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A REPORT OF A LANDSAT AND  
COMPUTER MAPPING PROJECT

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(E78-10070) A REGIONAL LAND USE SURVEY  
BASED ON REMOTE SENSING AND OTHER DATA: A  
REPORT ON A LANDSAT AND COMPUTER MAPPING  
PROJECT, VOLUME 1 Final Report (Federation  
of Rocky Mountain States, Inc.) 25 F

**A Regional  
Land Use Survey**  
*based on remote sensing  
and other data*

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**Executive Summary**

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## PREFACE

This report describes a multi-state project developed and coordinated by the Federation of Rocky Mountain States. The project developed and tested methods for combining earth resources satellite (LANDSAT) data with other multi-source data via computer mapping techniques for use in natural resources and land use planning in the Western States.

The project was carried out by mutually defined procedures in six states -- Montana, Wyoming, Colorado, New Mexico, Utah, and Arizona. Colorado State University and Los Alamos Scientific Laboratory provided technical assistance. Two interstate areas of 5,000 square miles each and two intrastate areas of 3,000 square miles each were delineated for all subsequent LANDSAT and high altitude remote sensing during the project. Four 7.5-minute quadrangles were selected within these large areas as test sites. LANDSAT computer-compatible tape classification mapping for 1.1 acre cells was conducted with multiple date imagery. Land use and cover categories were selected by the states, ranging from 19 categories in one state to 81 in another.

In order to place the LANDSAT application within the context of a regional data bank, various non-LANDSAT maps were collected on complementary topics. These were all converted into the 1.1 acre grid system and computer composited with the LANDSAT maps for deriving and displaying the complex patterns involved in determining feasibility for surface mining or urban development, etc. A key purpose was to demonstrate the appropriate mix of LANDSAT utilization, data banking and compositing relevant to regional planning.

The approach was designed for large areas of interspersed federal, state, and private lands, with dynamic interrelationships in mineral, water, agricultural and recreational land uses. This approach raised numerous administrative questions, such as standardization of the ground truth data analysis, standardization of land use categories/subcategories, and systematic central processing of LANDSAT tapes.

For this project, state governments designated state lead agencies to coordinate work among other state agencies. Through the lead agencies, state participation and understanding of LANDSAT use and regional data banking progressed toward more centralized operations in most participating states.

Although this was a relatively brief and modest project in this large and dynamic region, it developed several innovative procedures worthy of continuation: (1) a new LANDSAT Mapping System (IMS) for LANDSAT digital interpretations; (2) use of cellular mapping and compositing for combining the LANDSAT maps with other forms of data; (3) training new groups in each state; (4) defining the need for a ground truth manual; and (5) the need for fixed, repetitive ground truth sites for continual LANDSAT use.

This project marks the beginning of state, interstate, and federal collaboration in these techniques which should now be converted into more extensive operational systems to meet the characteristic problems of energy, agriculture, settlement, and water utilization in the West.

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16. Abstract This final report describes the activities undertaken and results of a regional land use survey project in the Rocky Mountain states. The report is in three volumes: (1) an Executive Summary, (2) the Final Report, and (3) Appendices. The project mapped land use/cover classifications from LANDSAT computer compatible tape data and combined those results with other multisource data via computer mapping/compositing techniques to analyze various land-use planning/natural resource management problems. Data was analyzed on 1:24,000 scale maps at 1.1 acre resolution. New LANDSAT analysis software and linkages with other computer mapping software were developed. Significant results were also achieved in training, communication, and identification of needs for developing the LANDSAT/computer mapping technologies into operational tools for use by decision-makers. LANDSAT processing was conducted by Eugene Maxwell Colorado State University; most multisource computer mapping was handled by Richard Voge, Los Alamos Scientific Laboratory; project advisory committee was chaired by A. Keith Turner, Colorado School of Mines.			
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## 1.0 INTRODUCTION

### 1.1 Scope

This is the Final Report of a project to demonstrate the utility of satellite remote-sensed data in combination with other multisource data as an aid to natural resources and land use planning decision-making.

This was a genuinely cooperative regional project involving the six Rocky Mountain states of Arizona, Colorado, Montana, New Mexico, Utah, and Wyoming. Colorado State University (CSU) and Los Alamos Scientific Laboratories (LASL) provided technical assistance, while the Federation<sup>1</sup> and its Earth Resources Technology Applications Committee of its Natural Resources Council coordinated all participants.

This effort combined LANDSAT digital data with other types of data from a variety of sources via a computer composite mapping process (see Figure 1.1). The process and results are designed to demonstrate the utility and potentials of such multisource analyses for use in solving land use and other geographic-related planning and decision-making problems.

### 1.2 Background

This project is closely related to and logically follows past Federation projects that develop and demonstrate the use of computers for multisource mapping and geographic analyses.<sup>2</sup> The U.S. Economic Development Administration (EDA) has sponsored continuing Federation efforts in this area.

