MANAGEMENT ISSUES OF INTEGRATING EARTH RESOURCE SATELLITE DATA INTO THE UNITED STATES DEPARTMENT OF AGRICULTURE'S DOMESTIC CROP-AREA ESTIMATION PROGRAM*

GEORGE A. HANUSCHAK
CHARLES E. CAUDILL

U.S. DEPARTMENT OF AGRICULTURE
STATISTICAL REPORTING SERVICE
STATISTICAL RESEARCH DIVISION

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ABSTRACT

Since the launch of the earth resources monitoring satellite, Landsat 1 in 1972, the Statistical Reporting Service (SRS) of the U.S. Department of Agriculture (USDA) has investigated and developed uses of this new technology for its domestic agricultural statistics program. SRS has expanded this investigation to applied research programs in seven states. This report focuses on the management practices used while incorporating this new technology into SRS. The report is a case description and does not necessarily fit any particular management theory or model.

I. BACKGROUND

SRS is an agency of the USDA with the legislated responsibility for estimating domestic crop production, livestock inventory, number and size of farms, agricultural prices and related agricultural statistics. The major statistical tools used are random sampling from list or area sampling frames and the appropriate statistical estimators. For selected sample units data are collected from farm operators using mailed questionnaires, personal interviews, and telephone interviews.

Since the launch of Landsat 1 in 1972, SRS has investigated the potential contribution of data from earth resource monitoring satellites to the SRS domestic crop area estimation program. The data from the Landsat satellites basically provide a set of measures of energy being reflected, emitted or absorbed by the earth's surface.[1] For approximately each acre on the earth's surface these energy measurements are recorded and transmitted in digital form to ground receiving stations. The data are then distributed in two basic forms. The forms are digital data recorded on computer compatible tapes and photographic-like products on paper or transparencies. SRS has developed uses for both types of products. The photo-like products are used to develop more up to date area sampling frames by providing more current land use patterns.[2,3] The digital data are used to develop more precise crop area estimates.[4,5,6] The energy readings for different crops such as corn, soybeans, wheat, oats, grain sorghum, rice, cotton, etc. are somewhat unique. However the satellite data by no means stands alone as a data source for crop area estimation. The satellite data is used as a supplement to the SRS ground-gathered data.[7] The value of the Landsat data to SRS depends heavily on

(1) the timing of the satellite coverage (2) the extent of cloud cover (3) the rapid delivery of Landsat products to SRS and (4) the cost of Landsat products to SRS and other users of the data.

There are numerous reports written by SRS on these topics and no further detailed reporting on methodology will be given in this paper. The focus of this paper will be the management issues associated with incorporating this new technology into the SRS research program.

II. PROJECT MANAGEMENT

The management of the Remote Sensing Program (RSP) will be the focus of this portion of the paper and will be divided into six major categories: (1) personnel (2) data processing and telecommunications (3) internal and external communications and linkages (4) organizational structure (5) project plans and implementation schedules and (6) financial. In some management literature a different ordering might be found. There are several reasons for the ordering of management categories in the RSP. The first reason is common to most high technology efforts and that is the need for specific personnel that are willing to learn and apply new knowledge, skills and abilities. Secondly, the need for state of the art data processing and telecommunications is also essential for high technology projects. Thirdly, the RSP is a public program without a profit incentive.

A. PERSONNEL MANAGEMENT

Concerning personnel, the original staff in 1972-73 consisted of one supervisory mathematical statistician, three mathematical statisticians, one survey

statistician, one systems analyst/programmer and secretary. None of the staff had any prior formal training in remote sensing techniques or software to analyze satellite data. There was some prior experience gained from aircraft remote sensing projects in the late sixties. We believe that the first group possessed several desirable characteristics that have become somewhat of a "tradition" for the RSP. These characteristics were:

