAL YIELD MODELS
- RD&T WEATHER/CROP ASSESSMENTS[2]
- RD&T ON USE OF CONVENTIONAL AND SATELLITE-DEFINED MET DATA APPLIED TO RENEWABLE RESOURCES, CONSERVATION, AND POLLUTION
- RD&T ON TECHNIQUES FOR DETERMINING SOIL MOISTURE

USDI

- LANDSAT DATA STORAGE, RETRIEVAL, AND DISSEMINATION

AID

- EVALUATE UTILITY OF RD&T RESULTS FOR APPLICATION IN DEVELOPING COUNTRIES

[1] Primary emphasis on assessment of crop conditions (e.g., yield, production) using meteorological data as an input to develop needed information.

[2] Primary emphasis on acquisition and evaluation of meteorological data in terms of its utility for crop condition assessment.

o Conduct a pilot test of winterkill.

o Initiate R&D for meteorological satellite techniques.

o Initiate R&D on data handling methodology.

2. FY 81

o Collect data and initiate R&D for rice, cotton, soybeans, corn, and small grains.

o Conduct a pilot test on Landsat EW techniques for small grains.

o Pilot tests for selected meteorological satellite techniques.

3. FY 82

o Conduct a LSAT on soil moisture and selected meteorological satellite techniques.

o Collect data and conduct analysis for rice, cotton, soybeans, corn, and small grain.

o Conduct a pilot test of developed early warning techniques for selected crops.

o Conduct LSAT's of selected techniques employing spectral data.

o Develop improved technology for sampling and analysis of Landsat data to support crop condition assessments.

4. FY 83

o Develop EW technique improvements based on pilot test/LSAT results.

o Conduct pilot test and LSAT of available techniques.

o Improve methodology for sampling and analysis of Landsat data to support crop condition assessments.

5. FY 84-85

o Develop EW technique improvements based on pilot test/ LSAT results.

o Conduct pilot tests and LSAT of available techniques.

1.1.2 Foreign Commodity Production Forecasting

1. FY 80

   o General

     - Complete installation of Supporting Research and Pilot Experiment data processing system.

     - Establish DOMSAT link for Landsat transmission.

     - Complete development of a baseline multicrop sampling and aggregation strategy.

   o U.S. - Corn/Soybeans

     - Complete initial development and exploratory test of corn/soybeans separation procedures and multicrop sample strategy.

     - Complete FY 81 pilot experiment design and initiate data acquisition.

   o U.S./Canada - Wheat/Barley

     - Complete exploratory test of wheat/barley separation procedures.

     - Complete experiment design and data acquisition for FY 81 pilot.

   o USSR - Barley

     - Develop agronomic data base.

     - Select USSR pilot test areas.

     - Select U.S./Canada foreign similarity regions.

   o Brazil - Corn/Soybeans

     - Allocate samples and initiate data acquisiton for Brazil exploratory experiments.

     - Develop agronomic data bases.

     - Define Brazil similarity region in the U.S.

   o Australia - Wheat

     - Complete Landsat data acquisition for full crop year.

     - Initiate experiment design for FY 83 pilot.

2. FY 81

   o General

     - Complete automated data processing interface to selected end item and university contractors.

- Complete development and test of procedure for area estimation accuracy evaluation without ground truth.

o U.S. - Corn/Soybeans

- Test and evaluate (pilot experiment) corn/soybeans (at harvest) technology in corn belt (Indiana, Illinois, Iowa).

o U.S./Canada - Wheat Barley

- Test and evaluate (pilot experiment) spring wheat/barley technology in northern U.S. Great Plains and over Canadian ground truth sites.

o USSR - Barley

- Complete experiment design for FY 82 pilot experiment.
- Develop sample frames, allocate samples, and prepare data.
- Develop initial early season procedure.

o Brazil - Corn/Soybeans

- Develop initial procedures for separating soybeans from cotton (U.S. data).
- Complete pilot experiment design.
- Develop sample frames and allocate samples for pilot experiment.
- Complete exploratory data acquisition and initiate pilot data acquisition.

o Argentina - Wheat/Corn/Soybeans

- Develop agronomic data base.
- Define Argentina similarity region in U.S.
- Initiate exploratory experiment data acquisition.

o Australia

- Initiate investigations of alternate production estimation approaches for regions without adequate historical statistics.
- Complete experiment design and perform data acquisition in preparation for FY 83 pilot.

3. FY 82

- o U. S. - Corn/Soybeans

  - Complete initial development of techniques for advanced machine processing procedures for analysis of Landsat data for area estimation.

  - Develop preliminary Landsat D TM analysis tools.

  - Design Landsat D TM exploratory experiment and initiate TM data acquisition.

- o U. S./Canada - Wheat/Barley

  - Complete initial data collection and research for development/adaptation of advanced machine processing procedures.

  - Develop preliminary Landsat D TM analysis tools.

  - Design Landsat D TM exploratory experiment and initiate TM data acquisition.

- o USSR - Barley

  - Complete pilot experiment data analysis and perform preliminary evaluation of results.

- o Brazil - Corn/Soybeans

  - Complete development, test and evaluation of candidate procedures for crop identification, crop development stage estimation, and area and production estimation for FY 83 pilot experiment.

- o Argentina - Wheat/Corn/Soybeans

  - Complete exploratory experiment data acquisition and development of crop identification and area estimation procedures.

  - Develop sample frames and allocate samples for pilot experiment.

  - Complete pilot experiment design and initiate data acquisition.

- o Australia - Wheat

  - Complete development of procedures and data acquisition for FY 83 pilot.

- o India - Wheat
  - Develop agronomic data base.
  - Design exploratory experiments, allocate samples and initiate data acquisition.
- o U. S. - Rice
  - Develop preliminary TM analysis tools.
  - Design exploratory experiment and initiate TM data acquisition.
- o India - Rice
  - Develop agronomic data base.
  - Design exploratory experiment.

4. FY 83

- o U. S. - Corn/Soybeans
  - Complete exploratory test and evaluation of advanced machine processing procedures and design pilot experiment.
  - Complete development of first generation TM analysis tools.
  - Complete design of FY 85 TM pilot experiment.
- o U. S./Canada - Wheat/Barley
  - Complete experiment design and initiate data acquisition for pilot test of advanced machine processing procedures
  - Adapt first generation TM analysis tools to wheat/barley and initiate evaluation.
  - Complete design of FY 85 TM pilot experiment.
- o USSR - Barley/Wheat
  - Complete LSAT.
- o Brazil - Corn/Soybeans
  - Conduct pilot experiment data analysis and preliminary evaluation of results.
- o Argentina - Wheat/Corn/Soybeans
  - Complete Landsat data acquisition and development of procedures for pilot experiment.

- o Australia - Wheat
  - Complete pilot experiment data analysis and preliminary evaluation of results.
- o India - Wheat
  - Complete initial TM data acquisition and adaptation of TM procedures.
- o U. S. - Rice
  - Adapt first generation TM analysis tools to rice and initiate evaluation.
  - Initiate design of FY 85 pilot experiment.
- o India - Rice
  - Allocate samples and initiate data acquisition for FY 85 exploratory experiment.

5. FY 84

- o U. S. - Corn/Soybeans
  - Complete exploratory experiment evaluation of first generation TM analysis procedures and conduct data acquisition for FY 85 pilot experiment.
  - Complete pilot analysis and preliminary evaluation of results utilizing advanced machine processing procedures.
- o U. S./Canada - Wheat/Barley
  - Complete exploratory evaluation of first generation TM analysis tools, develop analysis procedures and conduct data acquisition for FY 85 pilot experiment.
  - Complete exploratory test and evaluation of advanced machine processing procedures.
- o Brazil - Corn/Soybeans
  - Complete LSAT.
  - Design exploratory experiment and acquire data for adaptation of advanced machine processing procedures.
- o Argentina - Wheat/Corn/Soybeans
  - Complete pilot experiment data analysis and preliminary evaluation of results.

- Design exploratory experiment and acquire data for adaptations of advanced machine processing procedures for corn/soybeans.

o Australia - Wheat

- Complete LSAT

o India - Wheat

- Complete exploratory test and evaluation of TM procedures and refine procedures for FY 85 pilot experiment.

o U. S. - Rice

- Complete exploratory experiment evaluation of first generation TM analysis tools, develop TM analysis procedures, and conduct data acquisition for FY 85 pilot experiment.

o India - Rice

- Complete development of analysis procedures and acquire data for FY 85 exploratory experiment test and evaluation.

o U. S. - Cotton/Sorghum/Sunflowers

- Complete data acquisition and initial research on crop identification - procedures and crop development stage estimation.

6. FY 85

o U. S. - Corn/Soybeans

- Complete pilot analysis and evaluation of results for TM oriented technology.

o U. S. - Wheat/Barley

- Complete pilot analysis and evaluation of results for advanced machine processing procedures and TM oriented technology.

o Brazil - Corn/Soybeans

- Complete exploratory analysis and evaluation of adaptation of advanced machine processing procedures.

o Argentina - Corn/Soybeans/Wheat

- Complete LSAT

- Complete exploratory analysis and evaluation of adaptation of advanced machine processing procedures for corn/soybeans.

- o India - Wheat

  - Complete pilot experiment analysis and evaluation of results.

- o U. S. - Rice

  - Complete pilot analysis and evaluation of results for TM oriented technology.

- o India - Rice

  - Complete exploratory test and evaluation of area estimation technology.

- o U. S. - Cotton/Sorghum/Sunflowers

  - Complete exploratory development and preliminary evaluation of crop identification, area estimation, and crop development stage estimation procedures.

1.1.3 Yield Model Development

1. FY 80-81

o Develop or select, test, and implement regression crop yield forecast models using primarily meteorological and existing yield data to support foreign commodity production forecasting pilot test schedules.

o Conduct tests and evaluations of existing empirical candidate crop yield models and either select from these models or develop alternative empirical models for application in scheduled foreign commodity production forecasting pilot tests.

o Initiate a program to develop or select, test, and implement second stage crop yield forecast models that utilize plant phenology in the model structure with correlative or point measurement input variables. Models of this type for a limited number of crop/country combinations will be available for pilot testing in the 1981 timeframe.

o Conduct a basic research program to determine how basic environmental variables affect plant processes. Basic understanding of these relationships will be used to simulate plant growth and development, permitting a refined crop yield forecast modeling capability. Satellite sensor data (Landsat and Environment) will also be investigated to determine the basic plant processes being measured by the sensors.

2. FY 82-85

o Complete development or selection, testing, and implementation of second stage models for all crop/country combinations in the foreign commodity production forecasting pilot test schedule.

o Utilize input variable relationships with plant processes to refine simulation models, and initiate pilot testing for a few crops in the U.S.

1.1.4 Supporting Research

1. FY 80

o Complete installation of supporting research data system.

o Conduct technique development for crop development stage estimation and for labeling and machine processing for area estimation.

o Completion of evaluation of area estimation labeling procedures, conduct technique development of improved machine procedures, and condcut technique development for crop stage estimation for spring wheat/barley in U.S./Canada.

o Conduct technique development of labeling procedures to support area estimation and of crop development stage estimation for barley in USSR.

o Conduct initial research to support area estimation for corn/soybeans in Brazil.

o Conduct technique development for wheat/barley/corn spectral inputs to yield.

2. FY 81

o Complete automated data system interface (including to selected contractors).

o Conduct technique development for crop development stage estimation and for labeling and machine processing for area estimation.

o Conduct technique development research of improved machine processing for area estimation for corn/soybeans in U.S.

o Development of techniques for area estimation of barley in USSR.

o Collection of data and initial research in area estimation for corn/soybeans in Brazil.

o Collection of data and initial research in area estimation for wheat/corn/soybeans in Argentina.

o Conduct techniques development of spectral inputs to yield for wheat/barley/corn/soybeans.

o Collect data and conduct initial research on rice in U.S. as part of supporting field research.

3. FY 82-85

o Complete research and development of area estimation techniques (e.g., crop development stage estimation, labeling procedures/techniques and machine processing algorithms development from MSS and TM) in support of the FCPF Exploratory Experiments and pilot experiment schedules.

o Conduct techniques development research in spectral inputs to yield in support of Yield Model Development.

o Develop techniques for crop development stage estimation for Early Warning and Crop Condition Assessment.

1.1.5 Soil Moisture Project

1. FY 80

o Acquire soil moisture data sets with P-band radiometer system.

o Convert one-truck system to dual active/passive measurement capability.

o Complete analysis of Seasat SAR data set over Oklahoma.

o Complete testing of real-time scatterometer data processor.

o Complete survey of techniques for in-situ measurement of soil moisture.

2. FY 81

o Determine soil moisture sampling depth for various sensors and wavelengths.

o Develop a preliminary definition of optimum sensor combinations.

o Complete assessment of the effect of surface roughness and vegetation cover on measurement accuracy.

o Estimate the level of uncertainty imposed by natural soil moisture variability in an agricultural field.

o Evaluate remote sensing capabilities for frozen soil assessment.

3. FY 82

o Use surface layer measurements as inputs to soil moisture budget models.

o Perform an interim assessment of optimum sensors and associated measurement accuracies.

o Determine the resolution and measurement accuracy needs for various user application models.

4. FY 83

o Perform an assessment of the diurnal soil moisture variability.

o Complete assessment of salinity effects and saline soil detection.

5. FY 84

o Complete technique development for moisture gradient observations.

o Complete development of model to extrapolate surface soil moisture root-zone depths.

o Complete sensitivity studies for determining importance of soil moisture data in user application models.

o Complete testing of in-situ soil moisture sensors.

6. FY 85

o Complete evaluation of measurement accuracy capabilities.

o Complete evaluation of remote sensing utility for soil moisture applications.

o Develop recommendations for in-situ soil moisture sensors.

1.1.6 Domestic Crops and Land Cover

1. FY 80

o Assess current technology for land cover and crops.

o Complete a pilot test for crops in two states.

2. FY 81

o Achieve expected precision for crops.

o Complete implementation of registration procedures for land cover application.

o Complete design of change monitoring system.

o Prepare classification procedures/algorithms for land cover application.

o Complete a pilot test for crops in four states.

3. FY 82

o Prepare multitemporal analysis procedures (crops and land cover).

o Prepare sampling procedures (crops and land cover).

o Prepare procedures for TM application (crops and land cover).

o Complete change monitoring procedures for subsequent testing.

o Complete development of integrated procedures for fast throughput (crops and land cover).

o Initiate integrated pilot test in four states (crops and land cover).

4. FY 83

o Demonstrate location and mapping of crops and land cover with known accuracies.

o Demonstrate change monitoring system, including data base.

o Complete integrated pilot test for eight states.

5. FY 84

o Initiate LSAT, completing ten states.