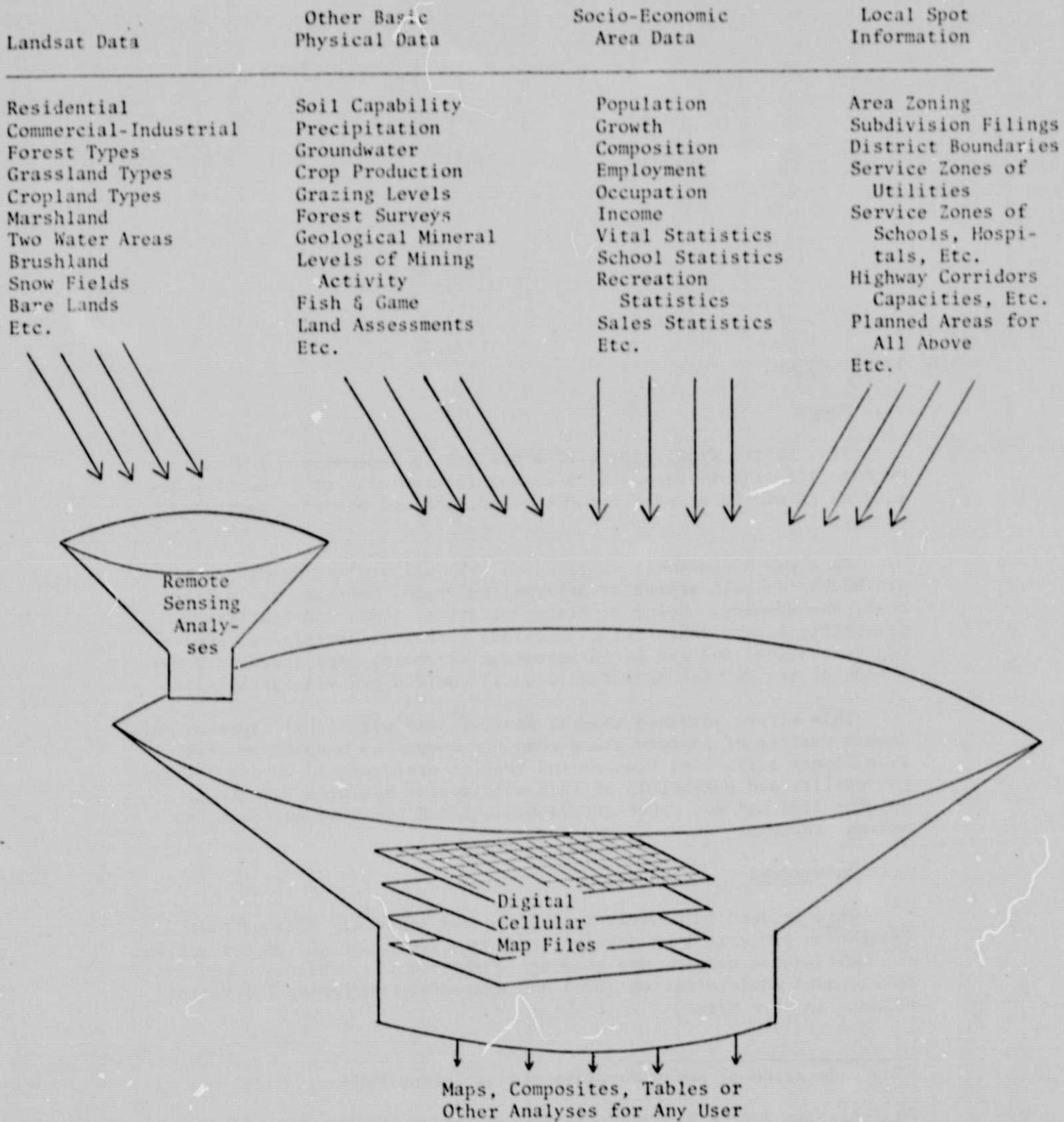
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<sup>1</sup>The Federation of Rocky Mountain States; also, FRMS.

<sup>2</sup>See Section 7.0 -- References/Bibliography of the Final Report for a complete listing of FRMS reports on these subjects.

FIGURE 1.1

SCOPE OF A REGIONAL INFORMATION SYSTEM



The need for this type of automated data analysis (and storage) system is mounting, especially in the West. Many new and pressing demands are being made on the region's resources and way of life. Decisionmakers from all levels of government and the private sector are faced with increasingly complex problems concerning land use, resource management, environmental quality, and socioeconomic development.

Issues of energy development, urban planning, air quality, agriculture production, water allocation, and so on, are compounded because of interjurisdictional authority, mixed land ownership patterns, seasonal fluctuations, and other common situations. Attention to these issues on the part of the states, the private sector and the many multistate and intrastate organizations within the large Western area, has created an enormous amount of data and information that can be used to make decisions -- at both the policy and program levels. Therefore, a system that can analyze this variety of multisource data and show the implications of various decisions is highly desirable.

