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Integrated Use of Landsat Data for State Resource Management

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Contents

Errata

Figure 1, page 3, should have indicated that Iowa and South Carolina have state environmental resource information systems under development rather than operational.

Foreword

State government responsibility for natural resource management and environmental protection has precipitated an acute awareness of the need for reliable information upon which to base management decisions. Challenged with establishing mechanisms to compile volumes of dispersed and oftentimes nonexistent data, many states have built computerized systems and experimented with new technologies to meet their information requirements. The computerized approach to environmental and natural resource data management marks a popular trend and one which many states are finding to be an absolute necessity.

The federal government has played a major role in promoting the development of resource information systems at the state level. Valuable new data-gathering and analysis techniques have been disseminated through research, training, and demonstration programs. This report highlights the efforts of states and the federal government to better utilize an innovative data source within the context of resource management--satellite remote sensing data. Recommendations focus on the cooperation required to ensure that progress continues toward the construction of effective decisionmaking tools.

Lexington, Kentucky
November 1979

William J. Page, Jr.
Executive Director
The Council of State Governments

Preface

Management of natural resources and the environment has reached a level of sophistication in many states that requires the use of computers to assist in carrying out agency responsibilities and to cope with the volume of data necessary for informed decisionmaking. In the past 10 years, the development of computer-assisted resource management tools in state government accelerated from near zero to 16 states with a centralized automated data bank. Ten more states are currently in the advanced design phase, while still others have performed feasibility studies.

As the fifth research report in the Council of State Governments' series on environmental resource data-related issues and problems, this publication focuses on institutional trends in the development of computer-based systems for natural resource information management. Specifically, the study concentrates on the integration of satellite remote sensing data into state environmental and natural resource information systems. Efforts by the National Aeronautics and Space Administration (NASA) to increase the use of the data by states and the attitudes of state officials toward the effectiveness of these technology transfer programs are discussed. Another component of the report is an examination of state experiences with universities and the private sector in building satellite-derived data analysis capabilities.

The appendix to this report contains case study summaries based on visits to state environmental resource information system offices. The comments of Mike Castro of Arizona, Dave Ferguson of Texas, Rich Giddings of North Dakota, and Bruce Rado of Georgia are gratefully acknowledged.

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Associate Director
for Environmental Resources

Introduction

Computerized techniques are widely used by state governments in the management of environmental and natural resources information. These automated approaches to information handling are given various titles. Most often they are referred to as a "data-base" or an "information system." More than likely their names contain the words "geographic," "resource," "land resource," or "natural resource." All have two basic characteristics: they are spatial and relate to specific locational or geographic coordinates, and they are automated, which means that electronic data processing is used to store and manipulate the data elements. This report deals with spatially-oriented, automated data bases for resource management.<1>

In this report, the term "information system" and several interchangeable descriptive identifiers are employed to characterize computerized techniques which produce text, tabular, and mapped data. However, technical capabilities must be developed, maintained, and directed in a manner that provides services necessary to the user. Therefore, an information system should be considered to also include the program office, division, or unit which manages the resource information system.

This study places emphasis on the integration of a particular information resource--data from the earth orbiting satellite known as Landsat--with alternate forms of data to structure a state resource data base.

Chapter 1 provides an overview of current state activity in the development of resource information systems. Factors such as organizational setting, cooperative arrangements, computer hardware trends, user needs, and financing are discussed.

State use of Landsat data within a comprehensive resource management scheme is examined in Chapter 2. It focuses on the attention given Landsat analysis capability in state resource information system development and the continued use of satellite-derived data based upon case studies conducted in four states: Arizona, Georgia, North Dakota, and Texas. A review of these case studies is contained in the appendix.

Chapter 3 examines the efforts of NASA--the agency responsible for the development and operation of the Landsat program--in the transfer of this new space technology to state resource management applications. A summary of state participation in NASA-sponsored technology transfer programs is presented, along with a discussion of the effect that these demonstrations have toward institutionalizing satellite remote sensing data into programmatic uses. The promotion of computerized techniques for resource management by other federal agencies is also addressed.

The role two nongovernmental sectors, universities and private industry, play in assisting states to develop Landsat data analysis capability is described in Chapter 4. The extent to which university staff and facilities and private vendors are involved in establishing satellite-derived data as a tool for resource management varies from state to state. Therefore, viewpoints of state officials in defining appropriate interaction with universities and the private sector are presented.

Chapter 5 is a summary of findings and recommendations.

1. State Environmental Resource Information Systems

There appears to be no model approach to the development of state environmental and natural resource information systems. Differences exist in the locational setting, organizational structure, user services, relationship to universities and local governments, technical capabilities, and focus. In short, resource information systems are as diverse as the states in which they operate. This lack of commonality makes the preparation of a "how-to" manual for the development of resource information systems a difficult task, although there have been several notable attempts.<2> This diversity also means that an analysis of the current state-of-the-art in system development would be difficult. However, without claiming to be either comprehensive or technical in nature, this chapter seeks to present an overview of state resource information systems.

Through a survey of state officials, a study of recent literature, and information compiled by the National Conference of State Legislatures, resource information systems were identified in 16 states. At least 10 other states are at various stages of system design or preliminary implementation. (See Figure 1.) Computerized data bases for specific resource programs (i.e., water quality, air pollution, or wildlife management) are not considered in this evaluation. These individualized data systems deal with only a single element of a state's total resource management program and, in the absence of a coordinating mechanism, lack the focus sought by this report. Neither does the use of a state's central computing facilities for administrative aspects of resource management meet the criteria of an information system.

ESTABLISHMENT OF INFORMATION SYSTEMS

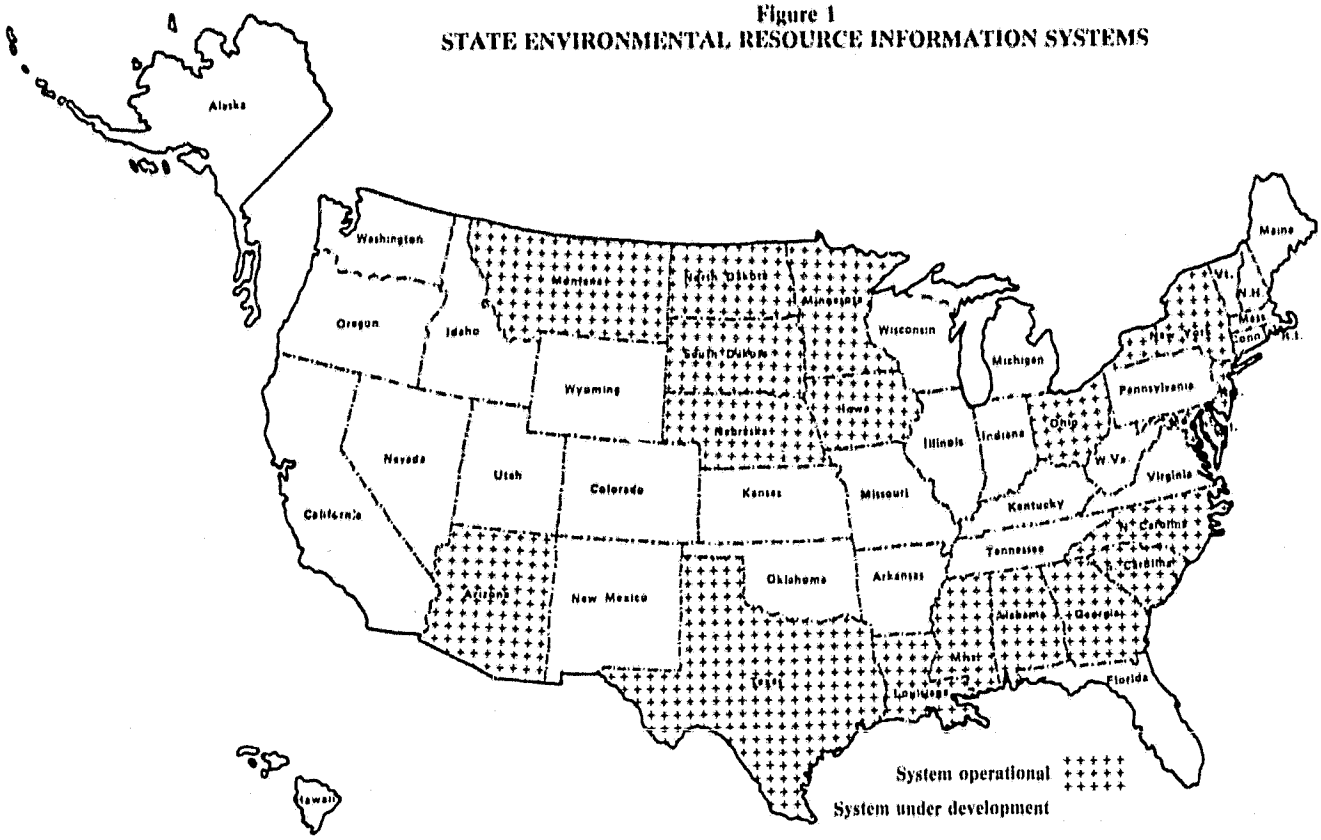
Resource information system development is a recent phenomenon. Aside from the establishment of New York's Land Use and Natural Resource System (LUNR) in 1966, all other systems have been initiated within the last 10 years, the majority since the mid-1970s. Reasons for the establishment of these systems vary.

Information systems for resource data management may grow out of a crisis situation within a state. The Texas Natural Resource Information System (TNRIS) evolved from the Texas Water-Oriented Data Bank, established after a period of severe drought followed by heavy flooding in the 1960s. The energy crisis of the early 1970s made possible massive coal-related development in North Dakota, which led to the establishment of the Regional Environmental Assessment Program (REAP).

Systems are commonly established to serve a single purpose or fulfill a specific program's data requirements. Maryland's Automated Geographic Information System (MAGI) was originally developed to assist in preparation of a state land use plan. The New Jersey Geographic Base File was established in response to a need for water quality data. Other systems were designed to conduct statewide natural resource inventories.

Also varied are methods of establishment. Several information systems were established or approved by formal legislative action. Arizona, Nebraska, and South Dakota, among others, have enacted laws which describe the mission of their resource management systems. The North Dakota Regional Environmental Assessment Program was established by the legislature in 1975. Legislative consideration of several information systems currently in the design phase is expected in the 1980 sessions.

Figure 1
STATE ENVIRONMENTAL RESOURCE INFORMATION SYSTEMS



Governors have also been instrumental in promoting information system development in several states. In at least one instance, gubernatorial veto terminated an operating system. Such was the case in North Dakota when REAP's funding for the fiscal 1980-81 biennium was vetoed by the governor.

Universities have not only participated in the development of the more long-standing LUNR, MAGI, and Minnesota's Land Management Information System (MLMIS), but university personnel and facilities also figured prominently in establishing systems in Alabama, Mississippi, and North Dakota, among others.

ORGANIZATIONAL SETTING

Trends in location of the information system within state government are recognizable. Table 1 shows that the organizational setting for system operation is divided between the state planning agency (seven states) and the natural resource agency (six states). Other institutional arrangements were established in Mississippi, New York, and North Dakota. The university research center provides a setting for natural resource information management in Mississippi. In New York, the Department of Commerce is responsible for LUNR. North Dakota's Regional Environmental Assessment Program was unique in its placement as a research arm of the legislature.

Table 1
ORGANIZATIONAL SETTING FOR STATE RESOURCE INFORMATION SYSTEMS

State Planning Office	*Natural Resource Agency*	*Other*
Alabama	Arizona	Mississippi—University Research Center
Louisiana	Georgia	New York—Commerce Department
Maryland	Nebraska	North Dakota—Legislative Branch (a)
Minnesota	North Carolina	
Montana	Ohio	
New Jersey	Texas	
South Dakota		

(a) North Dakota Regional Environmental Assessment Program was terminated on June 30, 1979.

