A Proposal in Response to NASA Research Announcement 87-OSSA-6

Compiling and Editing Area Sampling Frames using Digital Data for Land Use Analysis and Boundary Definition

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NASA

Reply to Attn of: SLE:242-4

Mr. Ray J. Arnold
Code EPM-20 (NRA)
National Aeronautics and
Space Administration
Washington, DC 20546

Dear Mr. Arnold:

Please accept this proposal for consideration for funding through the Remote Sensing Applications/Commercialization Program (NRA-87-OSSA-6). I authorize the commitment of this organization to the proposal and its contents.

Sincerely,

James G. Lawless
Chief, Ecosystem Science and Technology Branch

Enclosures

United States Department of Agriculture
National Agricultural Statistics Service
Washington, D.C. 20250

NOV 6 1987

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Code EPM-20(NRA)
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Dear Mr. Arnold:

Please accept this proposal for consideration for funding through the Remote Sensing Applications/Commercialization Program (NRA-87-OSSA-6). I authorize the commitment of this organization to the proposal and its contents, subject to availability of appropriate funds.

Sincerely,

Charles E. Caudill

CHARLES E. CAUDILL
Administrator

Enclosures

Executive Summary

An area frame is a construct used as sampling vehicle for large area surveys. It is compiled by dividing the area to be surveyed into contiguous parcels — each parcel easily located on the ground and suitable for a sample-based survey.

The National Agricultural Statistics Service (NASS) of the U.S. Department of Agriculture has been using area frames as an integral part of its procedures for gathering information on crop acreage, cost of production, farm expenditures, livestock and other agricultural items in the United States since the mid 1950's. Current probability-based surveys require an area frame to ensure complete coverage of agricultural operations.

The existing procedure to develop and edit area frames is slow, labor intensive, subject to error, and expensive. A considerable amount of manual labor is required. The development of an area frame for a single state may require 11,000 hours of labor and incur $150,000 in cost.

As an extension of research in the use of remote sensing/digital data processing for area estimation, and advances in display hardware and microprocessor performance, the possibility of creating and editing area frames for NASS using a microprocessor based workstation and an interactive display device has emerged. The basic elements of an all-digital area frame procedure now exist. The objective of this proposal is to complete the process, i.e. complete the development of the software tools needed for an efficient use of digital data in area frame creation and editing, design an area frame procedure that will use the tools efficiently, and implement the procedure in an operational environment.

The offices that will participate in the project are the Survey Research Branch (SRB) and Survey Sampling Branch (SSB) of NASS, and the Ecosystem Science and Technology Branch (ECOSAT) at NASA-Ames Research Center. NASS and ECOSAT have a long history of cooperation in the development of digital data processing techniques.

The project will run three years. ECOSAT will be responsible for the development of the technology; NASS will be responsible for testing the elements of the procedure and implementation. The course of the project will be guided by the users of the technology. The initial year will proceed with a critique of the existing software tools by personnel in the Area Frame Section of the Survey Sampling Branch. Commercial software that might be appropriate is being evaluated as well. A study will be made of the advantages and disadvantages of the digital frame construction approach. Following the study, the decision will be made whether or not to proceed with the digital system, and if so, whether to use commercial or in-house software. Modification of software tools and writing of new tools will start following the study. At the conclusion of the three years, the new system will be in place and operational.

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CONTENTS

Introduction

The National Agricultural Statistics Service (NASS), formerly the Statistical Reporting Service, has a mandate from Congress to report on agricultural productivity in the United States on the state and national levels. The accuracy and timeliness of those reports are crucial to producers, public agencies, and private enterprises concerned with agriculture.

The area frame concept has been the backbone for the agricultural statistics program of NASS since 1954 (Cotter and Nealon, 1987). An area frame for a state or county is a geographic partitioning of all parcels of land within the area of interest. An area frame is assembled and used in sampling surveys for acreage estimation in the following manner:

1. Each state is divided into manageable units, usually counties. The major homogeneous areas of land use within the county are determined (urban, agricultural, rangeland, etc.) and the boundaries of these units are drawn on mosaics of aerial photography. The boundaries stratify the county relative to land use. Clearly identifiable features such as roads and rivers are used to define the boundaries of the strata. Aerial photography, quad maps, and hardcopy Landsat imagery are some of the data used to determine where the strata boundaries should fall. The Landsat imagery is particularly useful for determining the extent of the agricultural stratum, especially if it is current year imagery.

2. The strata boundaries are transferred from the photography to county highway maps. The boundaries are drawn by hand using a zoom transfer scope.

3. The strata are sub-divided into blocks called primary sampling units (PSU). These units vary in size from .2 to 10 square miles. The use of primary sampling units introduces economic saving into area frame sampling, because an entire frame need not be further divided into ground sample segments in order to select a sample. Ground sample segments are the units of area within which survey data are collected. In delineating primary sampling units, the main concerns are to maintain uniform size within a stratum and ensure that each PSU is representative of the stratum as a whole.

4. The strata boundaries and the primary sampling units are digitized. The strata digitization is used to determine the probability of selection for each PSU.

5. A random sample of PSUs is selected from all strata. Ground sample segment boundaries are drawn only in the selected PSUs. A random sample within each PSU determines which segments will be enumerated during the survey.