(1) a supervisor with strong technical and interpersonal skills

(2) a staff with strong technical skills

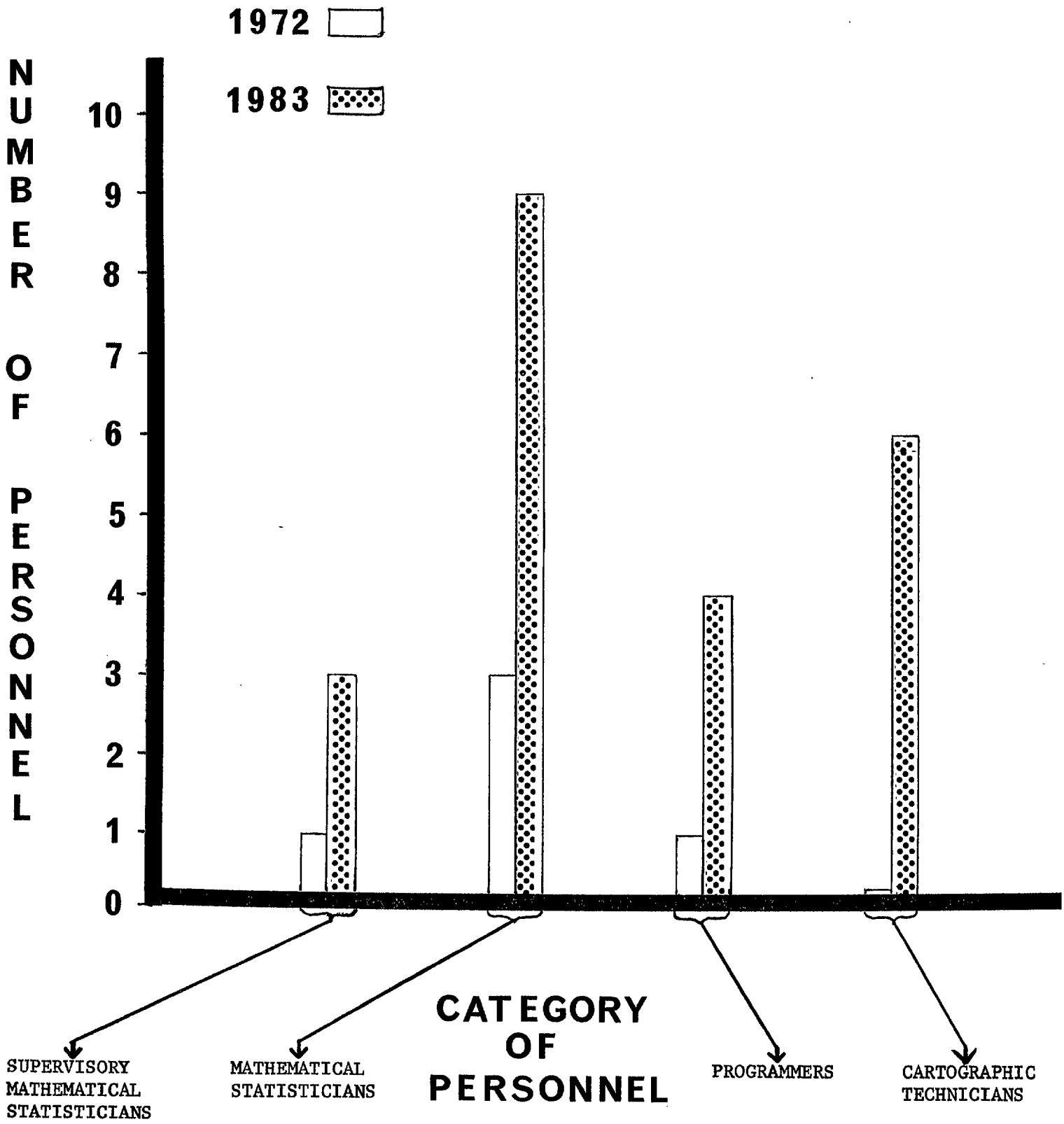
(3) a staff willing to work as a team

(4) a staff willing to learn and apply new knowledge, skills and abilities through formal and on the job training.