COMPUTER HARDWARE TRENDS

Another noticable trend is in the acquisition of computer equipment. More recently established resource information systems favor the purchase of minicomputers because of their relatively low cost and flexibility in operation. Other systems are converting portions of their operations to minicomputers to avoid problems experienced in accessing large computers used by central state processing units. Oftentimes, the resource information system must compete with a variety of higher-priority tasks (i.e., budgets and payroll) for a limited amount of computer time. Interactive systems (those requiring continuous communication between user and computer) are hampered by the unavailability of computer time.

USER NEEDS

User needs are being taken into consideration by system designers and operators--a direction being pursued by states. Many systems, such as those in Arizona and Texas, provide facilities for public and private users to request data and maps. Others, including the Ohio Capability Analysis Project (OCAP), perform evaluations for local governments. Nearly all systems provide environmental resource data management services to various state agencies. TNRIS is the most notable example in this regard. Thirteen state agencies participate in a task force which decides on data management priorities and services.<3> Federal agencies are users of resource information systems in several states.

Coordination between data users and producers at the state government level has been achieved by several mechanisms, both formal and informal. Examples of formal system coordination are provided by Texas and North Dakota. As previously mentioned, TNRIS employs an interagency task force mechanism. Oversight for REAP was provided by a committee of legislators, agency staff, university faculty, and private citizens. These formal relationships serve to promote use of the information system by a larger community.

Informal coordination between the system and its users is often achieved through more passive means. Location of the information system within a large state agency leads to utilization of its services by the various divisions within that agency. A user-producer relationship is also fostered during construction of the data base. The information system staff will gather specific data and inventories that have been compiled by agencies responsible for individual environmental resource programs. Once this data is included in the information system, the agencies then take advantage of the analysis capabilities provided by computerized methods, thus becoming users.

Communication between users and producers is necessary to reduce duplication in

data collection and, more important, to prevent the proliferation of discrete and competing computerized data systems within state government. An awareness among users is vital to make sure that limitations of the data are recognized and that the information produced by the system is properly used.

Continued operation of a resource information system is dependent upon support from users of the information. State appropriations for information management activities may be severely reduced without constituent backing. System operators are well aware of false starts and failures in other states which resulted from a concentration on technical capability rather than user service.

FINANCING

Financing of information system operation is generally provided through user charges, general fund appropriations, and federal assistance. A state may rely upon one or a combination of these funding sources for system upkeep. User fees vary from state to state with many systems offering differential rates to government and private users. In some states, only costs of computer time are assessed. Many systems apply user charge revenues to costs of operation. Others must forward all revenues to the state's general fund.

The most common form of system financing is by budgetary appropriation. An information system may receive operating funds as part of a total agency budget, or it may be a specific item subject to scrutiny by the legislative and executive decisionmakers. General tax revenues are the primary source of funding, but special funds have been set up to support resource information systems, such as a surtax on coal to support North Dakota's REAP or a cigarette tax in Minnesota which provides funding for MLMIS.

Funding assistance also comes from federal agencies. Many state environmental resource programs that receive federal dollars include planning components that require data collection and analysis. These federal funds can be passed on to the information system for task performance. Other federal agencies, such as NASA and the Department of the Interior, have provided indirect assistance in the form of data, equipment, facilities use, and technical guidance that supplement state funding sources. Some states, including Georgia, Nebraska, and South Dakota, contract with universities for use of computer facilities. Cooperative development and operation of environmental and natural resource information systems represent a cost-effective choice by state governments in many instances. Personnel and equipment costs for an agency-staffed, state-owned system often exceed the budgetary limits set for information system development and maintenance.

SUMMARY

State interest in environmental and natural resource information systems is abundant. The data demands of environmental resource programs should continue to provide the impetus for more states to establish computerized data management systems. If the past provides any indication, future system development will have a variety of locations and technical capabilities, fulfill various user needs, expand upon cooperation with universities, and offer numerous services.

2. Operational Landsat Analysis Capability

The existence of an information system for resource data management provides a foundation upon which more specialized analytical tools can be built. Some states have chosen to develop sophisticated graphic capabilities using interactive display terminals and pen-plotters which can illustrate various data items in mapped or charted form. Others have sought to link up with any of several national, federally supported data banks that contain numerous environmental and natural resource data inventories. The use of satellite remote sensing data by states can also be tied directly to the presence of an information system for resource management. In fact, in several states the development of an information system can be directly attributed to Landsat data analysis programs.

USE OF LANDSAT DATA

Information derived from Landsat can be acquired in either digital or imagery forms. Imagery has the appearance of high-altitude aerial photography, and techniques of photo interpretation are used to analyze a "scene" from Landsat. Digital data from Landsat is available on computer compatible tapes which enable the user to perform a more precise computer processing of a view from space.

The majority of states have had some experience with Landsat-produced data. Many applications have been one-time demonstrations or limited tests. Satellite remote sensing data has been used in conjunction with land cover analysis for forest and crop inventories, wildlife habitat mapping, water quality management, flood damage assessment, geological mapping, and numerous other applications. However, the ultimate test of Landsat's utility to state resource management is its continued use and integration with other forms of data to constitute an information system suited to the needs of various resource programs.

Development and continued application of Landsat data by states have been achieved according to recent surveys. The Intergovernmental Science, Engineering and Technology Advisory Panel report on the use of Landsat by state and local governments observed that "seven states are considered to have independent on-going operational Landsat analysis and application capabilities" and that nine others "are likely to have operational programs under way within several years" of the June 1978 release.<4> In a recent NCSL document, "operational or quasi-operational Landsat capabilities" were identified in six states subsequent to the discontinuation of REAP.<5>

The use of the term "operational" in reference to a state's ability to process and utilize satellite remote sensing data has generated much discussion. An ambiguous term, "operational" means different things to different people. Some state officials are reluctant to designate their Landsat capabilities as "fully operational" and feel more comfortable in designating them as "quasi-" or "semi-" operational. The conflict, it would appear, results from a distinction between "operational capability" and "operational use."

Operational capability, for purposes of this report, refers to a state's ability to convert raw satellite remote sensing data (either by imagery interpretation or computer processing of digital tapes) into a form that can be applied to resource management activities. Since some states have elected to contract with private vendors to supply Landsat data products, this capability need

not be an in-house procedure. The key element to reaching operational capability is the possession of a Landsat-derived data base applicable to a variety of land-related information needs.

On the other hand, operational use is defined as the actual application of the converted satellite data in a continuing mode for functional resource management programs. Under this definition, a state information system may possess the operational capability to produce Landsat-derived land cover maps and tabular data summaries; but for these products to be put to operational use, a functional agency must apply them to ongoing data requirements and management decisions. Operational use implies continued application and product refinement. Therefore, a one-time application of generalized land cover map for water quality planning does not fulfill the definition of operational use.

This distinction must be clarified in the discussion of state utilization of satellite remote sensing data. The cost of generating Landsat products can rarely be justified for a single-purpose application. The value of Landsat data lies in its repetative characteristics and wide-area view. Landsat coverage of the same geographic area is every nine days with the two satellites currently in operation. The ability to detect changes in land activity over a period of time is one of the major advantages of Landsat data over conventional data collection methods. However, the shortcomings of satellite remote sensing data (discussed in the last section of this chapter) have inhibited some states from making the step from operational capability to operational use.

A recent tabulation indicates that the number of states having operational capability with respect to Landsat data is increasing and bypasses the number of states actually using satellite-derived data in ongoing applications. In North Dakota, for example, the capacity was built into REAP, but the products generated by Landsat failed to command much interest among potential users. Several applications were tested, but demand for new or refined utilization of the data did not exist. A similar situation occurred in Ohio. The accuracy and level of detail of a Landsat-produced land use inventory were not sufficient to include it as an element of the Ohio Capability Analysis Project. Other states have recently developed the capability to process digital Landsat tapes. However, the use of the data is still in the experimental stage and is confined to only a few agency users.

NASA appears to recognize the contrast between capability for and actual use of Landsat data. One objective of its Regional Remote Sensing Applications Program is to transfer to states the operational capability to use remote sensing technology for resource and environmental quality management. (The role of NASA will be examined in Chapter 3.) NASA officials realize that experimental or demonstration uses of Landsat will not provide sufficient rationale for establishing a permanent satellite remote sensing program. Only through development of a significant base of repeat users will the Landsat program become institutionalized.

In promoting state use of Landsat-derived data, NASA places emphasis on the integrated use of various data forms. The agency believes that the optimum value of Landsat can be achieved when used in conjunction with other more conventional data forms. This integration of data sources is provided by a state resource information system.

SEVERAL STATE APPROACHES

The states now putting Landsat data to operational use do so within an overall framework of an information system. In states such as Arizona and Georgia, a Landsat data analysis program provided a strong impetus for the development of a geographic information system. Others, including Texas, have made Landsat data files a component of an ever-expanding data base for resource management.

The Arizona Resources Information System (ARIS) provides a centralized source of maps, aerial photography, and satellite imagery. The information system is currently building the capacity to process digital Landsat data. ARIS staff achieved integration of Landsat with other data sources and aided a variety of governmental and private users in performing analyses for specialized applications. "Future change detection" is seen as a primary benefit derived from Landsat data. The resource management tool is well suited to Arizona's sparse population, rugged terrain, and large government land holdings. Rapid population growth and development in urban areas can also be monitored by repetitive satellite coverage.

ARIS received legislative recognition in 1978 and was charged with providing a data bank for the State Land Department. The information system is designed to use computer compositing of remote sensing data and data from other technical sources. ARIS is also responsible for the coordination of state and local Landsat utilization for agriculture, wildlife, forestry, minerals, water, and other resources.

In Georgia, digital processing of land cover map and statistics for the entire state was accomplished by the Department of Natural Resources for a consortium of 12 user groups. Coinciding with this development of digital processing capabilities was the implementation of a computerized data base for manipulation of natural resource information. The data base was developed to merge satellite remote sensing data with other machine-readable natural and cultural features. Under this concept, Landsat-derived information is one of many data sources used by the resource assessment program in performing computer analyses for land and resource management.

The Regional Environmental Assessment Program in North Dakota was responsible for the development of an integrated natural resource data base. Acquisition of data was scheduled for the categories of air quality, geology, historic site identification, land cover analysis, meteorology, socioeconomic data, water resources, and wildlife. Land cover analysis was the first data collection effort to be completed. Landsat digital tapes were used to produce color-coded maps of the entire state. Tabular data summaries were generated by township and aggregated to the county and state level. Computer software was developed to convert Landsat and other data files into a compatible format for inclusion in REAP's computerized information system.

In Texas, TNRIS is divided into six component data categories. The data base category includes maps, aerial photographs, satellite imagery, and digital files. TNRIS has the capability to store and process these map-related data and to produce maps at various scales. Base data files contain both imagery and digital tapes from Landsat. Equipment is available for imagery interpretation and computerized classification of satellite data. Future plans call for the implementation of a computerized interface between land cover maps from Landsat and the other five data categories: biological, meteorological, geologic and land, water, and socioeconomic.

Not all state resource information systems have sought to take advantage of Landsat data as a management tool. It is interesting to note that the forerunners in state resource information systems--Maryland, Minnesota, and New York--have, until recently, experienced minimal integration of Landsat with their data bases. Other states have viewed Landsat data as a lower-level acquisition priority. North Carolina's Land Resource Information System, one of the newer systems, did not develop Landsat analysis capability in its initial implementation phase.