Creating a new area frame is a laborious process. Only 2-3 state area frames are re-drawn every year. As a frame ages, it may become inefficient if there are significant shifts in land use patterns. The loss in efficiency affects the precision of the acreage estimates. Editing an area frame is virtually impossible with the existing procedure, because each time a frame is edited, it must be re-drawn.

Interactive display graphics and new digitized data sources may serve as the basis for a significant increase in the efficiency of area frame creation and editing. NASS and ECOSAT at the Ames Research Center began exploring the possibilities for a new procedure in 1986-1987 based on advances in digital data technology.

Research Background

NASS has been deeply involved in satellite remote sensing since the launch of Landsat 1. NASS staff has published extensively and has received significant recognition for their research efforts (Hanuschak et al, 1982). NASS was a principal investigator in digital analysis of satellite data for crop acreages, working with NASA for agriculture for ERTS 1. NASS management, in particular, William E. Kibler and Charles E. Caudill, were extensively involved in LACIE and led the management team for AgRISTARS. Mr. Kibler is the recently retired Administrator of NASS and Mr. Caudill is the current Administrator of NASS. Both have a long history of commitment to productive research in the use of remotely sensed data to improve U.S. agricultural statistics.

Ames Research Center, through ECOSAT, is well equipped to address the remote sensing research needs of NASS. ECOSAT was active in NASA's applications programs in the 1970's, particularly in the transfer of technology to government agencies. ECOSAT is currently organized to perform research in four areas - closed system science, e.g. closed environment life support systems; open system science, e.g. global biogeochemical cycling; applications and technology development, e.g. in agriculture, forestry, geology and human health; and image processing and sensor research. The branch has experience in the development and operation of microprocessor-based workstations, and it is linked to the advanced computational facilities at Ames (see Appendix A for more information on ECOSAT).

NASS and ECOSAT have a history of cooperation in remote sensing research. The two agencies have worked together on a number of projects since the late 1970's. EDITOR, a software package for large area crop acreage estimation utilizing Landsat MSS data and associated ground data, was written by NASS and ECOSAT personnel. Eighty percent of PEDITOR, a portable version of EDITOR, i.e. a system suitable for implementation an a variety of hardware devices, was written at ECOSAT. PEDITOR is the primary software tool for remote sensing operational work in NASS. ECOSAT assembled a prototype microprocessor-based workstation, called MIDAS, for NASS and assisted with an experiment to determine the performance characteristics of the system when generating area estimates in NASS operational environment (Hlavka and Sheffner, in press). ECOSAT created display software for NASS that is compatible with PEDITOR and a precursor for the system required for the area frame task.

Planned Development

The development of the area frame software will be an iterative process. The software supplied by ECOSAT to NASS last year will be evaluated for completeness and ease of use by the staff of the Area Frame Section. From the evaluation will emerge a list of specifications that will be addressed by project personnel at ECOSAT. Review of system performance and needs, along with a survey of current commercial systems, will determine if further custom software and hardware or a commercially available package is best suited for implementation. This decision will be made by the end of the first year of this development project.

NASS has used the PEDITOR software since the mid-1970's for both research and operational remote sensing. The NASS operational remote sensing program prepares annual acreage estimates of major crops in eight midwestern states. Approximately 150 Landsat MSS scenes are processed and analyzed each year during the preparation of these estimates. The remote sensing estimation procedures are intimately tied to the area sampling frame via the JES survey.

Thus, the development of the automated area frame procedures falls naturally into the domain of the PEDITOR system. A new frame system based on PEDITOR concepts and integrated in the PEDITOR software will strengthen both the research and operational remote sensing program at NASS and NASA and the development of area frames. One particular advantage to this approach is the ability to use digital information relating to land use from previous years' surveys during the construction and updating of frames.

Commercial software that can be adapted to the frame construction methodology requirements is being evaluated in this project. Setting up links with the PEDITOR system and its files could serve the Agency's needs as well as a system that is extensions to PEDITOR.

Objectives

The following are the objectives of this joint project.

1. Select a software package that will supply the tools necessary for compiling and editing area frames using Landsat thematic mapper data (TM) and U.S. Geological Survey digital line graph (DLG) data. The software will 1) generate files compatible with the PEDITOR software where necessary and 2) operate on a Sun workstation with a display device such as the Raster Technology Model 1. The software will be either a commercially available product modified for integration into the PEDITOR system, or an extension of current prototype software designed for area frame functions.
2. Design a procedure for area frame compilation and editing based on manipulation of Landsat TM digital data and DLG data. The procedure must be easy to learn, and the hardware and software systems easy to operate so that the procedure can be followed efficiently by a non-technical staff.
3. Implement a digital area frame compilation and editing procedure in an operational environment.

These objectives developed from research performed by ECOSAT for NASS between 1982 and 1986.

In 1983, ECOSAT began work on three projects for NASS — rewriting EDITOR in a portable format (Angelici, Ozga, Ritter, and Slye, 1986), assembly of a microprocessor-based workstation (Erickson, Hofman, and Donovan, 1983), and development of procedures for large scale crop area estimation. The three separate tasks culminated in 1985-86 in a project called the California Cooperative Remote Sensing Project (CCRSP) which demonstrated the feasibility of performing large area crop estimation on a microprocessor and mainframe network using PEDITOR software (Sheffner, 1985).