NASA's<sup>3</sup> LANDSAT earth resources satellite is a new, powerful source of information that can contribute substantially to more informed decision-making. The LANDSAT is continually circling the earth, returning to the same point every 18 days. It is producing multispectral data that can provide a user with information at low cost for large areas. This information can be in the areas of geology, land cover, land use, water quality, crop conditions, etc.

This project demonstrated the repeatable LANDSAT survey procedures, together with composite mapping of all other types of data "invisible" to LANDSAT but needed for resource planning. It placed remote sensing and particularly LANDSAT digital data into its appropriate role in the overall process of producing complex surveys of agriculture, strip mining, urban development and water management, where numerous forms of evidence, in addition to LANDSAT data, are needed on land ownership and leasing, industrial activity, subsurface resources, etc.

### 1.3 Objectives

The project was aimed at several long-term objectives of the Federation of Rocky Mountain States: (a) improved land and water use studies through systematic surveys, automated data banking and analysis; and (b) the transfer of technologies between levels of government; and (c) especially to improve the states' capacity to make better decisions.

Specific objectives were to:

- encourage interstate cooperation in the use of earth resources satellite technology for solving land use planning problems;

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<sup>3</sup>National Aeronautics and Space Administration.

- work toward the development of compatible inter-agency, interstate information system procedures;
- test and adopt a common land use classification;
- evaluate the efficiency and applicability of using satellite data in combination with other data in a land use information system; and
- provide an institutional mechanism for the exchange of information about remote sensing and geo-information systems.

## 2.0 SUMMARY CONCLUSIONS AND RECOMMENDATIONS

### 2.1 Regional Data Analysis Needs:

- Additional investments are required to continue the design and development of institutional mechanisms for increasing earth resources technology utilization.
- Regional data banking and analytic services should include a variety of multisource data and formats, should be flexible so that many users can be served, and should have the capacity to rapidly cover large areas.
- A regional earth resources technology applications center should be established in the West to provide for user awareness and education, information exchange and networking, technical assistance and capacity building, and mobilization of resources within the region.

### 2.2 For Centralized State Services:

- Additional information, training, and assistance should be provided to state agencies consistent with their present capabilities and needs for multisource data analysis.
- A system that upgrades LANDSAT products and combines their use with other multisource data should be developed to encourage state efforts in central data use and management.
- The system should standardize procedures for using LANDSAT which will result in improved accuracy and lower cost.

### 2.3 For Operational Use of LANDSAT:

- Improved management products such as computer-enhanced imagery and composites of LANDSAT with base maps or other data will provide users with more acceptable results.
- A standard training site procedures manual for LANDSAT users non-technical personnel would help by streamlining ground truth and verification procedures.
- A series of standard, permanent training sites in each state, and designation of a lead state monitoring agency, would help to take LANDSAT use out of the research project stage and into the operational stage by supplying immediate, accurate and detailed ground-truth data to all users.

### 2.4 The LANDSAT Mapping System (LMS):

- Optimum use of LANDSAT through automated digital analysis procedures requires that users understand and supply adequate information for class selection, training data selection, and signature development.
- Documentation of the LMS system and its use are required for efficient, continued use of the system.

### 3.0 STUDY AREAS

Figure 3.1 outlines the large study areas selected to represent characteristic natural resources and economic activity zones in the Rocky Mountain region.

The Montana-Wyoming area contains some of the vast Powder River coal deposits. Energy developments will significantly affect the prevailing grazing and farming land uses. This area, part of the Great Plains physiographic region, is mostly rolling grass and brush prairies with scattered, wooded uplands.

The Utah area was selected because it is a rapidly urbanizing corridor along the Wasatch mountain range. A major issue is the transition of agricultural and grazing lands to urban and industrial uses. There is commercial timber in the Wasatch range and large wetlands along the Great Salt Lake. The capital city, Salt Lake City, is in the study area.

The Colorado-New Mexico area is characteristic of southern Rocky Mountain physiography. It covers part of the Rio Grande river valley. Grazing, irrigated agriculture and forestry are important land uses. Second home developments are increasing in the study area. Santa Fe, New Mexico's capital city, and a number of other small population centers lie in the study area.

The Arizona study area covers the Phoenix metropolitan area, where widely spreading urbanization is moving into areas of irrigated agriculture and desert. Located in the Basin and Range physiographic region, the area has a hot desert climate.