OUTLOOK

State officials express feelings about Landsat data use ranging from enthusiasm to cautious optimism to reluctance. A few who have successfully employed Landsat as a resource management tool are confident of the product's value. Others approach

the use of Landsat incrementally and are willing to undertake demonstrations of the technology. Still others are skeptical about the reliability and cost-effectiveness of the data.

Reluctance and uncertainty among officials toward utilization of Landsat data stem from two basic issues. First, many officials have yet to be convinced of the true applicability of satellite remote sensing data in a "real world" program setting. Several officials that were contacted characterized NASA's original efforts to promote use of the data as an "oversell" of the tool's capability. Problems in the timely delivery of data continue to plague the technology. Some states have paid relatively large sums of money to private consultants for Landsat data products only to be disappointed by their utility. Second, state officials that are satisfied with the usefulness of the data are concerned about the lack of federal support in establishing permanent satellite remote sensing programs. These officials do not wish their state's investment in equipment and trained personnel to be lost if the federal government ceases to provide funding for the still experimental Landsat program. Many states are unwilling to make commitments to a data system which changes with each successive satellite launched into orbit.

Some of the problems encountered by states in the application of Landsat data are internal. Political differences, such as those which led to the demise of REAP, are often unavoidable. Loss of strategic personnel can seriously affect the continuity of a state's Landsat program. Reductions in state budgets can prevent acquisition of equipment and staff necessary to implement a satellite remote sensing capability.

On the other hand, the increase in state natural resource and environmental programs has created a demand for data that many feel can be supplied, in part, by Landsat. The advent of compact, low-priced computer equipment has made Landsat data use a more attractive option. Recent NASA programs for technology transfer have led to an increase in the number of states that are now participating in Landsat demonstration projects. The effectiveness of these projects can be measured partially through the state's commitment in terms of computer hardware and software purchase, information system implementation, staff training, and redirection of personnel. There is reason to believe that this broad exposure to satellite-derived data will add to the number of states using Landsat in an operational context.

3. Federal Agency Role

NASA TECHNOLOGY TRANSFER

The transfer of remote sensing technology has been referred to by NASA officials as "user development." Technology transfer is important to NASA because of its charter as a research and development agency. Operational use of Landsat technology is provided by governmental and private applications. The value of satellite-derived data must, therefore, be demonstrated to these user groups within a user environment.

NASA has established programs to transfer this new technology to the ultimate user. The basic steps in these user development activities are (1) to investigate basic Landsat capabilities, (2) to demonstrate and verify beneficial applications, and (3) to disseminate proven applications among various potential users.

To accomplish the initial testing of Landsat capabilities, the Application System Verification and Test Program was developed. The purpose of the program is to promote new applications of remote sensing technology in the operational environment of a given user. Beginning with fiscal 1979, this technology transfer effort is divided into two components: the Applications Pilot Test (APT) and the Applications System Verification and Transfer (ASVT).

The objective of the APT program is to prove the concept of a particular use of Landsat data and assure the technical feasibility of that use within a user setting. By nature a research and development program, APTs investigate the operational utility of satellite remote sensing data applications. To date, 16 APT projects are under way or have been completed. Two of these projects involve direct participation by agencies from three different states. A project to demonstrate the use of an automated natural resource information system based on Landsat-derived data was instrumental in developing operational capability in Georgia and Mississippi. The California Department of Water Resources is presently engaged in an APT to demonstrate the utility of Landsat for compiling an inventory and assessment of irrigated lands for water management purposes.

The ASVT program involves demonstrations of proven Landsat applications to verify that these new techniques are, in fact, transferable to a broad community of users. Emphasis is placed on a reduction of user costs, the adaptation of software, and modifications to improve compatibility with other information sources.

In all, 14 states have participated in ASVT. The majority of demonstrations have been conducted with federal agency participation other than NASA. The degree of state agency participation has varied greatly, ranging from limited involvement by seven Appalachian Regional Commission member states in a project to test Landsat's utility for lineament analysis and mapping of Devonian shale deposits, to an intenstive effort by TNRIS to inventory and monitor natural resources by employing satellite remote sensing data. This latter project, scheduled for completion in fiscal 1980, is designed to assist participating Texas agencies to meet their legislated mandates. Integrated use of Landsat-produced data and conventional data is being emphasized.

Another ASVT project with direct state involvement is the Pacific Northwest Land Resources Inventory. This multistate venture, involving Idaho, Oregon, and Washington, demonstrates the use of Landsat data for conducting resource inventories.

NASA has spent approximately $7.5 million on APT/ASVT programs from fiscal 1977 to fiscal 1979. The programs do not involve direct transfer of funds to state agencies, but do provide computer hardware and software, personnel, and support activities. APT and ASVT are usually large-scale and multiyear projects: the Pacific Northwest Project involved over 40 state and local agencies in 20 demonstration applications at a total investment of about $6 million by all participants over a three-year period.

As a means to develop the broader use of proven Landsat data applications and techniques from successful APTs and ASVTs, NASA established the Regional Remote Sensing Applications Program. Emphasis is placed on small-scale demonstrations with state and local government users. The intent is technology transfer, but in a low-risk operational setting that enables the user to apply Landsat-derived data for ongoing information needs. Integrated use of satellite data within an information management system is promoted in a majority of regional program demonstrations.

Three regional centers are responsible for coordinating transfer activities in their respective geographic regions of the nation. Ames Research Center in California, Earth Resources Laboratory in Mississippi, and Goddard Space Flight Center in Maryland provide on-site training for state personnel using NASA equipment and facilities specially designed for Landsat data interpretation and manipulation. Demonstration projects address existing resource information needs. Follow-up technical assistance in establishing self-sustaining operational capabilities is available from regional center staff.

Since the regional program's inception in fiscal 1977, there have been demonstrations with 26 states. Twenty-two of these test application projects have involved one or more state agencies. Information system personnel in 10 states have participated in regional remote sensing demonstrations. Total NASA funding for the regional program has exceeded $8 million in a three-year period. Regional Remote Sensing Applications Program demonstrations are being contemplated for other states with the intention of providing a demonstration opportunity for each state by the end of fiscal 1981.

Many state personnel receive training at the NASA regional centers without formal participation in a demonstration project. NASA records indicate that the program has provided training to about 670 state employees. The regional program has also been used to train university and local government personnel. NASA plans a full-scale effort to involve substate agency staff in fiscal 1981.

NASA technology transfer programs--APT, ASVT, and regional--have involved state agencies in 29 states (see Table 2). Direct participation by state resource information system staff has occurred in 10 of the 16 states previously identified as having information systems for resource management. Of the states now using Landsat data in an operational setting, all but South Dakota have participated in one or more of these NASA-sponsored programs. It is unclear, however, to what extent these technology transfer efforts effected operational use of Landsat. In several instances, such as in the case of Georgia and Mississippi, state involvement happened to coincide with the development of a computerized information system. Direct impact can be attributed to the NASA program. Some states may have already achieved operational status prior to participation. In Arizona, for example, the capability to use Landsat data was enhanced by taking part in a technology transfer program. Several other operational states have obtained spin-off benefits as personnel, in addition to the information system staff, have received training at NASA regional centers.

Table 2
NASA REMOTE SENSING TECHNOLOGY TRANSFER PROGRAMS

State	APT program	ASVT program	Regional program	University program
Alabama	...	...	...	...
Alaska	...	...	★	★
Arizona	...	★	★	★
Arkansas	...	...	...	...
California	★	★	...	★
Colorado	...	★	★	★
Connecticut	...	...	...	...
Delaware	...	...	...	...
Florida	...	...	★	★
Georgia	★	...	...	...
Hawaii	...	...	★	...
Idaho	...	★	...	...
Illinois	...	...	...	...
Indiana	...	...	...	★
Iowa	...	...	★	...
Kansas	...	...	★	★
Kentucky	...	★(a)	★(b)	...
Louisiana	...	...	★(b)	★
Maine	...	...	...	...
Maryland	...	...	★	...
Massachusetts	...	...	...	...
Michigan	...	...	★	★
Minnesota	...	...	★	★
Mississippi	★	...	...	★
Missouri	...	...	★(b)	...
Montana	...	...	★	...
Nebraska	...	...	...	★
Nevada	...	...	★	...
New Hampshire	...	...	...	...
New Jersey	...	...	★	...
New Mexico	...	...	★	...
New York	...	★(a)	★	★
North Carolina	...	...	...	...
North Dakota	...	...	...	...
Ohio	...	★(a)	★	...
Oklahoma	...	...	★(b)	★
Oregon	...	★	...	★
Pennsylvania	...	★(a)	...	...
Rhode Island	...	...	...	...
South Carolina	...	...	★	★
South Dakota	...	...	...	★
Tennessee	...	★(a)	★	...
Texas	...	★	...	★
Utah	...	...	★	★
Vermont	...	...	★	★
Virginia	...	★(a)	★	★
Washington	...	★	...	...
West Virginia	...	★(a)	...	...
Wisconsin	...	...	★	★
Wyoming	...	...	...	...

(a) Project coordinated by Appalachian Regional Commission; participation by state agencies minimal.
(b) Regional program participation by state universities only.

STATE VIEWPOINTS

Overall, state reaction to NASA technology transfer efforts is favorable. Many officials feel that through its Regional Remote Sensing Applications Program, NASA is beginning to recognize the importance of state involvement and, in particular, the preference of states to develop Landsat processing capabilities in-house rather

than hire outside contractors. According to state officials, training received at the regional centers enables them to make more intelligent decisions about hardware acquisition and use of system consultants. The regional program also allows states to conduct a low-risk test of the feasibility of using Landsat in actual program settings while training staff to be knowledgeable about new techniques and applications. NASA officials estimate that state governments have invested $2.5 million in equipment and capacity building, and an additional $3 million in operational expenses, including personnel costs.

On the negative side, some state officials have expressed concern over NASA's use of relatively high-cost equipment in its regional training programs. These officials feel that the agency should adjust its approach by using computer hardware similar to that which is available to the state agency when conducting test applications. Others that have become skilled in the use of satellite-derived data feel that their technical assistance needs have advanced beyond the fundamentals of digital processing of Landsat data tapes. These officials also point out that changes in the next satellite to be orbited, Landsat-D, will require the development of new analysis techniques and new systems for data processing. Preparation should be under way to revise technology transfer programs in order to keep abreast of improved state capabilities and future satellite modifications.

This need for continuing technology transfer to states also prompts many state officials to oppose near-term NASA outreach efforts with substate level users. Many feel that the timing of such a program is premature since the majority of the states are as yet unprepared to meet the program needs of local agencies.

State officials also suggest that NASA user development activities would be more successful if a stronger federal commitment were made to Landsat. NASA should make a more pronounced effort, according to the officials contacted, to institutionalize a satellite remote sensing system at the federal level. This could be accomplished by promoting broader acceptance of Landsat data among federal agencies and by pushing for congressional action to establish an entity with operational responsibility. It now appears likely that either congressional or presidential action will soon designate an operational "home" for the federal satellite data system. NASA will continue to provide research and development activities for future satellites.

OTHER FEDERAL AGENCIES

Technology transfer and the promotion of computerized techniques for resource management have been carried out by federal agencies other than NASA in recent years. The U.S. Department of the Interior, through its EROS Data Center, has sought to integrate both satellite and aircraft remote sensing technology into agency programs. Activities in training, technical assistance research and development, and cooperative demonstration projects have involved various state-level user groups. The data center, located in Sioux Falls, South Dakota, is also the primary source for state users of Landsat data. Unfortunately, difficulties in coordination between NASA and the U.S. Geological Survey (USGS), which operates the facility, have created substantial delays in the delivery of data to users.