6. FY 85

o Complete LSAT for twelve states.

1.1.7 Renewable Resources Inventory

1. FY 80

o Complete Phase I of the Multiresource Inventory Methods Pilot Test.

o Complete testing of South Carolina Planning Model

- Stratification
- Sample size and allocation
- Estimation of population variances
- Sampling technique
- Documentation

o Initiate Phase II of the Multiresource Inventory Methods Pilot Test.

o Initiate preliminary design and sampling testing for a

- Western state (TBD)
- Develop preliminary inventory design plan
- Develop and complete requirements definition
- Initiate Western State Planning Model

o Complete test and evaluation of Landsat input to the Resource information Display System (RIDS).

o Develop and test procedures to update RIDS from Landsat change information.

o Evaluate Landsat spectral values of vegetation cover types for association to the National Land Classification System (NLCS).

- Complete South Carolina analysis

- Initiate test site for analysis in a Western State

o Continue assessment of various classifiers for classification analysis.

o Complete precision registration of South Carolina Landsat data (50) scenes.

o Evaluate Landsat 3 geometrically corrected data.

o Initiate research on comparative efficiencies of sampling procedures for estimation of renewable resource values.

o Initiation of Accuracy Assessment techniques for evaluation of geometrically restored and registered Landsat data.

o Initiate an evaluation of Advanced Technology Focal Plane Array, CCD sensors for application to improved renewable resource evaluations.

o Development of procedures for analysis of TM data.

o Development of procedures for using SLAR visual data.

o Data processing and acquisition support.

o Initiate research on textural classification algorithms.

o Initiate an analytical task to evaluate effectiveness of SAR data for forest inventories and monitoring.

o Initiate development of an integrated digital system which incorporates capabilities now found in DTIS, TOPAS and DMS.

o Initiate development of efficient and precise method for analytical determination of UTM coordinates of REU plot. Locations identified on resource photography.

o Initiate design for spacecraft oriented study of vegetation stress.

o Initiate sensor parameter definition study.

o Initiate remote sensing research and development related to detection, classification, and measurement of forest disturbances.

o Initiate a stand risk rating and change detection task using high altitude photography with non-conventional format cameras.

o Initiate development of site specific change detection methodology for events less than one acre in size.

o Initiate development of image enhancement techniques for extracting insect and disease impact information from small scale aerial photographs.

o Initiate development of an early warning capability for identifying weather phenomenon affecting renewable resources.

o Initiate task to improve methods of habitat type mapping.

o Initiate task for improving landuse classification using topographic data with Landsat.

o Initiate task to investigate feasibility of using remote sensing for analysis of urban soil water potential.

o Initiate task to locate and characterize snow in forested areas with satellite data.

o Initiate task for determining site suitability classes for multiple resource values.

o Initiate task for evaluation of wildlife habitat using remote sensing.

o Initiate task for defining a general spatial data structure.

o Initiate task for testing and evaluation of alternative geobase information systems optimized for renewable resources.

o Continue development of a system to provide labeling, vectorizing and editing of line data based on line following of automatically scanned rastor data.

o Initiate development of a system for digitizing digital display systems.

o Continue development of more user oriented Digital Terrain Information System (DTIS).

2. FY 81

o Complete Phase II of the Multiresource Inventory Methods Pilot Test.

o Initiate Phase III of the Multiresource Inventory Methods Pilot Test.

o Complete testing of a Western State Planning Model.

o Operational support to the Multiresource Inventory Methods Pilot Test.

- Test and evaluate large format camera application to RRI.
- Continue full frame precision registration of 100 Landsat scenes.
- Continue data processing and acquisition support.
- Continue assessment of classification algorithms.
- Continue research on the cooperative efficiencies of sampling procedures for estimation of renewable resource values.
- Complete accuracy assessment techniques for evaluation of geometrically restored and registered Landsat data.
- Initiate a comparison of alternative methods for computer classification of forest cover types, using MSS data.
- Initiate assessment of advanced technology remote sensing systems.
- Initiate evaluation of cost, accuracy and precision of MSS versus TM data to estimate land cover areas.
- Continue data processing and acquisition support.
- Continue development of methodology for identification of UTM coordinates for REU plot locations found on resource photography.
- Complete and document TMS data studies.
- Develop experimental design for testing TM data.
- Continue to test and evaluate large format camera application to RRI.
- Continue research on textural classification algorithms.
- Continue analytical task to evaluate effectiveness of SAR data for forest inventories and monitoring.
- Test and evaluate alternative methods for detection, classification and measurement of change phenomenon five acres or larger on Landsat.
- Complete design and evaluation of spacecraft oriented study of vegetation stress.
- Continue sensor parameter definition.
- Continue remote sensing research and development related to detecting, classification and measurement of forest disturbances.
- Continue development of site specific change detection methodology for events less than one acre in size.

o Complete development of image enhancement techniques for extracting insect and disease impact information from small scale aerial photographs.

o Continue development of early warning capability for identifying weather phenomenon affecting renewable resources.

o Complete stand risk rating and change detection task using high altitude photography with non-conventional format cameras.

o Continue development of classification procedural assessment.

o Continue feasibility study for applying remote sensing to analysis of urban soil water potential.

o Continue task to improve methods of habitat type mapping.

o Continue task to locate and characterize snow in forested areas with satellite data.

o Initiate an evaluation of techniques for combining Landsat and spatial data for classification improvement.

o Continue task for determining site suitability classes for multiple resource values.

o Continue task for evaluation of wildlife habitat using remote sensing.

o Initiate activity for site mapping existing timber stand classes versus potential natural vegetation classes.

o Initiate task for modeling timber suitability classes and site indexes.

o Initiate task to evaluate alternative formats to array the analysis of remotely sensed data to support land management planning.

o To perform a design study for a Digital Information Analysis and Display System to meet future national needs of the Forest Service.

o Complete task for defining general spatial data structure.

o Initiate development of new methodology for interactive graphics display of multiple resource information layers registered for a geodetic land net.

o Complete task for test and evaluation of alternative geo-base information systems optimized for renewable resources.

o Continue to develop and evaluate improved automated digitizing and labeling techniques for multiple resource layers.

3. FY 82-85

Specific R&D tasks for FY 1982-85 have not been defined at this time nor have R&D priorities been established. However, it is known that task definition and priorities will support the objectives and needs of the Multiresource Inventory Methods Pilot Test as a first priority.

Generally, tasks underway in FY 1981 will be continued if justified and new tasks will be brought forward if they support the objectives of the Multiresource Inventory Methods Pilot Test and the long term objectives of Renewable Resources Inventory, as established by the Nationwide Forestry Applications Program.

1.1.8 Conservation and Pollution

Conservation

1. FY 80

   - Complete historical data assemblage.
   - Collect initial ground data.
   - Collect initial space data.
   - Identify models to be modified/tested.
   - Begin evaluating model needs.

2. FY 81

   - Initiate sensor products evaluation for inventory and snowpack.
   - Complete identification of snowpack parameters.
   - Initiate model adaptations.
   - Initiate algorithm developments.
   - Initiate pilot tests.

3. FY 82

   - Complete pilot tests for snowpack and hydromodel.
   - Document procedures, results, snowpack, and hydromodel.
   - Initially plan LSAT, inventory and water management.

4. FY 83

   - Complete pilot test, inventory and water management.
   - Initiate LSAT, inventory and water management.

5. FY 84

   o Complete LSAT, inventory and water management.

   o Document procedures of LSAT's.

6. FY 85

   o Initial operations, inventory and water management.

Pollution

1. FY 80

   o Conduct research on air pollution.

   o Site selection for sediment runoff and air pollution.

   o Select models to be modified/tested.

   o Collect data for conservation practices.

   o Obtain laboratory spectra data for conservation practices.

2. FY 81

   o Acquire data for air pollution.

   o Develop initial model products for air pollution.

   o Obtain and analyze laboratory spectra data for conservation practices.

   o Initiate pilot test/experiments.

3. FY 82

   o Conduct pilot tests.

   o Test for different air pollutants.

4. FY 83

   o Document pilot tests and results.

   o Initiate LSAT's.

5. FY 84

   o Complete LSAT's.

   o Document results.

   o Plan initial operations.

6. FY 85

   o Initiate operations.

2.0 BACKGROUND

This joint program of research, development, test, evaluation, and application of remote sensing technology is specifically designed in response to the USDA's requirements for more reliable, timely, and objective information in monitoring and managing Earth resources. These requirements are listed in Section 1.0, SUMMARY.

The USDA has been actively engaged in developing and using remote sensing in support of major departmental missions since the 1940's. Until the past decade, remote sensing efforts primarily involved the use of aerial cameras mounted in fixed-wing aircraft to obtain photographs of the country's land area. In July 1972, the first Earth Resources Technology Satellite (ERTS), now called Landsat 1, was successfully orbited. Since then, it has been demonstrated that digital products, as well as image products, derived from the data collected by the Multispectral Scanner (MSS) on Landsat, combined with appropriate analysis techniques, can provide useful information to those engaged in monitoring and planning the development and conservation of the Earth's resources.

In 1974, NASA, NOAA, and USDA began the Large Area Crop Inventory Experiment (LACIE) to research, develop, apply, and test a technology which was designed to estimate wheat production worldwide, with a goal of achieving improved accuracy and timeliness over current global estimates. Wheat area estimates were based on analysis of Landsat data, and weather effects models were used to estimate wheat yield. LACIE, completed in 1978, demonstrated that this technologu met the established goal (90 percent accuracy with a 90 percent confidence level at harvest) in the U.S. Great Plains and the USSR for two consecutive years. In addition, the LACIE results indicated that technology improvements are needed in certain other important wheat growing regions, primarily where field size is close to present satellite resolution limits and where spring wheat is difficult to separate from other small grains such as spring barley.

Following several years of a small-scale research effort, the Statistical Reporting Service (now part of the Economics, Statistics, and Cooperatives Serivce of USDA) completed an experiment in 1977 for using Landsat digital data to improve crop acreage estimates for all major spring-planted crops in Illinois. This experiment, using full frame classification combined with ground data collected from a probability sample, demonstrated the usefulness of remote sensing data for estimating domestic crop acreages and for supporting land use estimation activities.

The encouraging results of the above-mentioned two experiments (LACIE) and Illinois Crop Acreage Experiment) have led government planners to support additional exploration of the possibilities for extending applications of remote sensing to other domestic uses, as well as to additional crops in other countries.

3.0 GOALS AND OBJECTIVES

1. To develop, test, and evaluate procedures for adapting remote sensing technology to improve USDA's capability to provide early warning and timely assessment of changes in crop conditions.

2. Develop, test, and evaluate procedures for using satellite remote sensing technology to provide more objective and reliable crop production forecasts several times during the growing season and improved pre-harvest estimates for a range of countries and crops.

3. Develop, test, and evaluate procedures for adapting remote sensing technology to domestic small area (multi-county) land cover estimation and the inventory and assessment of U. S. land, water, and other renewable resources to support the national inventory by 1985.

4. Develop a cost base to help determine the future USDA budget levels required for integrating remote sensing technology with the existing data systems, and/or implement an independent remote sensing data system.

The specific objectives for each are described in more detail in the project plans contained in subsequent sections of this document.

4.0 PROGRAM APPROACH AND LOGIC

In order to understand the underlying program approach and the major program elements, it is necessary to view the program in terms of the product flow or program phases. The major phases envisioned are shown in Figure 4-1. The initial efforts in the aerospace program start out as a part of the RD&T phase that is primarily aimed at component technology capability. Typical components include yield models/crop calendars, classification procedures, and sampling frames/sampling strategies. RD&T involves a multi-agency team engaged in component research, development, and pilot testing of components.

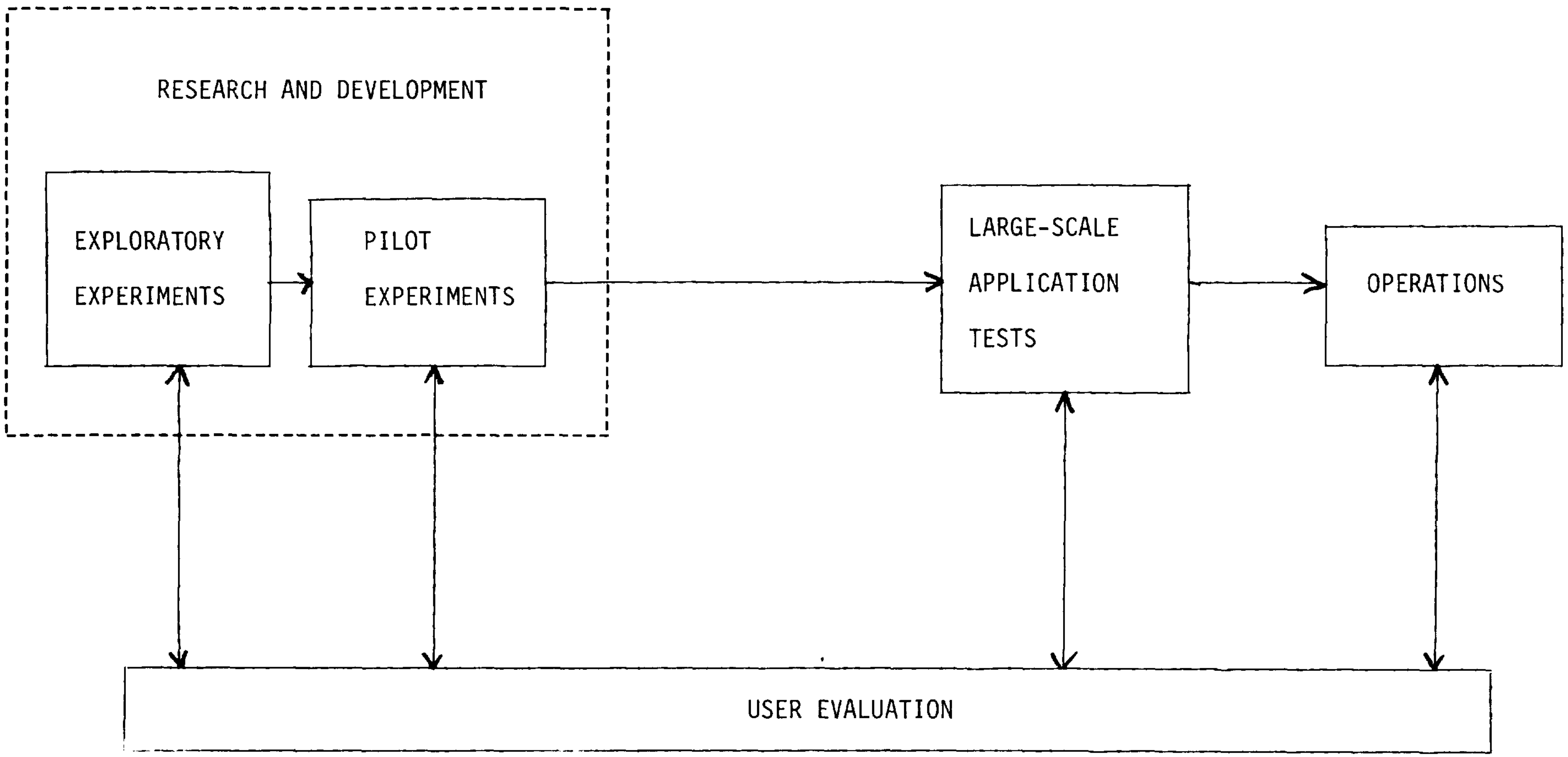
When adequate development has been completed, a pilot experiment is scheduled and performed. This may be for either a major component or a first integration of the components into a particular system. User evaluation and large scale application tests are the responsibility of the USDA. User evaluation is an ongoing effort of the program and provides guidance to all phases of the program.