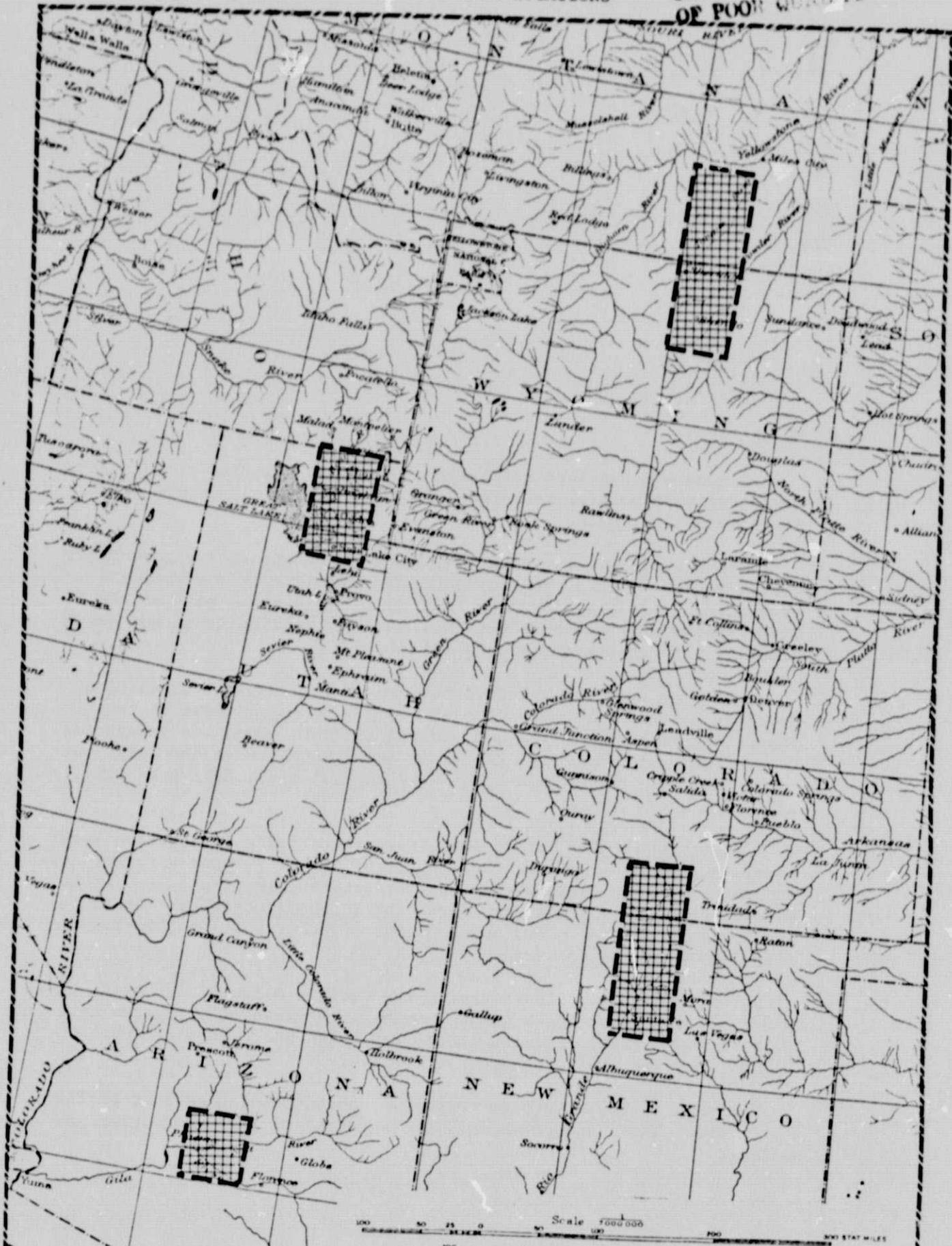
Within these large study areas, each state selected four smaller test sites. These served as foci of the detailed data collection and analysis.

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FIGURE 3.1

STUDY AREA LOCATIONS

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#### 4.0 APPROACH

##### 4.1 Organizational Approach

The organizational structure shown in Figure 4.1 was developed and used for this extensive regional application. Project participants were advised by the Federation's Earth Resources Technology Applications Committee (see Figure 4.2). That group met three times along with several regional resource-using enterprises and agency staff members from the U.S. Geological Survey, Bureau of Land Management, Bureau of Reclamation, and U.S. Fish and Wildlife.

A key feature in this project was the State Lead Agency, designated by state governors' offices to coordinate other interested agencies in each state, perform training site work and LANDSAT verification, formulate the composite mapping projects, gather all auxiliary data, evaluate the outputs, prepare and circulate project reports, and provide liaison and training for concerned state agencies. These lead agencies designated their representatives to perform managerial and technical work.

Colorado State University was selected by the Earth Resources Technology Applications Committee to process the LANDSAT data because CSU's departments of Earth Resources and Civil Engineering have substantial skills, experience, and equipment for this project.

Los Alamos Scientific Laboratories volunteered to consult on various technical aspects and to perform computerized composite mapping, using LASL's substantial machine capacity, consistent with LASL's policy to pursue practical applications of the use of technology to monitor regional energy resources.