The U.S. Department of the Interior has also been instrumental in the development of state information systems through the now-defunct Office of Land Use and Water Planning, and the Resources and Land Investigations (RALI) program of USGS. Building on state-level concerns over passage of natural resource and environmental quality legislation, in particular a national land use planning act, these offices published an extensive series of reports on the development of state programs for resource management, including information and data-handling

requirements. Many issues were addressed: options, methods, equipment, technical specifications, and case study samples. Information needs and various approaches to handling spatial data were discussed. For many states, these documents served as a how-to handbook for the development of information systems.<6>

Regionally based federal agency programs to further the development and use of environmental resource information systems are also noteworthy. The U.S. Geological Survey's Program for Technical Assistance in the Analysis of Land Resources is being conducted as a two-year demonstration in conjunction with the Ozarks Regional Commission. Agencies from five states, Arkansas, Kansas, Louisiana, Missouri, and Oklahoma, are receiving assistance from USGS in the use of geographically oriented land resource and related data and in the use of computer hardware and software for maximum usage of available data on land resources. Workshops, seminars, and projects are being coordinated from the Mid-Continent Mapping Center at Rolla, Missouri. The program emphasizes the use of USGS data products by state and local governments.

In another effort, the U.S. Fish and Wildlife Service, Western Energy and Land Use Team, has provided nearly $500,000 to develop a state-of-the-art computer-based mapping tool designed to accept, store, spatially analyze, and output natural resources and socioeconomic information in mapped or tabular format. The project was jointly developed in 1976-78 with the Western Governors' Policy Office (WESTPO), a regional coordinating council representing Alaska, Arizona, Colorado, Hawaii, Montana, Nebraska, New Mexico, North Dakota, South Dakota, Utah and Wyoming. The computer software has been developed and has been designated the Map Overlay and Statistical System (MOSS). It is one of three software systems within the Ecological Information and Data Analysis System (EIDA). Documentation on the system is available to state users. The geographic information system is particularly suited to use by state fish and wildlife management agencies, but according to system designers it can easily be adapted for overall natural resource data purposes. However, since its prime function is to support U.S. Fish and Wildlife Service programs, the technical training program needed to implement the information system at the state level has yet to be designed.

Both of these regionalized activities include elements of satellite remote sensing data. USGS, in a seminar/workshop on remote sensing, addressed Landsat as a data source. The information system developed by the U.S. Fish and Wildlife Service has data items on land cover and vegetation types derived from satellite remote sensing. Despite those efforts, state officials continue to express concern about an overall lack of emphasis by federal agencies on the integrated use of Landsat in environmental and natural resource programs. This concern is underscored by the fact that little knowledge exists at the administrative levels of many federal agencies about the ongoing use of Landsat by state governments.

4. University and Private Sector Roles in Landsat Utilization

RESEARCH AND DEVELOPMENT PROGRAMS

Universities have played an integral role in the development of computer-based information systems in state government. Many of the data processing techniques are products of university research and development. A number of states use computer facilities located in universities through cooperative or contractual agreements. University research and development has contributed much to the state-of-the-art in Landsat data use as well. In an educational role, universities have also assisted potential users to learn Landsat data analysis techniques.

NASA has prompted university research and development of Landsat applications. Since 1974, schools in 22 states have been supported by the University Applications Grant Program. The objective of the program is to encourage direct interaction between universities and state and local governments, while building capacity for remote sensing within the universities. The universities can continue to support Landsat data users after NASA funding has been phased out.

Under the university program, NASA funding is provided to participating schools. The step-funded grant approach enables the agency to progressively build capacities for Landsat utilization in other areas of the country as previously supported programs become self-sustaining. NASA budgets approximately $2.2 million annually to university applications. As funding is withdrawn from a given institution, contracts with governmental and private users are necessary to maintain the analytical and service capability. In this sense, the NASA university program provides seed money to demonstrate Landsat applications. NASA officials suggest a direct correlation between the university program and operational capability in states. State universities in four operational states have received NASA grants.

CONFLICTING VIEWS

The cause and effect relationship between university participation in NASA-sponsored remote sensing research and development and state agency capabilities to utilize Landsat data was met with mixed reactions from officials in certain operational states. In two states, officials indicated minimal interaction with universities receiving NASA grants. Two other states having operational Landsat analysis capability reported close working relationships with universities, even though no university in either state has participated in the University Applications Grant Program.

Some state officials noted their inability to affect university demonstration activities. They felt that projects were not serving state needs. Others expressed displeasure over the difference in funding approach between the university program and other NASA technology transfer efforts (APT, ASVT, and regional). Under the university program, direct funding goes to participating schools while state agencies can receive no grant monies from NASA. Added to this perception of inequity was the complaint that some universities charged fees for state staff to attend Landsat training seminars.

A portion of these grievances can be attributed to a lack of understanding by state officials of the appropriate university role in conducting independent research and development. Conversely, university researchers often operate in an

environment which is not constrained by the need for practical application and, therefore, fail to address actual state data requirements. There appears to be little willingness on the part of NASA officials responsible for the university program to mediate these differences. They maintain that universities should not be required to submit research proposals to state agencies for review and comment. They also contend that many state agencies want "free" information from universities. A fear expressed by these officials was that NASA-funded schools would be obligated to perform a state agency's operational responsibility.

PRIVATE INDUSTRY ROLE

Private industry provides a range of information management services to state government. Computer hardware, software, information system design, and even data products have been supplied to states by business. Several states with operational Landsat data analysis capability contracted with private sector firms for initial land cover maps and tabular data.

State officials presently express reluctance toward complete reliance upon private industry in the development of information systems and Landsat data-processing capabilities. This concern is not so much over the quality of data products supplied or the competence of industry; rather, it stems from an awareness that privately developed software and analysis procedures are often inflexible and can become obsolete. State staff, not having been involved in the system development, are unable to make the necessary alterations. The private firm must then be called back for modifications. In some cases, the original contractor may have gone out of business.

State agencies are becoming more sophisticated in their technical abilities. Many are opting to develop computer-based systems in-house on the assumption that it will be less expensive, that the data products will be better suited to user needs, and that the system can be modified by staff if changes become necessary. Industry still supplies equipment and software, but states are now making detailed selections in acquisition.

Some state officials contacted felt that NASA is placing private industry in the inappropriate role of technology transfer agent. State use of Landsat data has, according to some officials, been impeded by NASA's historic relationship with the private sector. They suggest that development of user capabilities is not in the interest of the private sector; instead, industry should concentrate on the development of equipment and services to support NASA technology transfer programs. State officials propose that NASA and private industry work more closely to provide hardware and software which are both flexible and affordable. Private industry can also serve the demands of private users of environmental and natural resource data.

The unstable position of the private sector with respect to state use of Landsat is due primarily to a lack of federal commitment to a satellite remote sensing system. State agencies that might otherwise invest in computer hardware for Landsat data processing delay purchases because they are not assured of a constant data source. Private industry lacks the incentive to develop a complete line of products. Institutionalizing Landsat would increase demand for industry-supplied products, stimulate technological advances, and promote competition in the private sector.

Many state agency personnel are also wary of the private sector's potential role in an operational remote sensing satellite system. Industry has expressed a desire to be involved in the distribution of the data in addition to marketing products derived from it. States fear that in turning over the sale of Landsat data to the private sector, government would lose control of the pricing mechanism. A higher cost for the raw data would lead many states to discontinue use of the tool

for resource management. Another concern of the states is that industry would concentrate on serving the data demands of the private sector if it gained marketing control.

5. Findings and Conclusions

This summary of research findings and attendant conclusions is designed to capsulize the major issues surrounding integrated use of Landsat data within state environmental and natural resource information systems. Some of the conclusions presented seek to identify trends. Others are in the form of recommendations that suggest action by state officials, NASA, and others involved in the use of Landsat data for resource management. Both findings and conclusions are based primarily on staff research and analysis with guidance from review panel comments.<7>

(1) State interest in automated resource information systems is abundant and expanding. In addition to the coordinated data management systems already in operation, a recent survey of state officials indicated that information systems were under development or being contemplated in numerous other states. New environmental and natural resource legislation at state and federal levels should continue to provide the motivation for more states to establish computerized mechanisms for information management.

Recent actions by federal agencies responsible for resource management may also stimulate state efforts to better coordinate data management. The U.S. Environmental Protection Agency has proposed to consolidate four permit program requirements under the Resource Conservation and Recovery Act, the Safe Drinking Water Act, the Clean Water Act, and the Clean Air Act. Five agencies, three in the U.S. Department of the Interior and two in the U.S. Department of Agriculture, have signed an interagency cooperative agreement to work toward a standardized classification and inventory of natural resources. Both of these efforts could substantially affect state data collection activities and place the information system at the focus of coordination among individual program agencies in a state.

(2) Integrated use of Landsat-derived data with other conventional data forms has been accomplished by states in operational settings. Satellite remote sensing data is being used in a variety of program-related applications. States have developed this capability in-house and through the assistance of NASA technology transfer programs and private contractors.

States find Landsat data valuable as a complement to conventionally produced data. The repetitive nature of satellite-derived data is a major advantage, as is the ability to view large geographic areas. These factors enhance the cost-effectiveness of Landsat as a resource management tool.

Landsat data analysis is being refined by states for application to environmental and natural resource programs most conducive to its capabilities. Coastal zone management, water quality, forestry, and wildlife management programs have provided opportunities for Landsat-derived land cover applications. State implementation of the Surface Mining Control and Reclamation Act will likely provide a new impetus for the use of Landsat-produced data.

After more than five years of exposure to Landsat, states now realize that the data also has limitations. The fact that 35 states have applied Landsat to program uses on at least a demonstration basis, and that only one fifth of these states now operationally use the data, can partially be attributed to shortcomings in quality and detail. Many of the disappointments with respect to satellite-derived data can be attributed to "raised expectation" and be discounted; i.e., there was the incorrect assumption that Landsat could solve data collection problems. In addition, many states lacked a trained staff capable of implementing a Landsat

program. Other applications were, in fact, experimental or in response to one-time requirements. For many, however, the costs involved were excessive for the benefits to be gained.

Start-up costs for Landsat data analysis capabilities and a lack of federal commitment to a satellite remote sensing system remain as major obstacles to further state utilization. Low-cost systems are becoming more attractive to states, but inaction by Congress and the reluctance of some federal agencies to accept Landsat-derived data or to allow costs incurred in developing Landsat processing capability to be included in program grants have inhibited use of the data.

(3) NASA technology transfer programs have assisted many states in developing Landsat data analysis capabilities. State agency participation in NASA-sponsored demonstrations was instrumental in establishing operational use of satellite remote sensing data in at least two states. The Regional Remote Sensing Applications Program has provided training to hundreds of state personnel and is expected to raise additional states to operational status.

State involvement in NASA technology transfer programs is far from being uniform. Approximately 20 states have had no agency participation in a NASA-sponsored demonstration. On the other hand, four states have been involved in three separate technology transfer programs.

Future federal efforts should be directed toward involving more states in technology transfer programs and toward an appraisal of the Regional Remote Sensing Applications Program's ability to provide for the changing needs of states. States having little or no experience in the use of Landsat data for resource management need the opportunity to evaluate its applicability to their own requirements. States possessing operational capability may require advanced training and technical assistance to more effectively utilize the tool

NASA has recently initiated a study to identify specific legislative mandates which contain data-gathering components suitable for Landsat utilization. The agency intends to focus future training activities toward development of data processing capabilities to meet these requirements. Technolofy transfer efforts should also be directed at making federal agency administrators aware of Landsat's value as a data source ald the widespread use of satellite remote sensing by states.

Future programs should not lose sight of the cyclical relationship between federal assistance in the application of Landsat technology and the use of satellite-derived data by state government. States have made a substantial commitment to Landsat data processing, but continuing federal support is necessary to ensure its ongoing use. The use of Regional Remote Sensing Applications Program funds to develop university training seminars should not mark the beginning of a trend to shift the focus of technology transfer activities away from states.

