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1974 SUMMER STUDY ON PRACTICAL APPLICATIONS OF SPACE SYSTEMS

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PRACTICAL APPLICATIONS OF SPACE SYSTEMS

Supporting Paper 3

LAND USE PLANNING

The Report of the
PANEL ON LAND USE PLANNING
to the
SPACE APPLICATIONS BOARD
of the
ASSEMBLY OF ENGINEERING
NATIONAL RESEARCH COUNCIL

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PREFACE

In November 1973, the National Aeronautics and Space Administration (NASA) asked the National Academy of Engineering* to conduct a summer study of future applications of space systems, with particular emphasis on practical approaches, taking into consideration socioeconomic benefits. NASA asked that the study also consider how these applications would influence or be influenced by the Space Shuttle System, the principal space transportation system of the 1980's. In December 1973, the Academy agreed to perform the study and assigned the task to the Space Applications Board (SAB).

In the summers of 1967 and 1968, the National Academy of Sciences had convened a group of eminent scientists and engineers to determine what research and development was necessary to permit the exploitation of useful applications of earth-oriented satellites. The SAB concluded that since the NAS study, operational weather and communications satellites and the successful first year of use of the experimental Earth Resources Technology Satellite had demonstrated conclusively a technological capability that could form a foundation for expanding the useful applications of space-derived information and services, and that it was now necessary to obtain, from a broad cross-section of potential users, new ideas and needs that might guide the development of future space systems for practical applications.

After discussions with NASA and other interested federal agencies, it was agreed that a major aim of the "summer study" should be to involve, and to attempt to understand the needs of, resource managers and other decision-makers who had as yet only considered space systems as experimental rather than as useful elements of major day-to-day operational information and service systems. Under the general direction of the SAB, then, a representative group of users and potential users conducted an intensive two-week study to define user needs that might be met by information or services derived from earth-orbiting satellites. This work was done in July 1974 at Snowmass, Colorado.

For the study, nine user-oriented panels were formed, comprised of present or potential public and private users, including businessmen, state and local government officials, resource managers, and other decision-makers. A number

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*Effective July 1, 1974, the National Academy of Sciences and the National Academy of Engineering reorganized the National Research Council into eight assemblies and commissions. All National Academy of Engineering program units, including the SAB, became the Assembly of Engineering.

of scientists and technologists also participated, functioning essentially as expert consultants. The assignment made to the panels included reviewing progress in space applications since the NAS study of 1968* and defining user needs potentially capable of being met by space-system applications. User specialists, drawn from federal, state, and local governments and from business and industry, were impaneled in the following fields:

Panel 1: Weather and Climate
Panel 2: Uses of Communications
Panel 3: Land Use Planning
Panel 4: Agriculture, Forest, and Range
Panel 5: Inland Water Resources
Panel 6: Extractable Resources
Panel 7: Environmental Quality
Panel 8: Marine and Maritime Uses
Panel 9: Materials Processing in Space

In addition, to study the socioeconomic benefits, the influence of technology, and the interface with space transportation systems, the following panels (termed interactive panels) were convened:

Panel 10: Institutional Arrangements
Panel 11: Costs and Benefits
Panel 12: Space Transportation
Panel 13: Information Services and Information Processing
Panel 14: Technology

As a basis for their deliberations, the latter groups used needs expressed by the user panels. A substantial amount of interaction with the user panels was designed into the study plan and was found to be both desirable and necessary.

The major part of the study was accomplished by the panels. The function of the SAB was to review the work of the panels, to evaluate their findings and to derive from their work an integrated set of major conclusions and recommendations. The Board's findings, which include certain significant recommendations from the panel reports as well as more general ones arrived at by considering the work of the study as a whole, are contained in a report prepared by the Board.**

It should be emphasized that the study was not designed to make detailed assessments of all of the factors which should be considered in establishing priorities. In some cases, for example, options other than space systems for accomplishing the same objectives may need to be assessed; requirements for

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*National Research Council. *Useful Applications of Earth-Oriented Satellites, Report of the Central Review Committee.* National Academy of Sciences, Washington, D.C., 1969.

**Space Applications Board, National Research Council. *Practical Applications of Space Systems.* National Academy of Sciences, Washington, D.C., 1975.

institutional or organizational support may need to be appraised; multiple uses of systems may need to be evaluated to achieve the most efficient and economic returns. In some cases, analyses of costs and benefits will be n needed. In this connection, specific cost-benefit studies were not conducted as a part of the two-week study. Recommendations for certain such analyses, however, appear in the Board's report, together with recommendations designed to provide an improved basis upon which to make cost-benefit assessments.

In sum, the study was designed to provide an opportunity for knowledgeable and experienced users, expert in their fields, to express their needs for information or services which might (or might not) be met by space systems, and to relate the present and potential capabilities of space systems to t their needs. The study did not attempt to examine in detail the scientific, technical, or economic bases for the needs expressed by the users.

The SAB was impressed by the quality of the panels' work and has asked that their reports be made available as supporting documents for the Board's report. While the Board is in general accord with the panel reports, it does not necessarily endorse them in every detail.

The conclusions and recommendations of this panel report should be considered within the context of the report prepared by the Space Applications Board. The views presented in the panel report represent the general consensus of the panel. Some individual members of the panel may not agree with every conclusion or recommendation contained in the report.

PANEL ON LAND USE PLANNING

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INTRODUCTION

OBJECTIVES OF LAND USE PLANNING

The Panel on Land Use Planning was comprised of persons who have been involved in remote sensing, processing of the data acquired, and actual utilization in the field of remotely sensed information. Thus, the group was multidisciplinary in terms of the technology involved, the application of such technology, and the perception of the future utilization of remote sensing in land use planning.

The approach included interaction with the advisory resource persons, the technology team, the interactive panels, and representatives of the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), the Environmental Protection Agency (EPA), and the European Space Research Organization (ESRO) who were present at the study. The first phase of the study evaluated ideas, applications, and future opportunities. The second phase isolated those areas in which further information and definition were required. In the third phase, user requirements were developed in accordance with the Space Applications Board's plan for the Summer Study and findings and recommendations were formulated as a basis for further discussion and development by the Space Applications Board.

The objectives of the Panel were to:

Define the land use planning discipline,

Define the current state-of-the-art as it may make use of information obtained by remote sensing,

Present a 5- to 15-year scenario for the impact of remote sensing from air and space platforms on land use planning, and

Identify critical factors in the applications of remotely sensed data to land use planning.

The Panel conducted its deliberations from the viewpoint of operational users at the local, regional, state, and federal levels. The Panel believes this differs from that of previous studies in which the definition of user needs was apparently based primarily on outputs from principal investigators drawn from the research and development community.

Contained in the report are the Panel's views on progress since the study of practical uses of space systems conducted by the National Academy of Sciences in 1967-68, the utility of remote sensing, user requirements, users' educational needs, a review of technical requirements, some information on costs and benefits, and summaries of case studies of three states -- Colorado, California, and Alaska.

DEFINITION OF LAND USE PLANNING

Land use planning is defined as planning for the allocation of activities to land areas in order to benefit humans. The discipline involves three sets of tasks as follows:

Forecasting requirements or demands for goods and services,

Estimating the supply of land available to produce these goods and services (in terms of amount, location, quality, suitability, or capability), and

Evaluating, implementing, and monitoring alternative management and control strategies.

Land use planning deals with all possible uses, including urban (residential, commercial, industrial, institutional), transportation, agriculture, forestry, mining, and outdoor recreation. The Panel on Land Use Planning has attempted, in preparing this report, to adopt as broad a view as possible of the land use planning process.

All three of the tasks listed above have substantial information requirements which may be satisfied by remote sensing. For example, information derived from remote sensors is potentially useful in the first task area to calibrate models which forecast growth pattern by extrapolation. In the third task area, planning decisions which have spatial implications (such as assessing the impact of urbanization on critical environmental areas) are more easily monitored by satellite than by conventional ground checks. Investigators for the Earth Resources Technology Satellite (ERTS-1, since renamed LANDSAT-1) have demonstrated this capability. However, the most significant potential contribution of remote sensing will be in the second task area. We believe that the principal element in future land use planning will be evaluation of the available land resources. This task is particularly difficult because current information-gathering techniques result in incomplete coverage, inappropriate scale, poor reliability, or untimeliness (because of inherent lags in the information-gathering process). Remotely sensed information may provide significant augmentation of more conventional methods.

THE PLANNING PROCESS

The methods by which planning decisions should be made involves the following steps:

Definition of the problem

Acquisition of data relevant to the problem

Establishment of goals and policies

Implementation of a specific plan of action

Evaluation and monitoring of progress through the plan toward the goals.

The Panel believes that the problem of acquiring relevent data is currently the limiting factor in land use planning. In the experience of the Panel members, the difficulties in acquiring adequate data are such that the succeeding steps in the land planning process (establishment of goals and policies, and implemention of specific plans of action) are often based on imperfect information, and the final step (evaluation and monitoring of progress toward the goals) is done only superficially. A supply of remotely sensed imagery may reduce the amount of effort devoted to data acquisition and allow more resources to be applied and rational decisions made in the later stages in the planning process.

A flow of remotely sensed imagery might also help to pace the planning process, since problem identification can be established as a responsibility of the planning agency to be carried out on a regular basis as remotely sensed data are received.

PARTICIPANTS IN LAND USE PLANNING

The participants in land use planning (and, therefore, the potential users of remote sensing-derived information) are as follows:

Entrepreneurs (individual and corporate)

Elected and appointed officials

Citizen groups

Professional planners in private and public service

Educators (through their training of planners)

Researchers (through their study of planning techniques).

Most of these participants regularly use images from aerial photography. Some individuals in the last three groups are familiar with multispectral scanning (MSS) and the characteristics of space images. Professional planners, particularly at the federal and state levels, are becoming increasingly interested in these data. College teachers of geography, geology, ecology, forestry, natural resources, conversation, and similar subjects studied by planning students are increasingly incorporating discussions of remotely sensed imagery into their presentations. At the graduate level, however, planning curricula tend to be based on the social sciences, and remote sensing and space imagery are little

used or understood. The land use planning research community is not a homogeneous group but is scattered throughout several disciplines. To date, it is geographers who have been primarily interested in studying the potential applications of remote sensing and space imagery in land use planning.

PROGRESS SINCE 1967-68

Since the summer study on space applications in 1968, there have been many developments which are important to land use planning. The number of problems has increased, important federal and state laws have been passed, and the technology of data collection and processing has advanced. This section presents and discusses these developments.

REVIEW OF 1968 STUDY

The report of the Forestry-Agriculture-Geography Panel* of the 1968 summer study was reviewed to assess the adequacy of the study recommendations for meeting present and future needs, and the nature and extent of government, industry, and user response to study recommendations.

The 1968 report recommended two programs: one short-range program, Global Land Use (GLU), and one long-range program, System for Earth Resources Information (SERI). Both used data from a polar orbiting spacecraft. GLU was intended to be a 4-year program and SERI an operational program after a 12-year development effort.

GLU was intended as a global collection and dissemination system for land use information. The 1968 study panel postulated a data collection system with a synoptic view and output capable of photointerpretation as well as computer processing. The collection system was to be modest to facilitate its acceptance and to encourage development of favorable international policy and thus pave the way for more complicated systems to follow.

SERI was conceived as a considerably more complicated system, employing GLU as well as other data sources and concentrating on providing data for agriculture, forestry, and land use planning. The structure conceived for SERI is very similar to that of information systems that employ remote sensing input today.

In the context of the situation today, the 1968 program recommendations need review because:

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*National Research Council. *Useful Applications of Earth-Oriented Satellites: Report of the Panel on Forestry-Agriculture-Geography*, (Panel 1). National Academy of Sciences, Washington, D.C., 1969, p. 4.