At the conclusion of the CCRSP, NASS requested ECOSAT examine the prospects for a digital procedure in area frame compilation. The advantages of a digital system are:

- the potential for a reduction in the manual labor required to construct the frame;
- an increase in the precision of surveys based on the area frame, because the area frame can be updated with greater frequency;
- the potential to use remote sensing techniques to improve frame stratification; and
- the ability to update an area frame by editing rather than recompiling.

ECOSAT responded to NASS' interests by writing a number of software modules, in PEDITOR format, that would perform basic display functions and tape functions required in an area frame procedure. The software did not meet all the requirements for an area frame procedure but addressed the basic elements of such a system including:

- ☐ read DLG data from tape to disk;
- ☐ display single channel and multi-channel imagery;
- ☐ display DLG data;
- ☐ register DLG data to Landsat MSS or TM;
- ☐ enhance displayed image;
- ☐ draw polygons on display; save polygons in a file.

The software also filled a deficiency in the PEDITOR package — the lack of display capability. The software was submitted to the Survey Research Branch in the fall of 1986, and a demonstration of its capabilities was given to personnel from the Area Frame Section and NASS managers in January, 1987.

Based on the demonstration, NASS agreed to proceed with development of a digital area frame construction methodology and processing procedure. The methodology and procedure will be implemented through this project either as extensions to PEDITOR or through commercial software adapted to the specific requirements with links to PEDITOR.

Preliminary work with the ECOSAT software indicated that Landsat TM was the preferred raw data to use because the 30m resolution was sufficient for land use stratification and boundary delineation of PSUs and ground sample segments, DLG data was satisfactory to identify suitable boundary features for strata and PSU boundaries, interactive digitization on a display device was feasible and efficient, and a 512×512 pixel display of TM data included sufficient area for PSU delineation without losing the context of the strata.

Specific technical issues are discussed in the Technical Approach.

Technical Approach

The approach will draw upon the work started in 1986. This section describes the environment for software development and the technical issues that will be addressed in the design of a digital area frame procedure. The mechanism for integrating the software with the digital area frame construction methodology is described in the Technical Plan.

Software and Hardware

The software demonstrated in January was written within a developmental environment with constraints on hardware devices and software form and function. That environment will be enhanced during the course of the project with the purchase of Sun workstations.

The software was written on a MIDAS workstation with a Raster Technology Model 1 display. The MIDAS workstation was selected because an identical system was in service at NASS, it had a display device, it was the same system used for the EDITOR to PEDITOR conversion project at ECOSAT, and NASS/SRB wished to pursue the workstation concept for its in-house processing. Toward the end of FY-86, some software development was shifted to the Sun 2 workstation at ECOSAT. The Sun 2 was attached to an identical Raster Technology display. The Sun proved to be superior in every way to MIDAS. Software development will continue on Sun devices in light of NASS/SRB's decision in 1987 to convert its Technology Research Section operations to networked Sun 3 workstations.

The Raster Technologies Model 1 display has the minimum capabilities required for area frame analysis. i.e., three image planes, two overlay planes, and a 512×512 display coordinate system. The configuration allows for display of up to three bands of raw data in the image plane while reserving one graphics plane for DLG data display and one graphics plane for display and digitization of polygons.

Role of PEDITOR

For the purpose of this project, PEDITOR area frame modules will be used by the Area Frame Section as a vehicle for establishing a methodology for digital area frame construction. Commercial software that can be adapted to the area frame requirements, e.g., ERDAS and I^2S, will also be evaluated. A commercial package would be required to have hooks to PEDITOR so remote sensing research procedures and resulting techniques can be applied to the area frame procedures.

The current preliminary version of the in-house area frame software is part of the PEDITOR system but is independent from it, i.e., all programs and libraries associated with area frame processing can be removed from PEDITOR without affecting the original functions of the PEDITOR system.

NASS has used the PEDITOR software since the mid-1970's for both research and operational remote sensing. NASS' operational remote sensing program prepares annual acreage estimates of major crops in eight midwestern states. Approximately 150 Landsat MSS scenes are processed and analyzed each year during the preparation of these estimates. The remote sensing estimation procedures are intimately tied to the area sampling frame via the JES survey.

Thus, the development of the automated area frame procedures falls naturally into the domain of the PEDITOR system. A new frame system based on PEDITOR concepts and integrated in the PEDITOR software will strengthen both the research and operational remote sensing program at NASS and the development of area frames. This approach has the advantage of making remotely sensed and ground survey information from previous years' surveys available during the construction and updating of frames.

The rules regulating the development of PEDITOR were applied to the area frame software in order to provide a modicum of consistency in all the software written. As a consequence of these rules, the area frame software is modular: major functions are written as separate programs; all codes are in Pascal; the code is portable (the software, except for calls to the display device, can be compiled and executed on a number of large and small systems); and common functions and procedures are placed in libraries.