(4) There is a need for better coordination between universities funded under the University Applications Grant Program and state agencies. Cooperative relationships should be fostered in order to make university demonstration projects more responsible to state agency needs. Coordinating councils could be established that would include representatives of federal, state, and local governments, private groups, and universities. Their role would be to identify resource data management needs, suggest possible applications, and develop personnel training programs. A closer working relationship between agency personnel and university staff may lead to contractual arrangements for data services.

Cooperation between state agencies and universities might also be achieved in the Regional Remote Sensing Applications Program through concurrent training of university and agency staff. This is being accomplished in several current demonstrations. By participating in a project devised to meet state program needs, university researchers could become aware of a range of practical Landsat data applications. Personal relationships would also evolve out of concurrent training.

(5) Federal technology transfer programs can provide significant market opportunities for private industry. NASA, or the designated operational agency, should act as a liaison between states and the private sector. The agency's user development activities should be directed toward states, while product development initiatives should be made with private industry. The agency could translate state hardware and software requirements to business, thus assuring a closer resemblance between user demands and market supplies. States could benefit from federal advice in the selection of equipment and services. In the absence of federal commitment to a satellite remote sensing system, private market forces are inadequate to fill the void between existing user needs and current products. Unless actions are taken to influence the development of low-cost systems, services, and data products, state government will remain wary of the private sector's ability to provide for state Landsat-related needs. Increased involvement of private industry in technology transfer programs is a positive step in this direction.

Footnotes

(1) For an example of a nonautomated approach to resource data management in Connecticut, see the Council of State Governments, Environmental Resource Data: Intergovernmental Management Dimensions (Lexington, Ky.: 1978).

(2) See Michael Kennedy and Charles R. Meyers, Spatial Information Systems: An Introduction (Louisville, Ky.: 1977); Devon M. Schneider and Syed Amanullah, Computer-Assisted Land Resources Planning, Planning Advisory Service Report No. 339 (Chicago, Ill.: 1979); and the U.S. Department of the Interior, Information/Data Handling: A Guidebook for Development of State Programs (Washington, D.C.: 1975).

(3) A more complete Analysis of TNRIS is contained in the Council of State Governments, Environmental Resource Data: Intergovernmental Management Dimensions (Lexington, Ky.: 1978).

(4) Executive Office of the President, Intergovernmental Science, Engineering and Technology Advisory Panel, State and Local Government Perspectives on a Landsat Information System (Washington, D.C.: 1978), p. 11.

(5) National Conference of State Legislatures, State Institutional and Technical Approaches to Landsat Utilization, final draft (Denver, Colo.: 1979), p. 1.

(6) See the U.S. Department of the Interior, Information Data Handling: A Guidebook. Also see supporting reports of the U.S. Department of the Interior: Information/Data Handling Requirements, Technical Report C Information Systems: Technical Description Software and Hardware, Technical Report D and Issue Papers, Technical Report E. (7) Action by Congress or the administration, subsequent to this report, may place operational responsibility for the Landsat system in a federal agency other than NASA. In all probability, NASA would continue to provide research and development of satellite technology, but efforts to transfer Landsat technology to users may be restructured and placed within another operational agency. The recommendations contained below should apply to the agency designated to carry out a technology transfer or user development programs.

Appendix 1
Case Studies

ARIZONA RESOURCES INFORMATION SYSTEM

HISTORY

In 1972, the Arizona Resources Information System (ARIS) program was established within the governor's office. Its function was to coordinate the development and acquisition of an "orthophotoquad" base map series for the entire state Orthophotoquads are composite high-altitude aerial photographs and USGS quadrangle maps. The orthophotoquad program was a cooperative effort by the state, USGS, and NASA. The base maps were designed for a variety of resource management uses, recreation, and transportation planning.

Mapping was completed in mid-1973. ARIS initiated efforts to distribute the products among public and private users. In-house application of the orthophotoquad maps was minimal; rather, ARIS concentrated on making the maps available and assisted users in developing the information to suit specific needs. The information system gained recognition among state agencies and, by executive order, was relocated within the Department of Revenue. Rationale for the move was that the Department of Revenue was a central point for information gathering and dissemination in state government.

However, the Department of Revenue initially made little use of ARIS, which resulted in a reduced budget for the program. Subsequently, executive and legislative review of ARIS revealed that the information system performed a valuable function and had user support. ARIS was given the directive to investigate the use of Landsat by state government and to assume the functions of the EROS Applications Assistance Facility in Phoenix, namely, accessing U.S. Department of the Interior imagery from both aircraft and satellite.

ARIS had undertaken an increased role in the collection, maintenance, and distribution of spatial data. Building on the orthophotoquad program, the information system was now actively developing expertise in the use of Landsat satellite imagery. Landsat data was used to monitor changes in land use. This "future change detection" application is an important resource management tool that is particularly suited to Arizona, which is sparsely populated with rugged terrain and large government land holdings, but experiencing rapid population growth and development in a few urban regions.

RECENT ORGANIZATION

During the 1978 legislative session, a bill was passed which established a Resources Division within the State Land Department, a coordinated natural resource agency. This statute had the effect of establishing ARIS as one of seven functional divisions in the Land Department. ARIS personnel, equipment, and funds were transferred intact. The legislation contained certain mandatory provisions to be carried out by the Resources Division, which include:

1. Provision of an information data bank for the State Land Department by computer composing the data from remote sensing technology, other technical sources and the orthophotoquad program.
2. Change detection by remote sensing.
3. Production of maps and inventories for various geographic and governmental units.
4. Classification of state trust lands to assist in valuation.
5. Function as the state's affiliate for the National Cartographic Information Center (NCIC).
6. Coordinate state and local use of Landsat data for agriculture, wildlife, forestry, land, minerals, water and other resources.

Additionally, the law permits the Resources Division to establish a liaison with local government for collection, maintenance, and distribution of resource information.

Legislative commitment to ARIS is further reflected through an authorization to develop in-house computer capability. Like many states, Arizona has a computer centralization policy which reserves the purchase or operation of automatic data processing to a single state agency. However, ARIS was able to overcome this policy barrier and receive appropriations for acquisition of a minicomputer, digitizer, drum plotter, and other hardware and software.

The use of computers will enable ARIS to operate with a minimum staff and to stay within a relatively tight budget. The division has an average of six full-time employees with an annual budget of approximately $250,000. Legislation that limits property tax increases to 7 percent annually has forced administrators to make tough spending decisions and to seek economically sound techniques.

CURRENT SYSTEM USE

ARIS provides a centralized source of maps, aerial photography, and satellite imagery for Arizona users. Federal, state, and local government users have obtained data products from ARIS for a variety of land use applications. The State Land Department, which administers about 9 million acres of state land,

employs Landsat imagery to determine land cover and monitor use changes. The Office of Economic Planning and Development has applied Landsat to locate remote subdivisions throughout the state. The Water Commission identifies watersheds, vegetation, and flood-prone areas using satellite imagery. Landsat has been used to complement high-altitude photography and other conventional data sources in most applications. The advent of digitally processed Landsat data in Arizona will likely promote increased use of satellite remote sensing in state government.

Federal management agencies in the U.S. Department of Agriculture and Department of the Interior have utilized Landsat to a lesser extent and have relied more heavily upon the orthophotoquads. Private users, primarily consultants, utilities, and extractive industries, represent a large segment of the ARIS user community. These private companies have used both imagery and high-altitude photography in their applications.

Although ARIS is a centralized supplier of information, its data base is for the most part restricted to maps, orthophotoquads, and imagery. At present, ARIS does not possess a computerized file of spatial data which describes various geographic units. However, ARIS staff has achieved integration of Landsat with other data sources and has aided users in performing analyses for specialized applications. The products obtained through ARIS have made an impact on governmental programs and public and private decisionmaking.

FUTURE DEVELOPMENT

The information system is currently building the capacity to process digital Landsat data. Computer processing of satellite data tapes will enable ARIS to undertake more detail analysis of land use changes and to better monitor activities on public lands than can be achieved by photo interpretation of Landsat imagery. ARIS personnel consider, however, that information produced from Landsat has been used in an operational mode for the past several years. This contention is based primarily on the combined utilization of imagery and the orthophotoquad maps; that is, the repetitive nature of Landsat has enabled ARIS to monitor changes since 1972-1973 when the high-altitude photography was taken.

Digital analysis will prove to be an even greater resource management tool for state government and other users, according to ARIS staff. The improved resolution of Landsat D, plus the technological advantages of computer processing, will make satellite data more attractive to primary users in the Land Department and other state agencies, and also to universities, private users, and the federal government. ARIS personnel believe that Landsat is the answer for Arizona. From a cost standpoint, Landsat represents the only economical alternative to update the orthophotoquad coverage of the entire state. Satellite-derived data can be substituted for the more costly high-altitude aerial photography which can be conducted at five- or 10-year intervals, if the funding is available. The staff also stressed that increased acceptance and use by state agencies is a continuing educational process and that federal agencies, which own or administer about 45 percent of the land in Arizona, need more economical ways to collect data.

ROLE OF NASA

Initial capability to utilize Landsat data was developed with no direct assistance from NASA. More recently, Ames Research Center has been requested to modify software for use on a newly acquired minicomputer system. The center is also coordinating a demonstration project to produce a geocoded mosaic of digital Landsat data for the entire state. ARIS staff will soon be involved in NASA's Regional Remote Sensing Applications Program with other Arizona state agencies to investigate the utility of satellite data in several ongoing state program applications.

NASA does provide direct support to the University of Arizona through the University Applications Grant Program. ARIS staff contends that state government has not received benefits from this NASA investment and that technology transfer did not occur as a result of the university's participation. Staff felt that workshops being held by the university on the use of Landsat would not be of interest to state agencies because of a substantial tuition fee. According to ARIS personnel, NASA is not targeting its resources to state government users. The question is, "What happened to the states?"

According to ARIS operators, the federal government should take a lead role in helping states implement ongoing utilization of Landsat for resource management. They are skeptical of private industry's ability to provide reliable support to government agencies wanting to acquire Landsat analysis capability and feel that NASA should work with the private sector to develop hardware and software which are both affordable and able to be maintained by agency staff. In the opinion of ARIS staff, the private sector is not operational. The staff cites that no firm that marketed Landsat products has remained in business longer than five years and that products from a private vendor were not practical from a price standpoint.

SUMMARY

The success and steady growth of ARIS can be traced to the support it has received from both the executive and legislative branches. Conversely, this recognition by the elected officials is a result of

performance and service to government and private industry.

In many ways, ARIS is still in the embryonic stage Manual techniques of photo interpretation will soon be converted to more sophisticated methods using computer processing. Digital analysis techniques are expected to provide increased ability in environmental resource management.

ARIS may be unique in its approach to the development of Landsat data analysis capability. Landsat was first tested in-house, using imagery. Its utility was proven for a variety of applications, though few of them employed Landsat as the sole source of data. The second phase, computer processing of digital Landsat tapes, again to be applied in conjunction with alternate forms of data, will provide more powerful resource management tools.

NASA efforts at technology transfer were not instrumental in building ARIS capability to use Landsat data. NASA grants to the University of Arizona had little positive impact on ARIS development. However, future plans call for ARIS to participate in NASA's Regional Remote Sensing Applications Program. Arizona has made a commitment to Landsat as a continuing source of data through expenditures to purchase hardware and employ qualified staff.

GEORGIA RESOURCE ASSESSMENT PROGRAM

ORGANIZATION

In 1972, reorganization in Georgia state government combined a multiplicity of separate units into a single agency, the Georgia Department of Natural Resources (DNR). Structured as a consolidated natural resource and environmental protection agency, DNR has broad responsibilities for resource management. A program was established to create a manual data base comprised of mapped information. However, it was determined that existing data sources were insufficient for many functional applications.