The development of the land use planning function at the state level has increased rapidly (driven mainly by state and some federal legislation);

Public awareness of environmental quality and land use issues has increased nationwide so that the information requirements for land use planning have become more detailed than they were at the time of the 1968 study;

It may be difficult for foreign countries to accept international land use information programs of the complexity of SERI for several reasons -- perhaps mainly because of fear of exploitation by outside interests more able to use the land resource data than the country surveyed; and

Increasing emphasis on estimates of benefits achieved in domestic applications to justify further space program expenditures may force concentration of work on domestic applications in order to more precisely define the cost-benefit picture.

DEVELOPMENTS IN LAND USE PLANNING

In 1968, planning was primarily concerned with the internal organization of cities (particularly for redevelopment) and the provision of regional services such as transportation. While these are still central tasks, there have been added a strong concern for the environmental consequences of growth and a spread in responsibility and interest to the local or neighborhood level and to the state and federal level. No corresponding change has occurred in the use of remote sensing data in land use planning during this period. In the 1968 study, no panel was primarily devoted to land use planning. This activity was covered by the Forestry-Agriculture-Geography Panel. Little information on land use planning has appear in published reports or research done in the applications of remote sensing since then. However, considerable work has been done by investigators in the discipline of geography on such topics as land use mapping -- which is potentially useful in planning. Land use planners have remained, in effect,iin the research and development phase, in which disciplinary research is done to provide the basis for an operational mode yet to come. This situation is illustrated by Figure I, which also suggests the possible future trend.

In Figure I, the size of the remote sensing circle is intended to portray what we feel was, is, and will be the size of the national remote sensing effort. The changing position and overlap of the remote sensing circle with the geographers' and land use planners' circles is intended to portray the relative impact of remote sensing on the activities of these two groups of people. It also indicates the change of the remote sensing effort from research and development (impact on geographers) to operational (impact on land use planners). We do not mean to imply, by the portions of the remote sensing circles overlapping the geographers' and land use planners' circles, a suggested size of the land use planning effort within the national remote sensing program.

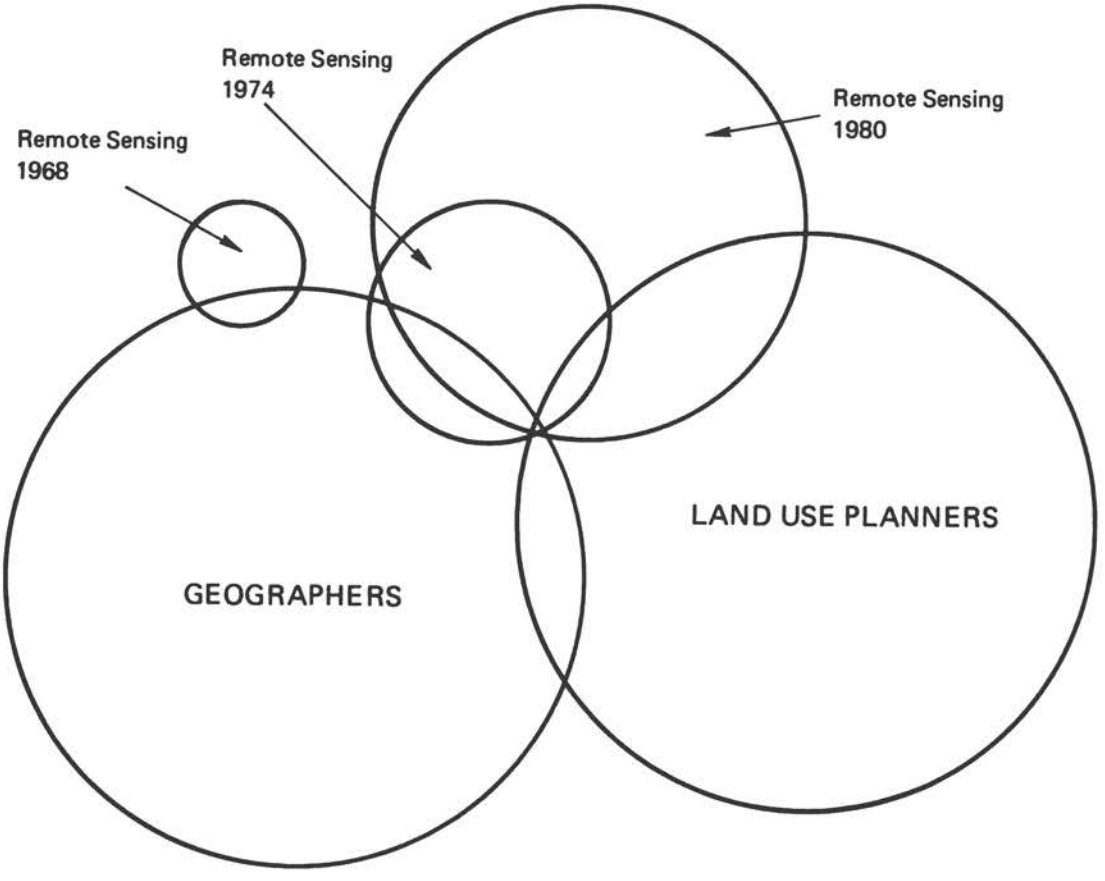

FIGURE I THE TREND IN USE OF REMOTELY SENSED DATA FOR LAND USE PLANNING BY GEOGRAPHERS AND LAND USE PLANNERS

LEGISLATION

Significant legislation has been passed and proposed in the land use and associated environmental fields since 1968. One effect on the land use planning discipline has been a need for a more complete inventory and analysis of resources and uses. Another is the need for coordination of all land use associated activities on a state, regional, and local basis, and closer control and monitoring of all uses in both urban and rural areas.

Some of the land use legislation that has been enacted since 1968 follows:

Year	Legislation
1969	National Environmental Policy Act (NEPA); Oregon Land Use Planning Act SB-1
1970	California Environmental Quality Act; Maryland Wetlands Act; Michigan Shorelands Protection and Management Act; California State Planning Act AB-2070
1971	Vermont Act 250; Delaware Coastal Zone Act; Alaska Native Claims Settlement Act; State of Alaska Land Use Planning Coordination Act
1972	California Coastal Zone Conservation Act; Federal Coastal Zone Management Act (Public Law 92-583); Delaware Beach Preservation Act; Florida Environmental and Water Management Act: New Jersey Wetlands Act; Pennsylvania Constitutional Amendment; Florida State Comprehensive Planning Act
1973	Colorado Land Planning and Policy Act; Delaware Wetlands Act; Washington State Planning Act
1974	Maryland State Land Use Act

In addition, there have been executive orders and local ordinances which have restricted land use and established higher standards for air and water quality.

The version of the National Land Use Policy and Planning Assistance legislation introduced by Senator Henry Jackson* was passed by the Senate. However, the version of this bill brought before the House of Representatives by Congressman Morris Udall was not reported out of Committee. This bill would have encouraged all states to become involved in land use planning. The Jackson legislation proposed that the federal government (through the Department of the Interior) would appropriate to the states $982 million over an eight-year period to assist in the planning process. A similar bill is likely to be introduced in the next session of Congress. However, as may be seen from the chronology of legislation,

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*U.S. Senate, Bill No. S.268, 1973.

many states have moved forward on their own. Currently, most federal funds for state planning come from the Department of Housing and Urban Development.

TECHNOLOGY DEVELOPMENTS

The technology of remote sensing as it applies to land use planning has developed considerably during the last six years. Three achievements are most significant: the perfection of high altitude aircraft photography and the development of satellite sensors, the successful demonstration of all-digital image rectification techniques, and the development of machine spectral pattern recognition processing.

Since 1968, data from aircraft-borne sensors have begun to be used to identify current land resource patterns and to describe changes. While the use of high altitude photography has penetrated to regional and county governments in some areas, the use of high-altitude aircraft data for complete and detailed land resource surveys at the state-wide level seems impractical for all but a few states because of the enormous amount of data which must be collected and analyzed. One of the principal uses of satellite-derived data may be to solve this problem by deciding which areas in a state really need detailed coverage by aircraft. ERTS data in both image and computer-compatible-tape form are being analyzed to determine land resource information for states and large remote areas. The potential for improving recognition of land resources from the ERTS repetitive coverage to obtain multi-temporal scene data is being investigated but work has only just begun. Finally, ERTS data for several states (e.g., Florida, Wyoming, California, Michigan, and the Eastern Seaboard from New York to the District of Columbia) have been assembled into mosaics to portray regional views of terrain. These mosaics have been used to educate prospective users on the advantages of ERTS coverage and the potential that exists for large-area land use mapping using ERTS data. This potential is beginning to be exploited now by the U.S. Geological Survey, using data from ERTS and other satellites, in cooperative programs with states.

Techniques for machine processing to map land use categories are being developed, but need further refinement, testing, and documentation before they can become an operational tool. The advantage of machine processing -- and it is an important advantage -- lies in the fact that the data are processed in digital form with increased radiometric fidelity and possibility of easy direct entry into computer data bases.

A land use classification system developed by the U.S. Geological Survey* identifies four classification levels, as follows:

Level I	Satellite imagery, with little supplemental information
Level II	High-altitude aircraft and satellite imagery combined with topographic maps

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*Anderson, James R., Hardy, Ernest E., and Roach, John T.: *A Land-Use Classification System for Use With Remote Sensor Data*. U.S. Geological Survey Circular 671, U.S. Department of the Interior, 1972.

Level III Medium-altitude aircraft remote sensing (1:20,000) combined with detailed topographic maps and substantial amounts of supplemental information

Level IV Low-altitude aircraft imagery with most of the information derived from supplemental sources.

A more complete description of these classification levels is given in the Appendix.

PROJECTED DEVELOPMENTS IN LAND USE PLANNING

The Panel expects activities in land use planning to be considerably increased in the next 10 to 15 years, as a result of requirements specified by present and expected legislation at the federal and state levels and by increased activities of citizen groups and other elements of the private sector.

ANTICIPATED LAND USE LEGISLATION

The Panel expects two kinds of land use legislation to be proposed and passed in the next 15 years. First, Congress will eventually, if not in its next session, pass national land use planning legislation, and may very well follow this with additional measures which further define national values for land resources. This legislation may well have an effect of the same magnitude as the National Environmental Protection Act. Second, the states are expected to continue to pass planning and critical environmental area legislation that is appropriate to their particular land use problems and to their natural environment. It is very possible that this state legislation will have a more significant effect on land use in some parts of the country than national legislation. This will be true particularly in states with fragile ecosystems and attractive land resources. California, Colorado, Vermont, Delaware, and other states for example, have already passed acts which have more stringent requirements than are likely to be considered in federal legislation.

The Panel expects that local ordinances and international agreements will have considerably less influence on land use planning than state and national legislation. However, the current international crises of food and energy shortages could shift priorities in this nation and influence new state and national legislation.

ASSOCIATED REQUIREMENTS

Legislative programs, both existing and proposed, will establish requirements similar to the environmental impact statements for major federal projects and legislative proposals required by the National Environmental Protection Act. This Act has required that literally thousands of statements be filed, that meetings be held, that hearings be conducted, and that reports be written and published. The benefits have been many -- in the form of better and

environmentally sound projects; better coordination between federal-federal, federal-state, and local projects; and toward a general improvement in the quality of life.

The Coastal Zone Management Act of 1972 is another example of a federal law which imposes requirements in land use planning. This Act allows for federal grants on a two-thirds cost-sharing basis for the states to develop coastal zone management programs. Annual grants are allowed in each of three succeeding years for developing the management program. After the management program has been approved by the Secretary of Commerce and adopted by the state, the Act allows for federal funding of two-thirds of the total cost of implementation. The Act requires public hearings and coordination with federal, state, regional and local governments. The Act also requires the establishment of state regulations for use and management for both land and water resources, and provides for state power to enforce these rules and regulations. The effects of requirements established under this Act are manifold in the land use planning in each of the thirty coastal-zone states. Many coastal wetlands of the type found along the East Coast and in other parts of the country are large enough and of such a nature that useful information about these areas can be provided by remote sensing techniques, particularly multispectral analysis. The uniform flatness of marsh topography eliminates variations in reflectance due to sloping surfaces and shadows. The most common marsh plant species are few in number so that photo-interpretation is simplified. Environmental changes, whether natural or man-made, generally take place over large horizontal distances in the marsh. Zones of relatively uniform vegetation or land use are therefore usually large enough to be discernible in current low-resolution satellite imagery. The major plant species, in particular, are different enough in their morphologies to have distinct reflectance characteristics. This facilitates the use of multispectral imagery to make detailed wetlands maps showing vegetation growth patterns which are related to local environmental factors. As a result, automated digital techniques have been successfully used to prepare from ERTS-1 digital tapes, precision map overlays showing at least 12 categories of coastal land use and vegetation with interpretation accuracies of over 90 percent for all categories mapped.