In 1986, ECOSAT, with design consultation from NASS/SRB, developed prototype software as extensions to the NASS PEDITOR, for area frame processing. The software consisted of the following modules:

Module Name	Function
rtinit	initialize display device; load macros
eraspl	clear display
dspdlg	display DLG data
regdlg	register DLG data to Landsat TM/MSS
rtdisp	display multi-band data set
mapima	alter color mapping functions
segdsp	display segments and strata
tapdlg	read DLG data from tape
setdst	alter/show display status
poly	digitize area on display

Manual and Digital Procedures

The principal elements in the manual procedure and how they will be addressed in the digital procedure are described below. Technical issues associated with each element are described. The test data to resolve the issues will be from Missouri. Landsat TM and DLG data for Missouri have been acquired. The area frame for the state will be compiled using the existing manual procedure and alternative digital methods to determine the suitability of digital processing and the most effective digital analysis methods.

Function	Stratification of area of interest into broad land–use categories.
Manual Procedure	The analyst identifies strata on Landsat MSS hardcopy imagery (single band, small scale) and/or mosaics of aerial photography. Approximate boundaries for strata are drawn in.
Digital Procedure	Stratification will be done using Landsat TM. The spectral and spatial resolution of TM may be sufficient to allow an analyst to clearly identify strata boundaries. A simple classification of the data may also be performed. NASS personnel in the Survey Research Branch used the area frame software with existing PEDITOR software to perform a classification of a 512×512 window from a TM image (3 bands, single date) of small farms and mixed land use along the Georgia-Alabama-Tennessee border. The module POLY was used to identify areas of similar land use. The output from POLY is a segment network file suitable for input into the PEDITOR functions for extracting training data from Landsat TM or MSS digital data. The training data in the NASS test was clustered with the PEDITOR clustering algorithm and the image was classified with a maximum likelihood classifier. The resulting classification was judged informally to be of value for stratification, i.e., the boundaries of the classes were suitable as a first approximation of strata boundaries.
Issues	Raw data vs. classified data — both approaches will be tested using a single quad of TM data from Missouri. Data enhancements for raw data display, i.e., enhancing and/or compressing data, may improve interpretability for raw data display or classification. An image enhancement package is now available (module MAPIMA) for functions such as remapping the display; data compression techniques (band ratios, principal components) will be added. Analysts will need to be familiar with all techniques as it is unlikely that a single enhancement or data compression approach will be appropriate at all times of the year or for all parts of the country. Multiple acquisitions — experience with CCRSP and NASS/SRB indicate that no more than two acquisitions per year will be necessary for stratification. Two acquisitions for one TM quad will be tested for improvement in stratification accuracy.

Function	Fix boundaries of strata and PSUs.
Manual Procedure	Strata boundaries are copied from aerial photography or Landsat imagery to county highway maps.
Digital Procedure	The Landsat raw data or classified data will be overlain with DLG data. The features used in the manual procedure as boundary markers, roads, drainages, county boundaries are available on DLG. All DLG features, called attributes, or a subset of features, can be displayed simultaneously. The analyst will use the displayed image and DLG data to locate boundaries.
Issues	How best to display DLG data; current options include different attributes in different colors and/or line values, e.g., lines, dashes, dots. A display with more than three image or two graphics planes in which planes could be switched off/on easily would give greater flexibility for DLG display.

Function	Digitize strata and PSU boundaries.
Manual Procedure	Digitization is performed from county highway maps using a digitizing table.
Digital Procedure	Digitization is performed interactively from the display device using a bit pad and cursor or a light pen. Interactive digitization has several advantages over manual digitization:

- The need to transfer strata and PSU boundaries to county highway maps will be eliminated.
- The software will keep a running total of the area contained within the polygon being digitized so that the analyst will be able to keep all polygons within size requirements, and editing of PSUs to maintain conformity in size will no longer be necessary.
- The files output from the interactive digitization will be in a format suitable for use in PEDITOR area estimation procedure.
- The analyst will see errors in digitization immediately, reducing errors and avoiding the need to plot strata and ground sample segment files to confirm proper digitization.
- Editing strata, PSU and ground sample segment files will be relatively easy. Once in the system, in future years, files can be edited rather than re-compiled.

Issue	Maintain correct global coordinates for polygon vertices as displayed image is shifted within a scene and between scenes.

Function	Plot files to check digitization.
Manual Procedure	Convert digitized files to plot file format. Plot file on pen plotter or similar device.
Digital Procedure	Not required as data is checked as it is digitized. However, the module SEGDSP will display a digitized file on the display device without the need for changing the file format.

Function	Select PSUs for sampling.
Manual Procedure	PSUs are selected within each land-use stratum according to the statistical sampling plan. The sampling procedure considers the level of agricultural activity in each stratum, and the size of the PSUs, known accurately from having been digitized earlier. After the sample of PSUs is selected, each selected PSU is identified on the appropriate frame map showing the PSU boundaries.
Digital Procedure	The same sampling procedure is used as the manual process, but PSUs are identified on the satellite images.

Function	Define segments in selected PSUs.
Manual Procedure	Boundaries of the selected PSUs shown on the frame maps are drawn on the large scale aerial photography.
Digital Procedure	Segments can be identified on imagery and digitized on the display device.

Function	Select ground sample segments.

Manual Procedure — Segments in selected PSUs are drawn and labelled, then a sample of segments is selected using a table of random numbers.

Digital Procedure — Segments are drawn on the screen; selection of sample segments may be the same as the manual procedure or a new selection algorithm may be used.

Function — Generate hardcopy.

Manual Procedure — Segment boundaries are transferred by hand to large scale aerial photography.