Figure 4-1 shows the classic situation, but it should be recognized that the flow of technology through these program phases is not always straight-forward and that variations frequently occur. Also, the state of remote sensing technology clearly indicates that certain capabilities are ready for operational use now, some are in a developmental stage needing pilot experiment, and some are in a research stage.

FIGURE 4-1

TECHNICAL APPROACH

PROGRESSION OF THE TECHNOLOGY DEVELOPMENT



5.0 PROJECT TECHNICAL PLANS

This section contains eight separate project plans. Each plan contains objectives, technical content, approach, and schedules, as well as the responsibilities of each agency.

Section 5.1 Early Warning and Crop Condition Assessment Project

Manager - G. Boatwright, USDA/SEA-AR

Table of Contents

5.1.1 Overall Objectives and Rationale

The overall objective of this RD&T activity is to provide a capability for the U.S. Department of Agriculture to respond in a timely manner to factors which affect the quality and production of economically important crops. The response will involve identifying the occurrence of growing factors which influence crop conditions and determining the amount and condition of the crop area involved. This RD&T will be directed toward techniques which will augment and strengthen USDA's crop condition assessment activities. Much of the development of techniques and the identification of critical values will be based on the effects of past events that occurred in the U.S. or other regions for which adequate data are available.

5.1.2 Technical Approach

The early warning techniques to be developed and tested will utilize data acquired from both meteorological ground stations and environmental satellites, agricultural sources, and from the Landsat satellite. The meteorological data may provide an alert that an adverse event has occurred or is evolving. The Landsat data may also be used to provide alerts for certain factors and will provide information needed to determine the extent of the area affected. Associated RD&T will address 3 major task areas:

1. Provide improved definition of the climatic environment through a blending of surface weather observations with data from environmental satellites.

2. Develop, test, and evaluate an ability to use meteorological information with various simulation models and known environmental thresholds to provide alerts on a global basis.

3. Develop, test, and evaluate the ability to use Landsat data to identify, assess, and monitor the extent of cropland affected by anomalous growing conditions.

5.1.3 Early Warning Capability to be Developed

1. Crop water stress assessment.

2. Relationships between spectral data, plant components, and agronomic variables.

3. Winter-kill alarm model and assessment techniques.

4. Early season condition assessment.

5. Methodology for sampling from Landsat data based on analysis of spectral data.

6. Indications of significant departures from average crop yields.

7. Untimely freeze alarms and assessment.

8. Adverse temperature/wind alarms and assessments.

9. Disease/insect alarms and impact asssessments.

10. Abandonment of planted cropland.

11. Flood damage.

12. Snow cover.

13. Assessment of sensor bands.

14. Precipitation estimates from satellites.

5.1.4 Crops, Phenomena, and Geographic Region

The RD&T effort will proceed to develop the techniques to perform the pilot tests within the U.S. or other areas where adequate ground data are available. It may be necessary to use foreign equivalent analogs, both in refinement of techniques for geographic areas and for pilot tests. Table 5.1-1 shows areas of anticipated initial refinement of techniques for each crop.

5.1.5 Data Requirements

To carry out the necessary research and pilot testing leading to the desired capability, certain data will be essential. This falls generally into the 3 categories of: meteorological processed data, spectral data, and agronomic data. In most instances, retrospective data will be used for R&D; however, there will be occasional requirements for current data. Data elements needed are as follows:

5.1.5.1 Meteorological Processed Data

1. Elements: (generally on a daily basis)

   - Temperature extremes.
   - Wind velocity.
   - Humidity or dew-point depression.
   - Cloud cover.
   - Solar radiation.
   - Snow depth.
   - Precipitation amounts and type.
   - Soil temperature.

Table 5.1-1 Crop/Geographic Area Combination for the Large Scale Testing of Early Warning Techniques

	Wheat	Barley	Corn	Soybeans	Rice	Cotton
USSR	X	X				
Argentina	X		X	X		
Brazil			X	X		
Canada	X	X				
PRC			X	X		
Mexico			X			
Australia	X	X				
U.S.	X	X	X	X	X	X
Totals	5	4	5	4	1	1

2. Format:

• Data will be used in available form from historic records for research and pilot testing activity. These will be acquired from NOAA archives at the National Climatic Center.

• Data for Large Scale Application Testing will generally be current weather data provided by Joint NOAA/USDA Agricultural Weather Facility (JAWF).

5.1.5.2 Landsat Data

Research, pilot testing, and large scale application testing will utilize current and historical Landsat digital data for areas of interest.

5.1.5.3 Agronomic Data

Field observations, as well as statistical and historical agronomic data, will be necessary to provide coincident spectral, yield, crop stage, soil moisture, plant component, and other agronomic data sets which form the basis for research to develop predictive relationships. To the extent possible, reports and papers from prior agronomic research will be utilized.

5.1.6 Agency Technical Responsibilities in Early Warning/Crop Condition Assessment

1. NASA

• Develop techniques for spectral detection of crop stress. Acquisition and provision of Landsat full-frame and segment data.

2. NOAA

• Obtain satellite and surface-derived weather information to be used to identify freeze events, drought, dessication, or severe weather for use in determining probability of crop disease, insect infestation, winter-kill and livestock stress.

3. USDA

• Define information requirements to provide direction for R&D. Conduct research to develop relationships between meteorological events, spectral response, crop phenology, final crop yield, and production.

• Measure crop stress (vigor) using both meteorological and spectral data, correlated with ground data.

• Conduct research into predictability of crop condition and yield from soil moisture profiles.

- o Develop geographic data bases.
- o Conduct UE's.
- o Conduct LSAT's.

4. USDI

- o Provide Landsat data, storage, retrieval and dissemination.

5.1.7 Products to be Developed

The products of the early warning research program will be techniques that provide USDA a broad, more comprehensive capability to detect and assess factors influencing the quality and production of important crops.

The planned major output products are as follow.

1. From RD&T and pilot test:

o Methodology to alert and assess the impact of phenomena affecting the crops of interest. To consist of the following.

- Identification of meteorological alarms.
- Identification of spectral alarms.
- Algorithms and logic to react to these alarms in a timely manner.
- Procedures to track alarmed areas and assess impact.
- System to acquire, process, and interpolate meteorological and spectral input data.

o Estimate of performance that can be expected.

o Identification of needed additional research.

o Documentation of implementation procedures.

2. From LSAT:

o Appraisal of performance obtainable in a user environment.

o Preliminary operational guidelines and definition of elements of an operational system.

5.1.8 User Evaluation

1. Utility feasibility and cost effectiveness analyses.
2. Recommendations for adaptation for LSAT, return to research.

5.1.9 Technical Tasks during 1980

Technical efforts during 1980 will be principally involved with wheat, barley, corn, and soybeans. At that time, field data sets containing both spectral and agronomic data are expected to exist. During 1980, field data collection will be sponsored to extend the data sets to rice and cotton.

Research and literature searches will be initiated to begin developing needed relationships for wheat, barley, corn, and soybeans during 1980. At the same time, the results of published research describing key early warning parameters will be pilot tested. A limited number of techniques that have been evaluated during the 1978-79 LACIE transition program will be available for large scale application testing.

5.1.10 Schedule of Tasks

The proposed schedule of tasks beginning in FY 80 is shown in Table 5.1-2. It indicates the initial scope of research, development, and testing for wheat, barley, corn, and soybeans during 1980. Much of this research activity will begin on rice and cotton. All techniques produced by the research and development effort will progress into the pilot test and, if approved by USDA's UE, into the Large Scale Application Test portion of the program. Since it is not possible to precisely schedule the results of research, the plan must necessarily be general in its description of tasks for each year.

5.1.11 Supporting Research Requirements

Areas of common interest with the Supporting Research Project include:

1. Crop calendars and planting models.

2. Normal crop spectra (by crop and crop stage).

3. Soil moisture models.

4. Evaluation of vegetative index numbers (VIN's) for identifying anomalous crop conditions.

5. Evaluation of the TM for crop condition monitoring.

6. Specific relationships between spectral data and agronomic factors, such as plant components, yield potential, growth stage, insect damage, and disease incidence.

7. The development and maintenance of cataloged data sets from controlled field observation programs.

8. Evaluation of techniques to determine the areal extent of production-determining factors measured from Landsat data.

Table 5.1-2 Early Warning/Crop Condition Assessment

Phenomena Title	Initiate and Conduct R&D	Pilot Test	LSAT	Available for Initial Operations
Crop water stress assessment	1980-81	1981-82	1982-83	1984
Relationship between spectral data, plant components, and agronomic variables	1979-80 1/ 1980-82 2/ 1981-83 3/	1981 1/ 1981-82 2/ 1982-83 3/	1981-82 1/ 1982-83 2/ 1983-84 3/	1982-83 1/ 1983-84 2/ 1984-85 3/
Small grains winter-kill alarm models and assessment techniques	1979-81	1980-82	1981-83	1982-84
Early season condition assessment utilizing soil moisture climate data	1980-81	1982	1982-83	1983-84
Methodology for sampling from Landsat data	1980-81	1981-82	1982-83	1983-84
Indications of significant change in crop yields from mean	1979-81 1/ 1980-82 2/ 1981-82 3/	1981 1/ 1982 2/ 1983-84 3/	1982 1/ 1983 2/ 1984 3/	1983 1/ 1984 2/ 1985 3/
Untimely freeze and adverse harvest condition alarms	1980 4/ 1980 3/	1981 4/ 1982 3/	1981-82 4/ 1982-83 3/	1983 4/ 1984 3/
Adverse temperature/wind alarms for small grains	1980	1981	1982	1982-83
Disease/insect alarms	1980-82	1982-83	1983-84	1984-85
Snow cover estimates	1979-80	1981	1982	1983
Assessment of sensor bands for crop condition information	1979-82	1983	1984	1985
Precipitation estimates from satellites	1979-82	1983	1984	1985

Notes:
1/ Schedule for wheat RD&T
2/ Schedule for barley, corn, soybeans RD&T
3/ Schedule for rice and cotton RD&T
4/ Schedule for wheat, barley, corn, and soybean RD&T

Section 5.2 Foreign Commodity Production Forecasting Project

Manager - J. Dragg, NASA/JSC

Table of Contents

5.2.1 Objectives

The overall objective of the Foreign Commodity Production Forecasting (FCPF) Project is to develop technology for making improved production forecasts in the foreign areas. Such technology will be evaluated by USDA for possible integration into its crop information systems.

The specific objective of the FCPF project is to develop and test procedures for using aerospace and related technology to provide: more objective and reliable crop production forecasts several times during the growing season; and, improved pre-harvest estimates for a range of countries and crops.

5.2.1.1 Crops/Regions

The specific crop/country combinations to be investigated are as shown in Figure 5.2-1.

5.2.1.2 Performance Goals

Forecast accuracy goals for the USDA official forecasts for 1985 are shown in Figures 5.2-2 and 5.2-3. These goals will be used as a guide for the design and evaluation efforts for exploratory and pilot experiments. Performance goals will be developed within the project for each crop/region consistent with technical feasibility and available resources. Specific evaluation criteria will be established prior to the conduct of the pilot experiments.

5.2.2 Technical Approach

The flow for a commodity production forecast technology development and implementation is shown in Figure 4-1.

The exploratory experiments in support of FCPF are primarily aimed at component technology capability, including such components as:

1. sampling and aggregation strategies;
2. classification procedures;
3. yield models; and,
4. crop development stage models.

The FCPF Project encompasses exploratory experiments, pilot experiments, and large scale applications tests with user evaluations. Exploratory experiments are generally oriented to developing and evaluating components of a production estimation technology. A pilot experiment may be performed on a major component but generally is a first integration and test of all components as a production forecast technology. The UE's and LSAT's are the responsibility of the USDA and will be performed in a USDA operational environment. If major deficiencies are identified, they will be returned to the R&D element for resolution.

FIGURE 5.2-1

FOREIGN COMMODITY PRODUCTION FORECASTING

(CROPS AND COUNTRIES)

COUNTRY	RATIONALE	COMMODITY
USSR	IMPORTER POOR DATA	BARLEY
INDIA	IMPORTER	RICE WHEAT
ARGENTINA	EXPORTER FAIR DATA	WHEAT CORN SOYBEANS
BRAZIL	EXPORTER VERY POOR DATA	CORN SOYBEANS
U.S.	BASIC R&D AREA	CORN SOYBEANS RICE SORGHUM* SUNFLOWERS* COTTON*
U.S./CANADA	BASIC R&D AREA USSR ANALOG	WHEAT BARLEY
AUSTRALIA		WHEAT
CROP/COUNTRY COMBINATIONS		12

*Exploratory Experiments only

FIGURE 5.2-2

FORECAST ACCURACIES FOR ALL WHEAT PRODUCTION ESTIMATES

COUNTRY	FORECAST			
	EARLY SEASON	MID-SEASON	PRE-HARVEST	AT-HARVEST
		ACTUAL NOW		
Argentina	42/90	-	34/90	50/90
Canada	29/90	-	39/90	86/90
India	58/90	37/90	-	75/90
USSR	23/90	31/90	32/90	43/90
		GOAL 1985		
Argentina	60/90	-	75/90	80/90
Canada	50/0-	-	60/90	95/90
India	70/90	75/90	90/90	90/90
USSR	50/90	60/90	65/90	85/90

Early Season: 90-120 days ahead of harvest
Mid-Season: 45-60 days ahead of harvest
Pre-Harvest: 15-30 days ahead of harvest

FIGURE 5.2-3

FORECAST ACCURACIES FOR COUNTRY/CROP PRODUCTION ESTIMATES

COUNTRY/CROP	FORECAST			
	EARLY SEASON	MID-SEASON	PRE-HARVEST	AT-HARVEST
			ACTUAL NOW	
ARGENTINA/CORN	17/90	-	18/90	22/90
BRAZIL/CORN	34/90	-	37/90	37/90
CANADA/BARLEY	50/90	-	52/90	86/90
USSR/BARLEY	21/90	27/90	30/90	39/90
INDIA/RICE	57/90	72/90	-	95/90
			GOAL 1985	
ARGENTINA/CORN	30/90	-	50/90	75/90
BRAZIL/CORN	50/90	-	60/90	80/90
CANADA/BARLEY	60/90	-	75/90	90/90
USSR/BARLEY	50/90	60/90	70/90	80/90
INDIA/RICE	70/90	80/90	85/90	95/90

5.2.2.1 Research, Development, and Test Flow

The major activities required to bring the technology from a stage of initial development through a large scale applications test have been broken into exploratory experiments, pilot experiments, user evaluations, and large scale application test. In this context, exploratory experiments are conducted in the U.S. and Canada where confirming ground truth is available, as well as in the foreign regions of interest to gain early exposure of the technology to the foreign situations. The exploratory experiments are followed by pilot tests in a U.S. region of foreign equivalence. A further pilot test in the foreign region of interest, may be conducted to further isolate and resolve technical issues prior to the USDA user evaluations and large scale applications test.