As a result of activity by the Southern Growth Policies Board, NASA's Earth Resources Laboratory (ERL) sponsored a demonstration of Landsat land cover analysis capability at the National Space Technology Lab in October 1974. Subsequently, NASA and the state of Georgia participated in what could be described as an early prototype of the current Regional Remote Sensing Applications Program. Using ERL facilities to analyze satellite-derived information, a demonstration was conducted on two areas of the state in 1976. This first phase sought to determine the feasibility of using Landsat digital data for resource management. Processing of the two 100-square-mile "scenes" was conducted for various categories of land cover.

This test application was designed for general use by state agencies. The land cover categories selected amounted to an "all things to all people" approach, the rationale being that agencies would receive an overall picture of the technology and desire more specific program applications. However, consensus among state users was that total coverage of the state in general land cover categories was most wanted.

The second phase of the program included, therefore, the processing of all or part of 14 Landsat scenes to provide coverage of the entire state. The effort was coordinated by DNR as the lead agency in a consortium of 12 user groups that included four federal agencies, six state-level users, and two regional planning and development agencies. Of these 12, eight users contributed funds toward the $75,000 project while the others offered in-kind services.

The objective of this phase was to establish an operational capability in Georgia to process Landsat data and generate products required for specific resource management applications. Mapping of the entire state at a 1:250,000 scale has been recently completed. Statistics on land cover for the 159 counties and 198 water quality management units have been aggregated on an acreage basis. In addition, color land cover maps of all counties of the state have been produced.

POTENTIAL USERS

The Environmental Protection Division of DNR is using statistical Landsat data for elements of its water resource management program. The use of satellite data to identify potential solid waste disposal sites is being explored. Other state agencies will be testing the feasibility of using the data for developmental planning and reforestation projects.

Federal agencies operating in Georgia also perceive the need for Landsat land cover analysis. The Soil Conservation Service will utilize the data to determine areas of change relating to water quality and prime agricultural lands. The Army Corps of Engineers, Savannah District, wants to make satellite remote sensing information a part of its data base pertaining to dredge-and-fill permits and environmental studies. The Department of the Army, Fort Benning, envisions using Landsat data to identify certain land cover characteristics for forestry and wildlife management areas of the base. Regional agencies are looking to apply Landsat digital products for HUD 701 Comprehensive Planning programs.

SYSTEM DESCRIPTION

NASA has contributed computer software to the program. The Georgia Institute of Technology has been instrumental in the digital processing of Landsat data tapes on a contractual basis. The Environmental Protection Division, DNR, is now readying the finished products for distribution to the user agencies. An evaluation of the data products and their applicability to ongoing data requirements will be conducted following distribution.

Coinciding with the development of Landsat digital processing capabilities in Georgia was the implementation of a computerized data base for manipulation of natural resource information. This data base was developed to merge satellite remote sensing data with other machine readable natural and cultural resource data. Under the data base concept, Landsat-derived information was only one of many data sources used in performing computer analyses for land and resource management. This combination of manual and computerized data files, and the merging of remote sensing data, provided the basis for the Georgia Resource Assessment Program.

The automated data base and digital processing capabilities were developed for the program by the Georgia Institute of Technology on an interactive minicomputer system. This system, operated by the Georgia Tech Engineering Experiment Station, utilizes a minicomputer, color video display monitor, interactive terminal, printer, and other computer hardware. Software was modified and refined by the experiment station staff who had previous experience in digital data processing with NASA.

DNR contracts with Georgia Tech to provide data products. State government continues to operate a computerized storage and retrieval system of baseline data, including Landsat digital tapes. These in-house facilities perform various analytical techniques using spatial data files to carry out routinized, operational program responsibilities. DNR will continue to utilize Georgia Tech services in a research and development mode. Private vendors may also be called upon to provide specialized services and products.

Georgia Tech has integrated Landsat and other natural resource data in several applications for DNR. One analysis, performed for the Army Corps of Engineers on a reservoir project, employed 18 different data items. Only one of the data items was Landsat-derived. Geographic data elements, such as soil type, slope, land use, hydrology, historic and archeological sites, and jurisdictional boundaries can be combined in a computer overlay to identify areas suitable for certain land activities. Areas susceptible to erosion and flooding can also be delineated. Output can be both graphic and tabular.

AGENCY VIEWS

Staff at Georgia DNR describe Landsat as the building block for development of its computerized data base capability. The multitemporal nature of Landsat data is viewed as a positive factor in its continued use by state agencies. The use of Landsat by state government and federal agencies in Georgia within an operational setting is being achieved. The processing of Landsat digital data is feasible, but products generated by the DNR coordinated project are, as yet, untested by the user community. Evaluation and further development of the resource management tool are needed. As agencies receive data products and success of the specific applications are appraised, continuing reliability on Landsat as a data source is predicted to occur.

DNR, in serving as the lead agency for the Landsat technology transfer project, is user oriented. However, because of manpower constraints, this service orientation must be directed toward state agencies and other entities that can provide funds to support production costs. The provision of Landsat-derived data products to regional and local units has been limited to land cover maps already in stock. DNR staff sees the development of low-cost computer hardware and software as having the potential to bring digital processing capabilities to local government.

Georgia Tech staff look upon their data processing capabilities as research and development functions. Although digital processing of Landsat data is operational from a technical standpoint, Georgia Tech staff would prefer to pursue alternate applications of the data base rather than to perform repetitive, operational tasks. In transferring the proven capabilities to other entities, the university staff could concentrate more on research and development aspects of data processing.

SUMMARY

The development of analytical tools for resource management using computer-processed Landsat data has been achieved in Georgia through a unique partnership between state government and university staff. A state agency served to coordinate funding and data requests from a variety of federal, state, and local users. The university staff devised computerized techniques to integrate Landsat data and other conventional sources for producing maps and statistical information.

Through participation in a NASA-sponsored Applications System Verification and Transfer project, Georgia was supplied the computer software and other support to initiate development of an automated data base for resource management. At present, some 70 state and federal personnel from Georgia have been trained in the use of Landsat data and analysis techniques.

Landsat data products are being put to use in operational applications by a variety of users. The

effectiveness of the tool is currently under evaluation.

NORTH DAKOTA REGIONAL ENVIRONMENTAL ASSESSMENT PROGRAM

(NOTE: North Dakota's version of a resource information system, REAP, ceased to exist on June 30, 1979, upon the governor's veto of its appropriations bill for the 1980-81 biennium. This case study report is based on interviews made with REAP staff prior to the governor's action.)

INTRODUCTION

The energy crisis of the early 1970s made possible massive coal-related development in North Dakota. Recognizing the possible environmental and social impacts of rapid, large-scale growth in the energy industry, the 1975 state legislature established the Regional Environmental Assessment Program (REAP) to be funded through a special coal severance tax trust. REAP was designed as a research arm of the Legislative Council, governed by the Resources Research Committee, an assembly of state legislators, executive agency staff, university faculty, and private citizens.

REAP was given the legislative mandate to conduct research and to develop an information system regarding the state's natural resources "for the purpose of assisting in the development of new laws, policies, and governmental actions, and providing facts and information to the citizens of the state." A task force approach was undertaken involving technical experts from federal, state, and local government, and from the state universities and private industry. A total of 11 task forces identified existing data sources, data needs, organizations, and individuals able to assist in data acquisition, and further recommended system designs, future monitoring requirements, and modeling projects. Other system design work was performed by the Federal Systems Division of IBM.

The Resources Research Committee approved the conceptual design for REAP in December 1975. Four responsibilities were delineated:

--To develop an adequate data base on the environmental, economic, and sociologic characteristics of North Dakota.

--To design and implement a computer-based information system capable of meeting the needs of and being used by decisionmakers.

--To design and implement assessment and modeling systems capable of forecasting the implications of alternative development activities on the environmental and social characteristics of North Dakota.

--To design and implement a mechanism for monitoring changes in the characteristics of North Dakota.

In 1976, REAP staff began implementation of these directives through four major efforts.

First was the development of the REAP Resource Reference System (R3S), a system designed to monitor and catalog North Dakota-related research, expertise, data sources, and documents. R3S is a computerized on-line information bank available to any user. Researchers can quickly identify previous studies on a subject-by-subject basis. Technical experts in a variety of fields can be located. Sources of reports or other documents are also contained. Access is by telephone or mail request. A staff person will respond to inquiries and return the desired information on a computer-generated listing.

Presently, the data base contains over 11,000 references. Numerous automated data banks and selected bibliographies were searched for information relevant to North Dakota. Federal and state publications and reports are included.

The second effort was the implementation of an econometric-demographic (E-D) model to perform impact analysis on selected development alternatives. The model was first applied to southwestern North Dakota, the area of the state most affected by energy-related development.

Base data collection was the third activity undertaken by REAP staff. Acquisition of data commenced in the following areas: air quality, geology, historic site identification, land cover analysis, meteorology, socioeconomic data, water resources, and wildlife. A total of 20 contracts were made with outside consultants to collect the data. Cost was in excess of $1.2 million.

The first data collection effort to be completed was the land cover analysis. REAP contracted with the Bendix Corporation to provide statewide coverage using Landsat digital data tapes. Color-coded maps were produced for each of the 53 counties, and for the entire state, designating 10 land cover categories. Ground-truth information required in the processing of Landsat data was provided by the Institute of Remote Sensing at the University of North Dakota. In addition to mapped data, tabular summaries of land cover data were generated by township and aggregated to county and state levels.

Data acquired through these initial contracts with state agencies, private firms, and universities was converted into machine readable format for inclusion in REAP's computerized information system.

Design and implementation of a system capable of meeting decisionmakers' needs with respect to environmental research was the fourth major activity. Development of computer capabilities included the purchase of computer hardware and software, digitizers, plotters, and interactive graphic terminals. Many innovative system concepts have been developed internally by REAP staff. The information system is

user oriented and operates on a keyword basis. Users may request information by broad topics and are given more specific options by the system in order to further identify desired data. Output is available in a variety of forms: maps, charts, graphs, tabular data, and text.

REAP accomplished much in four years. Progress could partially be attributed to a substantial budget: $2.1 million in each of the two bienniums. This figure represented a noticeable portion of the state's total budget of approximately $600 million.

Competent staffing and exceptional relationships between REAP, state agencies, and universities also contributed to the program's achievements. In addition to the multidisciplinary composition of its advisory committee and formative task forces, REAP's original staff was assembled largely from state university faculty. For the first 30 months of operation, the position of director was held by faculty members, on leave or part-time, from the University of North Dakota. Staff size increased rapidly during development stages, but had been reduced to a stable complement of 11 full-time employees.

INSTITUTIONAL CHANGES

The organization and service structure of REAP had undergone near continuous change since its inception in an attempt to "depoliticize" its activity. REAP was unique in that it was established as a legislative information service. However, there was an ongoing controversy over which branch of government should control REAP. From the beginning, REAP conducted research and data collection in conjunction with state agencies. The executive branch leadership saw REAP as becoming an operational agency. The legislative branch maintained its requirement of an independent information source.

As a provider of information, REAP experienced difficulty in remaining neutral. A problem surfaced when REAP-produced data was a key element in a legislative debate over a major state issue. Opposing sides in the debate supported their positions using different interpretations of the same data.

As a result of amended legislation in 1977 and internal program modifications, REAP's primary charge was the promotion of research development; that is, REAP applied its expertise to specific research efforts in order to provide users with the tools to perform analyses rather than conduct the analysis in-house. REAP developed the capacity but turned the continued operation over to the user.

REAP divested itself of the computer hardware it once possessed. Day-to-day operation of the information system was transferred to a centralized data processing agency of state government. The State Library has taken over responsibility for the R3S.

