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NASA TECHNOLOGY TRANSFER IN THE SOUTHWEST STATES: ARIZONA, COLORADO, NEVADA AND UTAH

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I. ABSTRACT

NASA created the Regional Applications Program to provide a low risk opportunity to state and local governments to test and evaluate NASA technology. The transfer process was carried out in five steps: liaison, user needs assessment, training, demonstration projects, and evaluation and operational transition. Cooperative projects were conducted using Landsat multispectral scanner (MSS) data for user driven problems. Needs of the four southwest states in the Western Regional Applications Program area (Arizona, Nevada, Colorado and Utah) address typical issues in this dry region: water management, forest and range inventory, fire hazard, energy development, wildlife habitat, and urban expansion. The concerns of the southwest area are magnified by the very high proportion of federal land ownership. Technology transfer is greatly facilitated when new state issues such as the Sagebrush Rebellion or Water Rights Adjudication create serious information requirements for which MSS data can clearly assist. NASA demonstration activities typically emphasize digital techniques. Some states have, however, adopted more manual techniques using MSS data products to supplement digital methods. All four states now can continue image processing on their own, using mostly software developed by NASA. In each state, the software has been linked to some type of geographic information system primarily supplied by industry. The travel motif chosen for this program has proven value for the process of technology transfer because of concrete and proven results for user defined problems involving state personnel in all phases of the demonstration and judicious choice of software to match existing computational capabilities.

II. INTRODUCTION

Early in 1977, the National Aeronautics and Space Administration established a program called the Regional Application Program. The implementation of this program was assigned to three NASA centers with the responsibility divided geographically. Ames Research Center in California was assigned the fourteen western states including Alaska and Hawaii. The program's technical objective was to provide state and local land management agencies with an opportunity to test and evaluate emerging satellite technology in remote sensing. Specifically, test projects involving the use of Landsat MSS were developed. This paper will describe the program as it was implemented at Ames Research Center with specific reference to selected projects in the four southwestern states (Nevada, Arizona, Colorado and Utah). These states are all very large (50 to 80 million acres), all have mountainous terrain and are predominantly large semi-arid areas. As such, the management issues are similar. The regional program used the proven expertise developed by NASA research programs.

III. TECHNICAL APPROACH

The technical approach was based on historical NASA experience in technology transfer projects and this experience[1] helped clarify our policy guidelines. First, the projects were to be user driven; i.e., selection of the problem to be solved was defined by the user (state agency). This assured both state interest in the problem and the importance of the problem to an agency other than NASA. Second, users and cooperators were asked to commit staff resources to the project. This ensured institutional interest in the problem since state resources are usually very limited. Third, the implementation was to be suited to the state's computational environment and to represent a low technical risk by using proven technology.

Finally, no transfer of funds would occur between NASA and the state agency. This assured a genuine technical interest in the problem and eliminated the possibility that the program might appear to be a "federal grant."

The major technical tasks in the program flow are listed below:

1. Liaison and user needs assessment
2. Training
3. Demonstration projects
4. User evaluation
5. Transition to operational status
6. Operational status

Each task is important to the successful completion of the project. In actual practice, however, these tasks often proceeded in parallel. For example, the training classes were often conducted at a local university concurrently with the demonstration project.

Task 1 was critically important to the success or failure of a project because the communication linkages were develop at this stage. At this point, a match was made between the state agency list of problems and the ability of Landsat MSS data to provide relevant information. If a critical problem in the state could not be solved with the technology, the agency was informed. Frequently, however, the state elected to proceed with a reduced expectation of information content.

Task 2 involved basic training in remote sensing conducted by NASA or a state university. A project plan would be drafted and informally approved as part of Task 3. Responsibilities of each agency for the demonstration were identified. The plan served only as a working document and was amended as required. The fourth task required the agency to evaluate the usefulness of the technology and make an assessment as to its operational use in that state. In the last two tasks, NASA would provide technical information and assistance to the states as they developed their own capability either through a university, a commercial center, or their own facility.