1. Exploratory Experiments

- These experiments are oriented to provide component techniques and procedures with test results sufficient to indicate support of FCPF pilot test performance goals and evaluation criteria.

2. Pilot Experiments

- Region-specific, integrated testing, evaluation, and further refinment of technology components which have emerged from exploratory experiments as strong candidates to satisfy the commodity production forecasting performance goals.

3. User Evaluations

- Evaluations by USDA of the utility, cost-effectiveness, and feasibility of adaptation to USDA systems.

- Recommendations on the technology's adoption/adaptation for LSAT, referred to Research.

4. Large Scale Application Test

- Integrated testing and evaluation of remote sensing technology components which have emerged from pilot experiments.

- Test and evaluation in an operational user environment to permit user decisions on whether to recommend operational application.

5.2.2.2 Experiment Design

The purpose of the Experiment Design effort is to identify the complete sequence of steps to be taken in the development and testing of each of the components of a production forecasting system (e.g., sampling scheme, area estimation procedure, and yield estimation procedure) to insure that the appropriate data will be obtained in a way which permits objective analyses leading to valid inferences about the accuracy and suitability of the various components for an operational system. The experiment design will evolve throughout the experiment as issues develop or are resolved. However, the overall program structure of the experiment design will remain the same, consisting of 2 major parts: exploratory experiments and pilot experiments. In exploratory experiments, approaches for the various components of a production forecasting system will be initially researched and developed in representative regions in the U.S. where accurate supporting agronomic and meteorological data are available. These approaches will then be extended to selected foreign areas for further research and evaluation. Techniques that are successfully developed in the exploratory experiments will then be applied to more extensive pilot experiments over representative U.S. regions and target areas of the foreign producing regions.

5.2.2.3 Sampling and Aggregation

The purpose of the Sampling and Aggregation effort is to support advancing the multicrop sampling and aggregation technology to a level ready for inclusion in a future operational commodity production forecasting system that supports the performance goals defined earlier.

Sampling frames will be developed in each experimental region to support research and development, test and evaluation, and large scale application testing. Sample design for the exploratory experimentation will be oriented more along the lines of defining an experimental data set to explore the problems in classification, develop improved classification, and evaluate these improvements.

Exploratory experimentation in Sampling and Aggregation will consist primarily of exploration of various approaches with initial testing carried out using primarily historical data. Following exploratory experimentation, country-specific pilot studies will be conducted using satellite and meteorological based data for final assessments and subsequent refinement/improvements of the sampling and aggregation strategy prior to going into UE and LSAT.

These efforts will result in:

1. Usable procedures for pilot and LSAT activities (this includes the refinement of old procedures or development of new procedures for sampling unit size determination, stratification, allocation of samples, large area production estimation, and variance estimation).

2. Actual stratifications, sample allocations, production, and variance estimation for each pilot test.

5.2.2.4 Classification

The purpose of the Classification effort is to define and evaluate a procedure for estimating crop area at a region or country level. This is to be accomplished through a series of exploratory studies and pilot tests. The main objective of the exploratory studies will be to define the classification crop-region specific procedure. The main objective of the pilot test is to evaluate a given procedure with respect to its ability to estimate acreage to within the accuracy and precision limits established for the pilot test. To support these studies, Landsat data collected at multiple times within the crop year and for randomly selected (in accordance with a statistical sampling strategy) sample segments are needed. In addition, region- and crop-specific ancillary supportive data (such as crop calendar information, detailed weather/crop assessments for U.S. and foreign regions, and ground observations defining crop type and stand quality) will be required. The data will be used to develop and evaluate the classification and inventory technology. The result will be a crop inventory approach and evaluation on selected crops (wheat, corn, soybeans, barley, and rice) and region (U.S., Canada, USSR, Australia, India, Brazil, Argentina) combinations.

5.2.2.5 Yield

The development and exploratory experiments for yield estimation models will be performed by the Yield Project. The yield estimation goals in the FCPF Project are to utilize the yield models provided by the Yield Project in the conduct of pilot tests, user evaluation, and large scale application tests. These tests will be conducted for each country/crop region to verify compatibility of yield and area estimation methodology in estimates of production estimation technology. Estimates of the accuracy and precision of the yield estimates will be derived from tests using data from years other than the years used in model development.

5.2.2.6 Crop Development Estimation

Crop development estimation refers to the process of estimating the phenological development stage (e.g., flowering) and/or the vegetative development and thereby the Landsat spectral appearance for a particular crop in a particular region or location, based on historical, meterorological, and/or Landsat data.

The purpose of this task is to utilize, for evaluation purposes, crop spectral appearance/phenology models developed in Supporting Research. The outputs of these models are used in other technical areas (e.g., classification), and the goal of the evaluations is to quantify both the errors in the crop development estimation models and the errors included in other component outputs (e.g., classification) due to crop development stage estimation.

Input data consists of meteorological and/or Landsat data, which is inserted into models developed in Supporting Research to develop predicted values of crop phenological development, vegetative development, and Landsat spectral appearance.

5.2.2.7 Accuracy Assessment

The Accuracy Assessment (AA) effort is designed to evaluate the accuracy of agriculture remote sensing research products (the sampling scheme, the classification procedure, the crop development stage model and the crop yield model) during the pilot testing of these products and to assist in the evaluation during the large scale application tests. Its purposes are to identify any problem areas during the pilot tests, to estimate the accuracy achieved during pilot testing, and to make inferences as to whether the technology, as applied and under similar conditions as in the pilot tests, is ready for user evaluation prior to an application test. Most of the AA investigations will be conducted in the U.S. and Canada where reliable ground observations can be obtained. In the U.S. representative areas, evaluation of pilot tests will be based on available detailed ground truth at the segment level, as well as on comparisons with regional-level area, yield, and production estimates from an independent data source, USDA/ESCS. In the foreign areas, evaluation of pilot tests will utlize available ground data and inferences made from performance in U.S. foreign equivalent regions, as well as comparisons with independent official government estimates.

5.2.2.8 Supporting Systems

The Supporting Systems include the maintenance and operation of data systems and facilities required by FCPF research activities. These systems consist of a supporting research and test-oriented computer center, a correlated imagery, agronomic, and meteorological R&D data base, and a set of image processing services and software that is applicable to ongoing FCPF project support.

This includes all facilities, software, and data base operations, as well as maintenance and incidental updates, necessary to support FCPF activities plus remote data base and procedures interfaces to selected government, university and industry FCPF program participants.

The capabilities of this system will include areal and production estimation software coupled with high-speed processing components, multi-user system access, a geographically coded data base, and a modular software architecture permissive of program development in a ready fashion. A preprocessing (image correction) capability will exist for Landsat and other relevant sensors, and appropriate interfaces with coarse data facilities will be established.

5.2.2.9 Supporting Data

The purpose of the Supporting Data activity is to provide requirements definition and acquisition, preprocessing (where needed), and dissemination of the various physical and electronic data types required to support the other FCPF efforts.

The data collected under this activity fall into the following discrete categories:

1. Landsat - Both electronic and photographic products from Landsat are required to support the classification and analysis activity (which is the area estimation component). While the primary data source for classification will be the electronic multispectral scanner (MSS),

tests evaluating the Return Beam Vidicon (RBV) and TM (Landsat D) data for use in the classification activity are also planned.

2. Ground Data - Key written and standardized (where possible) observations as to crops grown and location of each crop, ground cover, plant height, and crop growth stage provide the needed data inputs to support the independent performance assessment activity.

3. Historical Data - Historical agricultural and meteorological statistics for at least a 10-year period are required to support delineation of agricultural areas, development of sampling and aggregation strategies, and yield and crop growth stage estimation models.

4. Ancillary Data - Maps and charts of the study areas, plus general written summaries of the basic agricultural, geographical, and climatological characteristics of the study areas, are needed to provide background information and support the analyst in his classification decision-making process.

5. Current Meteorological Data - Standard meteorological data inputs such as temperature and precipitation are required in electronic form to support the utilization of the yield and crop growth stage estimation models, as well as detailed weather/crop assessments for U.S. and foreign study areas.

5.2.2.10 Large Scale Application Test (LSAT)

A large scale application test in the FCPF Project is defined as an integrated test and evaluation of components that have emerged from the pilot test phase. The LSAT is the responsibility of the USDA and will be performed under USDA operational conditions. Such a test is an adaptation of the methodology (and/or technology) in a quasi-operational evaluation. Major deficiencies are identified and are returned to the R&D element for resolution. The LSAT element addresses operational costs and cost-effectiveness. Although the USDA is responsible for the lead role in the LSAT, participation by personnel from the R&D element may be mutually beneficial.

The primary objective of a LSAT is to provide the USDA with sufficient information to support a decision regarding integration into USDA systems of the methodology/technology being tested.

1. Major Tasks

The major tasks associated with a given LSAT are:

- Design the large scale test and select test areas.
- Obtain supporting data (e.g., Landsat, ground truth, historical statistics).
- Produce area, yield, and production forecasts or estimates as appropriate.

• Evaluate timeliness, reliability, accuracy, and utility of information.

2. Data Requirements

Major data requirements/input elements to support a LSAT for a specific country/crop combination(s) are:

- Historical area, yield, and production statistics.
- Landsat data for selected geographic area.
- Ground "truth."
- Crop calendars.
- Yield models.
- Historical meteorological data.
- Periodic current meteorological summaries (precipitation, temperature, and other designated parameters).

Since it is a user responsibility to determine the geographical scope of the LSAT, absolute specification of data requirements and resources has not been accomplished. It is assumed that when major or representative production regions are used for the LSAT the sample size will be large enough to support simulation of country-level accuracies.

3. Agency Responsibilities

Preparation for conducting a LSAT must begin 6-8 months prior to the scheduled start date if major milestones are to be met. This planning is extremely critical in terms of identifying test regions, specification and collection of required data to support evaluations, and providing adequate lead time for implementation of candidate methodology/technology in the user facility. General task responsibilities for participating agencies are specified below.

- USDA
  - Design system.
  - Develop LSAT operational plan.
  - Select regional samples.
  - Collect ground data.
  - Integrate area and yield estimates into production forecasts or estimates.
  - Evaluate accuracy.
  - Evaluate utility.

o NASA

- Provide designated MSS data.

- Support LSAT design.

- Support technology modification and transfer.

- Support accuracy assessment.

o NOAA

- Provide designated historical and current meteorological data and provide weather assessments.

Support from the RD&T element, especially in the planning, implementation, and user training phases of the LSAT, may be mutually beneficial.

o USDI

- Provide Landsat data storage, retrieval, and dissemination.

5.2.2.11 USDA User Evaluation

The UE is a detailed evaluation of technology, developed through the research, development, and test for its utility and potential application in USDA's information systems. The UE is the responsibility of USDA, and the technology will be evaluated by USDA end-user agencies. The USDA will, in advance of such evaluations, develop performance criteria based on end-user agency requirements. The evaluation will address the utility of information produced by applying the technology, the compatibility of the technology with USDA;s current systems, and the cost-effectiveness of the proposed technology. Based upon agreed to performance criteria, the USDA user will evaluate the:

1. Extent to which the technology will provide new, improved, or more timely information as compared to current USDA information systems.

2. Usefulness and value of such information to USDA analysts and decision makers.

3. Ease of adaptation and integration of the technology into existing information systems.

4. The costs to USDA of converting the technology to USDA data processing equipment in terms of equipment, software, maintenance, training, and other similar factors.

5. Annual operating costs.

Upon completion of the evaluation, the user will recommend adaption, referral to research, or non-acceptance by USDA of candidate technology.

5.2.3 Output Results

The principal output results of the FCPF Project build upon the results of the technology research conducted by the Supporting Research and Yield

Projects. These results include research and technology development in the following areas:

- o Data processing techniques
- o Crop identification, classification and mensuration procedures
- o Crop development stage estimation models and procedures
- o Sampling and aggregation procedures
- o Yield estimation models
- o Integrated area, yield and production estimation procedures.

The output products are:

1. Exploratory Experiments Results

o Candidate techniques and/or approaches for foreign commodity production information using remote sensing and ancillary data.

o Comparative evaluation of alternate approaches.

o Test and evaluations of production estimation methodologies at the component level for the region crop/regions of interest and similar U.S./Canada crop regions.

o Estimates of performance to be expected from an integration of the technology components to production, area, and yield for the crop/region/crop stage of interest.

o Identification of areas needing additional research.

2. Pilot Experiment Results

o Documented FCPF technology and procedures for transfer to the USDA for large scale application tests.

o A cadre of experienced personnel to define and implement the technology.

o Documented evaluation of the pilot tests and expected performance of the production estimation technology in the context of USDA goals (crop, region, time during the growing season).

o Isolation and identification of needed technology improvements.

3. Large scale application tests

   - Area, yield, and production estimates with estimates of precision for the specified geographic areas within the foreign crop/regions of interest.

   - Preliminary operational guidelines and definition of elements of an operational system.

   - Identification of needed technology improvements.

4. User Evaluation

   - Evaluation of results against evaluation standards.

   - Cost analysis.

   - Recommendations to USDA managers regarding future investments.

   - Identification of needed technology improvements.