(5) a staff with the knowledge of the Agency mission enabling them to direct the research to productive and useful products.

By comparison, in 1983, the staff consists of three supervisory mathematical statisticians, three secretaries, nine mathematical statisticians, four system analysts/programmers, six cartographic technicians, one survey statistician, and one agricultural statistician/remote sensing analyst. (See Figure 1) In addition, there are now several State Statistical Offices with part time cartographic technicians. We believe that the current staff possesses those five traditional characteristics of the original staff.

FIGURE 1. RSP PERSONNEL: 1972 VERSUS 1983



The six cartographic technicians now operate digitizing *tablets, network terminals, printers, plotters, video digitizing equipment and microcomputers. Most of the cartographic technicians were formerly statistical clerks or had manual mapping assignments. They were trained to operate the new electronic equipment by the statisticians and ADP analysts through on the job training. As a result the jobs of these personnel were enhanced to utilize their new knowledge, skills and abilities. As the RSP developed over time, the enhancement was continued with the addition of new responsibilities such as registering the satellite data to a map base and additional control over their work. This gradual vertical job enhancement[8,9] has also made the RSP more efficient since tasks once performed by research statisticians and ADP analysts can now be performed by cartographic technicians.

As noted by Dennis Lee and Thomas Allen, there are three general ways in which the technical staff of an R&D organization can stay informed concerning technological and scientific developments outside of the organization.[10] These are:

(1) through readership of the scientific and engineering literature and other forms of documentation.

(2) through contact directly or indirectly with knowledgeable individuals, outside of the organization.

(3) through hiring and assimilation of new technically trained personnel.

In the RSP program all three of these methods have been used. Lee and Allen also make the point that well trained technical personnel bring with them a wealth

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*Digitizing - The process of electronically recording points from a two dimensional X, Y coordinate system. In this context, the process is used to define crop field boundaries (polygons) in terms of latitude and longitude.

of knowledge, skills, and abilities but it will not be very useful unless it is successfully incorporated into the ongoing work of the organization. Even though the RSP program uses new high technology input products it does create an output product that the operational program of SRS is quite familiar with--a crop-area estimate with an estimated precision. RSP researchers have been cognizant of the point made by Lee and Allen that new technology efforts are often more successful when they can be incorporated into the ongoing work of the organization.

B. DATA PROCESSING AND TELECOMMUNICATIONS MANAGEMENT

The second major category of management concern for the RSP is data processing and telecommunications. For the RSP, there were three key requirements: (1) central processing unit and storage capabilities of a supercomputer facility (ILLIAC-IV in 1970's, CRAY-1S or CDC Cyber 205 in early 1980's) (2) reliable telecommunications link(s) to all RSP data processing sites and (3) software to analyze satellite and ground-gathered data jointly. Scientific supercomputers are necessary since one scene (13,000 sq. miles) of satellite data contains 10,500,000 data points and 42,000,000 observations and somewhat complex algorithms are used to analyze the data. Since SRS did not possess such data processing facilities, several external cooperators were involved in setting up the required data processing for the RSP. In addition to the SRS-RSP staff the cooperators were, the Center for Advanced Computation (CAC) at the University of Illinois, Purdue University's Laboratory for the Applications of Remote Sensing (LARS), the U.S. Geological Survey (USGS) of the Department of Interior, the private company Bolt, Beranek and Newman (BBN), the Department of Defense, and the National Aeronautics and Space Administration (NASA). All six partners contributed to the initial data processing efforts in 1974 - 1976 to develop a hardware and software system to analyze Landsat data for SRS and USGS purposes.