Land Use Commissions have been established by laws and executive orders in Colorado, Alaska, Hawaii, Vermont and other states. One of the first charges of each Commission has been to provide a basic inventory and analysis of all resources and uses from existing data. Such analyses could and probably should be made with the most sophisticated remotely sensed data available today.

The proposed National Land Use Policy and Planning Assistance Act (S.268) mentioned earlier would have provided encouragement as well as financial and technical assistance to states for land use planning, regulation and coordination of the use of federal and non-federal lands. According to the Act the states would establish within three years, a land use planning process, a planning agency, an advisory council, an inventory and analysis of resources, and a program to regulate land development projects. Within five years, the states would adopt a land use program which included methods for exercising control over critical environmental areas, key facilities, large-scale developments and new communities; establish a procedure for review of local regulations to protect the larger interests of the state and the public; and provide a method for consistently relating state and local programs with state land use programs.

THE PRIVATE SECTOR

The Panel believes that the gap between the potential use of remote sensing data and its application is of an order of magnitude greater in the private sector than in the public sector. As the scale of planning for new urban developments increases and as the citizen-consumer becomes increasingly aware of the importance of planning to optimize the use of land, the private sector will become more and more desirous of using remotely sensed data. Regional user centers, if they existed, could encourage and facilitate broad application of such information by the private sector. The Panel believes that in the future, awareness of the capabilities of remote sensing and use of remotely-sensed data by the private land development sector will more closely follow the trend in the public sector. This is expected because of the increasing interaction between private and public planners.

Land use planning is also becoming an accepted area of corporate responsibility. Some corporations -- Xerox and IBM for example -- have for some time planned for the settlement of their employees in such a way as to minimize environmental disturbances associated with new plant sites. More recently, heavy industrial developers have become aware of the need for land use planning.

CITIZEN GROUPS

The Panel expects citizen groups at the national level -- such as the Conservation Foundation, the Sierra Club, the Audubon Society, the National Wildlife Federation, the Wilderness Society, and the Environmental Defense Fund -- to maintain and possibly increase their lobbying and educational efforts. Even more significant changes will occur at the local level as groups which are either affiliates of national organizations or organized on an ad hoc basis become increasingly involved in the planning process. We anticipate that some of these groups will recognize planning problems, acquire information, and formulate alternative goals and policies independently of existing planning agencies.

ANTICIPATED INFORMATION REQUIREMENTS

As remotely sensed data becomes increasingly used in land use planning, data centers will need to be provided for distributing information. In determining a data center size, and in making decisions about the advantages of regional centers as opposed to one central facility, the demands of the user for the various types of products from the system must be assessed. The parameters of interest include the volume and type of data products required; the number of times per year the information must be updated; the format of the data product; the timeliness of delivery; the grid size of the information (as contrasted with the sensor resolution element size); and some statement of the complexity of information required and the uniformity of information classes over large areas. A final parameter is the accuracy of information. Ideally, these parameters would be listed for the research and development, transitional and operational phases of the program.

The volume of data required can be most easily specified by the user in terms of grid size of the area covered. Since data in various formats are required, and users may want different stages of processing, format definition may be broken into three parts: the type of data (e.g., color IR composite images); the kind of processing done to the data; and the delivery medium (e.g., film transparency, computer-compatible tape). For film products, the scale should be specified. Timeliness of delivery is the acceptable time between the occurrence of the event and the delivery of the product to the user. It includes the time spent acquiring, processing, and disseminating data. The grid size of information is a specification of how the user wants his information quantized. It affects sensor resolutions only in that they must be less than or equal to the grid size. The classes of information required and the uniformity of those classes over large areas are specifications relating to the extractive processing portion of the system. They determine the design of pattern-recognition devices, as does the required information accuracy.

At the present state of development of land use planning, requirements cannot be precisely identified for all users. In addition, this level of detail is beyond the scope of a two-week study. Thus, the Panel has chosen to describe user requirements qualitatively, to establish a scenario for the more precise identification of their requirements, and to present user case studies from three states to convey some understanding of user requirements.

USER REQUIREMENTS

Depending on whether the user is concerned with regional, local, or state level, the type and complexities, quantity, and grid size of information which he requires from the remote sensing and processing system will vary. Users will also require products at different stages of processing. For purposes of discussion, users are subdivided here into five groups: local, regional, state, federal, and international.

In general terms, as one proceeds from local to international users, the quantity of data needed increases, the areal coverage increases, the grid size increases, the number of classes (in pattern recognition outputs) tends to decrease, and the classes tend to be more homogeneous over large areas. Timeliness may be unaffected, since it is tied closely to the information update cycle which in turn is tied to the change rate of the land use phenomena. Some regional users of remote sensing data (EPA, for example) may require very short delivery schedules of processed data for enforcement of pollution laws. The general situation is summarized in Table I.

In Table I, a summary of user requirements, it may be seen that the required area coverage by individual users decreases as one moves from the national to the local scale. At the state level, the total area requirement is for land areas plus the offshore coastal zone or outer continental shelf. The total areas associated with regional sites probably add up to about 10 percent of the total U.S. land area. Central business districts, where 1-meter resolution is required, total about 1 percent of the U.S. land area. The total quantity of 1-meter resolution data (in terms of picture elements*) needed for a given area is 100 times greater than the quantity of 10-meter resolution data. There is also 100 times more 10-meter resolution data (in picture elements) than 100-meter resolution data.

Most users require geometric correction to map bases. The accuracy of the correction required is still a matter for debate by users and is more fully discussed in a later section of this report. The accuracy of the correction to map base for the 100-meter data should be within a fraction of a picture element. A preliminary definition, subject to future revision by users, is that corrections should be made with an accuracy of a fraction of the next largest grid size. Thus, 10-meter grid-size data should be registered within, say, 30 meters of true map grid, and the 1-meter data should be registered within, say, 3 meters of the true map grid.

A PLAN FOR IDENTIFYING USER REQUIREMENTS

In an earlier section of this report (p. 3), six classes of participants in planning were identified as having information requirements which may be satisfied by a remote sensing system. The order of these participants in terms of estimated benefits relative to costs is as follows:

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*A picture element (pixel) is the smallest discernible element of information in a remotely-sensed image of the surface of the earth.

User	Area	Type of Data	Type of Data Processing	Delivery Medium	Map Scale	Frequency	Timeliness (In Months)	Information Grid Size (In Meters)	Classes of Information*	Class Uniformity	Accuracy Percentage
National Land Use Agency	US and offshore continental shelf	Land use	Extractive; Geometric correction to map base	Tapes	--	One year	Six	100	Anderson I, II	Same classes nationwide	80-85
		Images	Geometric correction	Transparencies	1:1,000,000	One satellite orbit series	One	100	--	--	--
State and Multi-state Regional Monitors of Critical Environmental Areas	State areas to entire US	Land use change	Extractive; Geometric correction to map base	Tapes	--	Three to six months	Three	100	Anderson I, II#	Some differ at levels I, II between physical regions	85-90
		Images	Geometric correction	Transparencies	1:250,000	Three to six months	Three	100	--	--	--
State and Multi-state Regional Entrepreneurs	State areas to entire US	Land capability	Extractive; Geometric correction to map base	Tapes	--	One to three years	One to two	100	Land capability	Variation between physical regions	85-90
		Images	Geometric correction	Transparencies	1:250,000 to 1:1,000,000	One to three years	Twelve	100	--	--	--
Regional and Urban Private Entrepreneurs	Ten percent of total US in 5000 km^2 regional sites	Land capability	Extractive; Geometric correction to map base	Tapes	--	One year	One to two	10	Land capability	Site specific	80-90
		Images		Transparencies	1:24,000	One year	--	--	--	--	--
Central Business District, Urban Area, and Transportation Planners	One percent of total US in 500 km^2 regional sites	Land use	Extractive; Geometric correction to map base	Maps	1:24,000	As required; ~ one year	Three	1	Land use; Anderson III, IV	Site specific	80-90
		Images	Geometric correction	Images	1:10,000	As required; ~ one year	Three	--	--	--	--

* US Geological Survey Circular 671

\# with extension for unique data such as plant species

TABLE I GENERALIZED USER REMOTE SENSING INFORMATION REQUIREMENTS

Professional planners in public and private service

Elected and appointed officials (state, federal, regional, and local)

Entrepreneurs

Citizen groups

Educators and

Researchers.

Eventual operational user needs, transitional system needs, and research and development needs should be identified for all users.

Researchers and elected and appointed officials at the federal level should be more involved with user programs from the beginning -- initially to define the problem and potential solutions, and later to define system-operation parameters. For example, researchers and elected officials working with users should first define what types of information are required and in what formats. Whether the required information can be obtained at all and the level of accuracy at which it can be obtained should be typical of early program concerns.

In the transitional phase, more users become involved, and considerations of required accuracy, timeliness of delivery, updated cycle, and grid size become important. Costs of providing services are also of concern in this phase. More groups need to be involved here, working toward the ultimate goal of use of system information by all groups.

In fact, all groups will probably use the transitional phase remote sensing system to some degree, depending on their needs and the cost to them of using it. To the extent that the degree of use by a given user can be predicted early in the transitional phase, his operational requirements should be considered in the operational system design.

At present, system needs in the R&D phase seem well identified by the researcher (usually a geographer) working to some extent with the ultimate users. Transitional programs have only just begun, but the Panel believes that nearly all ultimate user needs should be considered before designing a transitional system (what may be referred to as an "applications system verification test"). In land use planning, the Panel feels that user needs can be established to the degree required by the following procedures:

Stratify the country into uniform physiographic regions.

Within each region, survey by personal visit, questionnaire, or other contact, samples of all potential users, soliciting the information listed in the earlier section entitled "User Requirements," for both transitional and operational systems. (The surveys proposed in a later section entitled "Required Study" may be incorporated with this information.)

Concurrently with an assessment of these user needs, NASA should assess the short- and long-range abilities of the various users to assimilate and use the remotely-sensed information and the factors which might inhibit their use of the information.

Design the transitional system to serve as many of the potential users as possible and take steps to encourage their participation and evaluation within each physiographic region.

The inclusion of state, regional, and local government, as well as private sector users at the transitional stage is important, and their needs should be considered.

Requirements for an operational system must be addressed before the transitional system is designed so that it can be structured to answer all the user's questions about the utility and cost of information -- questions that are of obvious concern. But quality control, the provision of auxillary products, user education, and provision to the user of limited ability to check the information himself are additional factors that will affect the design and cost of an operational system. The degree to which the user can participate in technical tasks such as data preprocessing and pattern-recognition processing should be assessed.

The Panel believes that involving ultimate users early in the conduct of research leading to operational applications of remote sensing systems will enhance user acceptance of the information once it becomes available. Considerable education of potential users will be required and should be provided for at the transitional stage of the program.

CALIFORNIA CASE STUDY

The land use program in the State of California is discussed here as a case study because there exists extensive documentation of activities (present or proposed) at the state level of government. In addition, California is representative of a heavily populated area, and provides opportunity for observation of a variety of land uses. The Panel believes that the California experience represents one of the best available examples of extensive utilization of land-use classification and of an accompanying expressed user demand for remotely sensed information.

Citizen interest, strong legislation such as the California Coastal Zone Conservation Act of 1972, and the Governor's "Environmental Goals and Policy Report" of June 1973 all helped to stimulate a strong mapping and documentation effort throughout the state. Mapping programs at scales of 1:24,000 and 1:62,500 have been undertaken to identify areas of critical concern. Thirteen state agencies are involved in projects which either use or propose to use remote sensing. The basic information requirements of these 13 state agencies are summarized in Table II.