IV. LAND MANAGEMENT ISSUES IN SOUTHWEST

This region is dominated by five major physiographic regions: Great Basin (Utah and Nevada), Southwest Desert (Arizona), Colorado Plateau (Colorado, Arizona, Utah), Rocky Mountains (Colorado), and Great Plains (Colorado). The landscape of the region is characterized by drought. Winter snowfall, as the main source of surface water, has led to large water impoundments to serve these state's water demands. Ground water withdrawal is a second major source of irrigation water. Irrigation is the main consumer of water in the West (89% in Arizona) and a prime issue in state government.[2] These four states also occupy very large land areas (50 to 80 million acres).

Despite their size, state and private land ownership is relatively low because of very large federal land control (86 % in Nevada). State policy, especially concerning lack of sovereignty over the disposition of reserves within their state, often conflicts with federal policy. This has led the western states to pursue new land policy typified by the so-called Sagebrush Rebellion formalized by recent state laws like Nevada's AB413.[3] These states want to reclaim control of their lands because Washington policy frequently fails to recognize western land concerns. This movement has led to an increased need for land cover and land use information as the states formulate their management plans. The pattern of state/federal land ownership complicates land policy. Because of lack of consolidated land holdings, the state is often forced to follow federal direction. This problem is especially acute in energy development and environmental safeguards. Energy reserves are rarely confined to a single section as commonly owned by state governments, thus the federal policy on development of surrounding lands leaves little or no choice for states to optimize the return from their parcel, whether for energy development, wildlife habitat protection, or grazing.

This fragmented ownership pattern has complicated land use policy in the western states. Remote sensing technology offers these states the opportunity to monitor development, to assess range condition of many remote areas for range management, and to effect policy decisions based on physical data regardless of ownership boundaries.

The western states also possess excellent forested lands. Some of these lands are managed for harvest revenue. The major management issue, however, is wildfire control.[4] Most state forestry departments are primarily fire control organizations with responsibilities to protect vast areas and scattered structures. During the summer, grass, brush, and timber fires consume thousands of acres and large budgets. This problem grows worse as urban expansion continues to increase. These four states lead the nation in population growth during the last decade.

The following issues present the

pressing concerns in the four states:

a. Water mangement
b. Federal/state ownership/policy
c. Energy development
d. Environmental impact
e. Timber and range inventory
f. Fire control
g. Urban expansion

V. DEMONSTRATION ACTIVITIES

The demonstration projects undertaken in each state are summarized in Table I. In each state, demonstration objectives, approach and schedule were developed cooperatively with state representatives, usually at the staff level or first line management level. NASA performed most of the digital analysis and training while the states contributed field data, participated in hands-on analysis with NASA analysts, and evaluated the results. In some cases, follow-on projects expanded the state's role in the analysis. Training for state personnel usually was directed at the staff people using written instructions, formal training by the WRAP Training Office, direct participation by the staff in all phases of the analysis, software guides, and by evaluation and documentation. A mobile image processing van was also used for training on site and for giving presentations to state officials.

A. ARIZONA

The Information Resources Division (IRD) of the Arizona Land Department used Landsat technology in two initial projects: (1), a digital mosaic of the state from MSS data, and, (2), an analysis of wildlife habitat for the Three-Bar Area of central Arizona in conjunction with the Arizona Game and Fish Commission. The first project resulted in a statewide data base.[5] The second project was inconclusive due to the inability of MSS classification techniques to discriminate the high level of vegetation detail required in this heterogeneous area. AGFC developed a follow-on project with the Kaibab National Forest to map the resources of the Kaibab Plateau and use them for habitat analysis. This project successfully delineated the species composition information desired and is now being used by the Kaibab National Forest in its wildlife planning efforts.[6] AGFC has no direct management responsibilities and these cooperative efforts through the Research Division are probably typical of its future involvement and eventual use of the resources being developed by IRD.

The U.S. Geological Survey at Flagstaff and the Coconino National Forest cooperated with ARC to classify an area in the San Francisco Mountains area of Arizona. Dominant species composition and soils type were mapped in this project. An exchange of software between USGS and NASA were the main results of this project.