Data files and messages were transmitted via the ARPANET. ARPANET is a high speed telecommunications network operated by the Department of Defense. Major computer hardware was acquired by NASA and through BBN. NASA provided the ILLIAC IV supercomputer which was used to process full Landsat scenes. The DEC-10 minicomputers at BBN were used to process Landsat data just for the small area sampled on the ground. SRS purchased digitizers, plotters, data terminals and more recently microcomputers, a minicomputer and video scanning equipment to analyze the ground-gathered and Landsat data. LARS provided the initial software which was restructured for SRS and USGS purposes by CAC.[11]

Thus in the area of data processing and telecommunications, the identification of skilled cooperators and organizational committments among the cooperators was an essential personnel management issue. This need for cooperative external linkage for several management categories will be outlined further in the next section.

C. INTERNAL AND EXTERNAL COMMUNICATIONS AND LINKAGES

One of the key ingredients in the RSP project was the managerial role as linchpin to the operational units of SRS and several scientific groups outside the Agency. In the initial project period, this linkage to the external organizations such as NASA, USGS, CAC, BBN and Purdue University's LARS was a critical project role. SRS did not possess all the knowledge, skills, abilities, computer equipment and software to analyze satellite data. Figure 2 shows the major external linkages of the RSP.

Strong relationships between personnel and institutional committments were necessary to share knowledge and equipment to jointly analyze the satellite data and SRS ground gathered data. The joint efforts of several organizations turned

the RSP project into a reality. Some key characteristics of this joint effort over the years were:

(1) Roles and responsibilities of the various groups were clearly defined.

(2) The groups maintained flexibility in reacting to changes in the RSP or other organization changes.

(3) A relatively small number of personnel in each organization were given assignments with quite traceable responsibilities.

(4) Basically non-overlapping responsibilities and skill areas were assigned to the different groups.

(5) A multi-disciplinary team approach was used.

(6) The groups maintained flexibility to change roles if hardware, software or telecommunications efficiency dictated a change.

(7) Reliable measures of success were used for output products.

During the initial period of research (1972-1977) inside SRS, the liaison role with other operational SRS units was important but not yet at a critical stage. Since the 1978 Iowa project, which was the first operational demonstration of the technology, close linkage with the other operational work units of SRS has become a critical role for RSP management and management of the other work units.

Figure 3 shows the SRS work units involved in the RSP. During the period of applications (since 1978), the linkage between these units has increased concerning the RSP. Some key characteristics of the linkage have been:

(1) SRS top management backed and supported the RSP.

(2) RSP staff established the initial communications link between the RSP and other operational units.

(3) The philosophies of the incumbent managers and workers of both

the operational units and the RSP about the new technology and its value can affect the link.

(4) The team association is increasing but the linkage is still delicate and in its infancy.

(5) The output product is understood both by the RSB staff and operational staff.