Digital Procedure — Generate an image from TM data showing segment TM data in and around the segment, segment boundaries and relevant DLG data. The DLG data will assist the enumerator locate the correct fields on the ground.

The transfer of ground sample segment boundaries to aerial photography completes the work of the Area Frame Section staff. The photographs are taken into the field by enumerators during the June Enumerative Survey (the primary data gathering event for NASS), and field boundaries are drawn in. The fields are then digitized on a tablet. With the digital procedure, the segments will have been partially digitized already, and the function of the enumerator may change to confirming field boundaries rather than drawing them in.

Development

The development of the project will proceed in five interrelated stages:

1. evaluate stratification data options
2. determine software specifications and construction methodology
3. evaluate commercial and in-house software and write extensions as required for the methodology
4. test software and systems
5. implement operational procedure

Development will occur within the general considerations of producing software that is easy to learn and easy to use for the benefit of the intended users, the Area Frame Section.

To assure that the procedure will meet the functional and performance requirements, an iterative approach will be taken in which the users will be fully involved in the software development. New software and systems will be submitted to and tested by the users, leading, as necessary, to modification prior to implementation.

Essential details concerning the system development and evaluation are provided in the Technical Plan section, following.

Technical Plan

The objectives of this project will be met through a three year plan. The plan reflects the present state of the project and the iterative nature of the approach.

Year 1 — Developing the methodology and technology - testing existing PEDITOR software and evaluating commercial systems.

The Area Frame Section will become familiar with the current PEDITOR software and the image display system. The MIDAS image display system and workstation has been moved to the AFS offices. A study area consisting of three counties in Missouri has been chosen, and the necessary TM and digital map data has been procured. AFS staff will experiment with the system and the data sources. In consultation with SRB, AFS will solidify the methodology for computer-assisted area frame construction.

Concurrent with this development, a survey of commercial software packages will be made by SRB and ECOSAT, and the adequacy of these packages for this application will be assessed. Commercial software will be evaluated by examining the documentation and by the AFS staff conducting tests at the vendors' sites, using test datasets and procedures developed by AFS using the Missouri study area. It is judged impractical to purchase any of these systems at this stage, due to the high cost. Commercial software will be evaluated on elements such as its ability to implement the emerging digital area frame methodology, its flexibility for establishing additional procedures required by AFS, and for setting up connections to the PEDITOR software, and its compatibility with the Sun computer platform in place in SRB and ECOSAT. The licensing and software update costs of commercial systems will be weighed against the cost of continued development of the in-house software. The costs of establishing the custom links to the commercial systems and preparing special software for particular requirements of AFS will also be considered.

The AFS staff, with SRB assistance, will conduct the pilot analysis of the Missouri study area with the current manual frame construction procedure proceeding in parallel. During this test, the AFS staff will more precisely define their requirements and identify the strengths and weakness of the computer-assisted approach. The testing is expected to be done on both the in-house and appropriate commercial systems.

To facilitate the development of the methodology, ECOSAT and SRB will make additions and modifications to the existing PEDITOR modules and user interface. Modifications of the current system will be reviewed in light of the current commercially available systems.

At the end of the first year, the decision will be made by AFS (consulting with SRB and ECOSAT) about the feasibility of the computer-assisted approach, because staff time, materials, and equipment costs will be known; and whether further development of extensions to PEDITOR is appropriate, or a a commercial package should be used. The benefits and costs of the approaches will have been identified and documented by the project participants, with data collected during the various system tests.

Year 2 — Beginning of implementation: procuring and establishing a pilot system.

If the decision is made to proceed, the required modifications to existing modules will be made, or the selected commercial package will be procured and enhancements to it will begin. As the software is modified and the system stabilizes, a full-scale operational test will be conducted of the frame construction of an entire state. Equipment and software enhancements will be identified by AFS that will be required for operational implementation. Information collected during this test will be used to prepare an implementation plan to be presented to NASS management concerning the decision whether or not to go operational with the system. Information available for this decision will include the statistical improvements to the frame quality, observations about the ease of updating and maintenance, and such costs as staff time, digital materials, and system maintenance.

Year 3 — Digital procedure will be brought on-line — manual procedure will be phased out.

The selected system (hardware and software) will be installed. The users of the system will be trained by ECOSAT, SRB and AFS staff. The methodology and procedures for implementing the methodology will be documented by SRB, ECOSAT and AFS, and provided to AFS for their continued use.