FIGURE 4.1

TABLE OF ORGANIZATION

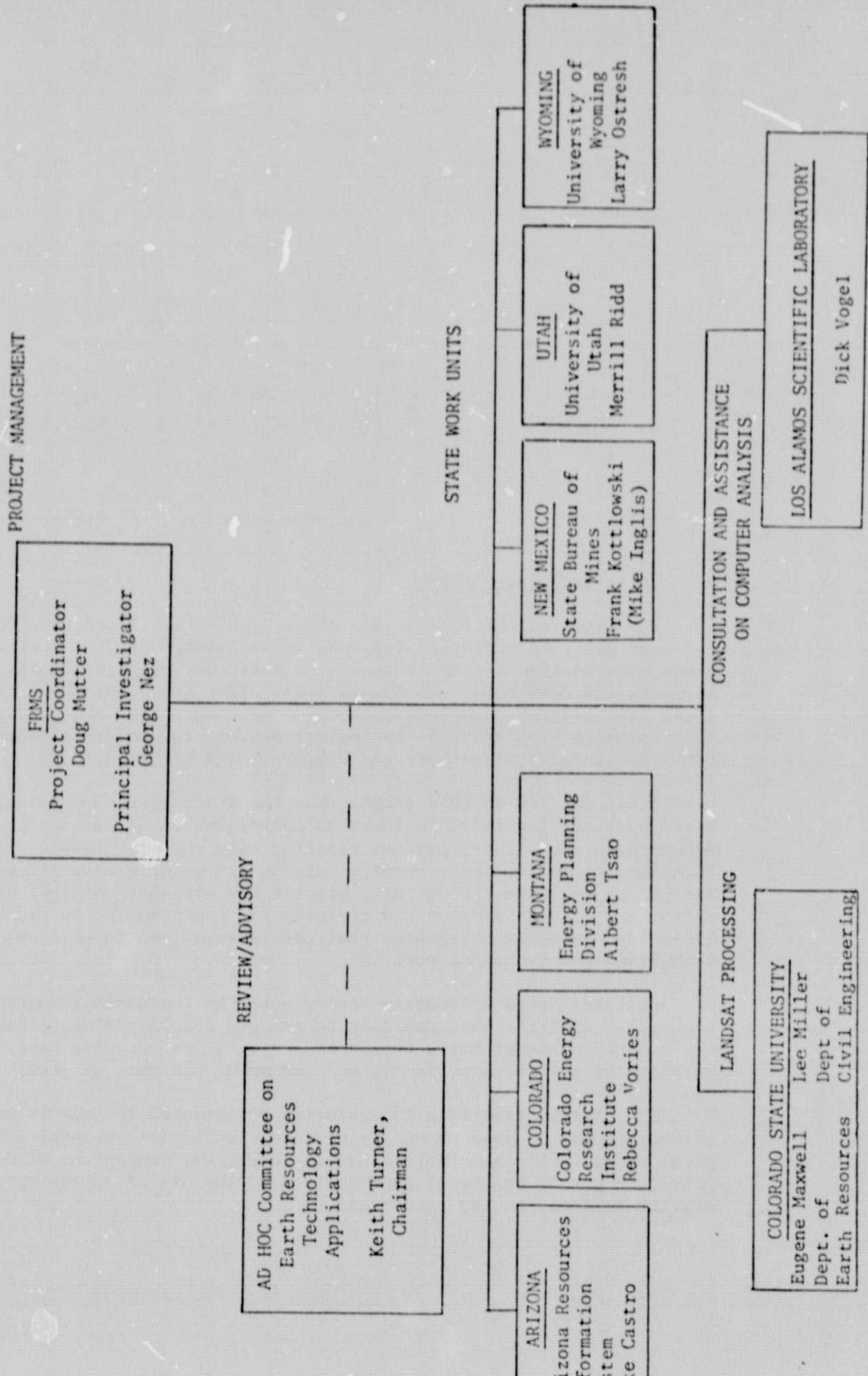


FIGURE 4.2

AD HOC EARTH RESOURCES

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The Federation staff coordinated these numerous activities and provided technical assistance to the states in setting the land cover classifications and in the composite mapping. This was accomplished in several ways: through the dissemination of example material; through periodic issue of a project journal (The Remote Sensor); through procurement and distribution of color infrared (CIR) photography; through assistance and manuals from cellular mapping; and through field visits and state workshops.

To discuss and resolve key questions of policy and technique, the Federation Committee on Earth Resources Technology Applications (representing scientific and administrative bodies in the region) periodically met and reviewed the project.

#### 4.2 Procedural Approach

Four general phases were followed as outlined in the following summary of the project procedure:

1. Data procurement and preparation for later analyses.
  - Large study areas were reviewed and four 7 1/2-minute quadrangles selected in each state.
  - Initial land use and cover classes were selected, beginning with 19 classes of Level I adapted from the USGS Anderson-Hardy table. These were later modified to those shown in Figure 4.3.
  - Initial rules and procedures were defined for selecting sites and describing and documenting site data.
  - High altitude color infrared photography was procured from NASA to aid in the training site work.
  - Multidate LANDSAT imagery was selected for three or four seasons (1974) for each test area.
  - Compositing exercises were formulated for the comprehensive test quadrangle in each state according to a characteristic resource management problem existing in the area.
  - Corresponding types of multisource data (maps) were selected and converted into 1.1 acre grid cells, with various weights assigned for relative importance. LANDSAT cellular maps were edited for selection of certain features to be used in the composites.