In order to implement the requirements of these 13 agencies in the land use planning process there has been proposed a California Land Use Classification Program which includes 23 major classifications with 162 subcategories, as shown on Table III.

AGENCY	REMOTE SENSING APPLICATION
Department of Food and Agriculture	Differentiate between major classes of land use, major crop types, and individual crops; evaluate crop damage.
Department of Water Resources	Identify and map various features related to water resource development and management, including land use, evaluation of inter-relationship between water and agriculture, and urban and native lands.
Department of Conservation, Division of Forestry	Identify and map type and distribution of vegetation, fuel condition classes, timber site classes, and environmental hazards.
Department of Conservation, Division of Mines and Geology	Map soil and geology; analyze geomorphology and tectonic relationships, including faults; map vegetation as an indicator of parent materials.
Department of Fish and Game	Monitor seasonal changes in wetlands; inventory wild animals, waterfowl, and marine mammal habitats and migrations.
Department of Parks and Recreation	Prepare landscape province analysis, with emphasis on wildland vegetation mapping to determine recreation site potential.
Department of Transportation, Division of Highways	Evaluate land use and geologic factors related to transportation planning and design; evaluate environmental impact of highway construction.
Department of Navigation and Ocean Development	Evaluate near shore current patterns, littoral transport, shoreline erosion, estuarine exchange, river discharges and sediments, and tidal flushing actions.
State Land Commission, State Lands Division	Map water line demarcation; identify underwater features; detect oil spills; map land use.
Department of Public Health	Inventory flooded and wetlands for mosquito abatement planning; identify waste discharges.
Air Resources Board	Detect pollutant concentrations and evaluate their spatial distribution and movement.
Water Resources Control Board	Detect, identify, and monitor non-point source pollution problems relating to agriculture and urban land use, salt accumulations, erosion, siltation, pesticide residues, and bacterial contamination.
Office of Emergency Services	Assess damage and develop a pre-disaster data base; land use and site classification.

TABLE II BASIC INFORMATION REQUIREMENTS FOR THIRTEEN CALIFORNIA STATE AGENCIES

	URBAN LAND	
Residential	- Distinguish from other urban uses - Determine dwelling unit density - Evaluate quality - Single family vs. multiple family	- Older residential from newer - Urban fringe detection - Water using surfaces - Conversion to other uses
Commercial	- Strip vs. large shopping centers	- Large hotel/motel complexes
Industrial	- Heavy industry (primary conversion) - Storage and distribution	- Extractive (oil fields, quarries, dumps, gravel pits, etc.)
Transportation	- Airports - Highways	- Railroads and yards - Terminals
Open Space and Recreational	- Parks - Golf courses	- Stadiums, arenas, race tracks, baseball parks, etc.
Other	- Schools - Institutions (hospitals, prisons, reformatories, asylums, etc.) - Large paved areas - Communications and utility facilities (power, water, waste, etc.) - Urban renewal	- Recreation/second home subdivisions - Cultural facilities (libraries, churches, museums, historical sites, etc.) - Disaster assessment - Change detection (spatial, temporal) - Military facilities
	CROPLAND	
Crop Type	- Orchards - Vineyards - Grain crops (dry farmed) - Truck and field crops	- Pasture (improved) - Horticultural crops - Rice lands - Selected specialty crops

(continued)

TABLE III AN EXAMPLE OF A LAND USE CLASSIFICATION SCHEME

CROPLAND (continued)

Crop Condition	- Disease detection - Plant leaf temperature - Crop stress (nutrient deficiency, wilting, etc.)	- Albedo - Stage of growth and ground cover condition
Water Use	- Irrigated vs. non-irrigated - Heating, cooling, and insect control - Type of irrigation system - Tail water ponding - Reuse of tail water - Irrigation frequency and number - Consumptive use	- Wintertime irrigation (recharging soil moisture in low precipitation areas) - Leaching (wintertime irrigation, ponding of water, etc.) - Detecting agricultural waste water discharge sites - First and last irrigations
Crop Cultural Practices	- Stubble burning - Crops for hay or pasture (non-typical uses) - Winter cover crops - Intercropping - Non-till operations - Planting and harvesting dates - Crop rotation patterns	- Defoliation - Spraying for sunburn protection - Seed crops - Row vs. broadcast plantings (for typical irrigated row crops) - Pruning/training practices - Leveling/terracing
Other	- Salinity detection - Special problems (erosion, wind damage, drainage, etc.) - Change detection (spatial and temporal) - Fallow land	- Dry farmed vs. native vegetation - Multiple cropping - Size of economic units - Soil moisture conditions (surface and subsurface)

GRASS AND BRUSH LAND

Vegetative Type	- Grasslands (annual, perennial, mountain meadow) - Savanna (oak-grass) - Brushland	- Unique biotic communities/individual plant species - Riparian

Cultural Practices	- Managed vs. unmanaged - Irrigated native vegetation (treated effluent) - Controlled burning	- Range improvement - Hay harvesting - Winter vs. summer grazing - Fertilization
Other	- Overgrazing - Burned areas - Grassland phenology - Slumping, slides, water erosion - Stage of plant succession - Monitoring conversion of lands to grass or brush - Fuel types - Fire hazard/land value rating - Plants as indicators of soil type, nutrient status, and moisture condition	- Grassland condition predictions - Rate of plant succession - Damage from human uses - Recreational uses - Animal carrying capacity (present and and probable future) - Presence of forage-damaging agents (weeds, rodents, diseases, etc.) by type - Vegetation density - Wildlife habitat assessment - Historical/archaelogical sites
	DESERT LAND	
Vegetative Type	- Grass (meadows) - Shrub (sage, creosote brush) - Joshua trees	- Juniper/big sagebrush - Phreatophytes - Rare and/or unique species
Cultural Practices	- Grazing	
Other	- Off-road vehicle use - Historical/archaelogical sites - Mining activity - Plant succession rates	- Wind and water erosion effects - Salt playas - Wildlife habitat assessment
	FOREST LAND	
Vegetative Type	- Hardwood - Mixed evergreen - Coniferous - Riparian	- Mountain meadow - Unique biotic communities/individual plant species

(continued)

TABLE III AN EXAMPLE OF A LAND USE CLASSIFICATION SCHEME

FOREST LAND (continued)

Cultural Practices

- Clear cutting
- Selective cutting
- Managed vs. unmanaged
- Controlled burning
- Grazing
- Reforestation
- Logging practices

Other

- Overgrazing
- Burned areas
- Stage of plant succession
- Fuel types
- Timber site classes (yield)
- Disease detection and mapping
- Fire hazard/land value rating
- Tree blowdown assessment
- Slumping, slides, water erosion
- Frost damage
- Assessment of harvesting practices on watershed conditions, water quality, fish, etc.
- Rate of plant succession
- Recreational uses
- Soil-vegetation relationships
- Damage from human uses
- Present tree and stand vigor by special and size class
- Present and probable future yield by species and size class
- Energy balance/consumptive use estimates
- Wildlife habitat assessment
- Historical/archaelogical sites

WATER (selected examples)

- Detection of pollution sources
- Monitoring change in lake and reservoir storage
- Monitoring direction and rate of pollution movement

GEOLOGIC FORMATIONS (selected examples)

- Identify land forms
- Evaluate fault lines
- Identify and map contact zones
- Evaluate beach morphology
- Evaluate alluvial processes

NATURAL DISASTERS (selected examples)

- Delineation of flooded areas
- Mapping burned-over areas

TABLE III AN EXAMPLE OF A LAND USE CLASSIFICATION SCHEME

Thus, the information requirements of California state organizations constitute an excellent sample listing of potential user demands which may be satisfied in whole or in part by remote sensing. California also may well be a laboratory for evaluating trade-offs and cost effectiveness of various techniques for acquiring data. Emphasis that the real objective is decision-making based on good information, and not simply data gathering, is evident from the following excerpt from the 1973 Annual Report of the California Coastal Zone Conservation Commission*:

> "EMPHASIS ON DECISIONS, NOT DATA. The emphasis of the Commission's planning is on reaching decisions, not on accumulating data. Volumes of information about the coastal zone already exist because of the work of the many local governments along the coast, the preparation of the Comprehensive Ocean Area Plan (by the Department of Navigation and Ocean Development in the State Resources Agency), and the work of many other State and Federal agencies.
>
> "Data is the necessary foundation for planning, but data is not of itself a plan. What is needed now is to use all available information, along with other necessary research, to arrive at policies for the future of the coastal zone. For example, should "superports" for supertankers be built in the coastal zone? Should large coastal areas be used for housing, or should recreational development have a higher priority? Can better public access to the ocean be provided in built-up urban areas?"

COLORADO CASE STUDY

The Summary Report of the Colorado Land-Use Commission (December, 1973)** exhibits a substantially different user requirement than the California case study. The Colorado report does not go deeply into land use classifications and specific user needs but rather provides a perspective of a state land use management program which depends on a data base and information system for its successful operation. As of January 1974, maps and resource inventories were available in the following areas:

Existing land use

Land ownership

Selected energy resources and pipelines

Electrical power plants and distribution systems

1973 Annual Report, California Coastal Zone Conservation Commission, San Francisco, California, 1974, pp. 5-6.

**Available from the Colorado Land-Use Commission, 1550 Lincoln Street, Denver, Colorado 80203.

Selected mineral lode resources

Potential available groundwater

Snow depth

Water service areas

Potential for irrigated agriculture

Potential for non-irrigated agriculture

Sediment yield

Soil shrink/swell potential.

The maps and inventories were prepared by utilizing standard cartographic techniques based on existing data sets, low-altitude aerial photography furnished by others, as well as by specific field investigations. Significant contributions were made to the mapping process by many federal, state, and local agencies, and innovative formatting techniques were utilized to a large extent. The use of remote sensing was considered but was discarded because of the practical problems of matching ERTS imagery with existing base maps.

For furtherance of land use legislation enacted by the General Assembly of Colorado, for the past three years the Colorado Land Use Commission has been building a program designed to provide a framework and a process by which the state and its political subdivisions can guide future development. As in California, emphasis in Colorado is on decisions based on data rather than on data alone. As the Commission sees it, its recommended land use program:

> Emphasizes the local and regional levels of government as the primary decision-makers on local questions of land use;
>
> Focuses on enhancing the quality of life, not just on restraining the quantity of growth; and
>
> Provides a flexible framework and process for guiding growth, not just a traditional mapping and inventory plan.

Given the diversity of regional needs, the Commission had to formulate a set of goals for the state, reflecting regional diversity yet providing a focus for a statewide land-use policy. The Commission first formulated broad goals, and then outlined targets (what ought to be done, where, and by when) and policies (who ought to do what, and how). Next came the consideration and adoption of program elements (the tools for carrying out the policies), and finally the development of an organizational structure and a set of short- and long-term strategies. The Commission adopted goals for four major areas related to land use -- environment, economic development and population, natural resources, and related social concerns.

Those goals, seemingly relevant to information needs to which remote sensing might contribute, are listed below:

> Control development to conserve natural environmental amenities, including air and water.
>
> Control development in hazardous or environmentally fragile areas.
>
> Initiate measures to inhibit land uses which result in the unnecessary conversion of prime agricultural land.
>
> Establish a state forest policy.
>
> Encourage effective and rational use of the state's water resources.
>
> Provide for explicit analysis of social implications and impacts of public or major private land use decisions, as in provision of and access to health, educational, recreational, housing, and employment opportunity.

In addition, the following policy themes which guide the development of programs appear relevant to the characteristics required of the information collection and distribution system:

> Regionalism constitutes the base for land use program planning and control. Within five regions, complementary land use planning activities are carried out by planning and management districts and county and local governments.
>
> Monitoring and control of new development projects is a basic program element of the land use program.
>
> The continuing comprehensive planning process (rather than a static master plan) is the key to an effective and workable land use program.
>
> Broad citizen awareness, involvement, and support are sought at all levels of the system.
>
> Land use program capability is developed at the local and regional levels.