With the passage of SB1001[7] by the Arizona State Senate, the state mandated that agricultural water use would be strictly controlled. Rights to ground water withdrawal are based on maximum irrigated acreage by farming unit during the period 1975-1980, i.e., a grandfather clause. This law also created the Arizona Department of Water Resources out of the previous Arizona Water Commission. This powerful new organization regulates water use in Arizona, probably the single most political issue in the state. The law also created a tremendous data need -- irrigated land acreage by parcel for a five year period. Before embracing satellite technology to fill this need, ADWR wanted proof of concept that the desired information could be derived accurately (within 10%) and used to satisfy a concurrent data requirement, the inventory of irrigated lands by water district. Based on the success of identifying irrigated lands in California,[8] this project used band ratioing techniques and also classification techniques for comparison to take advantage of the stark contrast between the irrigated fields and the dry desert landscape. The acreage results were within 1% of the ground survey conducted contemporaneously and convinced ADWR to install image analysis software. This installation was coupled to a hands-on project for a larger area, the East Salt River Valley, using three scenes for different seasons and crops. ADWR created an annotated atlas with geographic overlays for all of the Landsat scenes having irrigated lands in them statewide. They also purchased the corresponding digital data tapes. The atlas is used daily to introduce farmers and others to Landsat data and to resolve disputes over irrigated acreage.[9] A step-by-step "cookbook" manual based on VICAR/IBIS job calls was compiled to guide ADWR staff through the required digital processing.

B. COLORADO

A number of Colorado agencies adopted and used an inter-agency approach to technology transfer. This helped to economize on training and allowed everyone to share the analytical tasks jointly for one common test site. The County of Pueblo was chosen as the site. The State Planning Division had been conducting land use mapping surveys of Pueblo County for several years using 1974 aerial photography.[10]

STATE AGENCY(S)	ISSUE	SITE	DATA USED	TECHNIQUE DEMONSTRATED	SYSTEM USED
AZ Dept. of Water Resources	Inventory irrig.lands	MCMWCD	MSSx2	Multi-date band ratio	VICAR/IBIS
	Operational inventory for irrig. lands & water rights	ESRV San Pedro	MSSx2	Band ratio Classification	VICAR/IBIS
Dept. of Lands	Data base devel.	Statewide	MSS	Digital mosaicking	JPL(VICAR)
Game & Fish Comm.	Wildlife habitat	Three-Bar	MSS	Sup.class.	EDITOR
GFC & Kaibab N.F.	Forest type mapping & wildlife habitat	Kaibab Plateau	MSS & DMA	Stratified sup. class.	EDITOR/IDIMS
Coconino N.F. & USGS/Flagstaff	Forest and soils mapping	Coconino N.F.	MSS	Sup. class.	EDITOR/IDIMS
NV Div. of Forestry	Resource mapping Big game winter hab. Timber harvestability Mechanical Operations Fire hazard	Douglas County Carson City	MSS & DMA	Sup. class. Interpretation Spat. model Terr. model Spat. model	EDITOR/IDIMS
Div. of Forestry USDA/FS,IF&RES USDI/BLM USGS/Carson City NV DWR	P/J inventory Wildlife habitat Irrig.land/hydrology	BLM Carson City District	MSS & DMA & Inven. plots	Sup. class. Stratified sampling Spat. model	IDIMS RIPS VICAR/IBIS
UT Dept. Nat'l Res: Div. State Lands Geol.& Mineral Survey	Desert/forest land cover mapping Range condition	Book Cliffs	MSS	Unsup.class. Cond.ranking	EDITOR IDIMS
UUtah Research Inst.	Timber mapping	LaSal	MSS	Sup. Class.	EDITOR
Same plus: Oil, Gas & Mining Div.Wildlife Res. State Palnning	Energy petition Wildlife habitat GIS development	Alton Coal Field	MSS & (GIS by others)	Sup. class.	EDITOR (PIOS/GRID)
CO Dept. Local Affairs Div. of Planning Pueblo Area COG State Forest Serv. DNR/Wildlife Div. Dept. of Ag	Land cover map Land use map Timber type/disease Wildlife habitat/GIS Urban encroachment	Pueblo County	MSSx3	Stratified sup. class. Interpretation Change detect. Overlay tech. Multi-date classif.	EDITOR VICAR/IBIS IDIMS