FIGURE 4.3

LAND USE/COVER CLASSIFICATION	
<u>Level I</u>	<u>Level II</u>
Urban Land	Residential Commercial/Industrial
Forest Land	Deciduous Forest Coniferous Forest
Rangeland	Shrubland Desert Shrubland Irrigated Grassland Nonirrigated Grassland
Agricultural Land	Orchards & Vineyards Irrigated Cropland
Water	Water Wetlands
Barrenland	Barrelands Other Bare Rock
Unclassified	Unclassified

## 2. LANDSAT data analysis.

- A new LANDSAT Mapping System (LMS) for CCT processing was developed by Colorado State University.
- Initial grey scale LANDSAT printouts at 1.1 acre (pixel or picture element size) were produced for state quadrangles, showing unsupervised variations in reflectance.
- Classified land use/cover maps were produced for several quadrangles in each state, using their given third and fourth level land-use categories.
- Field verification work was conducted by the states, using common forms and procedures as adapted in regional workshops.

## 3. Multi-source computer map compositing.

- Computer work was performed by Los Alamos Scientific Labs for four of the states, using a special interactive grid mapping program, Generalized Map Analysis Planning System (GNAPS), developed from the Composite Mapping System (CMS-II) by Dr. Keith Turner, Chairman of the FRMS Advisory Committee.
- Two states -- Utah and Montana -- performed their own composite mapping with original programs (Resource Analysis Program (RAP), and Environmental Resource Geo-Information System (ERGIS)).

## 4. Evaluation and reporting.

- Three formal advisory meetings were held to discuss and evaluate project progress and findings.
- Several other review sessions and state workshops were held.
- Individual reports were developed by each of the six states, CSU, and LASL (see appendices).
- This final report will be distributed widely to technicians and policymakers alike.

### 4.3 The Multisource Approach

One of the project objectives, of course, was to use LANDSAT data in conjunction with data from other sources to demonstrate procedures and applications.

The decision to use the finest grid size of 1.1 acre cells followed the initiative of Colorado State University in programming a new LANDSAT Mapping System for the purpose of efficient output of pixel level maps (see the CSU report, Appendix A). This cell size was finer than necessary for most of the other relevant data to be used in compositing, yet permitted the preservation in the data bank of full details for other purposes. The 1.1 acre cellular format provides the most discrete resolution for LANDSAT mapping, and offers a convenient line printer output scale of 1:24,000 which corresponds with the 7 1/2-minute quadrangle map series of USGS and, therefore, enables use of overlays. A very significant commitment was that of using multidate (seasonal) imagery to demonstrate the efficiency of the new LMS software and provide as complete a series of land cover signatures as possible. This began with a search for good LANDSAT coverage during three or four seasons of one year, and the resulting adoption of an optimum sequence during 1974 (three seasons in some states and four in others).

Several workshops were held in which training-site analysis procedures were formulated. Subsequently, forms and instructions for documentation were developed by CSU and the Federation and published in the project newsletter, The Remote Sensor.

The LANDSAT Mapping System (LMS) was the software used by CSU for LANDSAT data analysis and is composed of four steps. Each performs a specific task in the production of the final results. The tasks involve (1) preprocessing of LANDSAT data, (2) analysis of class acceptability, (3) development of class signatures, and (4) final classification and display.

The compositing objectives required the selection of other non-LANDSAT topic maps -- social, economic and physical. Section decisions were reached through several project workshops and additional meetings of interested agencies in each state, under the guidance of the state lead agencies. Compositing exercises were developed to analyze relevant resource planning problems in each test site area, as shown in Figure 4.4.

In this procedure, the land-use/cover information from LANDSAT served variously as positive or negative overlays or as land-use constraints in relation to the geological or urban characteristics, etc., shown by the other maps. Studies have been made in each state and in each federal agency concerning land-use classification systems for various purposes. Every state has several agencies concerned with this. Consolidation studies have been made by the Regional Planning Council of the Federation of Rocky Mountain States.<sup>1</sup> But the user diversity persists, and the more appropriate agreement would be in a process for interchanging area land-use studies and observing essential nesting definitions (levels of classification)

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<sup>1</sup>FRMS Land Use Classification Project. 1971.

FRMS Toward a Common System of First Order Land Use Classification. 1971.

FRMS Toward a Common System of Land Use Classification. 1972.

FRMS Data Applications in State Land Use Planning. 1972.

FIGURE 4.4

COMPREHENSIVE TEST SITE ANALYSIS		
<u>State</u>	<u>Comprehensive Test Site</u>	<u>Computer Composite Analysis</u>
Arizona	Hedgepeth Hills	Optimal locations for residential development
Colorado	Fox Creek	Index of revegetation capabilities
Montana	Colstrip, SE	Mined land reclamation feasibility
New Mexico	Santa Fe	Restrictions against urban development
Utah	Farmington	Constraints to nonagricultural development
Wyoming	Buffalo	Physical limitations to urban growth

plus establishing common geographic boundaries for polygon-grid and grid-to grid nesting. In each functional area -- agriculture, natural resources, etc. -- there will inevitably occur different classifications of particular activities or conditions or resources. Therefore, a "general purpose" system must be approached from "elementary indicators" which can be mixed into more complex activities and functions.