In examining this case study the following facts became apparent to the Panel:

> Colorado's mapping program and resource inventory did not make use of data obtained by remote sensing from space even though the program was accomplished during the period when data were being provided by ERTS-1. This decision was reached

because of practical problems in matching ERTS imagery with existing state base maps. This subject will be dealt with later when the matter of map projection is taken up.

Colorado's land use management program re-emphasizes the need for continued monitoring, identification, evaluation, and other data programs which are not now being provided in any substantial way by space-based remote sensing systems. Improvements are needed in ERTS map matching capability.

The emphasis on land use program capability at the lowest level of government in the state underscores the need for a distribution system which assures rapid dissemination of information.

The Colorado example underscores the need for a reliable information system and monitoring capability in the implementation of "growth centers" which are planned to maintain and increase the social and economic viability of rural areas, the slowing down of urban growth where it is appropriate, and the protection of prime agricultural lands and other natural resources.

ALASKA CASE STUDY

Alaska offers an excellent opportunity for the application of remote sensing technology. There are many important needs for information on natural resources and on land use -- actual and potential -- but conventional means of data acquisition are difficult and costly because of difficulty of access to the greater part of the state and the lack of communication facilities. At the same time there are important onshore and offshore resources in Alaska of great value to the state and the nation.

Growing requirements for fish, wood, oil, gas, minerals, recreation, clean air and water, while at the same time maintaining the quality of the environment, are putting great demands on planners in Alaska. Land use planners and resource managers need the best data possible. Remote sensing, from aircraft and from spacecraft, using most of the capabilities of available sensors would be very useful now and in the future. ERTS data and imagery have proven very useful in Alaska. ERTS imagery is available now for all of the state except parts of the cloud-shrouded Aleutian Islands. The Joint Federal-State Land Use Planning Commission and the Soil Conservation Service of the U.S. Department of Agriculture have published a statewide set of ERTS mosiacs at 1:1,000,000 scale. The University of Alaska has mosiacs for key areas at 1:500,000 scale. The University has done an outstanding job in the research and development phase, but there is now a need for both operational and extension service. Remote sensing data from high altitude aircraft are needed now.

It is the Panel's opinion that a joint federal-state remote sensing center for Alaska should be established now to assist the native village and regional corporations (established under a federal law), the state, the federal government, and private users in all phases of land use planning and land management. The reasons are as follows:

Alaska is one-fifth the size of the conterminous United States, and has about one-third of the nation's outer continental shelf.

The state's resources -- particularly its energy and minerals -- are important to the state and nation.

Under the provision of the Alaska Native Claims Settlement Act of 1971, important and extensive claims of land ownership must be decided within five years. The Joint Federal-State Land Use Planning Commission assembled and is publishing with the state an inventory of the resources of Alaska. The Commission has also conducted cooperative training programs on the application of ERTS data and has assisted in publishing an ERTS mosaic of the state. The Commission could serve as a valuable interface between the proposed remote sensing center and the user community. The center should provide not only research and development but operational and extension or educational services.

A review of the state resources and recent developments may be helpful in understanding the needs of Alaska. Alaska is a complex combination of mountains, muskeg, forest, tundra, glaciers and ice fields, rivers and lakes, islands and fiords, beaches and rocky coast, seasonally bounded by ice-free or ice-choked waters. It is bordered by an outer continental shelf one and a half times the land area (375 million acres of land and inland waters). Major oil and gas deposits exist both onshore and offshore. Alaska may have from three to eight times the known oil reserves found to date in the contiguous forty-eight states. The mineral resources of the state are also very important.

Alaska is relatively undeveloped. At present, only one-fourth of the state falls in local political subdivisions. This situation, however, will change rapidly. The state will soon be divided into major areas of native, state, and federal ownership. The Alaska Statehood Act of 1958 gave the state the right to select by 1984 about 104 million acres from the federal public domain. As of July 1972 only 14.5 million acres of this selection had been approved. The Native Claims Settlement Act allows native corporations to select approximately 44 million acres of public land; their selection must be completed by December 1975. In addition, the Act authorized the U.S. Secretary of the Interior to withdraw up to 80 million acres of "National Interest Lands" for possible additions to the National Park, Forest, Wildlife Refuge, and Wild and Scenic Rivers Systems. He was also authorized to withdraw lands for "public interest." In December 1973 the Secretary submitted to Congress (in the proposed Alaska Conservation Act) his recommendations for the 80 million acres to be added to the four national conservation systems. In addition, he has withdrawn about 60 million acres of "public interest" lands that will be controlled by the Bureau of Land Management.

The federal and state governments are in conflict over the withdrawal of the land and as to what ownership and management systems are best. The interests of the native corporations are also in conflict with state and federal interests in some areas. In addition, various industry and special interest groups, both in the state and the nation, have strong concerns about the final disposition of Alaskan lands.

In this case the Congress, the President, the Secretaries of the Interior and Agriculture, the Governor, and the Commission are the potential "prime users" of remotely sensed data. They need the best inventory and analysis of Alaskan

resources that current technology can provide to assist them in decision-making relative to land use planning in the state. The remote sensing center for Alaska recommended by the Panel is needed now. It is the Panel's opinion that the needed technical expertise resides in NASA and that NASA should be authorized by Congress to engage in operational aspects of remote sensing and in the extension or educational field. The other federal agencies involved in remote sensing could supply key personnel and other services to assist. The State of Alaska should be a full partner to provide specification of user needs and to assist, at the state, regional, municipal, local, and private levels, in interpretation of the data.

ISSUES FOR THE USER COMMUNITY

In the course of its consideration of user requirements and ways in which they may be better determined, the Panel has identified four issues common to all planning users which must be addressed and resolved by the user community before decisions may be made on sensor design and information extraction procedures. These four issues involve the establishment of standards for (1) the matching of the space imagery grid with the existing planning grid; (2) the accuracy of information extracted from data obtained from spacecraft compared with the accuracy of currently used data; (3) the categories which are required for the information extraction process; and (4) the map projections in which space imagery and present planning data are presented. For each of these, it will be necessary for the planning community to assess present standards and practices and to discuss desired standards.

GRID MATCHING

The grids used by various segments of the planning community differ. For example, the property boundaries of the cadastral grid are used at the local level while political boundaries of counties are used at the state level. Processing of data from satellite observations is most suited to regular grids -- a matrix of either square or rectangular cells. The user decision needed on grids, therefore, is concerned with how they will be matched and within what spatial tolerances. If the planning community requires a close match, then the resolution requirements of the sensor system must be refined, the space imagery must be accurately registered with ground control, and, perhaps most important, the data volume must be substantially increased. For example, let us assume that the State of Colorado wishes to prepare and regularly update a land use map in which the planning grid is ownership boundaries, and the required resolution is 10 meters. This resolution would require a total of 2.4 billion cells in the space imagery, a volume of data which would severely strain the computer resources of most states. More importantly, this degree of precision may not be necessary, since it may exceed the standards of conventional surveys.

A suggested degree of precision is difficult to identify at this time, but a preliminary definition of a grid cell size for statewide inventory is contained in Table I (e.g., 100 m). As a further example, California land use planners want 4000 m^2 (one acre) resolution to assess changes in critical environmental areas, but could accept 4-16 hectare (10-40 acre) resolution for general land use applications.

ACCURACY

Accuracy is a measure of the success of a manual or computer classification of remotely sensed imagery, expressed as a percentage of the certainty that the category identified on the image actually occurs at the corresponding point or area on the ground. Desired accuracy is a critical design parameter for both the sensor and the classification system.

In its attempt to assign desired accuracy levels to various data categories and planning problems, the Panel has become aware that the planning community is not certain of the accuracy of the data it is now using. The Panel believes that many of these data may have relatively low accuracies (lower than 75 percent).

DATA CATEGORIES

The set of land use categories proposed by Anderson *et al* (see Appendix) is considered adequate for land use description at the national level. For planning at state, regional and local levels, however, it may be desirable to have a somewhat different set of categories which are specific to the type of problem or the characteristics of that particular area. A land-quality classification, for example, will be much more elaborate than the Anderson system. Local jurisdictions may wish to include a category for land which is under development. It appears that specific category requirements such as these could be accommodated within the Anderson classification at Level IV. However, planning agencies at present use widely different systems and it must be expected that it will be difficult to arrive at standard categories which will be accepted by a majority of regional and local planners, especially in critical environmental areas.

MAP PROJECTIONS

Data sensed from space must be presented in a known coordinate system or map projection. The UTM (Universal Transverse Mercator) is generally considered to be the most suitable projection for large scale maps except at high latitudes. It is used for most national topographic map systems.

The UTM projection and the closely related State Plane Coordinate System are among the several map projections which are used by planning agencies. Others are the polyconic, the Lambert conformal, and local map projections. These variations in user demands mean either that space imagery must be provided in the projection requested by the users, or the user must convert his existing spatial data to the projection of the space imagery. The Panel sees considerable difficulties with either alternative.

REQUIRED STUDY

The Panel recommends that an integrated comprehensive study to resolve these issues be initiated and completed as soon as possible. The results of such a study will be useful for the design of future sensor systems, and in

addition will assist in leading to better recognition of the usefulness of space imagery in the existing planning process. The study should contain the following elements:

A survey of planning grids and the spatial tolerance required to match them with space data to the same precision as exists in conventional map matching,

The determination of accuracy standards in data presently used in planning,

A survey of variations in data categories and map projections, and

An estimate of the costs and benefits of standardized classification systems and map projections.

The Panel makes no recommendation as to what agency should be responsible for this study except that it should include planning users. Parts of this study may be incorporated with the user survey recommended earlier. (Refer to section entitled "A Plan for Identifying User Requirements.")

RECOMMENDED REMOTE SENSING PROGRAM

The Panel recommends a remote sensing program for the next 10 years which focuses on three key areas of land use planning:

> Monitoring of change in non-urban and critical environmental areas,
>
> Detailed survey of critical environmental areas and their surrounding land use, and
>
> Land capability mapping.

Users require information in these areas to satisfy requirements of laws and executive orders, to identify problem areas, and to prepare revisions of comprehensive plans.

The Panel believes that if adequate research and development is completed in these three areas, operational programs could begin as early as 1980 and no later than 1985. Several new institutional arrangements will be required however, if this program is to succeed.

To provide a context in which to consider more thoroughly the scenarios for implementation of each of these applications, the Panel hypothesized a remote sensing system identical to the one conceived by the Information Services and Information Processing Panel*. For such a system, Figure II shows the steps between the collection of data by any of several remote sensors, and the ultimate use of information derived from the data to make decisions beneficial to society.

The process begins with the collection of data by any of several remote sensing systems. Then the data are preprocessed to remove effects peculiar to the instrumentation, to calibrate the data radiometrically, and to perform geometric corrections so that the data conform to a selected map base. The next step is information extraction in which parameters of interest are developed from the data (e.g., the acreage of a crop is estimated, or the temperature of a body of water is determined). Frequently the output of the information extraction step is not exactly what the user requires and must be converted before he can use it to help him make a decision. For example, if the user

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*Panel on Information Services and Information Processing. *Practical Applications of Space Systems; Supporting Paper 13: Information Services and Information Processing.* Report to the Space Applications Board, National Research Council. National Academy of Sciences, Washington, D.C., 1975.