5.2.4 Agency Responsibilities for FCPF

1. Task Areas

Task Areas	Responsiblilty
● Experiment design	NASA
● Sampling and aggregation	
- Exploratory studies	NASA
- Sample frame development	USDA
- Sampling and aggregation strategy	NASA
- Pilot test and evaluation of production estimation	NASA
● Classification	
- Procedures development and exploratory test	NASA
- Pilot test and evaluation	NASA
● Crop development stage estimation	
- Model development and exploratory test	NASA (SR)
- Pilot test and evaluation	NASA
● Yield	
-Model development and test	NOAA (Y)

• Accuracy assessment	NASA
• Supporting systems for exploratory and pilot tests	NASA
• User evaluation	USDA
• Large scale application tests	USDA
• Supporting data	
- Landsat data	USDI
- Domestic aircraft data	NASA
- U.S. and foreign ground observed agronomic data	USDA
- U.S. and foreign historical and current agricultural statistics	USDA
- U.S. and foreign historical and current meteorological data and weather assessments	NOAA

5.2.5 Schedule

The schedule of FCPF activities by fiscal year is shown in Figure 5.2-4 for the crop/regions of interest. The crop/region is shown in the fiscal year within which the experimental phase (excepting final evaluation and documentation) is completed. These schedules and resources are predicated on the state-of-the-art of crop forecast technology as of June 1979. In summary, this consisted of a USSR wheat forecast technology and a definition of a number of needed technology improvements such as improved sensor resolution for small fields and methods for direct separation of spring wheat and spring barley. In addition, modifications of that technology for U.S. corn and soybeans are anticipated to have advanced the technology to the point of pilot experiment commencing in FY 80 with completion in FY 81.

For purposes of a unified treatment, this schedule defines exploratory experiments (with relevant technology research performed by the Supporting Research Project) to develop and evolve both an initial capability and an improved capability, improved from the standpoint of either significantly increased accuracy or significantly reduced cost. The improvements noted in the schedule will focus on the development of an improved technology resulting from the increased spatial and spectral resolution of the TM after Landsat D launch in 1982 and accuracy and efficiency resulting from increased automation in the machine processing technology. Exploratory and pilot experiments for India, with its accompanying small fields problems, have been scheduled after 1982 to utilize the increased spatial resolution available from the TM aboard Landsat D. A pilot experiment evaluating the improvements realized from Landsat D. is scheduled for FY 85. A pilot experiment evaluation of a major improvement to machine processing technology is scheduled for FY 84.

FIGURE 5.2-4

FCPF SCHEDULE

80	81	82	83	84	85
EXPLORATORY U.S./Canada (3) Wheat/Barley U.S. (3) Corn/Soybeans USSR (1) Barley Australia (1)	USSR (2,3) Barley Brazil (1,2) Corn/Soybeans Argentina (1) Wheat/Corn/Soybeans U.S. (1)* Rice Australia (2) Wheat	Argentina (2,3) Wheat/Corn/Soybeans Brazil (3) Corn/Soybeans U.S./Canada (1) Wheat/Barley Procedure 2 Australia (3) Wheat U.S. (2)* Rice U.S. (1,2) Corn/Soybeans Procedure 2	India - TM (1,2) Wheat U.S. (3)* Rice U.S.- TM (1,2) Rice/Wheat/Barley Corn/Soybeans India - TM (1) Rice Argentina (3) Wheat/Corn/Soybeans U.S./Canada (2) Wheat/Barley Procedure 2 U.S. (3) Corn/Soybeans Procedure 2	U.S. - TM (2,3) Rice/Wheat/Barley Corn/Soybeans India - TM (3) Wheat India - TM (2) Rice U.S. (1,2)* Cotton/Sorghum/ Sunflowers Brazil/Argentina (1,2) Corn/Soybeans Procedure 2 U.S./Canada (3) Wheat/Barley Procedure 2	India - TM (3) Rice U.S. (2,3)* Cotton/Sorghum/ Sunflowers Brazil/Argentina (3) Corn/Soybeans Procedure 2
PILOT	U.S./Canada Wheat/Barley U.S. Corn/Soybeans	USSR Barley	Brazil Corn/Soybeans Australia Wheat	Argentina Wheat/Corn/ Soybeans U.S. Corn/Soybeans Procedure 2	U.S. - TM Rice/Wheat/Barley Corn/Soybeans India - TM Wheat U.S./Canada Wheat/Barley Procedure 2
LSAT			USSR Barley/Wheat	Brazil Corn/Soybeans Australia Wheat	Argentina Corn/Soybeans/ Wheat

1 = Data Collection and Research 2 = Techniques Development 3 = Test and Evaluation TM = Thematic Mapper

Procedure 2 is an advanced machine processing technology described in the Supporting Research Section.

*Exploratory experiments to be conducted as part of supporting field research using ground-based, airborne and satellite sensors including TM.

Section 5.3 Yield Model Development Project

Manager: N. Strommen, USDC/EDIC

Table of Contents

5.3.1 Objectives

Develop mathematical models using environmental and plant measurement characteristics that represent the yield potential of a crop at an aggregate unit level (stage, region, national). Models that have utility for both forecasting and estimation will be developed for the crop/country combinations shown in Figure 5.3.1.

Crop yield modeling processes are as follows:

1. Identify the basic relationships of how plans respond to their environment and measure variables that relate plant processes to the environment.

2. Integrate these relationships with economic and technological factors which influence yield (basic research).

3. Structure relationships between measured variables and grain yield (modeling).

4. Iterate and refine variables and relationships (testing).

5.3.2 Organization for Yield Modeling

Agency responsibilities are as follow:

1. USDA
   - Lead responsibility for plant process oriented yield model development
   - Acquire, test, evaluate and select yield models for application tests
   - Develop and verify agronomic/ancillary data bases
   - Coordinate needed ground data collection
   - Provide user evaluation input

2. NOAA
   - Lead responsibility for empirically oriented yield model development
   - Yield model acquisition, development, testing and evaluation
   - Develop and verify meteorological data bases
   - Conduct weather impact assessments
   - Participates in adapting spectral data for model input

3. NASA
   - Assist in yield model development and evaluation
   - Provide Landsat data acquisition and RD&T data base development
   - Provide RD&T spectral inputs to yield models

4. USDI
   - Provide Landsat data storage, retrieval and dissemination

5.3.3 Model Development Process

Yield model development is to be viewed as a continuum from the development of regression models to the complex causal or physiological models; however, for the purpose of implementation, the continuum must be divided into stages.

There are needs and uses for regression models, and these models will be developed (or selected from existing candidate models) tested, and implemented.

The next stage of model implementation is the phenological-correlative models that utilize known plant processes in the model structure and correlate yield with these processes. These models will be developed (or selected from existing candidate models), tested, and implemented.

The third stage of model implementation is the causal or physiological-type model. This model is an extension of phenological-correlative models, the primary difference being that measured variables drive processes which in turn are modeled to simulate plant growth, development, and maturity. Many of the variables are obtained from probability point measurements rather than from "area" average or "grid interpolated" values. This type of modeling has application for uses other than yield forecasting, such as guiding varietal improvement and determining sensitivity to input variables (fertilizer, moisture, etc.).

Model development will progress from less complex forms which can be readily assembled from available data to the more complex forms which will require extensive research and the collection of detailed plant observations over a wide range of growing conditions. Refinement of each model form will continue as new variables, improved measurement procedures, and additional processes are developed and understood. As basic research produces models which demonstrate a specified level of performance,these will bepilot tested over selected regions. Successful performance in such tests will lead to user evaluation and potentially to a large scale application test as the final step prior to implementation. While testing of basic models progresses, research on advanced and refined models will continue.

5.3.4 Model Input Requirements

Modeling skill, plant growth process understanding, and measurement variables are the raw materials for yield model research and development. Input variables, which can be cost-effectively measured or developed from basic data, are of major concern in implementation. This consideration for successful implementation must be addressed as models are prepared for testing, but need not be a concern in advanced model research. Substantial resources will be committed to the measurement of variables as possible inputs for model development, including new methods for measuring traditional variables (soil or plant available moisture, vegetative or fruiting characteristics, etc.), and relating new data source values (environmental and Earth observations satellite data) to plant processes or measurable variables that drive plant processes. Data bases containing crop yield, climatic variables, and crop development stages will be acquired and/or developed to support model development and testing.

5.3.5 Agency Plans

5.3.5.1 NOAA

5.3.5.1.1 Objectives

There are 3 basic objectives.

1. Utilize quantitative weather data from crop-growing regions to infer likely crop growth conditions and estimate yield potential for harvested acres.

2. Provide, over the crop-growing areas of the Western Hemisphere, daily measurements of solar insolation at approximately 1/2° latitude-longitude intervals with ±10 percent accuracy and test methods to extend this information to other global crop regions using either the U.S. operational polar-orbiting spacecraft or geosynchronous spacecraft operated by other countries.

3. Produce global max/min temperatures fro crop-growing regions on a scale commensurate with crop-reporting districts and with an absolute accuracy of ±2°C with a relative accuracy of ±1°C.

5.3.5.1.2 Technical Approach

1. Assessment - Ground-based meteorological observation will be integrated with satellite imagery and supporting upper air analysis to describe the current weather events that are favorable or unfavorable to crop growth from pre-planting through harvest. This qualitative assessment will be supportive of all RD&T efforts. This will be based on quantitative meteorological data, temperature, and precipitation estimates, required to support the yield model program.

2. Yield Forecasts - Will be derived from area-specific statistical regression-type models. These models will be under continual improvement as new variables are defined, improved measurement procedures developed, and additional climate-plant response processes are understood.

3. Solar Insolation - Using hourly measurements of reflected solar radiation, as detected by the U.S. operational geosynchronous satellites, and a small network of ground-based calibrated pyronometers to update regression coefficients, daily measurements of available solar energy will be made at a resolution of approximately 60 KM over Western Hemisphere areas of interest.

4. Canopy Temperature (Max/Min)- Automatic retrieval of surface brightness temperature over land from the infrared scanning instruments

on NOAA's polar-orbiting spacecraft and/or radiance measurements from the sounding instruments onboard the same spacecraft will be used in regression equations to determine maximum and minimum canopy temperatures. Interactive processing and display will be used to quality control the data. Use of infrared data from geosynchronous operational satellites will be used to refine this product.

5.3.5.1.3 Supporting Elements

Reports providing temperature and precipitation data on a global basis from approximately 8,000 meteorological reporting stations are received at NMC daily. Edit and summarization programs will be developed to improve consistency of these data. These data will then be associated with satellite data to prepare assessments of crop-growing conditions and for input to yield models.

1. Yield-Assessment Tasks

- Acquisition and summary of current global meteorological data will be accomplished by NOAA.

- Acquisition and quality control of historic meteorological data bases needed to support yield model RD&T will be accomplished by NOAA.

- Acquisition and quality control of historic agronomic data bases for yield modeling will be a joint USDA/NOAA effort.

- Statistical regression yield model development, testing, and estimates for input to FCPF will be a joint NOAA/USDA effort.

- Physiological yield model RD&T will be conducted by USDA.

2. Solar Insolation

- Approximately 6 fully-calibrated recording pyronometers placed at USDA cooperative agriculture test stations will be needed to periodically update the spacecraft regression coefficients to account for spacecraft instrument changes. Daily values over selected periods of time (to be determined) will be required. Measurements of this kind are normally available in the USDA program, and additional funds should not be required.

5.3.5.2 USDA

5.3.5.2.1 Objectives

1. Develop causal or physiological models that utilize variables which drive plant processes. Plant processes are joined to simulate attributes of interest, such as weight of grain or total above-ground vegetative production. Also, knowledge of plant processes allows scientists to develop optimum inputs or combinations of inputs to maximize production

and provides information to plant breeders for varietal improvements, and to improve early warning and crop condition assessments.

2. Provide basic input data, statistical support, modeling capability, and data processing to develop models at all levels of sophistication.

3. Develop appropriate survey design, including data collection methods, for extending basic modeling capability to implementation, both for yield forecasting and early warning/crop condition assessment.

5.3.5.2.2 Technical Approach

1. A multi-discipline approach will be used to conduct detailed experiments for determining input variables affecting plant processes. Variables will be related to plant processes by mathematical models. These models, in turn, will be associated by an overall mathematical modeling structure that defines the plant growth and maturing process. Simultaneously, forecasting and estimation methods will be developed to project variables to the time of harvest.

2. Basic relationships will be studied using a full range of test facilities, including greenhouse, growth chambers, and controlled field experiments. Extensive instrumentation and observation will be required utilizing statistical experimental design procedures with rigid quality control. Research locations will include agricultural research centers, land grant universities and experiment stations, and other sites where designated scientists may be located. Frequent communication between scientists at different locations will be required to coordinateand ensure control of research activities. As major components of plant processes are modeled and tested, they will be made available for pilot testing in models of less sophistication (such as the phenological correlative type). Also, as components are developed and tested, least cost methods for obtaining the required input variables will be investigated.

3. Through a joint team or group approach provide experimental basic field data collection support and general modeling expertise for yield model development.

4. Where required, establish cooperative and contractual agreements to assure the necessary expertise in areas not covered within the framework of the combined yield modeling effort.

5. Work with other teams and groups to integrate yield forecasting and estimating methodology with area estimation to provide production forecasts and estimates.

6. Conduct tests to determine the feasibility of operationally implementing components and models through all phases of the yield modeling activity.

7. Construct and archive data sets necessary for model development and testing.

5.3.5.2.3 Supporting Elements

1. Basic understandings are required for potential model input in the areas of spectral data. These responsibilities are addressed in the agency programs of NASA and NOAA. Also, support is needed in determining accurate dates for the critical maturity stages of growing crops and basic understandings for plant available moisture determination. Specialized equipment may be required for research observation, and these requirements will be met through contracts, cooperative agreements, and/or mutual development between organizational units of this research activity.

2. Through cooperation with units responsible for area estimation, develop procedures and models to generate meaningful production forecasts and estimates.

5.3.5.3 NASA

Appropriate sections in the "Supporting Research Project Plan" deal with research to provide spectral input for yield modeling and basic research concerning soil moisture estimation via spectral and related technology. As relationships between spectral data and soil moisture measurements are related to conventional measurements or plant processes, these will be passed to the Yield Modeling Team for testing in yield modeling.

5.3.6 Schedule of Forecast Model Development

Regression models utilizing available meteorological data and historic yields will be available as outlined in Figure 5.3-1. These models will be developed to align with strata used for production estimation. Models will be tested and requirements established for input data with a sufficient margin of lead time for the development of appropriate data bases and adapting algorithms for pilot testing as established by the schedule.

Simultaneous research will be conducted in both the development and testing of components for phenological correlative and causal or physiological models. These latter 2 stages of model development will be implemented at later points in the time-phased program. In general, it is anticipated that phenological-correlative models will be available for U.S., USSR, and Australia wheat in the 1981-82 time frame and for most of the other major crop/country combinations by 1985. For the more complex causal or phenological models, pilot testing would be late in or beyond the time-phased program.