Table 1. Technology Transfer Activities with Southwest States

They generated Colorado's first county series maps of land use and wanted to compare MSS data to these. The Arkansas River passes through Pueblo and supplies irrigation water for a belt of agricultural land east of Pueblo. This area has been under increased pressure to urbanize since 1974 and therefore was a site to examine change detection for urban expansion mapping. The Division of Wildlife recently completed statewide habitat maps for 20 species and wanted to compare land cover in the range and the forest lands with these maps. Dryland farming is also common in eastern Colorado including east Pueblo County. Mapping of dryland farming, the range and the forests of the Wet Mountains was therefore important to Colorado. Finally, the State Forest Service wished to examine the potential of multi-date MSS data to detect infestations of bark beetles. Participants in the Colorado project also have experience in image processing through state universities. Both Colorado State and Denver Universities conducted training courses for state participants.[11]

C. NEVADA

The demonstration projects with Nevada have the greatest potential benefit. Nevada is almost entirely federally owned. The vegetarion resources in Nevada are primarily limited to extensive pinon pine/juniper (P/J) woodlands and sagebrush. On almost every small valley scattered across the state, there is a small acreage of irrigated lands and still some homesteading going on. The state has been exploring new uses of P/J but lacks knowledge of its extent and volume. These ecosystems are also highly susceptible to wildfire. Finally, most of the lands are considered remote due to the low population density and the lack of roads.

The initial demonstration project emphasized these information problems in a project with the Nevada Division of Forestry. For Douglas County and Carson City, land cover by species and crown closure density was mapped and registered to ownership and digital terrain data (DMA). This data set was used to model fire hazard, timber harvestability (based on access for mechanical operations), and big-game winter range.[12] This site includes a portion of the eastern escarpment of the Sierra-Nevada including Lake Tahoe. Training for this project was partially supported by the University of Nevada-Reno.

The results of this project led to two developments: 1) software installation of image processing; and 2) a cooperative federal-state project to tie MSS data to many other needs. In cooperation with the Intermountain Forest and Range Experiment Station of the USDA Forest Service and the Bureau of Land Management, MSS data was evaluated for inventory estimation of P/J volume in conjunction with systematic ground measurements already taken. This opportunity came about because of difficulties encountered in obtaining in-place mapping statewide from photography by the federal agencies. Work is currently proceeding on the BLM Carson City District with statewide extension to follow. This will become the first P/J inventory ever within the state.[13]

D. UTAH

The initial demonstration in Utah emphasized the needs of the Division of State Lands, Department of Natural Resources. MSS was used to map range condition and timber resources for the Book Cliffs and LaSal Mountain area in east central Utah. These objectives were meant to show how remote areas could be assessed with a minimum of field visits. Very large stands of Aspen are growing in the LaSals and the state regularly conducts harvest operations contiguous to the Manti-LaSal National Forest.[14] The state evaluation of remotely sensed data led to a decision to install image processing software under the control of the Utah Geological and Mineral Survey. Later, this capability was combined with geograpic information systems (GIS) through the computer staff of the Department of Natural Resources.

Utah has been negotiating with the Office of Surface Mining to transfer the energy development petition process to state control.[15] Part of these plans called for a demonstration of the state's approach through the application of GIS and remote sensing to the Alton Coal Field petition. Development of this surface mine over a large area in southern Utah had important concerns for reclamation and disturbance of raptor habitat. MSS data was used to rank the land cover conditions of this area including the cliffs near Bryce Canyon National Park. This effort was done in conjunction with the Department of Wildlife Resources.[16]

VI. RESULTS AND ACTIONS TAKEN BY STATE GOVERNMENT

Technology transfer success can be measured by the extent to which the technology is adopted. These measure include software installation, hardware acquisition, institutional development of staff, linkage to related systems, and continued use and/or expansion including work on contract. To what extent the demonstration activities described above influenced these measures is reasonably clear, but not meaningfully separated from all the other activities going on in these states.