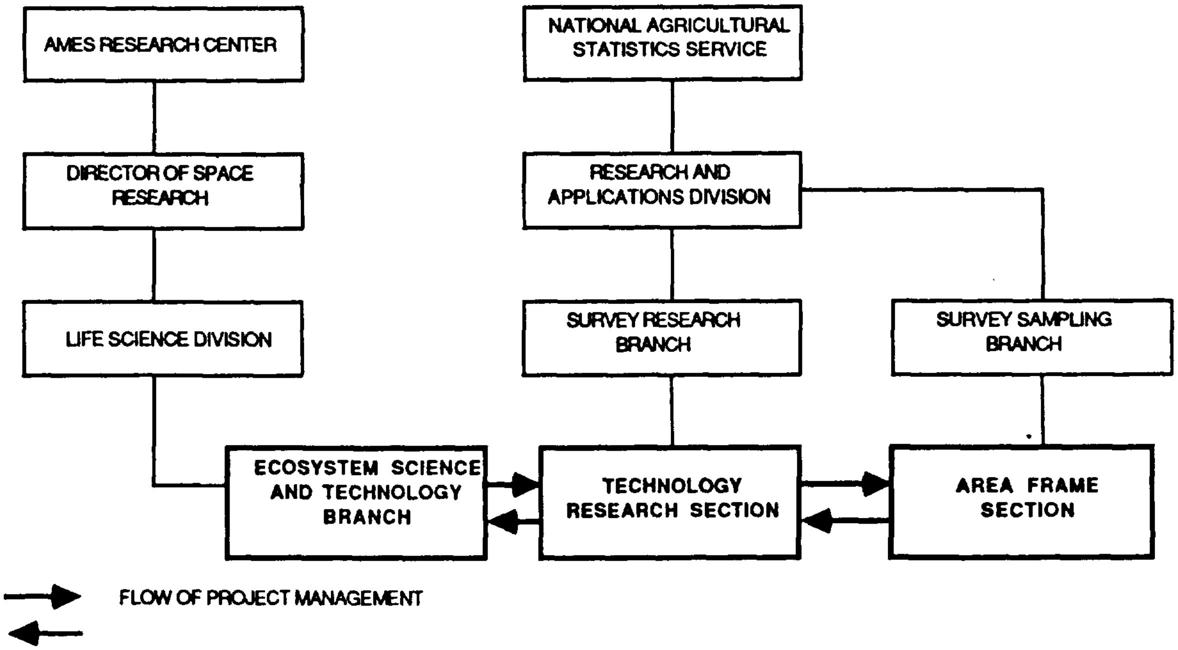
Many of the capabilities required for the system to meet the objectives as defined above have been identified and brought on-line under PEDITOR. Other requirements have been identified but have not been addressed. The list of requirements is expected to grow as users become acquainted with the system.

The existing requirements and capabilities of the system are outlined below (these are considered an essential starting point of a frame construction system):

Operational Requirement	Current PEDITOR Status
Read Landsat TM data from tape	Not available for workstations
Read DLG data from tape	Available for optional format; tested only on sample tape
Display TM data	On-line
Display DLG data	On-line
Register DLG data to Landsat TM on display	On-line
Shift displayed image	On-line
Image enhancements	Mapping functions on-line. Other enhancement options, e.g., principal components, ratio images, etc. needs unknown but capability probably required.
Boundary digitization	On-line for static image only, i.e. no capability to shift display and easily add more boundaries to a file.
PEDITOR file output	On-line

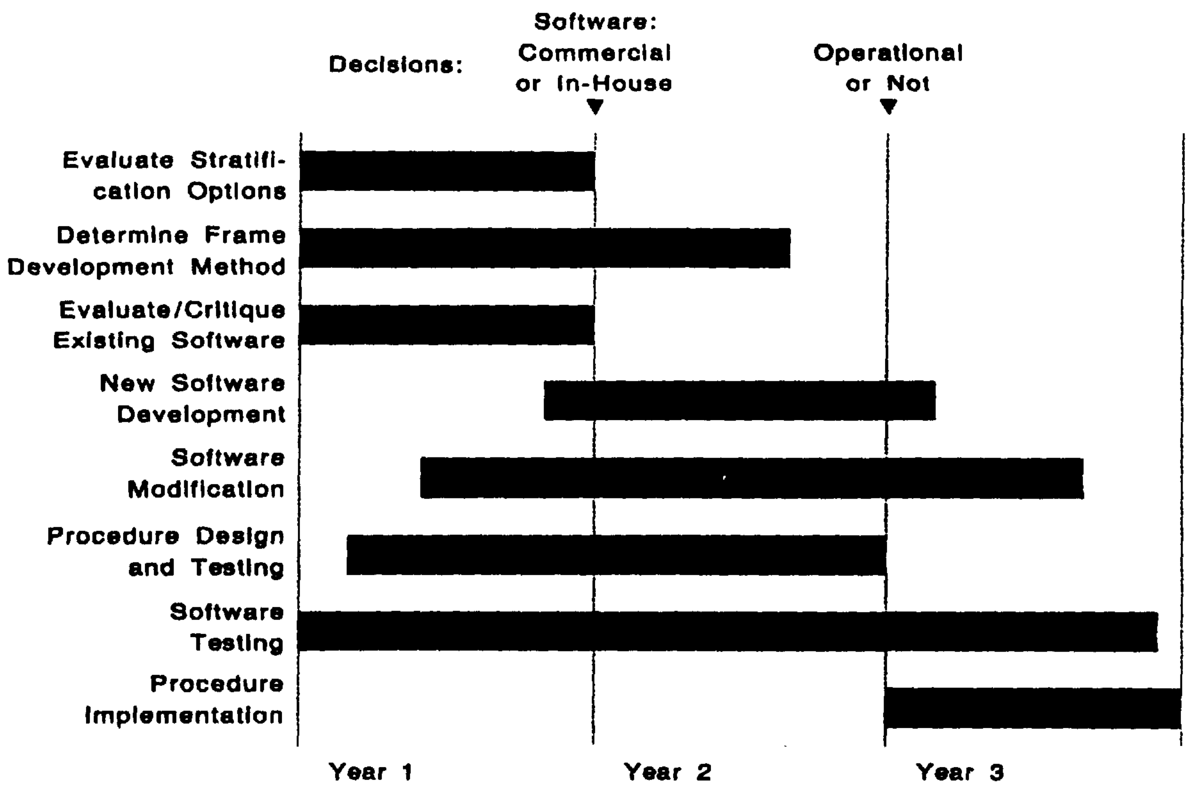
The area frame software package demonstrated in Washington in January 1987 is now available to the staff of the Area Frame Section. Comments and suggestions from the staff will serve as the basis for further development. Suggestions from the Area Frame Section will be channeled through the Survey Research Branch to ECOSAT (Figure 1). Input will be accepted regarding modification of existing functions, new functions, and design of the interface between the user and the system.