FIGURE 5.3-1

YIELD MODEL DEVELOPMENT SCHEDULE

COUNTRY/MODEL	80	81	82	83	84	85
ARGENTINA				CORN/ SOYBEANS		
AUSTRALIA	WHEAT					
BRAZIL			CORN/ SOYBEANS			
CANADA	WHEAT/ BARLEY					
INDIA			WHEAT		RICE	
U.S.	WHEAT/ BARLEY CORN/ SOYBEANS			RICE		COTTON/ SORGHUM/ SUNFLOWER
USSR		BARLEY				

Section 5.4 Supporting Research

Manager - J. Erickson, NASA/JSC

Table of Contents

5.4.1 Introduction and Objectives

The LACIE experience demonstrated the need for Supporting Research that addresses both near-term and long-range objectives in technology improvement. Supporting Research provides that "cutting edge" for new technology development which addresses advancing the technology in accuracy, efficiency, and applicability. The Supporting Research addressed in this plan will augment existing technology (e.g., upgrade Landsat analysis Procedure 1), and/or develop new approaches (e.g., Procedure 2), to improve the technology for projects in the joint program. It will address seven major information categories, but primarily FCPF. Some tasks are critical to first-year activities; others address problems that will be critical in later years.

Participation by the scientific community external to the participating agencies is greater in the Supporting Research Project than in any other NASA-funded portion of AgRISTARS. Directed research is carried out primarily by university, industrial, and non-profit research organizations.

5.4.1.1 Relationship to Other Projects

The Supporting Research Project develops technology which most directly supports the FCPF Project with support to the Early Warning/Crop Condition Assessment and Yield Model Development Projects. FCPF is dependent upon Supporting Research for research and development of new technology. Supporting Research also indirectly benefits each of the other projects through techniques developed in FCPF-driven tasks and the acquisition of research data. Ground data collection from FCPF is essential for technique development in SR.

5.4.1.2 Objectives

The overall objective of the SR Project is to develop improved remote sensing technology through research to assess crop condition and area. This includes the development of improved production forecasts in foreign areas, including early warning of changes and improved yield estimation. Such technology will be evaluated in other AgRISTARS Projects by the USDA for possible incorporation into its crop information systems.

The specific objectives of the SR Project are: (1) to understand the relationships between remotely sensed data and the crops, crop conditions, and growing conditions that the data signify thru field research and other means; (2) to develop, evaluate, and select (for exploratory and pilot experiments) systems and procedures to acquire and use satellite remote sensing data. These systems and procedures will aid in making more objective and reliable crop production forecasts several times during the growing season and improved pre-harvest estimates for a range of foreign regions and crops; (3) to develop procedures to aid in accomplishing early warning of changes significantly affecting production and quality of commodities; and (4) to develop procedures to aid in yield estimation including spectral crop canopy appearance as it conveys agronomic and environmental influences on yield.

5.4.2 Technical Approach

The seven project elements recognized within Supporting Research are as follows:

1. Area estimation research and procedures development.

2. Crop development stage estimation research and procedures development.

3. Research on spectral indications of agronomic variances related to yield estimation.

4. Crop stress research.

5. Soils research.

6. Supporting field research.

7. Supporting systems.

These project elements are similar to those in FCPF but are non-duplicative development activities preceding FCPF.

5.4.2.1 Research, Development, and Test Flow

The major activities required to bring technology from a stage of initial research through large scale tests have been structured into exploratory experiments, pilot experiments, and large scale application tests. In this context, Supporting Research conducts small-scale exploratory experiments in the U.S. These are followed by exploratory experiments and pilot experiments conducted by FCPF or EW Projects. Evaluation criteria for exploratory experiments will be developed by user evaluation and elements of the benefiting projects prior to design of tests.

5.4.2.2 Exploratory Experiments

Activities included in exploratory experiments may be grouped in three major categories:

1. Data Collection and Research

The fundamental analytical relationships between variables subject to observation with available technology and factors identified as critical to agricultural information are determined by means of theoretical and empirical investigations using data sets collected to adequately represent the natural variability of both the observations and the critical factors as much as possible.

2. Technical Development

Data analysis techniques which are based on the fundamental analytical relationships and which permit quantitative estimates and forecasts of events of interest to users of agricultural information must be developed.

3. Test and Evaluation

Test and evaluation of alternate remote sensing technology components under known conditions at a lesser scale than pilot test are required to design accurate and (cost-effective) technology options which will satisfy specified agricultural information needs.

5.4.2.3 Output Results

The Supporting Research Project develops technology which primarily supports the FCPF Project with subsidiary support to the Early Warning and Yield Model Development Projects. No planned activities provide products specifically for any other project; but, benefits will accrue to the Renewable Resources Inventory, Soil Moisture, Domestic Crop and Land Cover, and Pollution/Conservation Projects because of common needs. The principal Supporting Research output results desired for other projects are listed below:

1. Results for Foreign Commodity Production Forecasting Project

o SR provides a data acquisition capability and new generation methodologies for components of production estimation technology. For example:

- Landsat radiometric preprocessing techniques.

- Crop identification, classification, and mensuration techniques for MSS and TM.

- Spectral information on yield-related agronomic variables.

- Crop growth stage estimation techniques which incorporate Landsat spectral appearance information.

o Comparative evaluation of alternative approaches.

o Basic research on advanced methodologies

- Requirements for new sensors

--Multispectral

--Microwave

--Return beam vidicon

- Radiometric preprocessing.

- Crop identification, classification, and mensuration.

- Relations between crop vigor or stress, stage-of-growth, and spectral appearance.

- Effect of soil type on crop spectral response.

- Estimation strategies using spatial and temporal correlations.

2. Results for Early Warning Project

o New generation methodologies developed for FCPF, but are either directly transferrable to the Early Warning Project or contain usable subcomponents.

- Definition of dynamic ranges in input variables for spectral yield algorithms.

- Crop growth stage estimation techniques which incorporate Landsat spectral appearance information.

- Landsat radiometric preprocessing systems.

o Basic research developed for FCPF on advanced generation methodologies.

- Relations between crop vigor or stress, stage-of-growth, and spectral appearance.

3. Results for Yield Model Development Project

o New generation methodologies developed for FCPF, but are either directly transferrable to the Yield Project or contain usable subcomponents.

- Spectral information on yield-related agronomic variables.

- Landsat MSS and Landsat D TM.

- Crop growth stage estimation techniques which incorporate Landsat spectral appearance information.

- Landsat radiometric preprocessing systems.

o Basic research developed for FCPF on advanced methodologies.

- Requirements for new sensors.

- Radiometric preprocessing.

4. The expected benefits which will accrue to the Renewable Resources Inventory, Soil Moisture, Domestic Crop and Land Cover, and Pollution/Conservation Projects are:

o New generation methodologies developed for FCPF but which are either directly transferrable to the Renewable Resources Project or contain usable subcomponents.

- Landsat radiometric preprocessing.

o New generation technologies containing developments probably applicable with some further development to each project.

- Identification, classification, and mensuration systems.

- Spectral information on yield related agronomic variables.

- Crop growth stage estimation techniques which incorporate Landsat spectral appearance information.

o Basic research developed for FCPF on advanced generation methodologies likely to benefit each project.

- New sensor definition.

- Radiometric preprocessing.

- Identification and classification.

- Relations between crop vigor or stress, stage-of-growth, and spectral appearance.

5.4.3 Project Elements

The types of activities in the seven project elements are briefly described below.

5.4.3.1 Area Estimation Research and Procedures Development

Area estimation activities in Supporting Research are directed toward developing and evaluating more accurate and efficient procedures for estimating crop area to support production estimates at a region level. The approach will be to build on the classification technology developed in the LACIE for wheat and to improve it as required to handle problems related to barley, corn, soybeans, and rice. Within these specific problem areas, tasks are defined to improve analyst labeling procedures, machine classification methods, and early season estimation, to increase training efficiency through the use of "signature extension" methods (e.g., Procedure 2), and to develop techniques for use of TM. Major increases in efficiency of man-machine interaction and machine analysis to reduce the cost of both RD&T and operation are sought in addition to improvements in accuracy. An upgrade of current Landsat analysis procedures (LACIE Procedure 1) and a new approach using fewer labeled samples (Procedure 2) are planned. Development and testing will be done over "yard-stick" areas in the U.S. where detailed ground observations can be collected for comparison with satellite-derived results. A limited number of foreign data sets including ground "truth" will be studied to qualitatively validate that a design under consideration will not result in gross errors. This research is expected to define methods for estimation of area and assessment of crop condition that will be viable in subsequent pilot and large scale evaluation studies.

5.4.3.2 Crop Development Stage Estimation Research and Procedures Development

Crop development stage estimation refers here to the process of estimating (for a particular crop in a particular region or field) either the phenological development stage (e.g., flowering) or the vegetative development, and thereby, the Landsat signal to be associated with that crop. Such estimates will be based upon historical agricultural data alone and upon meteorologically-driven models incorporating meteorological and Landsat inputs.

The output of this technical area will consist of:

1. Techniques for estimating stage of development, which can be used by other elements of Supporting Research and by other projects.

2. Estimates of stages of development associated with particular experimental data sets for use in tests by other project elements (e.g., stress research).

3. A data base of historical stage-of-development data.

4. Statistical and other analyses of that stage-of-development to support other projects (e.g., FCPF or EW).

5.4.3.3 Research on Spectral Indications of Agronomic Variables Related to Yield

Supporting Research goals related to yield are to develop and test yield estimation techniques which involve Landsat spectral inputs in combination with conventional agromet data and to verify the validity of such techniques with a limited amount of testing in the U.S. Input data will include Landsat spectral data reduced to field means and standard deviations for fields which have been selected on the basis of an established sampling procedure. Input data will also include daily meteorological data from first-order met stations interpolated to the coordinates of the sample fields. Supporting Research will also pursue development of techniques for incorporating thermal infrared information into the yield estimation procedures.

5.4.3.4 Crop Stress Research

The crop stress element consists of tasks aimed at developing techniques for utilizing satellite data to aid in the discrimination and verification of major crop stress factors and, ultimately, to quantify the impact of stress or exceptional condition on crop production.

Supporting Research tasks will utilize satellite, agricultural, meteorological, and other information. At least three categories of tasks are planned:

1. Establish research priorities for study of various crop/stress/region combinations.

2. Develop spectral-stress relationships for identification of stress or exceptional condition utilizing satellite data.

3. Determine the influence of identified stress factors on the rate of crop development.

Products from this program that will improve the accuracy of crop production estimation in situations when stress is an important factor include:

1. Analyst aids to permit more accurate identification of crops.

2. Adjustments to crop development models.

3. Procedures for determining areal extent of stress.

4. Alarm/warning procedures for flagging potential stress problems.

5.4.3.5 Soil Research

The Soils element promotes technology development through efforts in the following major areas:

1. Identification of critical soil physical/chemical properties which will provide the soils information required by the technology development components.

2. Assessment of the utility of existing conventional soils information.

3. Establishment of fundamental relationships between soil properties and basic radiation patterns.

4. Application of fundamental relationships using Landsat-type data.

5. Establishment of techniques to utilize remote sensing to group soil features into products (e.g., maps) useful to the technology development components.

The product/accomplishments of the Soils Research tasks will be:

1. Identified principles that relate soil physical/chemical properties to remote sensing data with and without vegetative cover.

2. Methods for applying established principles to the extraction of required soils information from Landsat-type data.

3. An evaluation of existing conventional soils data in remote sensing applications.

4. A methodology for grouping key soil features using Landsat-type data.

5.4.3.6 Supporting Field Research

Supporting Field Research designs and executes experiments that collect data from plots and intensively-monitored commercial fields at sample segment sites. These detailed data, augmented by satellite data and sample field inventories with supporting measurements, are analyzed to determine the causes of observed differences in spectral response. The approach of Supporting Field Research uses a truck-mounted spectrometer to collect high resolution spectra of the controlled test plots and a helicopter-borne spectrometer to measure spectra of crops in commercial fields.

Supporting Field Research will provide a basic understanding of the relationships among spectral, agronomic, and meteorological variables. This will lead to development of models and new procedures for interpreting satellite data for:

1. Yield estimation.
2. Stress assessment for Early Warning.
3. Growth stage evaluation.
4. Soil background assessment.
5. Per field acreage and yield estimation.
6. Crop discrimination.
7. Crop condition modeling.

5.4.3.7 Supporting Systems

The Supporting Systems element of the Supporting Research Project addresses the definition, development, and operation of data systems and facilities required by Supporting Research. Requirements for many of these systems and facilities are shared by Supporting Research and other projects of AgRISTARS.

Supporting Research requirements include a computer facility with multi-user access and modular software architecture to facilitate program development and modification, an adequate means to transfer procedures developed by off-site contractors into the system, a correlated image/agronomic/meteorological data base that accepts data from multiple imaging sensors, and a set of standard and special processing services to be specified by the Supporting Research Project elements. Such a facility provides multi-user access to the data base and a common set of software, as well as specialized software.

5.4.4 Data Requirements

Data requirements for Supporting Research fall into the following discrete categories:

1. Landsat Data - The Landsat MSS is the principal source of satellite data used to date in the application of aerospace technology in agriculture. Continued development of techniques and procedures for agricultural applications using MSS data is planned as a transition to Thematic Mapper techniques using Landsat D TM data. Both electronic and photographic products prepared from the visible and reflective IR channels are required. Other Landsat data (RBV, thermal IR, and Landsat D TM) will be used for specific research tasks of limited scope.

2. Sensor Data from other Satellites - Exploratory development of technology to be used in the post-Landsat D time frame required the study of data from outside the visible and reflective IR regions of the electromagnetic spectrum. Sensors on satellites other than Landsat provide samples that can be used for preliminary research into the usefulness of data from other parts of the spectrum. Limited sets of data from Seasat and follow-on satellites, HCMM, and SIR are required for specific Supporting Research tasks that will be defined.

3. Aircraft Data - Field boundaries commonly shift between crop years in many of the major agricultural areas of the U.S. The collection of accurate ground observations requires the acquisition of current-year aircraft photographic coverage of the segment. TM research prior to the launch of Landsat D will require multi-date sets of TM simulator (NS-001) Aircraft Scanner data from a limited number of geographically distributed sites that include several crops of major interest. Imaging radar data will also be required.

4. Ground Observation Data - Development and testing of techniques and procedures by several elements of the Supporting Research Project requires ground observation data that are accurately related to the times of remotely-sensed data acquisition. Key agricultural factors such as crop identification, ground cover, plant height, and crop growth stage are observed at several segments that are distributed across the crop region of interest. The fields selected for observation within each segment sample the crops of interest at several locations to provide an indication of within-segment variability.