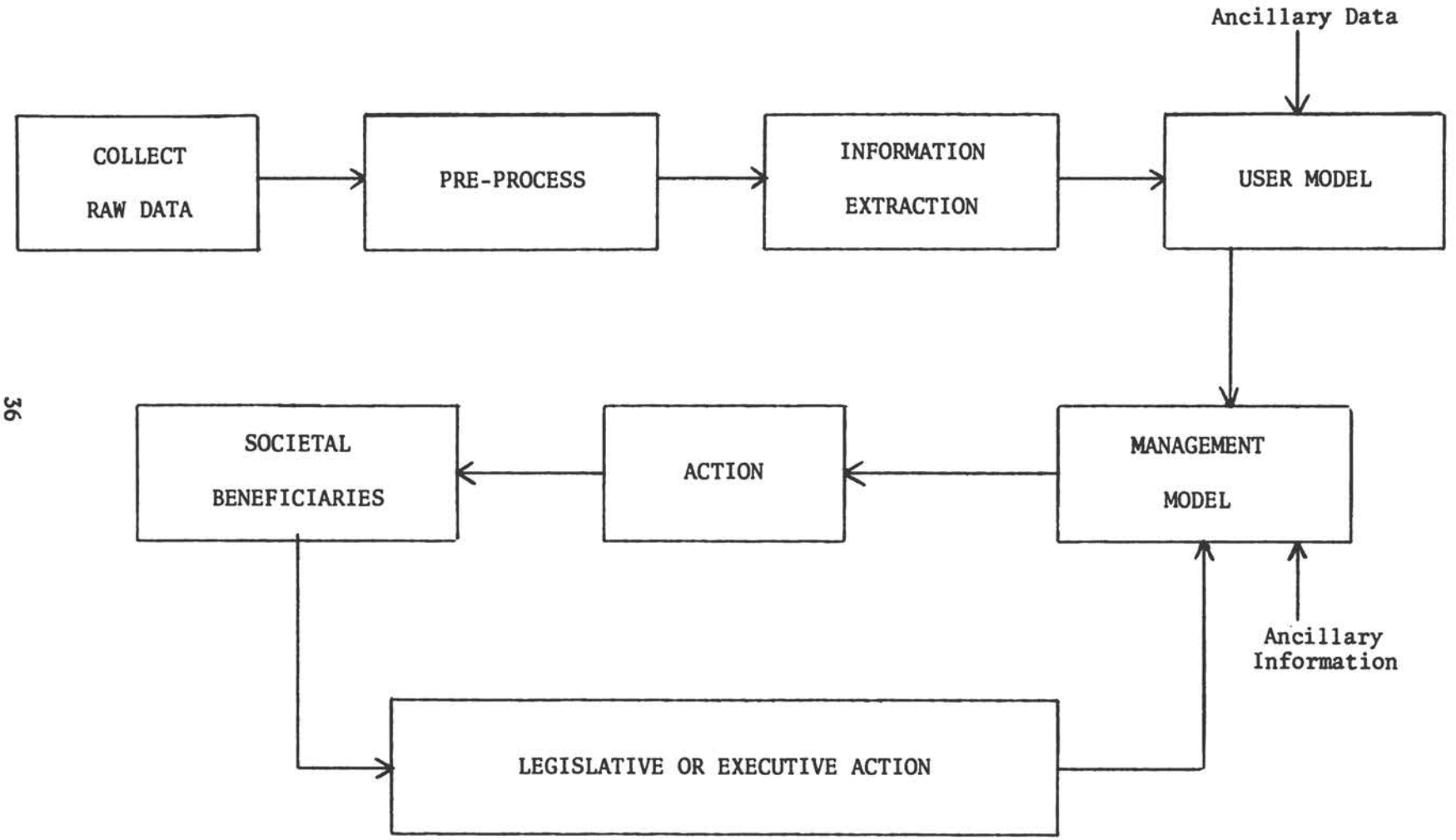

FIGURE II TYPICAL REMOTE SENSING SYSTEM FOR RESOURCES MANAGEMENT

wants to know how much area has been converted to urban use from open space in the last year, he needs a map of land use now and land use last year; he must then compare the two maps and consider only changes. Further filtering will yield a map showing changes from open space to urban. The model which performs this and similar jobs is termed a "user model." Here, the term model means an ordered set of procedures by which decisions are made or remote sensing parameters are converted to information useful to the user. In this case, the model is not necessarily a computerized mathematical algorithm, although many user models could be. The information from the remote sensing system is combined with other information in the user's management model, from which he makes decisions intended to be beneficial to society. The existence of a management model is almost invariably a result of reaction to legislation or pressure from society to identify and take action on a certain problem.

In the sections that follow, scenarios are developed for each of the three key areas mentioned in the beginning of this section. A time line (i.e., a schedule of events) for research and development, transitional, and eventual operational systems is presented, and critical factors are identified.

CHANGE-DETECTION (LAND USE AND CRITICAL ENVIRONMENTAL AREAS)

The area of change detection consists of the identification of changes in the use of land areas of states and regional areas monitored by particular federal agencies (e.g., national parks or national forests), and detection of change in the condition of critical environmental areas identified by states or federal agencies (such as the Environmental Protection Agency). There are current statutes which require state and federal agencies to monitor such changes. Some private groups and local governmental units also monitor changes in areas under their jurisdiction or of interest to them, and more may be expected to do so in the future.

It is the judgment of the Panel that the land use planning community will have a strong need for a system to detect land use changes by 1979. Such a system will be practical only if it includes the economies and speed of satellites such as the Earth Observatory Satellite (EOS). NASA should now emphasize programs in user education, data geometric rectification, and information handling to permit meeting user needs in 1979.

A schedule for the development of the necessary spacecraft by the late 1970's is presented in Figure III. Beginning in the 1974 time frame, the Panel finds some experimental evidence that the Anderson Level I and most of Level II (urban areas excluded) can be fairly accurately (70 to 90 percent) mapped from ERTS-1 data with spectral pattern recognition techniques.

R&D Phase

In the ERTS-2 period, the Panel recommends that emphasis be placed on establishing routines for the information extraction techniques and improving the accuracy of recognition through the use of temporal and spatial features in the recognition process. Examination of the utility of low- and high-altitude aircraft multispectral scanner (MSS) data for refining classification of Level II categories, especially in urban areas, and for delineating any required Level III

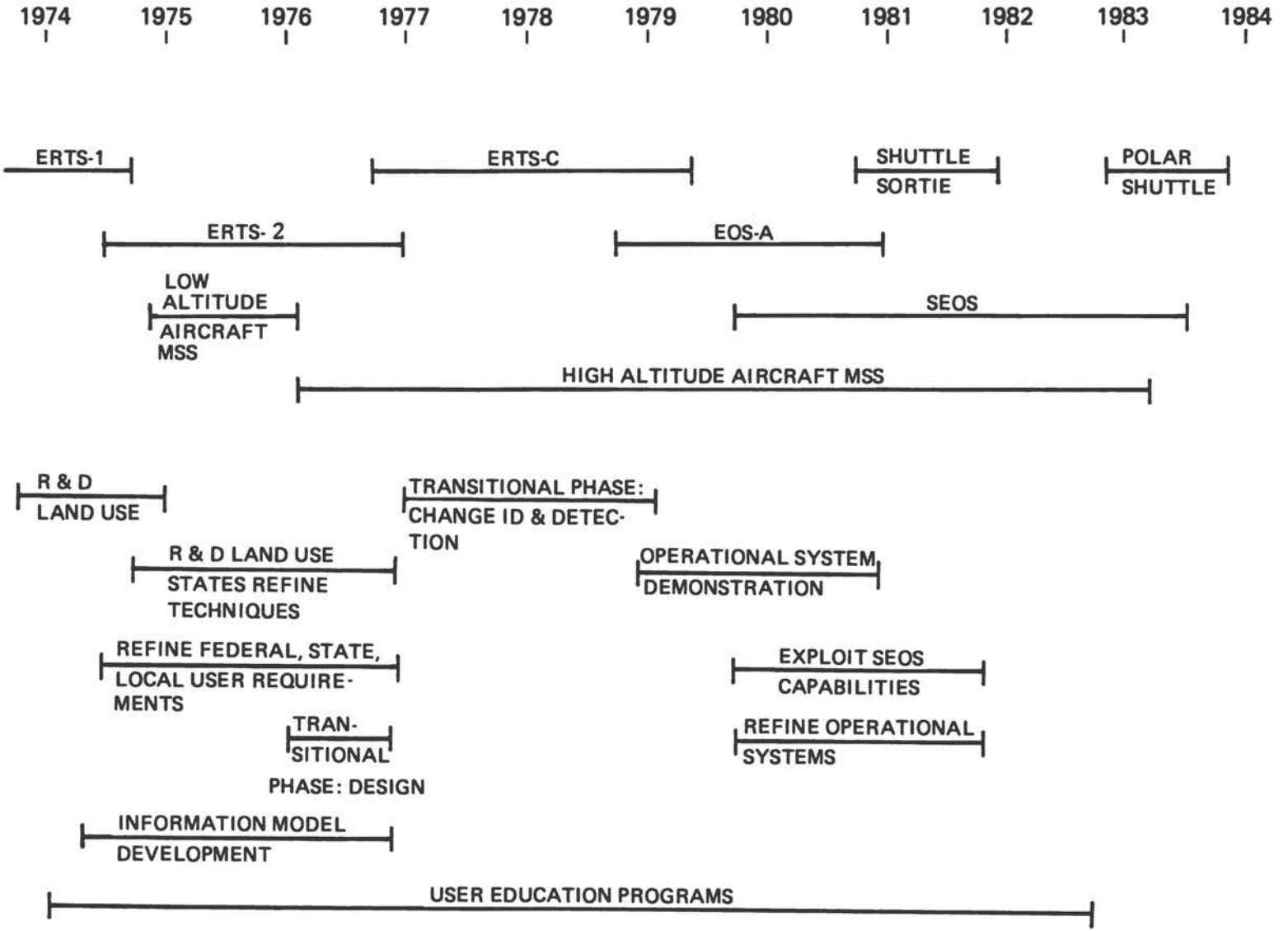

FIGURE III SCHEDULE FOR DEVELOPMENT OF LAND USE CHANGE-DETECTION AND MONITORING

data, should parallel the development of satellite data processing techniques.

The current emphasis on funding for collection and interpretation of primarily ERTS data, with less funding for collection and interpretation of high- and low-altitude aircraft data (collected in conjunction with ERTS data), should be changed in order to promote more orderly land use planning remote sensing system development. Relatively more emphasis and funding should be provided for collection and analysis of aircraft data.

The geometric rectification techniques being developed by NASA's Goddard Space Flight Center should be made available in late 1975. These techniques should be thoroughly exercised, and a capability for similar rectification of low- and high-altitude aircraft MSS data should be developed by late 1976.

At the same time that data techniques are being developed, surveys of federal, state, local, and private user requirements should be made as recommended in the earlier section on User Requirements. Federal agency requirements for information will particularly need to be assessed. In 1977, or after a federal land use planning bill eventually passes, the transitional phase program should be designed by a consortium of federal, state, and private users or their representatives, with NASA participation.

In the 1975 to 1977 time frame, the development of an information data base should be pursued. Such a data base should be capable of storing ancillary and remote sensing derived information in a grid format for areas the size of a state or region. This capability will be required by state and federal agencies in the eventual operational program, and should be exercised and modified in the transitional phase. Eventual users should definitely be on the design team to assure that their requirements are served.

Beginning in 1975, user education will be required to inform, especially, the state and local users of the capabilities and aspects of remote sensing technology. The education process can be accomplished by a combination of the U.S. Department of the Interior (USDI) Earth Resources Observation System (EROS) Data Center instruction, intensive seminars in various states conducted by NASA or other federal agencies, and education by universities and research groups in remote sensing. If users are to be convinced of the potential of remote sensing technology, the results of a complete change detection exercise, including the information data base results, should be presented before the implementation of the transitional phase.

In this advanced R&D stage, coincident with the life time of ERTS-2, NASA should supply preprocessed data to investigators working closely with state and federal agencies. The Panel considers it appropriate that NASA, with perhaps some state and federal support, fund the processing and analysis of data. The data should be evaluated by the users and NASA.

Transitional Phase

In the transitional phase (1977 to 1979), the updated extractive processing capability, the information data base development, and user requirements should be integrated for a semi-operational test of the change detection and monitoring technique. The Panel recommends that several large test sites, perhaps one in each physiographic region of the U.S., be used. The concept of a regional data processing center should be exercised at this time, since this is the probable data dissemination method of the ultimate operational system. With cooperation between centers, the adequacy of the data analysis procedures devised in the

R&D phase can be tested. Data for the transitional phase experiments will be supplied by the ERTS-C or EOS-A satellite system and by low- and high-altitude aircraft as required to permit assessment of Level II land use patterns within urban areas.