FIGURE 2. CURRENT EXTERNAL SRS RSP ENVIRONMENT

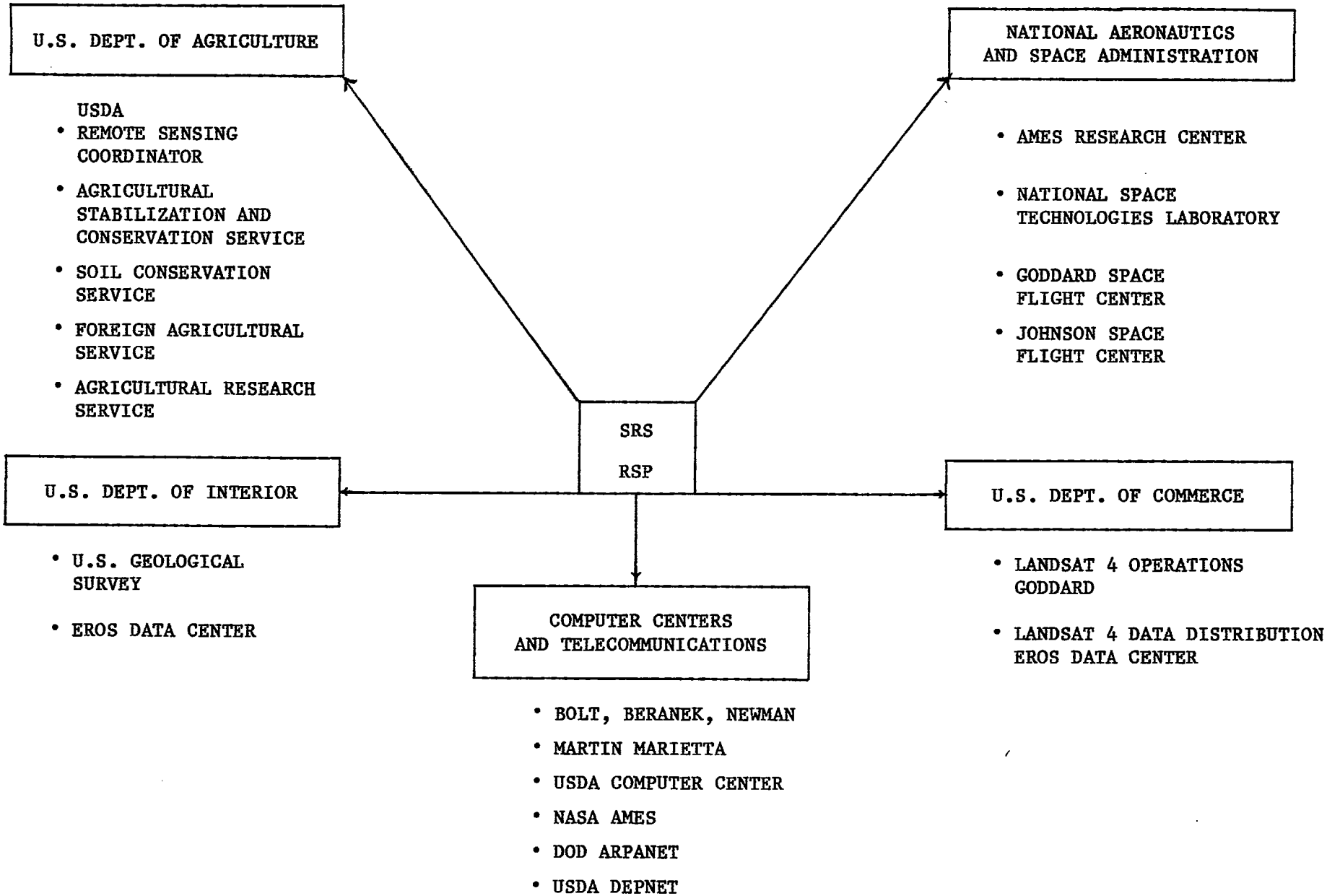
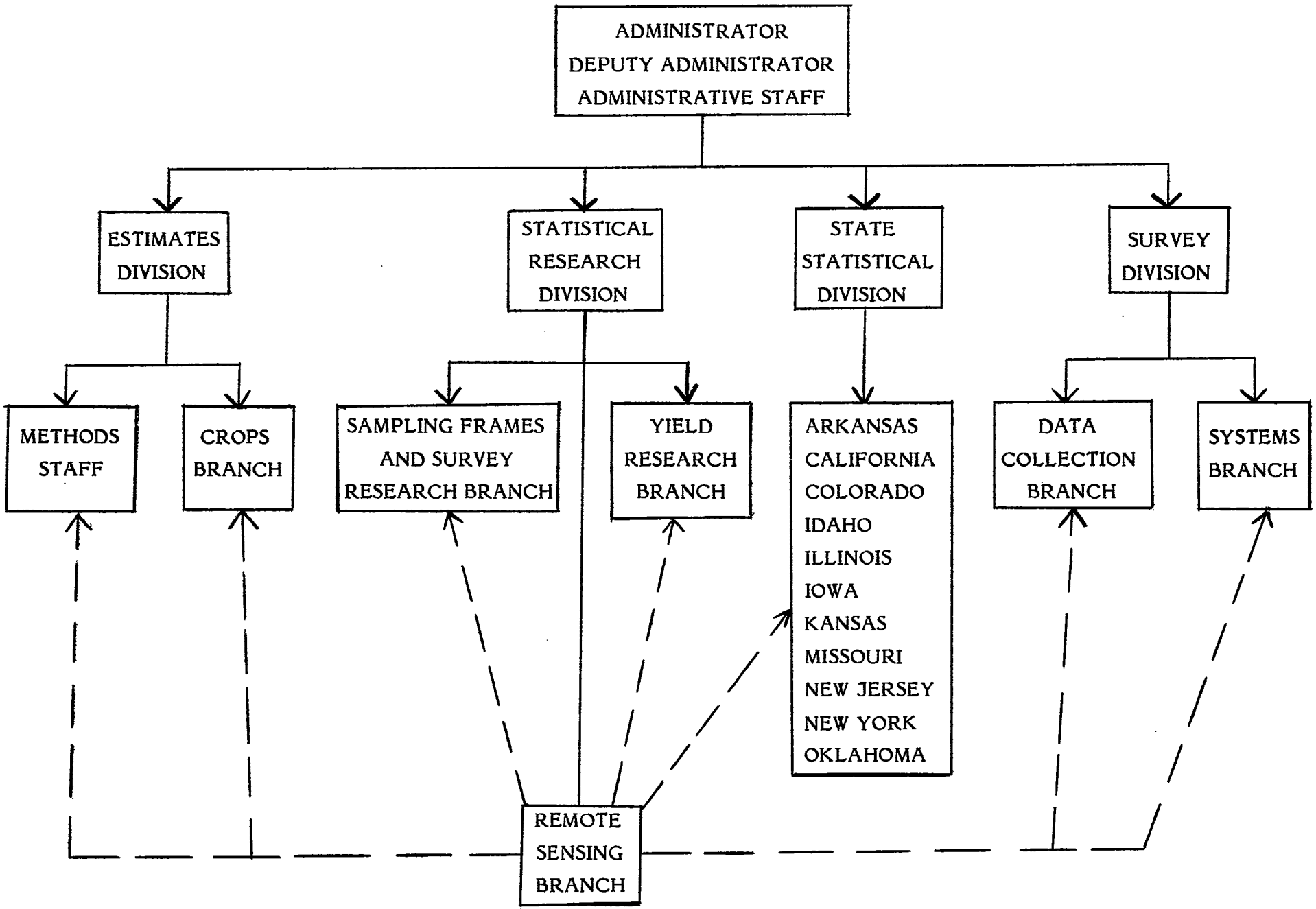