FIGURE 1. ORGANIZATIONAL CHART AND PROJECT MANAGEMENT



The schedule of major project activities is shown in Figure 2.

Figure 2 - Schedule of Project Tasks



Roles of the Cooperating Groups

The NASS Survey Sampling Branch (SSB), Area Frame Section, will be responsible for testing the elements of the procedure and implementation, consulting with the Survey Research Branch (SRB). The course of the project will be guided by these users of the technology.

SRB will be responsible for overall coordination of the project, and provide consultation on many technical issues. SRB will also provide software development assistance, documentation, and training as needed.

ECOSAT (NASA/Ames) will be responsible for the development of the technology. This includes responsibility for writing software as required and surveying commercial systems and hardware that can be adapted to the area frame methodology requirements.

There is further discussion of the work of each group in the Management Plan.

Anticipated Results and Implementation

Results and Benefits

At the end of the three year project the following results are expected:

- there will be a fully documented methodology and specific procedures for analysts to use in the construction and maintenance of area frames using digital satellite data and other digital materials;
- there will be a software system to implement the procedure; depending upon the outcome of the early stages of this project, the system will be based on either extensions to the NASS PEDITOR software or on commercial software with custom links to PEDITOR; and
- the new procedure will be fully operational in the NASS/SSB Area Frame Section, that is, the hardware and software systems will be procured, installed, operating, and documented, and the Section staff will be trained in the system's operation and use.

The following benefits are expected:

- many of the manual steps in the current procedure will be eliminated, reducing the number of errors;
- analysts will have better control over the design and construction of the frames;
- many of the subjective elements of the stratification process will be identified and removed;
- frames can be updated more frequently instead of being reconstructed from scratch at long intervals;
- digital data from previous surveys can be used to provide enhanced information during the identification of land-use areas;
- special-purpose frames for specific commodities or for certain geographical areas can be more easily constructed.

Since the area frame is central to the survey and remote sensing estimation work of NASS, improving the design and efficiency of the area frames means better and more efficient estimates of U.S. agricultural statistics.

Upon implementation of this system, NASS will purchase full-state Landsat and DLG coverage as each frame is built. For updating frames, satellite scenes of specific regions of interest will be purchased.

An additional benefit of this system is the availability of the image display and analysis capability to NASS and NASA remote sensing researchers and others.

User Involvement and Experience

Area Frame Section staff are involved in every step of the research and implementation. There is equipment on-site in the AFS that enables them to evaluate current and proposed frame construction methodologies. Their staff has frequent contact with staff in SRB and ECOSAT. The design of the project guarantees that the product meets the needs of the recipient. The recipient of this new technology, the Area Frame Section, determines the needs and is the prime motivator of the progress of the research work.

The Area Frame Section has used satellite imagery extensively for area frame development (Cotter and Nealon, 1987), and has acquired considerable experience in interpreting these images. The staff has had long experience using computer digitizing equipment and has used UNIX-based computers since 1984. They are well capable of absorbing the new technology into their operations.

Implementation

Implementation of the proposed research system proceeds as follows:

At the end of Year 1, both commercial software and extensions to PEDITOR will have been evaluated as systems for the emerging digital area-frame construction methodology. The benefits and costs of the approaches will have been identified and documented by the project participants, with SRB leading. The decision to proceed with which system will be made by AFS, consulting with SRB and ECOSAT.

At the end of the second year of this project, (1) a digital area frame construction methodology will be established and documented; (2) specific hardware and software will have been selected and tested; and (3) procedures for using this system to implement the area frame construction methodology will be documented. Testing will have revealed benefits and costs to NASS management (documented in the implementation plan written by SRB and AFS consulting with ECOSAT at the end of Year 2). A decision to go operational with the system will lead to procurement, installation, and use of the system by its recipients, the Area Frame Section. AFS staff will begin the transition by becoming trained by SRB and their own staff, in the new system, and reducing the role of the manual approach. Because of the high level of involvement by the AFS in this project, acceptance of the technology is assured.