Toward the end of the transitional phase, a first capability operational system could be defined. Further education of potential state and federal users, using the results of the transitional phase (which should include cost estimates of processing), should result in the identification of many more potential users.

Operational Phase

Toward the end of the transitional phase in 1979, the clear perception of the roles of satellite and aircraft sensors and the required data processing capabilities will permit a definition of an initial operational system. The operational system components cannot be specified in great detail at this time, but the collection system will probably consist of aircraft, polar and (later) geosynchronous spacecraft, and the users' ground and auxillary data collection procedures. Processing will probably take place partly in central facilities and partly in regional facilities. Users will require a variety of intermediate products as well as the final remote sensing information. The operational system should include the means to permit the user to check the accuracy of the final information product delivered and to assure its reliability. The institutional arrangements for the operational phase are not clear now, but it seems clear that the bulk of the cost will be borne by the users.

The Panel believes that a change-detection system could be operational by 1979, using data from the EOS-A satellite and low- and high-altitude aircraft sensors. As later sensor systems capabilities such as the Synchronous Earth Observatory Satellite (SEOS) become available, the proper role for these systems within the change-detection system should be defined. We expect that the impact of SEOS on change-detection capability will be positive and beneficial because of its ability to view areas under cloud-clear conditions at different times of the day and frequently, if necessary. For example, the monitoring of coastal-zone areas on schedules related to the tidal cycle would be well served by a SEOS system. The Panel feels that the capabilities of SEOS should be integrated into the change-detection program structure already defined for the polar orbiting spacecraft sensors and aircraft sensors, and this progress will justify additional research and modification on the information data base.

PERIODIC INVENTORY OF CRITICAL ENVIRONMENTAL AREAS

This application consists of the detailed inventory of critical environmental areas (CEA) on a periodic basis or as required if the change-detection system indicates a change in such an area. Typical state and anticipated federal legislation requires frequent monitoring of critical areas as well as surveys of changes by state and federal agencies. If periodic inventory of such areas is to be accomplished by techniques other than aerial photography -- an expensive technique -- considerable development of remote sensing technology will be required. Periodic inventory of CEA will undoubtedly require a mix of aircraft and spacecraft sensor data different from the change-detection application

because higher resolution is needed and area requirements are more restricted. Because of the varying character of different critical environmental areas, greater flexibility in the information extraction phase will be required for change detection. While an unsophisticated user model was required for change detection, a set of much more sophisticated user models may be required for obtaining the CEA information.

Since the criteria for defining critical environmental areas are generally not stated in legislation, the definitions used by state and federal agencies vary considerably. However, these agencies have mutually agreed upon certain critical environmental areas, as follows:

Power plant environments,

Coal and oil-shale surface-mining areas,

Coastal zones,

National and state parks,

Key wildlife habitat areas,

Hazardous areas (geologic, fire, flood),

Oil pipelines, refineries, and ports, and

Agriculture.

The state-of-the-art in remote sensing assessment of the areas listed above varies. Power plant sites have been monitored with low-altitude aircraft, primarily to assess heated water effluents. Coal strip-mining areas have been monitored successfully from ERTS, but greater spatial resolution (10 to 30 m) seems to be required for a detailed inventory of activities. Coastal-zone wetland areas have been surveyed with low-altitude aircraft, and wetlands and coastal water quality have been monitored from ERTS. Detailed species recognition is necessary for assessing coastal wetland quality, and this requires resolution on the order of 10 meters. Yellowstone National Park was surveyed by ERTS-1, and preliminary vegetation and other resource maps prepared. More detailed assessments, especially to assess wildlife habitat and recognize important conifer communities (e.g., white bark pine) require both higher spatial resolution and spectral bands different from those on the ERTS system. Wildlife habitat areas have been surveyed from low altitude aircraft and to some extent from spacecraft. In many cases, the size of many of the critical wildlife habitats is small (100 to 200 km^2) and a resolution of about 10 meters is required. These areas have been effectively surveyed in California with high-altitude infrared photography. The survey of hazardous areas (geologic, fire and flood) and of oil pipelines has only recently started, and considerable work is required. Agricultural lands have been surveyed by low-altitude aircraft for many years and now by ERTS.

Schedule for Research and Development of Periodic Inventory Capability

The schedule for developing capabilities for periodically monitoring certain environmental areas (e.g., power-plant impact, coal and oil-shale mining, coastal zones, national and state parks, agricultural lands and wildlife habitat areas) is more amenable to quantification than for monitoring other areas, such as geologic hazards and oil pipelines, because more research and development work has been done. All of these activities are viewed as in the R&D stage now. Additional work is needed to identify the spectral bands required and to define the necessary information extraction techniques. Because the trend in future satellites (e.g., EOS) is toward spectral bands optimized for those applications which are closest to the operational stage, R&D work on these areas should proceed using data from aircraft MSS, where data from a number of spectral bands may be obtained. Indeed, the relatively small extent of many of the critical areas and the generally high resolution requirements may justify use of multispectral scanners in high altitude aircraft as a part of the operational system.

The schedule for development of each of these capabilities calls for continued R&D with low- and high-altitude aircraft, ERTS, and EOS-A, with emphasis in the 1980 time period on the definition of operational system requirements. R&D work on potential EOS-A systems is justified because of the need for the high resolution pointable imagery (HRPI) devices potentially capable of providing the 10-meter resolution that these applications require, and the need to determine spectral bands, spatial resolution, and radiometric precision optimized for land use planning applications to guide EOS-A thematic mapper* development.

R&D Program

An R&D program is suggested to accomplish the considerable work yet to be done in critical environmental areas. The general state-of-the-art of assessment of critical environmental areas is such that four important requirements must be determined: (1) some estimate of the update cycle needed to monitor impact of new facilities (e.g., power plants, pipelines) on the environment, (2) the provision for 10-meter resolution and a determination of the fraction of the work that could be done at coarser resolution, (3) the spectral bands required for each assessment function, and (4) details of the information extraction procedure.

Because of the expected modest size of critical areas, and the requirement for about 10-meter resolution, there seems to be a need for both low- and high-altitude aircraft MSS. High-altitude aircraft MSS, if available by late 1976, could provide 10-meter resolution at swath widths nearly comparable to HRPI, with more spectral channel flexibility (if a modular scanner were used) in a time frame two years before HRPI might become available on EOS-A.

Geometric rectification techniques should be developed, at least for the high altitude aircraft data, to permit the registration of these data with those of other sensors in the information data base discussed in the section on Change

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*A moderate-resolution multispectral scanner being planned for possible use on the EOS-A satellite.

Detection. This development should also be undertaken because there is a reasonable expectation that aircraft monitoring of some of the environmentally critical sites might prove to be the most cost-effective operational solution.

Institutional Arrangements

The Panel suggests that for these R&D activities, NASA, other federal agencies, and state governments, where appropriate, share the costs of research, with NASA and such federal agencies as the Environmental Protection Agency and the Department of the Interior bearing the brunt of the costs. As operational requirements are defined, the federal and state agencies should be canvassed in accordance with procedures described in the section on Anticipated Information Requirements.

Transitional and Operational Phases

Because of current uncertainties in the length of the R&D program caused by limitations of available aircraft sensors, geometric rectification, and program funding, beginning points for the transitional and operational phases are difficult to identify. However, if optimum benefits are to be derived from an inventory of coal and oil-shale surface mining, at least a quasi-operational capability must be available before extensive development of the western oil-shale deposits begins. Similarly, an oil pipeline and refinery monitoring capability should be available before Alaskan pipeline construction is far advanced. Since many states have coastal-zone legislation now, the need for periodic survey of coastal areas exists. An anticipated national wetlands survey, to be conducted by the Fish and Wildlife Service of the Department of the Interior in the next five years, further encourages the research in this area.

LAND CAPABILITY INVENTORY

The Panel expects that major improvements in land use planning would occur if better estimates of land capability, suitability, or capacity were available. Initial examples of land capability information are found in the Soil Conservation Service soil-capability index, which provides land use planners with some indication of the suitability of given sites for agriculture, and measures of the suitability of sites for residential development based on such criteria as the engineering properties of soils and potential for on-site sewage disposal. At present, such classifications have been developed and applied to most agricultural and federal forest, range, and park lands. These schemes are relatively simple, however, and allow little detailed planning. Classification systems for urban uses have been developed and applied to areas around several cities, but coverage is incomplete, and classifications vary considerably. The Panel believes that an R&D program should be instituted to define the extent to which remote-sensing systems can contribute to the process of inventorying land capability and to define the sensor system, information extraction system, and user model requirements of such systems.

The definition of land capability for a given use is a multidisciplinary problem. It involves such disciplines as geology, geomorphology, hydrology, pedology, plant and animal ecology, climatology, agronomy, forestry, range management, civil engineering, architecture, and landscape architecture. Specialists in these disciplines, together with land use planners and technologists, will comprise a team whose goal is the development of information extraction techniques and user models to derive land-capability information from the remote sensing data.

CRITICAL FACTORS

The previous discussions have mentioned several critical factors that influence the use of remote sensing data for land use planning. In this section, recommended actions concerning these critical factors are given:

Development of operational geometric rectification capability by NASA's Goddard Space Flight Center by late 1975,

Development of high-altitude aircraft multispectral scanning capability and data rectification techniques to assist in research on critical environmental area and land capability inventory and perhaps as part of an eventual operational system,

Development of an information data base to store information pertinent to the land use planning process derived by both remote and nonremote sensing,

Involvement of ultimate users in the transitional phase of program development, accompanied by the development of regional analysis centers to assist in the information extraction task, and

Resolution of the issues of grid matching, accuracy, data categories, and map projections.

SPACE SYSTEMS

In the R&D, transitional, and operational phases of the land use change-detection program, the Panel sees a need for satellite systems of at least two sorts -- high-inclination systems (possibly sun synchronous) and geosynchronous. The Panel feels that ultimately an operational satellite to monitor changes in land use will be needed. In the interim, however, data from R&D satellites can be used for system development and prototype operations.

For system development, data from the ERTS, EOS-A and SEOS satellites can be used. These data may be supplemented by data from aircraft sensors as required for assessment of urban areas. For research in the periodic inventory of critical environmental areas, considerably higher resolution, smaller-area coverage and greater flexibility of spectral bands will require either high-altitude aircraft MSS capability, or some modular MSS in a shuttle sortie or spacelab mission. Microwave sensors and modular MSS may be required in the spacelab and in high-altitude aircraft for research or land use capability inventory.

ERTS TIME FRAME

ERTS-2 or ERTS-C data can be used to assist in the design of a quasi-operational test of the change detection system. For monitoring critical environmental areas, studies to date indicate that the spatial resolution and spectral band location are marginal for many cases. The possibility of using temporal variations in terrain signatures as an aid to automatic recognition of terrain objects remains to be thoroughly assessed.

EOS TIME FRAME

Data from the thematic mapper and from the high resolution pointable imager planned for EOS-A could be used in a quasi-operational (transitional phase) demonstration of the change-detection system. At the same time, data from the thematic mapper (with about seven spectral bands) and HRPI (potentially with 10-meter resolution) could be used to advantage in research on periodic assessment of critical environmental areas and research in land capability inventory. Low- and high-altitude aircraft multispectral scanner data may still be required for both research and operational uses.

SHUTTLE TIME FRAME

It is clear to the Panel that space systems will play a major role in the ultimate operational land use mapping and change-detection system. Although the exact roles cannot be defined at present, satellites with both high inclination and geosynchronous orbits are required. Some method of getting these satellites to orbit is required. Shuttle systems could emplace both operational high inclination and geosynchronous land use change-detection satellites as soon as the early 1980's. However, potential problems exist in not having a shuttle high inclination launch capability before 1982 because of the development schedule of the Western Test Range. The Panel feels that some high inclination launch capability should be provided in the early 1980's. Gaps in this capability, or the necessity of using more expensive expendable boosters, may delay the deployment of an operational change-detection satellite system.