5. Historical Data - Detailed agricultural and meteorological data for each region of interest are required by multiple elements of Supporting Research. These data include special data on crop development stage (by variety) in foreign areas.

6. Ancillary Data - Maps and charts of the study areas, plus general written summaries of the basic agricultural, geographical, and climatological characteristics of the study areas are needed to provide background information that supports the researcher developing and testing new techniques.

7. Current Meteorological Data - Standard meteorological data are required in digital form and as written weekly summaries for specified regions.

5.4.5 Agency Responsibilities Summary

The agency responsible for specific activities/functions that combine to make up Supporting Research are indicated below.

1. USDA
   - Agronomic/ancillary data base.
   - Ground data collection.
   - User evaluation.
2. NASA
   - Exploratory experiments.
   - Supporting field research.
   - Landsat data acquisition and RD&T data base.
   - RD&T spectral inputs to yield models.
   - Supporting aircraft data acquisition.
3. NOAA
   - Meteorological data base.
   - Weather/crop assessments.
4. USDI
   - Landsat data storage, retrieval, and dissemination.

5.4.6 Schedule Summary

The schedule for Supporting Research is driven by 2 factors:

1. The schedules of the projects which have requirements for output from the individual research tasks.

2. The time and resources required to accomplish the Supporting Research tasks.

The attached schedules show the exploratory research required to support the pilot experiments scheduled for FCPF (Figure 5.4-1).

Figure 5.4-1 shows the fiscal year in which the exploratory research is completed.

The superscript numbers indicate type of exploratory activity scheduled.

1. Data collection and research.
2. Techniques development.
3. Test and evaluation.

"TM" following the region name indicates TM data is to be used in the experiment. MSS data will be used for all others.

AN OVERVIEW SUPPORTING RESEARCH SCHEDULE FOR AREA ESTIMATION EXPLORATORY EXPERIMENTS
(EXPERIMENTS ARE LISTED IN THE YEAR WHEN THEY ARE EXPECTED TO BE COMPLETED)

80	81	82	83	84	85
EXPLORATORY					
USSR (2) Barley Labeling	USSR (2) Barley	Argentina (2) Wheat/Corn/Soybeans	India-TM (1,2) Wheat	U.S.-TM (2) Rice/Wheat/Barley	U.S.(2)* Cotton/ Sorghum/ Sunflowers
	U.S. Wheat/Barley Machine Process (3)	U.S./Canada (1) Wheat/Barley Procedure 2	U.S. (3)* Rice	India-TM (2) Rice	
	Brazil (1,2) Corn/Soybeans	U.S. (2)* Rice	U.S.-TM (1,2) Rice/Wheat/Barley Corn/Soybeans	U.S.(1)* Cotton/Sorghum/ Sunflowers	
	Argentina (1) Wheat/Corn/Soybeans	U.S. (1,2) Corn/Soybeans Procedure 2	India-TM (1) Rice	Brazil/Argentina(1,2) Corn/Soybeans Procedure 2	
	U.S. Corn/Soybeans Machine Process (2)		U.S./Canada (2) Wheat/Barley Procedure 2	U.S./Canada (3) Wheat/Barley Procedure 2	
	U.S. (1)* Rice		U.S. (3) Corn/Soybeans Procedure 2		

1 = Data Collection and Research   2 = Techniques Development   3 = Evaluation   TM - Thematic Mapper

Procedure 2 is an advanced machine processing technology.

*Exploratory Experiments to be conducted as part of supporting field research using ground-based, airborne, and satellite sensors including TM.

Figure 5.4-1

Section 5.5 Soil Moisture Project

Manager - R. Gilbert, USDA/SCS

Table of Contents

5.5.1 Objectives

The research objective is to develop, apply, and evaluate technology to estimate soil moisture profiles from remotely sensed and in-situ sensor data, for agricultural and water resources information needs. Achievement of this objective requires the following:

1. The measurement and extraction of soil moisture and depth information from a remotely-sensed surface region.

2. Modeling the root zone soil moisture profile using the measured surface region.

3. Develop the capability to infer sub-surface soil moisture.

4. Application of results to hydro and agro models, to obtain more useful results from the models.

5.5.2 Technical Approach

It is necessary to approach the problem through an orderly progression from modeling and ground-based studies up through analysis of existing space data. These various investigations can proceed in parallel rather than in sequence. In particular, they are to:

1. Develop a basic understanding of remote sensing capabilities with field measurements and modeling efforts involving a better definition of measurement capabilities, quantification of sources of noise, and sensitivity studies using representative and existing crop yield and runoff prediction models. Such efforts lay a sound basis for interpretation of higher altitude remotely-determined soil moisture information, as well as increase the understanding of ways in which the data can be best applied to user needs.

2. Test local results in soil moisture determinations and extend such efforts over larger areas with aircraft systems. Such studies will be done concurrently with the field measurements and modeling efforts through the use of comprehensive and coordinated field experiments. The aircraft flights would be scheduled to acquire data over specific study sites where detailed ground measurements are being taken (e.g., an agricultural yield experimental plot), as well as over larger units where the same type of detailed measurements are not possible (e.g., an experimental and representative watershed).

3. Analyze data from existing spaceborne systems for determination of soil moisture. Such efforts would be aimed at investigating whether lower altitude results can be extrapolated to a space platform,

as well as laying some ground work for the eventual design of soil moisture space mission sensor configurations. Of particular interest from such a platform will be an evaluation of the capability for repetitive observations for monitoring temporal soil moisture changes and the applicability of low resolution sensing of soil moisture information.

4. Mount a modeling effort to assess new approaches (or models) for better relating remote sensing observables (such as soil moisture) to agricultural and hydrological parameters. It seems highly likely that the utility of the new types of soil moisture information available from remote sensing will be maximized if used as an input to models (crop yield or hydrologic) particularly designed to take advantage of remote sensing capabilities. Evaluation of the new approaches will be accomplished by comparison with existing or conventional techniques.

5. Develop and test new techniques for in-situ soil moisture determination. Existing NASA technology should be surveyed for the purpose of adapting pertinent advances to automated ground measurement of soil moisture. In addition to improving the ground-based techniques, such development could be made amenable to real-time data relay which could be used for calibrating the remote sensing techniques.

In order to be successful in developing a remote sensing-soil moisture technology as outlined in the investigations listed above, specific research tasks must be carried out. The following questions/tasks will serve to guide progress in the program:

1. What are optimum wavelengths or combination of wavelengths for radiometer (microwave and thermal IR) and radar systems?

- What is the soil moisture sampling depth?
- Can moisture gradient information be obtained by multi-wavelength systems?

2. What are the limits on the accuracy of the soil moisture estimation imposed by:

- Surface roughness.
- Vegetative cover.
- Soil temperature variations.
- Soil heterogeniety.
- Incidence angle dependence.
- Surface cover heterogeniety.
- Atmospheric effects for space systems.
- Mixed scene in the large footprint of spaceborne sensors.

o Calibration of active microwave imaging systems.

3. What are the spatial and temporal variations of the parameter that will be observed?

o Assess diurnal soil moisture variations.

o Determine required sampling frequency/revisit time.

4. Can surface soil moisture be related to deeper layers in the soil (e.g., root zone) through use of models, correlations, etc?

5. What is the utility of remote sensing-based soil moisture determination?

o What user needs can or cannot be met?

o What are measurement requirements of these needs?

o Evaluation of improvement afforded by the use of remotely-sensed soil moisture data in crop yield and watersheds runoff models.

6. Can automatic in-situ soil moisture sensors be developed for use at unattended locations?

7. Other technical issues

o Can frozen soils be distinguished from unfrozen areas and through snow cover?

o Can the location of saline seeps be identified?

These specific questions which guide the approach will be discussed in detail in the next section - Supporting Elements.

5.5.3 Project Elements

5.5.3.1 Development of In-Situ Sensors

The objective of this effort will be to evaluate existing in-situ sensor techniques for possible use with data collection platforms and as a ground measurement sensor in support of remote sensing experiments. The most promising sensor from the standpoint of acceptance to the soil physics community is the neutron probe. However, because it involves the use of a radioactive source, licensing problems prohibit its use in unattended locations. Also, it is not effective for the surface soil layer. Therefore, other methods will have to be studied. They will include the measurement of electrical resistance and capacitance of the soils. There has been some recent work published on the capacitance technique, and it is currently being tested further at Army's CRREL Laboratory in New Hampshire. The resistance block technique has been around for some time. There are problems with hysteresis in the response, i.e., a dependence on whether the soil is in a drying or wetting portion of the cycle and with decomposition of the gypsum blocks used. For both of these approaches, there will be problems of calibration for the different soil types.

Thus, the development of a suitable in-situ sensor that will work for general applications will be a difficult task which will require much field testing.

1. Product

The output product of this task will be the definition of sensors for use on remote data collection platforms and for use as a rapid ground measurement to support remote sensing experiments.

2. Schedule

The target data for development of these sensors would be FY 83 so that they could be used to support the remote sensing experiments scheduled for later in the program.

5.5.3.2 Remote Sensor Field Measurement

Research to date indicates that the relationship between sensor response (e.g., brightness temperature or backscatter coefficient) and soil moisture depends on a number of environmental conditions. These include surface roughness, vegetative cover, soil temperature, soil type, and surface slope/incidence angle. The objective of this effort will be to determine how these environmental factors affect the accuracy of possible soil moisture determinations. This task will include the development of algorithms for incorporating the results from ancillary sources to minimize the effects of these factors (e.g., the use of vegetative cover determination from Landsat).

Additional noise factors will become apparent when these measurement approaches are extended to space platforms. A prime example of this is the effect that the mixed cultural scene over the large (10KM) footprint expected for radiometers operating from space will cause on the soil moisture estimates. The problem is currently being studied in the FY 78 Applications Notice. Other examples include atmospheric effects of thermal IR measurements and effect of limited radar swath width on the frequency of coverage possible with imaging radars.

1. Products

The output of this task will be determinations of expected measurement accuracies of the sensor combination recommended in Development of In-Situ Sensors. Included will be algorithms or models required to incorporate ancillary data used to minimize the effects of the noise sources.

2. Schedule

A preliminary estimate of the expected accuracies will be due when the preliminary sensor definition is presented early in FY 81. It is expected that not all the noise sources will be accounted for by that time and that the accuracy estimates will continue to be updated during the program.

5.5.3.3 Remote Sensor Aircraft Measurement

The objective of this effort will be to determine the best combination of sensors that can remotely sense soil moisture information. It is expected that this combination will depend on the measurement requirements (e.g., spatial and temporal resolution) of the particular application being investigated. The specific types of sensors to be considered include active and passive microwave imagers and the thermal IR. The need for visible imagery from systems such as Landsat to support the above sensor will be considered. The land use and bio-mass information obtainable from visible sensors may be required on as frequent a basis as the fundamental soil moisture determination. Included in this task will be a determination of the soil moisture sampling depth for a given experiment. For runoff prediction, a month-long test over a hydrologically active watershed should provide a suitable test. These tests will require the modification or development of applications models which can use this remotely-sensed data.

1. Products

The final output of this task will be comparison of the yield forecasts and runoff prediction made using conventional data only with those made using conventional data plus remotely-sensed data. Interim products will be sensitivity studies indicating the importance of soil moisture in these models and a specification of the type of measurements needed for these models.

2. Schedule

The sensitivity studies and specification of measurement needs should be completed in FY 82. Interim evaluation of improvement afforded by remote sensing data should be completed in FY 83 and FY 84. Pending the availability of space data, the final complete evaluation will be done in FY 85.

5.5.3.4 Modeling and Analysis

Studies of intensively sampled fields (e.g., 36 points in a 40-acre field) indicate that the minimum RMS variation across the field is 2 or 3 percent soil moisture by weight for moisture levels above 5 percent. This indicates a minimum level of uncertainty in soil moisture measurements and will impose a limit on the accuracy of determination of the relationships between our sensor responses and soil moisture. This level of uncertainty results from the natural variability of such things as soil type, drainage, and slope and cannot be reduced or eliminated from natural scenes. Thus, one objective of this task will be to estimate the level of uncertainty imposed by this natural variability and determine the number of samples required in our ground sampling procedures to achieve this minimum level.

The spatial variability of soil moisture produced by rainfall variations is another aspect of this problem. Rainfall variability is dependent on rainfall type, being the greatest for convective thunderstorms which are the major contributors to the total summer rainfall in the Great Plains. The objective here will be to determine the spatial scale of the rainfall variations and use this as one criteria for determining the required spatial resolution of spacecraft sensors.

The temporal variation of soil moisture will also be studied to determine if there is an optimum time of day for sensor overpass and the frequency of coverage. For infrared systems, it is clear that the optimum time for an overpass is early afternoon when surface temperatures are at a maximum and when plant stress will be most easily detected by thermal methods. The microwave approaches will measure the surface layer soil moisture at the time of the observation, and the objective will be to determine if there is an optimum time of day for relating this surface layer soil moisture to the root zone value.

It is necessary to determine the feasibility of and the methods for relating remotely-sensed surface soil moisture observation to deeper layers in the soil. Since there currently are few direct uses of surface layer soil moisture determination, it is imperative that methods be developed for relating regular and frequent observations of this parameter to root zone values. A possible first step in this development process is to use surface layer soil moisture observations as a means of estimating the spatial variation of rainfall about the rain gauge stations. Then existing moisture budget models could be used for a root zone estimate. A later step would be the development of models which use the surface soil moisture determinations directly. Another possibility to consider is the use of in-situ measurements of the profile relayed by data communcation satellite in real time for use in extrapolation of the surface measurements to deeper layers.

An evaluation is needed of the improvement afforded by incorporating remotely-sensed soil moisture information in applications models such as crop yield forecasts and runoff prediction. Included in this task will be a determination of what are the needs, in terms of resolutions and measurements accuracies, of these various application models. Sensitivity studies will be done to indicate importance of soil moisture in these models.

At the present time, it is believed that long-term repetitive observations from a space platform will be required to accurately do this evaluation. However, interim evaluations will be possible with repetitive aircraft flights over large areas. For yield forecasting applications, it may not be possible to obtain this type of data over the entire growing season, but a partial test may be possible with a shorter wavelength of observation, plus an evaluation of the possibility of obtaining the near-surface soil moisture gradient with multi-wavelength observation.