Table 2 lists the software installations by state and the computer systems on which they are used. In every state, the decision to install software was based on perceived need, available staff and compatibility with existing state systems. Software compatibility was solved by ARC because of the extensive capabilities maintained on ARC computers, including EDITOR, IDIMS, VICAR/IBIS, ELAS, Mini-VICAR, and familiarity with PIXSYS and STC. ARC prepared a chart of available routines, training materials, and the range of specifications including required peripherals. State agencies from Arizona, Nevada and Utah, working with state computer service staff, selected VICAR/IBIS to operate on the states' main frame computer facilities. ADWR initially installed VICAR on the Arizona De-

State	Agency	Software	Hardware	Present Activities
AZ	Dept. of Water Resources Planning Div.	VICAR/IBIS	Magnuson	Water rights adjudication Irrigation practice enforcement
AZ	Lands Dept., Information Resources Division	ELAS PIOS/GRID (ESRI GIS)	Prime 450	State land inventory
CO	State Cartographer	PIOS/GRID (ESRI GIS)	Prime 450	Census tracts
NV	Div. of Forestry	VICAR/IBIS	IBM 370	Land cover and ownership
NV	Univ. of Nevada-Reno	PIXSYS	CDC 6600	Range inventory
NV	U.S. Geological Survey Carson City Office	RIPS	Z-80 Prime 450	Hydrologic studies
UT	Dept. of Natural Resources	VICAR/IBIS PIOS/GRID	Amdahl V8 Prime 450	Natural resource studies
UT	Univ. Utah Research Institute	ELAS	Prime 450	Forestry, irrigated lands, urban expansion
UT	Univ. of Utah, Dept. of Geography	ELAS	DEC20	Range condition
UT	Brigham Young Univ.	VICAR/IBIS	IBM 370	Irrigated lands

Table 2: Status of Software and Hardware Implementation for Image Processing by State and Related Activities

partment of Transportation Amdahl but later switched over to its own Magnuson computer. All of these installations were straight forward, assisted by a step-by-step compiling procedure using different VICAR system options. The ELAS software was modified for a Prime computer by the Environmental Systems Research Institute, Inc. (ESRI) under NASA contract. This permitted installation of ELAS on the Prime 450 of the University of Utah Research Institute and allowed the Arizona Land Department to acquire ELAS image processing as part of the GIS package procured from ESRI. Under its own initiative and partly due to increased interest by many agencies in Nevada, USGS acquired the RIPS system from EROS Data Center. USGS continues to expand and share its capability with the state agencies. The University of Nevada-Reno has installed PIXSYS from Oregon State University, the University of Utah, Geography Department acquired ELAS for its new DEC-20, while Brigham Young University installed VICAR/IBIS. The State of Utah also acquired the ESRI system, PIOS/GRID. Finally, initial plans in Colorado called for installing ELAS on its ESRI GIS package, however, most image analysis by state agencies continues to utilize university capabilities on contract or cooperative agreement.

Training in image analysis received through these demonstration activities were directed at the staff level. Responsibility for image analysis has become mostly an additional job requirement at the staff level. In Arizona, staffs of both ADWR and ALD are specifically assigned to image analysis.

Continued use of remote sensing technology has been most successful when the technology is not simply replacement technology but an essential solution to mandated responsibilites. In Arizona, the passage of water rights legislation created a difficult information need, i.e. an independent means to adjudicate water rights based on historical irrigation practices. This problem was solved by collecting MSS scenes spanning the period 1975 to 1980, three dates per year to detect multiple year-round cropping, and the application of band ratioing techniques. The federal agencies (USFS and BLM) had a unique data flow problem associated with their initial inventory of pinon and juniper woodlands. Being unable to acquire in-place acreage estimates of P/J and other land cover classes by aerial photo interpretation, they turned to MSS data because of cost and the success of the Douglas County results. Continued image processing in Utah and Colorado follows their historical reliance on university cooperators while they pursue GIS technology within state government. The impressive development of GIS and image processing by ADL has permitted them to serve many users in the state and develop plands to satisfy ADL needs on state lands.

CONCLUSION

The NASA Regional Applications Program was concluded in 1981. The lessons learned involve the critical nature of the approach used for technology transfer. The user agency must be the final authority on the problem to be solved. Technology for technology's sake is not appropriate in a technical transfer project. Second, the continued use of remote sensing data has been most successful when the technology is not simply a replacement technology but an essential solution to a new, mandated information need. The Arizona need for historical data on irrigation practices over the past five years is perhaps the best example. It is these lessons which must be remembered before technology transfer can work. Current MSS technology can make important contributions to many resource issues in the arid Southwest.

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