Remote sensing can generally see only elementary indicators of certain kinds. It is equally important to use low-altitude photography, geological data, water data, industrial and urban data and other kinds of elementary indicators. These indicators, when converted into digital cells, are able to produce any sort of combinations for functional or activity maps at low cost; for example, "Forest Grazing Area", "Open Pit and Strip Mining", "Parks and Recreation Areas", or any index maps of specific environmental impact. This project attempts both the efficient reading of remote sensed data, and the efficient manipulation of the other conventional elementary data.

To bring the states along rapidly within the project calendar, the most general compositing (the compositing concept is outlined in Figure 4.5) relationship was used -- namely, arithmetic compositing in which each topic map was factored by some relative weight and all were summed into the composite map. In some states, these composites were further recomposited with relative weights (see New Mexico and Colorado reports). This approach implied a known relationship of the factors. The variety of compositing programs (GMAPS, RAP and ERGIS) was salutary and offered the basis for efficiency comparisons, some of which are noted in the state reports. A uniform data entry system was established.

#### 4.4 Related Activities

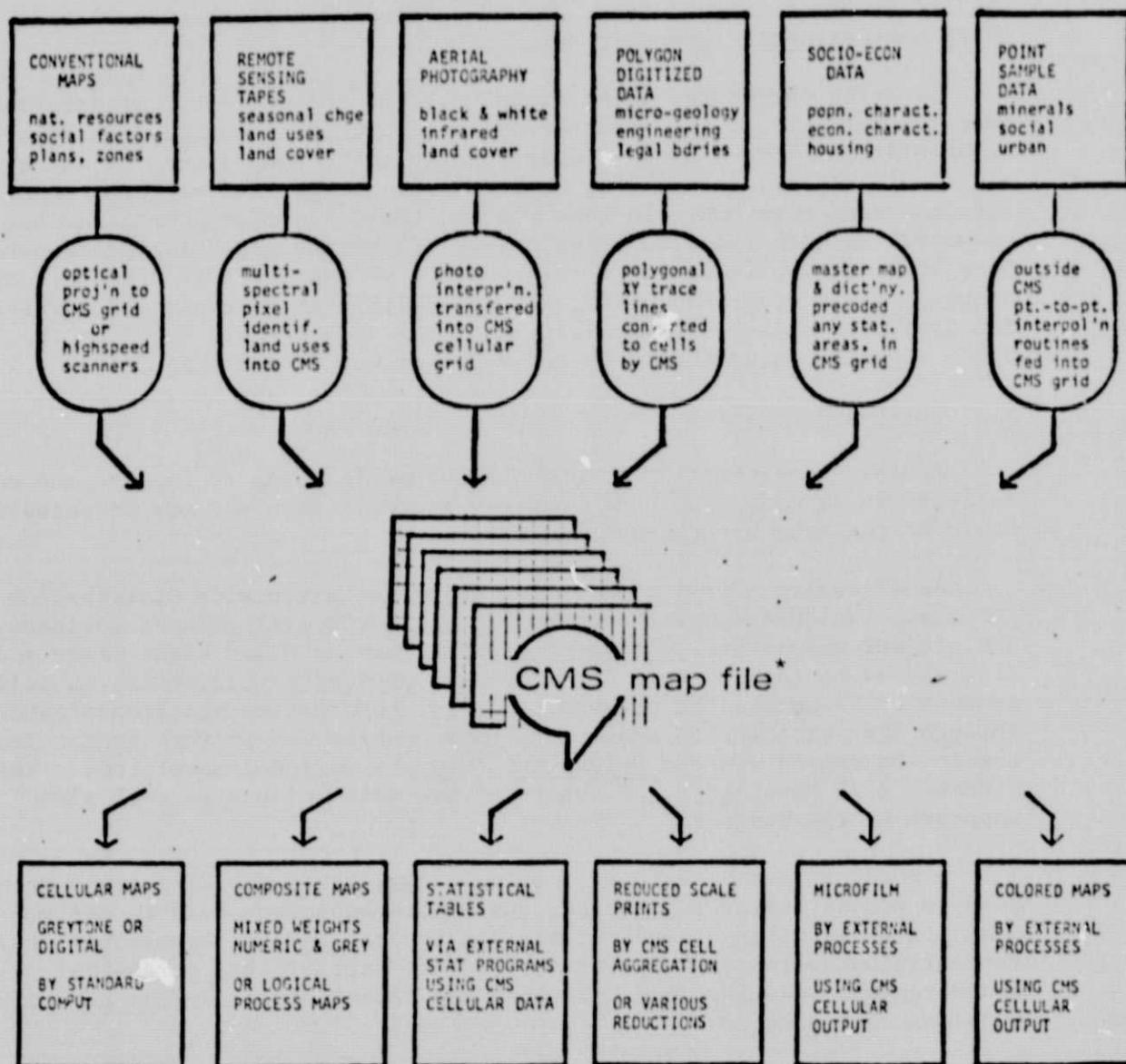
A basic consideration throughout the project was to involve and communicate to as many people as possible in the region who may be potential users of the type of process demonstrated.