Even when an operational change-detection system exists, continued upgrading of the system will be needed. For example, detailed inventory of critical environmental areas and land capability analysis will be added as these capabilities are developed. Advanced experiments in these areas could be profitably performed using specialized or prototype operational sensors in a spacelab. The use of microwave sensors (both passive and active) to provide all-weather terrain mapping capability and potentially to assist in the delineation of land capability could be assessed on a spacelab mission.

If an *operational* change-detection program is to be relied upon in the early 1980's continuity of service must be assured. The availability of a shuttle capability to launch replacement satellites, with the potential to calibrate and repair existing ones and to fill in critical data gaps, should not be minimized.

FINDINGS AND RECOMMENDATIONS

FINDINGS

Because of increased intensity of land use planning, and the potential for greater awareness on the part of land use planners of the potential usefulness of remote sensing, the Panel concludes that remote sensing systems will be useful in future land use planning efforts which are likely to be required because of expected legislation.

The Panel further concludes that information from an aircraft-spacecraft remote sensing change-detection system, augmented in later stages by capabilities to periodically inventory critical environmental areas and to survey land capability will be essential to land use planning by 1985.

The Panel concludes that remote sensing can act as a pacer and prod in the planning process because of the repetitive nature of the information provided and its rapid availability.

The Panel finds that although many land use planners are aware of the possible usefulness of remote sensing, few have been able to exploit its potential.

The Panel concludes that present methods for assessing the requirements of users for remote sensing data and information are inadequate to properly design and implement transitional and operational phases of the Panel's proposed change detection, periodic inventory, and land capability systems.

The Panel estimates that, if conventional means of data gathering are used, about $250 million per year will be spent in the next decade collecting information for nonfederal agencies. The Panel believes its proposed remote sensing systems could supply more up-to-date information at significantly lower costs.

RECOMMENDATIONS

1. The Panel recommends that three systems be developed to provide information essential for land use planning, as follows:

a. A change-detection system for monitoring land use and critical environmental areas, to be operational by 1979,

b. A system for periodic detailed inventory of critical environmental areas, to be operational by 1983, and

c. *A system for detailed land capability inventories, to be operational by 1983.*

2. *The Panel recommends that NASA take the following specific actions:*

a. *Provide a high-altitude aircraft multispectral scanner (MSS) capability to accelerate the development of periodic monitoring and land capability inventory systems,*

b. *Provide geometrically and radiometrically corrected digital tapes of ERTS-2 and ERTS-C data by the end of 1975 to permit development of the change detection system by 1979, and*

c. *Vigorously pursue a program of documentation of computer information extraction software and specification of special purpose computer hardware.*

3. *The Panel recommends that a program be established to make available to the public, on a regular basis, information on the current use of land in the state, region or local area and that this be done using an effective media such as color television.*

4. *The Panel recommends that studies be made to resolve issues in the user community concerning grid matching, accuracy, data categories and map projections.*

5. *It is recommended that the capability be developed to provide users with information products processed to varying degrees, and with means to verify the accuracy of the products.*

6. *It is recommended that joint federal-state remote sensing centers be established on a regional or state basis to provide area-oriented research, development, operational, and extension service to users, and, because pressing requirements and unique opportunities exist in Alaska, that a prototype remote sensing center be established there immediately. Consideration should also be given to another prototype in a state where needs and institutions are more firmly developed, such as in California.*

7. *The Panel recommends that NASA be authorized by Congress to provide operational and extension (education) services in the data extraction and utilization area to both public and private remote sensing users.*

8. *It is recommended that arrangements be made without delay for users to participate in the planning process, and that their participation take the form of providing information requirements rather than sensor design parameters.*

9. *The Panel recommends that a complete survey of all potential users be conducted to determine area coverage, grid size, update cycle, and required information, and that the survey be repeated at appropriate intervals to assess changes in user requirements.*

10. The Panel recommends that teams of users' representatives and technologists periodically review user requirements and convert them into system parameter definitions.

11. The Panel recommends that any reconsideration of national land use legislation include specific provisions for the use of remote sensing in the data acquisition process.

APPENDIX

A LAND-USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE-SENSOR DATA*

For many years, agencies at federal, state and local government levels have collected land use data, working for the most part independently and without coordination. Too often this has meant duplication of effort or acquisition of data for a specific purpose which were of little or no value for a similar purpose a short time later. Attempts to resolve these problems in the collection and handling of different types of data have led to some reasonably effective, though not perfect, solutions, as evidenced by current programs in soil surveys, topographic mapping, collection of weather information and the inventory of forest resources.

Remote sensing techniques, including conventional aerial photography, can now be used effectively to complement surveys based on ground observation and enumeration so that a timely and accurate inventory of the current use of the nation's land resources is possible. At the same time, data processing techniques permit the storage of large quantities of detailed information that can be organized in a variety of ways to meet specific needs. Development and acceptance of a system for classifying land use information, obtained primarily by use of remote sensing techniques but reasonably compatible with existing classification systems, is urgently needed.

Designing a Land Use Classification System for Use with Remote Sensing Techniques

There is no ideal classification of land use and it is unlikely that one will ever be developed. Different perspectives in the classification process and the process itself tend to be subjective. Land use patterns change, as do

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*Abstracted from "A Land-Use Classification System for Use with Remote-Sensor Data," James R. Anderson, Ernest E. Hardy, and John T. Roach for the Inter-Agency Steering Commitee on Land Use Information and Classification, U.S. Geological Survey, Circular 671, Washington, D.C., 1972.

demands for the natural resources which affect development of land use patterns. Each land use classification is made to suit the needs of the users and few users will be satisfied with an inventory that does not meet most of their needs. In attempting to develop a classification system for use with remote sensing techniques that will satisfy the needs of the majority of users, certain guidelines or criteria for evaluation must first be established.

"Land use" is defined as "man's activities on land which are directly related to the land." Some land use activities can be directly related to the type of land cover; for instance, farming can be inferred from planted corn. Other activities, especially recreational activities, can be related to land cover by use of remote sensing techniques only with difficulty; for example, hunting can not be directly inferred from land viewed as forest, range or agricultural. Land cover is therefore the basis for categorization at the first and second levels and the activity dimension of land use for the third and fourth levels of categorization.

A land use classification system must allow for the classification of all parts of the area under study and should also provide a unit of reference for each land use. A system for use with orbital imagery should meet the following criteria:

1. The minimal level of accuracy in the interpretation of the imagery should be about 90 percent.

2. The accuracy of interpretation for the several categories should be about equal.

3. Repeatable results should be obtainable from one interpreter to another and from one time of sensing to another.

4. The classification system should be usable or adaptable for use over an extensive area.

5. The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.

6. The classification system should be suitable for use with imagery taken at different times of the year.

7. Effective use of sub-categories that can be obtained from ground surveys or from the use of larger scale or enhanced imagery should be possible.

8. Inter-relation of categories must be possible.

9. Comparison with land use information compiled in the past or to be collected in the future should be possible.

10. Multiple-use aspects of land use should be recognized when possible.

In the use of this proposed classification system, an accuracy in interpretation may be attained that will make the information comparable in quality to that obtained in other ways. For many users of land use information, the accuracy of interpretation at the generalized first and second levels is satisfactory when the interpreter makes the correct interpretation 85 to 90 percent of the time. Greater accuracy will generally be attained only at much higher costs which may not be justified for the purposes for which the information is obtained.

The accuracy ultimately attainable at each level of the classification system will in large part be determined by the capabilities of the sensors. At present, the capabilities of aerial photographs at scales of 1:50,000 to 1:20,000 or larger are well known. There has been limited experience with imagery at scales between 1:50,000 and 1:120,000 and essentially no experience with imagery at ratios of less than 1:200,000. Experience in learning how to extract information from the commonly used 1:20,000 imagery, however, indicates that whatever the present ability may be, it will improve.

There have been a few major developments in automatic and semi-automatic equipment for interpretation, but for the most part, these are still experimental and there is very little expertise in their use. Thus classification of land use from imagery will remain a visual interpretation task for some time and will only gradually become a semi-automatic or fully automatic procedure.

The kinds and amounts of land use information that may be obtained from different sensors depend on the altitude or the resolution of each. There is little likelihood that any one sensor or system will produce good information at all altitudes. It would be desirable to evaluate each source of remote sensing information and its applications solely on the basis for the qualities and characteristics of the source. However, it is common practice to transfer the data to a base map, and no matter what the guidelines, it is difficult to use a base map without extracting some additional information. Topographic maps contain an abundance of information and even road maps or a detailed city map will contribute detail beyond the capabilities of the remote sensor image employed.

The land use classification system described herein has been developed on the assumption that different sensors will provide information for different levels of classification. In general, the following relations are anticipated between classification level and source of information:

Level I	Satellite imagery, with very little supplemental information
Level II	High altitude and satellite imagery combined with topographic maps
Level III	Medium altitude remote sensing (1:20,000) combined with detailed topographic maps and substantial amounts of supplemental information
Level IV	Low altitude imagery with most of the information derived from supplemental sources

Description of Classification Levels

Satellite imagery from ERTS-1 and ERTS-2 will generally be prepared for users at a ratio of 1:1,000,000. At this ratio, 1 centimeter represents 10 kilometers (1 inch = ~16 miles). Even if information is generated by transferring data to much larger scale maps, only a general classification based on major differences in land cover can be made. This would also be true for imagery at ratios up to 1:25,000 and Level I would be appropriate for these sources also.

Level II units of classification are based on retrieval from imagery at a ratio of about 1:100,000 (1 cm = 1 km; 1 in = ~ 1.6 mi). Information can be transferred within reasonable accuracy to fairly detailed maps, including the U.S. Geological Survey's 1:24,000 topographic maps, and a substantial amount of supplemental input can be obtained. The greater detail will allow classification on the basis of more specific uses of land rather than only nine major types of cover of Level I and the complexity of the inventory can be increased.

The categories proposed at Level II cannot all be interpreted with equal reliability. In parts of the United States, some may be extremely difficult to interpret from high-altitude aircraft imagery alone. Rather than distort the categorization and so reduce the number of useful applications, it seems preferable to suggest that additional steps be taken to obtain a satisfactory interpretation. Conventional aerial photography and sources of information other than remote sensor data may be needed for interpretation of especially difficult areas. On the basis of previous tests, it may be assumed that the cost of using such supplementary information can be held to reasonable levels.

Examples of the classifications of land use made at Levels I and II follow:

Level I	Level II
01. Urban and Built-Up Land	
	01. Residential
	02. Commercial and services
	03. Industrial
	04. Extractive
	05. Transportation, communications and utilities
	06. Institutional
	07. Strip and clustered settlement
	08. Mixed
	09. Open and other
02. Agricultural Land	
	01. Cropland and pasture
	02. Orchards, groves, bush fruits, vineyards, and horticultural areas
	03. Feeding operations
	04. Other
03. Rangeland	
	01. Grass
	02. Savannas (palmetto prairies)
	03. Chaparral
	04. Desert shrub

Level I (continued)	Level II (continued)
04. Forest Land	01. Deciduous
	02. Evergreen (coniferous and other)
	03. Mixed
05. Water	
	01. Streams and waterways
	02. Lakes
	03. Reservoirs
	04. Bays and estuaries
	05. Other
06. Nonforested Wetland	
	01. Vegetated
	02. Bare
07. Barren Land	
	01. Salt flats
	02. Beaches
	03. Sand other than beaches
	04. Bare exposed rock
	05. Other
08. Tundra	
	01. Tundra
09. Permanent Snow and Icefields	
	01. Permanent snow and icefields

At Level III, substantial amounts of supplemental information would be used in addition to remotely sensed information at ratios of 1:40,000 to 1:15,000. At a ratio of 1:24,000, 1 inch represents 2,000 feet and information can be transferred directly to the 1:24,000 topographic maps. Surprisingly detailed inventories may be undertaken and most land uses, except those of very complex urban areas or throughly heterogeneous mixtures, can be adequately located, measured and coded.

Level IV of the projected classification would call for much more supplemental information and remotely sensed data at a much larger scale.

Levels III and IV are closely related to regional requirements; therefore, no examples of these classification requirements are given.