FIGURE 3. INTERNAL SRS RSP ENVIRONMENT



D. ORGANIZATIONAL STRUCTURE

The organizational structure for the RSP can be divided into two major periods. These periods are: (1) the initial period of research and development (1972-1977) and (2) the second period (1978-1983) which consists of both large scale applications and continuing research and development on data processing, data from new sensors, methodology and land cover applications.

During the initial period there was one research and development section. Since this period was a frontier period, the structure was quite informal in the section. There were many brainstorming sessions where statisticians or support personnel often had as much input as the formal managers. Many alternative methods were recommended and researched over a seven year period. The best alternative paths at the time were selected and in 1978 a timely large scale application demonstration was completed, using the entire state of Iowa. After the Iowa project there was a change in the organizational structure. There was now a perceived need for two groups. One group to continue R&D and another group to design and implement large scale applications. The reorganization coincided with a major new U.S. Department of Agriculture remote sensing research program and was designed to suit both agency and departmental objectives.[12] So in 1979 the Branch was divided into two sections. However, strong communication lines remained so that new research ideas that were tested and proven were rather immediately applied in the large scale application projects. Over time the two Sections have developed individual identities but have remembered the common longer range goals.

E. PROJECT PLANNING AND IMPLEMENTATION SCHEDULES

Similar to organizational structure, project planning tools required were different for the two periods.