As a result, a Project Briefing Paper was given wide distribution in the West, including copies sent to sixteen governors' science advisors. The project newsletter, The Remote Sensor, was produced eight times and distributed to the Advisory Committee and project participants, as well as many other interested persons. General information was disseminated through five articles to several thousand public and private sector leaders in the region via the Federation Forum, a regional newsletter. The December 1976 Newsletter of the Rocky Mountain Science Council also reported on the project.

A total of seven regional meetings involving some 125 persons were held to project efforts. Another seven workshops were held in individual states involving some 76 state and federal agency representatives. Presentations were given by various project participants at several other regional meetings and workshops and report dissemination and discussions will continue.

FIGURE 4.5

POSSIBLE INPUTS AND OUTPUTS



\*Composite Mapping System

## 5.0 ACKNOWLEDGEMENTS

Many people are involved in the policy, program and resource management levels of a regional project of this nature. Listed below are the principal participants in the project. Key Federation leaders are listed on the last page. The project advisory committee is listed in Figure 4.2. Many others contributed both formally and informally. Others are acknowledged in individual reports located in the appendices.

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- Robert K. Timothy, President, Mountain Bell, Colorado
- John S. Rice, Chairman, Rice Truck Lines, Montana
- T. A. Bonnell, President, Bank Securities, Inc., New Mexico
- Warren E. Pugh, President, Cummins Intermountain Diesel Sales, Utah

*Regional Coordinating Councils:*

- Kent Briggs, Chairperson  
Administrative Assistant to Governor Matheson, Utah
- Roy R. Romer  
Executive Assistant to Governor Lamm, Colorado
- Judith H. Carlson  
Director, State Department of Community Affairs, Montana
- Nick Franklin  
Administrative Aide to Governor Apodaca, New Mexico
- Richard Skuener  
Administrative Assistant to Governor Herschler, Wyoming
- William G. Bruhn, Chairman of Housing and Community Development Council  
Executive Director, State Department of Community Affairs, Utah
- Jeffrey B. Hatch, Chairman of Telecommunications Council  
Treasurer, Communications Investment Corporation, Utah
- George Lackman, Chairman of Agricultural Resources Council  
Commissioner, State Department of Agriculture, Montana
- Wayne F. Mulcock, Chairman of Market Development Council  
Southern Division Manager, Utah Power and Light Company, Utah
- David E. Nelson, Chairman of Arts and Humanities Council  
Executive Director, Montana Arts Council, Montana
- Roy Peck, Chairman of Natural Resources Council  
President, Western Standard Corporation, Wyoming
- Pat Williams, Acting Chairman of Human Resources Council  
State Coordinator, Mountain Plains Education and Economic Development Project, Montana
- Chairman of Transportation Council (to be appointed)
- F. Kenneth Baskette, Jr.  
Assistant Director, State Department of Local Affairs, Colorado
- David Freudenthal  
State Planning Coordinator's Office, Wyoming
- James L. Higday  
Vice President and General Manager, Cheyenne Light, Fuel and Power Company, Wyoming
- Hugh Hood  
Owner, Hood Corporation, New Mexico
- Leonard H. Johnson  
Assistant Director of Natural Resources Activities, American Farm Bureau Federation, Illinois (representing Utah)
- Patrick E. Melby  
Deputy Director for Planning, Office of Budget and Program Planning, Montana
- Jack R. Ockey  
Associate State Planning Coordinator, Division of Technical Services, Utah
- Philip H. Schmuck  
Director, Division of Planning, Colorado

*Finance Committee:*

- Nancy E. Dick, Chairperson  
State Representative, Colorado
- Roy R. Romer  
Executive Assistant to Governor Lamm, Colorado
- Thomas C. Stokes, Executive Vice President,  
United Banks of Colorado, Inc., Colorado
- Robert K. Timothy, President, Mountain Bell, Colorado
- Frederick A. Fuchs, Partner, Touche Ross & Company, Colorado (ex-officio)
- John Fleming Kelly, Partner, Holland & Hart, Colorado (ex-officio)

*Officers  
and  
Principal  
Staff:*

- Jack M. Campbell, President
- George C. Hatch, Voluntary Secretary  
President, Communications Investment Corporation, Utah
- Theodore D. Brown, Voluntary Treasurer  
Executive Vice President, First National Bank of Denver, Colorado
- John Fleming Kelly, Assistant Secretary and Legal Counsel  
Partner, Holland & Hart, Colorado
- Philip M. Burgess, Vice President and Executive Director
- James M. Klump, Director of Finance
- James A. Pulver, Director of Information
- Douglas L. Matter, Director of Council Operations