1. Products

The outputs of this effort will be:

o An estimate of the limits of accuracy for ground measurements of soil moisture imposed by natural variability.

o A determination of the spatial scale of rainfall.

o A determination of the optimum time of day for relating surface layer soil moisture to the root zone value.

o The algorithm for relating the remotely-sensed surface soil moisture to root zone values, either directly, through the effective rainfall estimate, or through comparison with in-situ measurements.

o A determination of the required sensor parameters. These will include type of sensors, wavelength, look angles and polarizations, spatial resolutions and frequency of coverage. The algorithm for extracting the soil moisture information from the sensor observations will be included in this effort.

2. Schedule

The spatial variability studies are either ongoing or will be initiated in FY 80 so that results should be available for the preliminary sensor definition in early FY 81. The temporal variability study will take longer and be ready in FY 83.

Interim algorithms will be tested with ground-based and aircraft remote sensors. The useful models may not be completed until FY 85.

A preliminary sensor definition is expected in early FY 81. This will be updated as the research results indicate the need for changes.

5.5.3.5 Other Technical Issues

In the course of a program of this nature, other problems may appear that diverge somewhat from the main objective of soil moisture determination but which are interesting in their own right and may be addressable using the same remote sensing approaches. Two such problems that recently have been considered are the detection of frozen soil, with and without snow cover, and the observation of saline seeps in the northern Great Plains. It is expected that other problems of this nature will come up during the course of the program and there should be the flexibility to divert some resources to their study.

1. Products

No specific output products can be identified at this time; however, evaluations of the capability to map frozen and/or saline soils will be conducted.

5.5.4 Agency Responsibilities

1. NASA

NASA will be responsible for conducting the soil moisture supporting research as outlined in this document. Field data acquisition programs will be the responsibility of NASA, as well as for the bulk of data processing and analysis. USDA will participate in analysis of data especially related to model inputs.

2. USDA

USDA will also supply experienced personnel for ground truth data collection in various coordinated field experiments. In addition, USDA will take the lead in development of the in-situ instrumentation, assisted by NASA.

3. NOAA

NOAA will participate in hydrologic model evaluations associated with the remote sensing soil moisture determinations. User evaluation will be the responsibility of the USDA, and details of this activity be found in the Appendix.

4. USDI

Landsat data storage, retrieval, and dissemination.

5.5.5 Schedule with Milestones

See Table 5.5-1.

Table 5.5-1 Soil Moisture Schedule with Milestones

	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Element 1 - Development of In-situ Sensors						
-						
- Feasibility Study	———					
- Sensor Selection	———	———	———			
- Evaluation		———	———	———		
- Update Sensor Combination		—	—	—	—	—
Element 2 - Field Measurements						
- Surface Roughness	———	———				
- Vegetation Cover	———	———				
- Soil Temperature	———	———	———			
- Soil Heterogeneity		———	———	———		
- Incidence Angle		———	———	———	———	
- Surface Cover Heterogeneity			———	———	———	
- Atmospheric Effects	———	———	———	———		
- Large Footprint			———	———	———	
- Calibration Effects			———	———	———	———
- Update Accuracy Estimates		—	—	—	—	—
Element 3 - Aircraft Measurement						
- Data Collection/Interpretation	———	———	———	———	———	———
Element 4 - Modeling Analysis						
- Surface/Depth Model	———	———	———	———	———	———
Element 5 - Other Technical Issues						
- Frozen Soil Assessment	———	———				
- Saline Soil Tests		———	———	———	———	———
- Additional Issues						

Section 5.6 Domestic Crops and Land Cover Project

Manager - R. Allen, USDA/ESCS

Table of Contents

5.6.1 Goal

Develop, test, and evaluate, the use of satellite data for more precise, cost effective, and timely domestic crop and land cover acreage estimates at the state, Crop Reporting District (CRD), multicounty, and county levels in the U.S.

5.6.2 Technical Objectives

1. Investigate and evaluate digital analysis procedures to classify and estimate the acreage of crops and other land cover such as forest, rangeland, urban, water, etc., over a major portion of the U.S.

2. Test and demonstrate the usefulness of data collected by Landsat and other advanced remote sensing systems when using automatic processing procedures for improving the precision of domestic crop and land cover acreage determination at several levels such as counties, groups of counties, CRD's, and entire states.

3. Investigate and determine the most efficient and cost effective method of storing inventory information and retrieving the geographic location of change from one inventory to the next and the optimum size for the units of change, and develop a change monitoring system.

4. Implement pilot experiments over 2 states starting in 1980, increasing the number to at least 10 states by the end of 1984 in large scale application tests. The remaining states, if required, would be completed during initial operation of the system by USDA.

5. LSAT activities will include the estimation of major domestic crop and land cover acreages at the state, CRD, multicounty, and county levels with known and acceptable precision for the states involved. These LSAT activities will proceed when RD&T outputs and USDA user evaluations suggest LSAT is appropriate. For domestic crop and land cover acreage estimation, current RD&T activities support LSAT activities beginning in 1984.

5.6.3 Information Needs

The USDA must obtain major domestic crop and land cover acreage estimates at the county, multicounty, CRD, and state levels. Such a requirement is mandated by the USDA crop estimation program. Land cover inventories are also essential to establish baselines for change monitoring. Land and vegetation cover type information is used to inventory agricultural commodities and forecast their production, and in land planning. Land cover information is an essential component of the resources, conservation, and commodity management baselines for various USDA agencies, e.g., USFS, SCS, ESCS, and ASCS. The following is a requirement summary.

1. Crop Types - Major crops i.e., corn, soybean, wheat, cotton, rice, barley, sorghum - acreage estimation.

2. Land Cover Types - Various key land cover parameters, e.g., forest, range, urban, crops, and sub-breakouts of these parameters - acreage estimation and mapping.

3. Coverage - Most USDA agencies concerned with land cover analysis, resource management, crop estimation, and commodity production need this information for the entire U.S. Approximately 20-40 percent of the U.S. will be covered per year.

4. Timeliness - Requirements vary from semi-annual updates to periodic updates every 8 to 10 years, for all or part of the U.S.

5. Aggregation Requirement - County, multicounty, CRD, state, regional, and country levels.

6. Cell Size Requirements - Rural 20-60 acres (crops and land use); urban 5-20 acres (land use); critical impact areas 1-5 acres (land cover).

7. Accuracy - To be determined.

8. Change Monitoring for Land Cover - Units of change for rural 20-40 acres; urban and critical areas 5-20 acres.

9. Department Priority - This is a high priority requirement. Information on crop estimations and land cover is an essential component of the resources and commodity management baselines. Such information will serve SCS, FS, ESCS, and ASCS.

Most of the requirements for rural and urban/suburban areas can be accommodated by satellite coverage (30m - 80m). Critical impact areas, as well as detailed urban surveys, will be accommodated by aircraft photography (or other potential photography, e.g., Shuttle Large Format Camera).

5.6.4 Task

5.6.4.1 RD&T

5.6.4.1.1 Improve Precision in Acreage Estimation

1. Technical Approach

The technical approach to this task is divided into 2 parts.

- Investigating and developing methodology for classification and mensuration.

- Future sensor evaluation.

The scope of the first part requires that it be addressed in subtasks which will be discussed in the following paragraphs.

- Investigating and developing methodology for classification and mensuration.

-- Technical Assessment - Assess the current technology for using automated processing techniques to process Landsat data for land cover mapping in a large area such as a state(s). Items to be assessed are the level of land cover mapping obtained, accuracy of land cover maps, omission errors, commission errors, existing machine processing techniques, sampling versus total wall-to-wall classification or a combination of procedures, and types of improvements needed to improve classification and mensuration. This assessment will concentrate on existing technology, such as the Illinois and California studies conducted by ESCS, and also the experiences gained in LACIE.

-- Multitemporal Analysis - Technology has shown that some crops and land cover types can be mapped with greater accuracies when using a data set which combines Landsat data acquired at different times of the year, e.g., spring and fall. The definition of each crop and land cover type must investigate the optimum dates or combination of dates which would give maximum spectral separation of the features to be mapped within the scenes. This will minimize the amounts of data processing, i.e., permit a once-through classification.

-- Preprocessing/Registration - Based upon the crops and cover types to be classified, investigations must analyze the degree of preprocessing required for atmospheric, radiometric, geometric, and sun angle corrections.

For multitemporal processing, full frame data must be registered to each other to 1/2 pixel accuracy. Ground truth maps and annotated aerial photographs must be registered to Landsat digital data within ±50 meters RMS error. Classification map information and digitized boundaries must be registered to a geo-based reference system to 1mm accuracy at all map scales.

-- Sampling/Ground Truth Data Base - The domestic crop and land cover area estimation program will utilize the ground data collected in the area sampling frame by ESCS. This data will be available for all the 48 contiguous states. Additional ground truth data (over that gathered for crops) will be needed for land cover samples falling in study sites. Furthermore, spectral measurements are required for features to be classified.

Investigate alternative sampling strategies for use in this program.

-- Improve Algorithms - Develop, test, and evaluate new algorithms which have potential for improving crop and land cover classification and mensuration. Some specific candidates are masked classification, layered classification, and P-2.

-- Improve Throughput/Timeliness - Critique all the major elements of the domestic crop and land cover area estimation process for inefficient use of time and resources. Research and develop better divisions of tasks or procedures for greater efficiency.

- Future sensor evaluations for improving domestic crop and land cover classification and acreage estimation are required for TM and Synthetic Aperture Radar (SAR). The radiometric, spectral, and spatial characteristics of the data will be evaluated in terms of improving precision in domestic crop and land cover classification and acreage estimation. The utility of using current classification routines and other software packages to process TM data will be assessed. These evaluations will be closely coordinated with the Renewable Resources Project. In 1979 or 1980, TM simulator data (NS001 from AIRP) will be obtained over portions of 3 geographical areas - corn belt, west, and southeast. Emphasis will be given to the TM evaluations. Results will be used to develop procedures which will be incorporated into the classification and acreage estimation process.

2. Data Requirements

- Data required for pilot testing of crop area estimates will suffice for this requirement.

- Ground Truth - More comprehensive ground truth will have to be collected by ESCS enumerators for those states selected for study. Spectral and other measurements will be required from the Supporting Research Project.

- Landsat Data - A rapid delivery system of CCT's to the USDA/NASA is needed to support domestic crop and land cover classification and acreage estimation. Full frame Landsat CCT's are needed one to 2 weeks after the satellite data are acquired. This data must be preprocessed and registered. In addition, high contrast B/W images will be required.

- CPU - Computer capability equivalent to ILLIAC-IV must be maintained or provided until LSAT's are conducted by USDA.

- Aircraft Data - Aircraft high altitude photography will be required for segment verification and to assist in the overall verification of proposed tests. Flights of NS001 TM Simulator data and APQ102 Radar data will be required.

3. Output Results

- Multitemporal analysis capability.

- Expected precision for acreage estimates.

- Improved applications of statistical and data processing methodologies.

- Capability of new sensors to improve land cover classification.

- Location and mapping of land cover types with know accuracies.

- Additional land use parameter investigation.

- Timely land cover classification.

4. Agency Responsibilities

NASA and USDA will work closely on several of the subtasks, with USDA having overall lead responsibility. The following represents the activities and agency involvement.

- USDA
  - Technology assessment.[1]
  - Acquire ground data.
  - Acquire remotely-sensed data.
  - Sampling.
  - Improve algorithms.
  - Registration.
  - CPU processing.
  - Sensor evaluation.
  - Multitemporal analysis.
  - Throughput analysis.
- NASA
  - Technology assessment.[1]
  - Acquire remotely-sensed data.[1]
  - Provide CPU.
  - Registration.[1]
  - Sensor evaluation.[1]
  - Multitemporal analysis.[1]
- USDI
  - Landsat data storage, retrieval, and dissemination.

5. Schedules/Milestones

Investigate and develop methodology for classification and mensuration. (See Figure 5.6-1)

6. Performance Evaluation

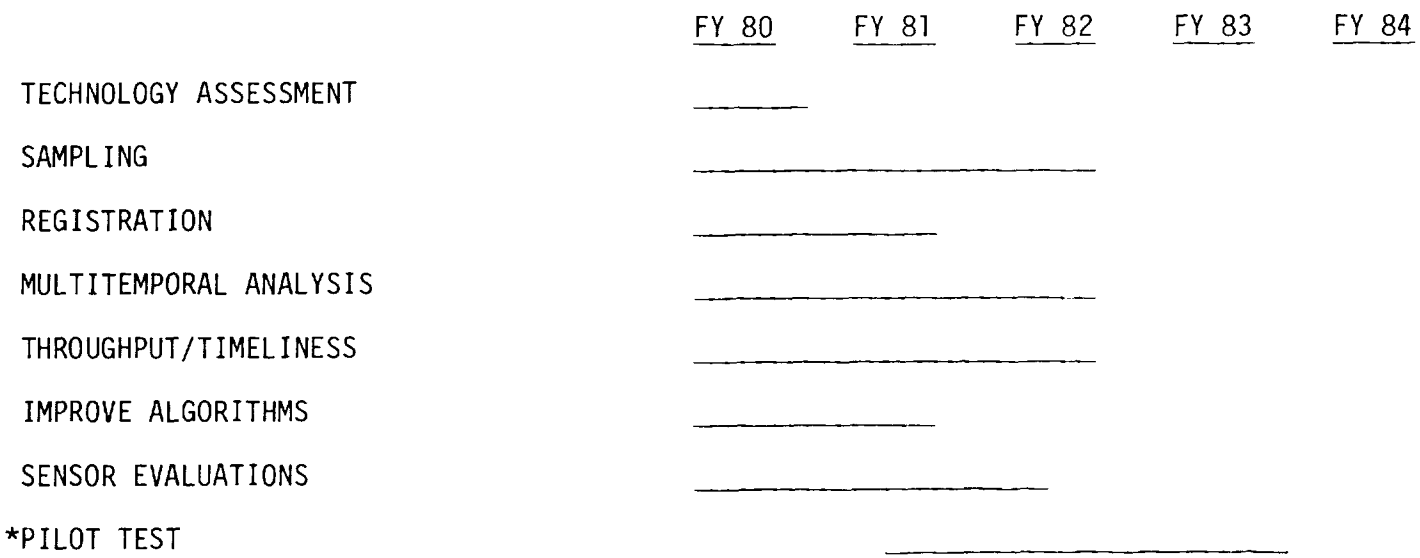
The R&D required to improve the precision in domestic crop and land cover area estimation will require well-defined and documented

[1]Lead responsibility

FIGURE 5.6-1

DOMESTIC CROP AND LAND COVER PROJECT SCHEDULE

INVESTIGATE AND DEVELOP METHODOLOGY FOR CLASSIFICATION AND MENSURATION



*PILOT TEST AS DEFINED HERE WILL BE AN INTEGRATED PART OF THE OVERALL DOMESTIC CROP AND LAND COVER AREA ESTIMATION PILOT TEST.