For the initial period, broad project assignments and time frames, were given with considerable room for creativity and methodology development.

For the second period of large scale applications and continued R&D, a multiple approach was used. For the R&D projects the tools used were the continuation of the broad project assignments as well as some detailed objectives. However for the applications projects, considerably more detailed planning tools were necessary. The planning documents included detailed project assignments, awareness of the interaction between assignments, and strict time schedules and ADP standards.[13]

F. FINANCIAL MANAGEMENT

The last major category of RSP management was financial management. The RSP financial management was accomplished using the already established USDA/SRS financial management tools. Major tools were: (1) Budget procedures of the Executive Branch and Congress that allowed funds to be requested and appropriated (2) U.S. Government salary and fringe benefit packages (3) U.S. Government equipment and space procurement regulations and procedures (4) Cooperative agreements with other government agencies such as NASA and USGS and (5) Competetive contracts with private companies such as BBN. In 1973 the funding level for RSB was $500,000. After the technology was proven feasible, then large scale applications were conducted. In 1983 the current level of funding is three million dollars.

The success in increasing the budget for this program is attributable to two factors. First was the use of available financial management tools by an interagency and interdisciplinary team in developing an overall program plan as well as annual implementation plans. Second was the previous positive research

results which clearly demonstrated the possibility of making this technology cost-effective. Use of the appropriate financial management techniques were extremely beneficial in obtaining the best mix of in-house resources with those obtainable through contracts and cooperative agreements. Restrictions imposed by Government regulations, such as personnel ceilings, were able to be overcome through judicious use of these vehicles, to obtain needed skills and abilities for successful staffing of the interdisciplinary team required for this program to be successful. Use of the automated financial management systems available within the Statistical Reporting Service (Administrative Records System) and the Department of Agriculture (National Finance Center) were important in record keeping through which we were able to document improvements in cost-effectiveness of the developing technology.

III. LOOK TO THE FUTURE

Assuming that at least one earth resource monitoring satellite is functional, the RSP management concerns and major future goals will be to (1) maintain and develop staff skill level (2) maintain and build on the team approach and cooperation (3) continue research on improved methodology and new satellite data sources and (4) maintain current ADP capabilities and also seek out new state of the art hardware, software, peripherals and telecommunications that are cost effective improvements in the RSP results - timely and precise crop area estimates.

Concerning organizational structure and project planning, there are two distinct possible structures in the forseeable future. The present structure or a new structure that would allow for an operational RSP and also continued R&D. The new structure and plans are yet to be completely determined but we are close

to recommending a structure if SRS decides to go operational with its RSP. At the present, the risk seems too great for SRS to go operational. The Landsat satellite data system currently has only one satellite and has not proven reliable enough for producing cost effective improvements in crop area estimates. With two satellites and a rapid data delivery system, an operational system would be feasible.

Concerning external linkages, the RSP will give a maximum effort to maintain current organizational relationships as well as develop new ones. The status of the President's proposal to sell the U.S. Government land and weather satellites to the private sector could create the need for a critical new linkage. The SRS-RSP would need to develop relationships with the company or companies responsible for the satellite data. This concept certainly is not a problem for the SRS-RSP as long as the satellite data can be obtained in a timely fashion and at an affordable price.

IV. CONCLUSIONS

This case describes the management practices used to incorporate satellite data into the SRS domestic crop area estimation program. It should be useful to developers of management theories and models. A case description does not provide any inference capability but often provides ideas for detailed hypothesis testing for specific management theories and models.

V. ACKNOWLEDGEMENTS

The authors are but two of several managers involved in the RSP. We owe considerable thanks to the other managers for their fine contributions and

inspirations to the RSP for the last decade. Among those managers are William Kibler, Donald Von Steen, Harold Huddleston, Galen Hart, William Wigton, Rich Allen, Richard Sigman and William Pratt. Certainly, key resource people have been all current and former members of the RSP as well as the other SRS units and other organizations listed in Figures 2 and 3.

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