Management Plan

The project will operate with the following personnel:

Team Member	Affiliation	% Time	Responsibilities
George Hanuschak	NASS-SRB[1]	5	Principal Investigator
Brian Carney	NASS-SRB[1]	15	Co-Investigator
Martin Holko	NASS-SRB[1]	15	
Mary Ann Ciuffini	NASS-SRB[1]	15	
Stan Mason	NASS-SRB[1]	20	
James Cotter	NASS-SSB[2]	15	Co-Investigator
Yvonne Dodson	NASS-SSB[2]	20	
William Bour	NASS-SSB[2]	20	
Jennifer E. Gallegos	NASS-SSB[2]	20	
Gary Angelici	Sterling Software[3]	50	Software Development
Edwin Sheffner	TGS Technology, Inc.[3]	75	Project Management-ECOSAT
Robert Slye	NASA-ECOSAT[4]	50	Software Development
TBD Technician	TGS Technology, Inc.[3]	100	Software Development

[1]National Agricultural Statistics Service — Survey Research Branch
[2]National Agricultural Statistics Service — Survey Sampling Branch
[3]Contractor at ECOSAT
[4]Ames Research Center — Ecosystem Science and Technology Branch

Figure 1 of the previous section shows the relevant parts of the organizational charts for NASS and Ames Research Center and the Management/Information flow for the project.

The three organizational units (ECOSAT, Survey Research Branch, and Area Frame Section) will have the responsibilities listed below.

Unit	Responsibilities
Technology Research Section (Survey Research Branch)	1. Project Coordination 2. Research goals and techniques (with ECOSAT) 3. Software development (secondary route) 4. Hardware operations 5. Testing coordination 6. Program evaluation 7. System training 8. Implementation
Area Frame Section (Survey Sampling Branch)	1. System testing and evaluation 2. System specification 3. Implementation
ECOSAT (NASA-AMES)	1. System design 2. Software development a) modules b) interface 3. System documentation 4. Analyst training

The facilities and capabilities available to the team from ECOSAT are described in Appendix A. Those available from NASS are described in Appendix B.

The history of cooperation between ECOSAT and the Survey Research Branch of NASS was described in the Introduction. The two organizations have demonstrated their ability to work together effectively, and continued support by NASS of research at ECOSAT indicates satisfaction with the work performed there.

Co-Funding (3 Years)
FUNDING REQUIREMENTS BREAKDOWN

COST CATEGORY	Totals per Cost Category ($Amount/%Total)	NASA Requirement ($Amount/%Total)	Funding Organization NASS ($Amount/%Total)
a. Direct Labor	603000.00/56.4	135000.00/30.3	468000.00/75.0
b. Overhead	64800.00/6.1	21600.00/4.8	43200.00/6.9
c. Materials	305000.00/28.5	254000.00/56.9	51000.00/8.2
d. Travel	26000.00/2.4	6000.00/1.3	20000.00/3.2
e. Other Costs	29964.00/2.8	12498.00/2.8	17466.00/2.8
f. G&A	41150.56/3.9	17163.92/3.9	23986.64/3.9
Cost Summary (Totals)	1069914.56	446261.92	623652.64

NASS DIRECT CONTRIBUTION TO ECOSAT: $150,000 EACH OF THREE YEARS, TOTAL $450,000.

	YEAR 1		YEAR 2		YEAR 3	
	NASA	NASS	NASA	NASS	NASA	NASS
1. Direct Labor(% time)						
Hanuschak-1		3.75(5)		3.75(5)		3.75(5)
Carney-1		9.38(15)		9.38(15)		9.38(15)
Holko-1		8.44(15)		8.44(15)		8.44(15)
Cuiffini-1		6.75(15)		6.75(15)		6.75(15)
Mason-1		6.25(20)		6.25(20)		6.25(20)
Cotter-2		8.44(15)		8.44(15)		8.44(15)
Dodson-2		6.00(20)		6.00(20)		6.00(20)
Bour-2		4.50(20)		4.50(20)		4.50(20)
Gallegos-2		4.50(20)		4.50(20)		4.50(20)
Sheffner-3		42.00(75)		42.00(75)		42.00(75)
Angelici-4		28.00(50)		28.00(50)		28.00(50)
Slye-5		28.00(50)		28.00(50)		28.00(50)
TBD						
Technician-3	45.00(100)		45.00(100)		45.00(100)	
TOTAL	45.00	156.00	45.00	156.00	45.00	156.00

1=NASS/SRB   3=T[illegible]S Technolo[illegible] Inc:ECOSAT
[illegible]/SSP   [illegible] So[illegible]
5=NASA

	YEAR 1		YEAR 2		YEAR 3	
	NASA	NASS	NASA	NASS	NASA	NASS
2. Overhead						
Image peocessing Lab-ECOSAT	7.20	14.40	7.20	14.40	7.20	14.40
Total	7.20	14.40	7.20	14.40	7.20	14.40
3. Materials						
TM (no charge)						
DLG		12.00		12.00		12.00
Image processing-ECOSAT	8.00	5.00	8.00	5.00	8.00	5.00
SUN3/Displ	75.00		75.00		80.00	
Total	83.00	17.00	83.00	17.00	88.00	17.00
4. Travel						
Consultation	2.50	5.00	2.50	5.00	1.00	10.00
Documentation and training						
Total	2.50	5.00	2.50	5.00	1.00	10.00
5. Subtotal= 1+2+3+4	137.70	192.40	137.70	192.40	141.20	197.40
6. Other Costs= 3% of 5	4.13	5.77	4.13	5.77	4.24	5.92
7. Subtotal= 5+6	141.83	198.17	141.83	198.17	145.44	203.32
8. G&A= 4% of 7	5.67	7.93	5.67	7.93	5.82	8.13
9. TOTAL = 7+8	147.50	206.10	147.50	206.10	151.25	211.45