PROGRAM TERMINATION

Program administrators initially resisted changes to redefine REAP as a research and development unit. However, they felt that the survival of the program may have been at stake. A proposed research and development effort was drafted for fiscal 1979-81 that contained 36 individual programs. To further underscore the position that it was not moving toward operational agency status, the proposed program budget stated that REAP would "attempt to contract for work with existing state entities, rather than...increasing the number of in-house staff." The staff supported the idea of contracting for research, but feared that REAP would be forced to provide "grant" money to agencies to perform operational responsibilities.

The legislation necessary to reauthorize REAP for the 1979-81 biennium included a provision to rename the agency. The new title of Scientific and Technological Research and Development Program was proposed, along with a budget of $2.6 million. The legislature passed the bill, but reduced the authorization to $1.6 million. However, the governor vetoed the bill, effectively terminating the agency as of June 30, 1979. The governor, in a statement about his actions, cited legislative attempts to gain too much control over REAP activities as a reason for the veto.

USE OF LANDSAT

Land cover data was identified as a base data priority need for a variety of state program areas. However, the contract with Bendix to provide maps and tabular summaries was only one of 30 projects executed during fiscal 1975-77. The decision to use private consultants for the analysis was due primarily to time constraints and the initial costs of acquiring the necessary computer facilities. Both state universities and a state agency had proposed in-house development of Landsat digital processing capabilities. Some problems were encountered in putting together the individual Landsat scenes in mosaic form, but these difficulties were resolved by Bendix to the general satisfaction of REAP staff.

Land cover products were received from Bendix in January to September 1977. During 1977-78, over 100 users requested Landsat-generated data from REAP. Workshops were held by REAP staff on the potential uses of the land cover maps and tabular data. Software was developed to make Landsat data more applicable to 208 water quality planning by combining land cover digital tapes with drainage basis files. Other state agencies and commissions employed maps and data summaries for a variety of uses.

REAP staff followed up on the use of Landsat products by conducting a user survey. Findings indicated that there were high expectations among user groups, but that, overall, the materials had low applicability. The multipurpose continued use of Landsat data that had been anticipated by REAP did not

occur. Staff noted a rapid decrease in requests for land cover products since the summer of 1978. REAP's inventory of Landsat data was described as a "pretty tool looking for someone who needs it."

REAP reported no further work with Bendix other than planning for follow-up activity. Bendix has since stopped processing Landsat data. Before program termination, REAP had begun an accuracy study of the land cover maps in conjunction with NASA's Regional Remote Sensing Applications Program.

However, despite a less than satisfactory first experience with Landsat, REAP staff stated that new applications for satellite remote sensing data were being explored for the coming biennium. It was felt that REAP should develop in-house capacity to best utilize Landsat data as a tool to get products of value. This development was planned to proceed cautiously. REAP staff intended to work with potential users to determine if further development of Landsat capabilities was appropriate. They stated that continued interest in Landsat did not stem from the belief that satellite-generated data was intrinsically more useful than previously shown, but once the information system's infrastructure was in place, the tool could be used in conjunction with alternate data sources.

SUMMARY

The rapid development and equally swift demise of REAP may provide a lesson for other states engaged in the establishment of environmental resource information systems. Its unstable position, dependent upon biennial renewal, and caught in a politically undesirable situation between legislative and executive branches, ended what could have been a model for comprehensive and integrated data management at the state level.

In North Dakota, limited integration of digitally processed Landsat data with a computerized information system occurred with no direct NASA involvement. State agencies did not participate in NASA demonstration and technology transfer efforts. Private industry and in-house development of computer software were instrumental in establishing a state land cover data base. The state universities also participated in this unique data management effort.

Major system capabilities had been distributed among various state agencies and institutions in North Dakota. No centralized data coordinating center now exists in the state.

TEXAS NATURAL RESOURCES INFORMATION SYSTEM

BACKGROUND

One of the most widely known state data coordination systems is the Texas Natural Resources Information System (TNRIS). Its beginnings can be traced to 1967 when the legislature charged the Texas Water Development Board with establishing a "centralized data bank incorporating all hydrological data" collected by state agencies and boards. Through the Water Oriented Data Programs Section (WODPS) of the Interagency Council on Natural Resources and the Environment (ICNRE), a coordinating body of resource agency heads chaired by the governor, an inventory of water-related data available from eight state agencies was compiled and the Texas Water Oriented Data Bank (TWODB) was established.

It was apparent to TWODB agencies that water resource management required other types of data in addition to water resources data. In 1972, a recommendation was made by the TWODB task force to the Interagency Council on Natural Resources and the Environment to establish TNRIS, with TWODB as a major subsystem. The TWODB task force was expanded to pursue the development of TNRIS. A conceptual design for the system was completed in late 1974, and in 1975 ICNRE approved the implementation scheme and endorsed the appropriation of operating funds by the legislature. Legislative support for TNRIS has been continuous.

ORGANIZATION AND UTILIZATION

Thirteen agencies participate in and guide the activities of TNRIS: Department of Water Resources, General Land Office, Air Control Board, Bureau of Economic Geology, Railroad Commission, Department of Agriculture, Forest Service, Industrial Commission, Department of Health, Department of Highways and Public Transportation, Parks and Wildlife Department, State Soil and Water Conservation Board, and Coastal and Marine Council. TNRIS Systems Central is administratively located in the Department of Water Resources (DWR). Although funding for TNRIS is included in the DWR budget, participating agencies also contribute staff time.

Initial TNRIS work identified six major categories of data: Base Data, Biological, Meteorological, Geologic and Land, Water, and Socioeconomic. Machine-readable data held by TNRIS member agencies was inventoried and catalogued in a "File Description Report" as one of the first efforts of the expanded system. Data is contained in the report by category. Each file is accompanied by a brief narrative description including source, geographic coverage, frequency of collection, units of measure, frequency of update, and a publications list.

The primary function of TNRIS is to provide users with a coordinating point for access to natural resources and related data. TNRIS maintains an inventory of natural resources data and provides a central index. The system has links to federal data banks and many other organizations in the public and

nonpublic sectors. Computer processing and limited analytical capabilities are available through TNRIS. System Central stores selected data deemed of general utility to member agencies. However, TNRIS is not a unique centralized data base. Participating agencies are still responsible for collection and maintenance of data to fulfill statutory requirements.

The initial focus of TNRIS services was to assist in meeting member agency requirements for information and processing. It has long been evident that the TNRIS user community is much broader than the 13-agency consortium. TNRIS facilities are available to users in all levels of government, education, and the private sector. The system charges a fee to all nongovernmental users to recover costs of computer time and products. No charge is made for staff time. All fees are returned to the operating budget.

TNRIS serves as a source for primary data rather than analyzing and making interpretations on data. The TNRIS staff is not charged with performing actual analytical work; rather, the data is provided in various formats so that the user may do the analysis and interpretation. This "neutral" stance improves the ability of TNRIS to maintain vital interagency cooperation.

Use of TNRIS is increasing as participating agencies and others become aware of its wide variety of services. In fiscal 1978, the system reported a 114 percent increase in the number of requests handled over that of fiscal 1977. There were 3,375 data inquiries from 795 different federal, state, regional, and local governmental units, educational institutions, and private concerns. Information requests were filled by computer-printed reports, published data and documents, magnetic tape files, punched card files, computer-generated plots, aerial photographic products, and microfilm copies. TNRIS distributes a newsletter on a quarterly basis to provide users with information about current system activities, acquisitions, and services.

TNRIS data and information are used in statewide resources planning, environmental assessments, enforcement activity, regional and local land use planning, and energy conservation. TNRIS has benefited state government by reducing duplication in data handling, equipment needs, and personnel. A report for the first quarter of fiscal 1979 showed that users from state government made over 45 percent of TNRIS requests.

SYSTEM DEVELOPMENT

TNRIS represents a comprehensive approach to data management. The fact that development of an automated Geographic Information System (GIS) is considered only as a component of the total information network illustrates the broad range of functions TNRIS seeks to perform. However, GIS will facilitate the use of data from the various categories either singularly or in combination; that is, computerized storage, retrieval, manipulation, and output of data can be achieved from one or more of the six data categories using GIS. Analysis can be performed which requires that information be accessed from two separate categories and then combined into, for example, map form for graphic display. The existence of GIS will likely cause an increase in the centralized information base and, as a result, demands for data services should continue to rise.

The computerized GIS is closely associated with the Base Data category. This category includes maps, aerial photographs, satellite imagery, and digitized files, and is supportive of the other five data categories. GIS provides TNRIS with capability to store and process this map-related data by computer and to produce maps at various scales in any of several different geographic projections. Specialized hardware includes digitizers, plotters, and interactive graphics terminals.

TNRIS Base Data files contain both imagery and digital tapes from Landsat. Equipment is available for imagery interpretation and computerized classification of satellite data. TNRIS can produce grey-scale maps using digital processing of Landsat tapes.

Landsat-produced data was first used in an operational setting by state government in a project designed to update the state's inventory of water impoundments. At about the same time, multiagency use of Landsat was investigated for inventorying and monitoring coastal wetlands and land uses in the Texas coastal zone. The long-term objective of this effort, not yet fully realized, is to establish a "quasi-operational" system using Landsat data to monitor activities and detect changes in coastal wetlands and land uses for decisionmaking purposes.

Satellite remote sensing data has been used by other state agencies to inventory dams, investigate transitory shallow lakes, and map wildlife habitat. The last application, undertaken by the Parks and Wildlife Department, is considered fully operational by staff who have developed procedures for processing digital Landsat data into vegetation type maps.

Landsat data has generated much interest among TNRIS users. The integration of Landsat-derived data within the system's information base is being facilitated by the multiagency aspect of TNRIS. Systems Central staff is currently testing digital processing of Landsat for utility and accuracy in several applications. Plans call for the implementation of a computerized interface between land cover maps from Landsat and GIS. Staff members speculate that the "optimum utility of Landsat may be reached when digitally processed data is used in concert with imagery, aerial photography, and other conventional forms of geographic information."

ROLE OF NASA

The development of Landsat capability in Texas has been both aided and inhibited by NASA efforts. NASA-sponsored training and support from the Johnson Space Center provided the state with the opportunity to proceed with investigations using Landsat early in the program. However, TNRIS staff contends that NASA's current Regional Remote Sensing Applications Program is of marginal use to Texas and other states that are beyond the start-up phase of Landsat investigation.

The acceptance of Landsat by state government was endangered by some of the initial attempts of NASA personnel to transfer satellite remote sensing technology. Agency operating employees of at least one TNRIS member agency say that NASA first talked to agency chiefs and executive staff claiming almost that Landsat alone could "solve the state's data problems." It took considerable time and effort to counter this overselling of Landsat. For example, the budget staff had been led to believe that use of Landsat could immediately bring significant reductions in the costs of data collection. Program managers in some cases had to prepare supplemental budget justifications in order to retain questioned appropriations.

State agency staff, on the other hand, wanted to know how Landsat could be used to supplement existing sources of data or to fill information gaps. TNRIS staff is aware of difficulties that have been encountered in other states which have embarked on a full-scale, costly investigation of Landsat use and therefore intends to be deliberate in its testing of Landsat applications.

Much of the current testing of Landsat digital data analysis is being conducted under a three-year cooperative program between TNRIS and NASA. The Applications System Verification and Transfer project is designed to improve existing capabilities and establish new ones for processing and analysis of remote sensing and natural resources data. The objective is to support ongoing needs of state agencies by establishing a capability from which user agencies can generate products on both a routine and per-request basis. Although there is no direct transfer of funds to TNRIS, it is estimated that NASA will contribute about $600,000 in personnel time and equipment use to be matched by $750,000 in staff and computing costs from TNRIS agencies. Evaluations of Landsat utility to provide operational support to programs in coastal monitoring, public lands inventory, and the identification of critical areas will be conducted.

TNRIS has had little experience with private vendors of Landsat products. A decision was made early in the development of Landsat tools to opt for in-house capabilities. The information system has used private sector suppliers for equipment and computer hardware along with specialized services, such as generation of color maps. TNRIS staff, however, also sees as a major role these companies supporting other private sector activities. For example, utility companies seeking Landsat-derived analysis of specific areas could contract with a private firm for such products.

Many associated with the matter of technology transfer have envisioned the private sector as the logical transfer agent to operationalize use of Landsat data by states. Because of rapidly changing technology (such as the modifications proposed for Landsat D), substantial lag times exist between the development of a new technology and the point at which the private sector can respond. As Landsat technology becomes more completely developed, these lag times should shorten; however, there will always be a need for transfer programs between the technology developers and state agency users.

TNRIS personnel feel that NASA must make a continuing effort to transfer new technology as it becomes accessible. Changes and new satellites will require the implementation of new analysis techniques and new systems for data processing. "Only a federal commitment to Landsat will make states truly operational." TNRIS staff sees Landsat having tremendous potential to impact federal and state programs, but fear that the potential will be lost without a guarantee of its permanence.

NASA has sponsored a University Applications Grant Program with Texas A&M University which aided in establishing a remote sensing center and in demonstrating digital processing techniques. TNRIS cites benefits of staff education and training, but states that no direct services were forthcoming with the exception of consulting work performed by Texas A&M on a contract basis. Relationships between TNRIS staff and Texas A&M personnel are described as good. TNRIS expressed its willingness to work with university researchers in the identification of potential demonstration efforts and to review and comment on proposals being submitted to NASA. This input had some impact on university research directions, but staff felt that NASA should make alterations in the University Applications Grant Program to better accommodate "real world" user needs in the applied research area.

TNRIS staff suggested that NASA has not adequately defined the university's role in technology transfer. They cited a general lack of structure to the program and called for better evaluation of university performance, particularly with regard to supporting "real world" needs. In the future, the applied research and development conducted by universities "should be more user driven." However, TNRIS representatives stated that Texas A&M University had done an excellent job in developing a capability to utilize Landsat even though TNRIS as yet has received few spin-offs from the program.

SUMMARY

The Texas example is one of success in coordinated resource information management. The growth and acceptance of TNRIS by state agencies and other users were achieved with only a limited mandate from the legislature. However, support from the legislature and the executive branch is reflected in continued

appropriations and supporting agency enablements.

TNRIS has excellent interagency cooperation, a capable staff, and a methodical approach to system development. This combination has produced an information system widely known and extensively utilized by state government in a genuinely operational mode.

Landsat use by TNRIS has been cautiously increasing. Satellite remote sensing data is now part of an extensive library of base data contained in TNRIS files. Participation by TNRIS member agencies in a NASA-sponsored program will likely succeed in making state agencies more aware of and more likely to use Landsat data to meet selected information needs. However, NASA must continue to provide assistance to states as technological changes come about or else current utilization will diminsh.

Appendix 2
ISETAP Recommendations

Recommendations of the Natural Resource and Environmental Task Force of the Intergovernmental Science, Engineering, and Technology Advisory Panel (ISETAP), June 1978.

1. FEDERAL COMMITMENT TO DATA CONTINUITY AND COMPATIBILITY

The federal government should make a firm commitment to assure Landsat data continuity and compatibility. In making such a commitment, it is not necessary to define the optimal earth resources information system or to freeze technology.

The functioning satellites, Landsat 2 and 3, and the planned Landsat D, provide the most reasonable basis for establishing a Landsat Information System (LIS). These satellites (with the addition of a backup satellite equipped with a Thematic Mapper and a Multispectral Scanner), the all-digital data preprocessing system now being installed, and the planned telecommunications links should provide a reasonable capability for rapid repetitive data acquisition and dissemination capable of supporting a wide range of applications, and are therefore appropriate for the initial configuration of the LIS.

2. FEDERALLY SUPPORTED LANDSAT INFORMATION SYSTEM

The issue of Landsat data cost is an obvious concern to state, regional, and local agencies. No matter how well the satellite performs its job, agencies will use the data only if it can be obtained at a reasonable cost.

The establishment and operation of an operational Landsat Information System should be considered in the same context as census, cartographic, geological, and meteorological data which are provided as a public service by the federal government. In establishing a pricing policy, no attempt should be made to recover the research and development cost of the experimental earth resources satellite programs (including Landsat D), or the costs of building, launching, and maintaining an operational system. All data acquisition, preprocessing, and storing should be considered a federal data expense. The task force recommends that the price of Landsat data be limited to the cost of data reproduction and distribution. However, state and local users recognize the appropriateness of paying a somewhat higher cost for corrected data. Thirty-three of the states responding to the survey indicated that a fivefold increase in the price of Landsat data would have a great impact on its use. It should be noted that the current cost to the states of purchasing the raw data is relatively inexpensive. But the processing and interpretation of this data into a usable product, which is usually borne by state and local governments, is very expensive.

State governments are presently beginning to apply Landsat data to their problems. However, the task force is certain that state and local government usage of this demonstrably valuable technology will be severely inhibited if the federal government adopts a policy of attempting to have state and local governments share in the development and operating costs of Landsat.

The task force feels that nearly the entire technology transfer program will need to be federally supported in order for state and local governments to participate. However, state and local governments can and should be required to commit staff time for demonstration projects. The states feel that after they have had some experience with Landsat and decide to acquire their own internal analysis capability, such hardware should be purchased at state expense.

3. DEFINE FEDERAL AGENCY RESPONSIBILITIES

The federal government should clearly define federal agency responsibilities for the Landsat Information System. It is essential that the federal government designate a lead agency for the LIS. The lead federal agency must have overall fiscal and policy responsibility for the space system, data processing and distribution, training, technology transfer, planning and management, and should be budgeted directly for its functions. A policy-level review and coordinating mechanism should be established to coordinate federal agency Landsat activities and resolve or provide advice on the resolution of federal interagency policy issues.

4. FEDERAL COMMITMENT TO INVOLVE STATES

The federal government should make the commitment to prior consulation with state and local governments and regional agencies in federal LIS decisions. The federal lead agency should develop a

structure process for the continual involvement of state and local governments in federal remote sensing plans and programs.

5. COMPREHENSIVE AND CONTINUING TECHNOLOGY TRANSFER PROGRAM

The federal government should make a strong commitment to a systematic and ongoing technology transfer program, as a public service, to help state, regional, and local agencies develop the capability for using Landsat. The key elements of the needed technology transfer program are:

--User awareness and comprehensive training.
--Technical assistance and consultation.
--Continued research, demonstration and validation.
--Communication with and among users (user networks).
--Development and dissemination of software.
--Cooperative regional assistance centers.

The technology transfer program should also involve state legislative and executive decisionmakers. The merging of Landsat data with data from other sources should be encouraged.

6. IMPROVED DATA PROCESSING AND DELIVERY SYSTEM

A data preprocessing and distribution system meeting the following criteria should be established at the earliest possible time:

--Raw and corrected (uncategorized) digital data within 14 days of satellite acquisition.
--A governor-activated emergency data access system to provide Landsat data within 24 to 48 hours to assist in disaster assessment
--An all digital data transmission and processing system for Landsat D Thematic Mapper data.
--Uncategorized (corrected and uncorrected) data as the standard digital products.

Appendix 3
National Governors' Association Resolution

National Governor's Association
Position on a Landsat Information System
(Adopted August 1978)

State resource management agencies are increasingly incorporating the Landsat data and information system into their programs and decisionmaking. Landsat has proved to be an effective and economical approach to complex resource management issues. However, the initial efforts by states to use Landsat data have been hindered by a lack of assurances of the future availability of the data and the failure of Landsat to be designated an operational system. Many states have been reluctant to invest state funds, request technical assistance for new uses, or make major program commitments until these issues have been resolved by the Administration and Congress.

Several steps have been taken to ensure continuity and compatibility of the data system. Among these are budget provisions for a backup satellite and scanning equipment as well as the June 1978 report on state and local government use of Landsat data by the Intergovernmental Science, Engineering and Technology Advisory Panel (ISETAP).

The National Governors' Association supports the conclusions and recommendations of the ISETAP study and urges the Administration and Congress to support an operational Landsat information system. The National Governors' Association further recommends that the states be recognized as one of the major users of the Landsat system and that any further development of the Landsat program have the strong involvement of the states.

Appendix 4
National Conference of State Legislatures Recommendations

National Conference of State Legislatures
Remote Sensing Task Force Recommendations
(Adopted August 1978)

1. POLICY AND INSTITUTIONAL RECOMMENDATIONS

a. The task force feels the federal government should make a firm commitment to assure the continuity of Landsat data and the federally run Landsat Program.

b. The task force believes that a configuration of satellites is needed to assure data continuity in the event of a satellite failure. At least one, and preferably two backup satellites should be available on the ground to assure operation over a number of years.

c. The task force feels the federal government should recognize the importance of involving governors and state legislators in technology transfer efforts.

d. Since state and local agencies having responsibilities in the natural resource and environmental areas represent a large and important segment of the current and potential Landsat user community and their involvement in such is vital, the task force strongly recommends that the federal government make a commitment to prior consultation with the state and local governments in all federal Landsat policy and technical decisions

e. The task force believes the federal government should increase funding for Landsat technology transfer activities. A coordinated program of orientation, training, demonstration projects and ongoing technical assistance must be complemented by research and development of new, practical applications and technological updates.

f. The task force believes that federal agencies, who have generally not been supportive, should be encouraged to use Landsat to meet their own data needs and to work with their state counterparts to collect and utilize Landsat data as appropriate. Federal agency use is likely to stimulate state use.

g. The task force strongly recommends that the federal government designate a lead agency to deal with Landsat matters.

h. The task force believes the involvement of the private sector is crucial to the success of the Landsat program and feels there are several potential areas to which they can contribute.

i. The task force feels that universities and other institutions of higher education will continue to be valuable in assisting states in the use of Landsat. State agencies should utilize university expertise to the extent possible in the development of state programs.

j. The task force recommends that the federal government recognize Landsat as a "public good" and encourage its use. It should also recognize the nonquantifiable nature and incremental benefits of better information for natural resource decisionmaking provided by Landsat.

k. The task force recognizes the Landsat D program, with improved Thematic Mapper capabilities, as a positive step.

l. The task force recommends that Landsat data products be in the hands of users within two weeks of ordering. Also, an emergency access system of data delivery (24-48 hours) during natural or man-caused disasters should be implemented.

m. The task force recommends that Landsat data be considered a public service and all research and development, data acquisition preprocessing, archiving and cataloging be considered a federal expense, with the price to state and local users limited to the cost of data reproduction and distribution.

2. TECHNICAL RECOMMENDATIONS

a. The task force recommends that the federal government implement and maintain an all-digital ground data handling system to provide a reasonable capability for rapid, repetitive data acquisition and dissemination capable of supporting a variety of applications.

b. The task force believes the current and planned selection of Landsat data products are adequate to states as baseline products.

c. The task force feels that future data should be compatible with existing information.

d. The task force believes the service-oriented Landsat system should be complemented by a continuing research and development program for remote sensing technology.

e. The task force feels that generally applicable software should be developed in a centralized operation and then distributed through a software library to the interested users.

f. The task force recommends that rapid, convenient access to suitable browse files be continuously

available and that an NCIC state affiliate in each state would be a viable method of improving state and local access to data.

g. The task force recommends that the Department of Defense declassify military aircraft and satellite remote sensing data of the U.S. to the fullest extent possible, consistent with national security concerns.