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EVALUATION OF SKYLAB EREP DATA FOR LAND RESOURCE MANAGEMENT

TECHNICAL REPORT

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PREFACE

This report was prepared in response to a request by NASA for a comparative evaluation of the suitability of Skylab EREP and aircraft data for extraction and analysis of detailed land use data suitable for regional, state, and local planning.

This report was completed under NASA Contract No. NAS 9-13314 by: Jack B. Bale, Wayne G. Rohde, Darryl Goehring, and David S. Simonett.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Effective land planning requires an awareness of all human and natural resources that may be impacted by various management alternatives. This necessitates data inputs from a diverse set of sources and disciplines, including remote sensing. Remote sensing offers powerful information gathering capabilities and can provide accurate and detailed data in a timely and cost effective manner for the planner.

It is not the intent of this report to review the early history of remote sensing as a source of land use information or to describe the many applications in traditional urban planning programs. Works by Branch (1971), Westerlund (1972) and Estes and Senger (1974), all with numerous references, will provide the reader an excellent overview of remote sensing as it has been applied to land planning and related environmental analysis. These volumes indicate that aerial photography has significant potential for meeting data collection needs of land planners and managers.

Recently, aerial photography from high altitude aircraft has become available to planners. Such data have been found useful for detailed land use mapping over large areas. Vegas (1974) presents a methodology for the use of high altitude photography in land use classification. Similar techniques have been employed to map land use over the entire State of Maryland (Brooner and Wolf, 1974). Many other states and counties have completed land use surveys from high altitude photography. In recent years, state, county and other regional planners increasingly are faced with the need for region-wide land use and related data to update existing information, develop land use plans and to monitor outcomes of the planning process. As new techniques to acquire needed data are developed, tested, and become operationally available, planners can adopt them as a means for meeting a part of their information needs. In addition to the use of high altitude aircraft imagery, the new imagery from the Earth Resources Technology Satellite (ERTS-1) and Skylab offer a potential source of data useful to the planner.

ERTS-1 has provided data from which changing land cover patterns over large regions can be rapidly mapped and monitored. The Skylab Orbital Manned Workshop, launched in early 1973, has provided color, color infrared, and multiband imagery over much of the United States which may be used for similar purposes. In the present study we compare Skylab image information with both ERTS-1 and aircraft imagery in the context of land planning and resource management.

These results should not be judged solely on the basis of present needs and practices of various planning communities. The functions and objectives of these groups are now in the process of rapid change. New Federal and State legislative mandates are already creating the need for new or updated information. In many cases different data than that previously used will be required. An understanding of the planning process, the diversity of institutions or organizations with planning responsibilities, and their various information needs, is therefore needed to provide a context within which the roles of remote sensing may be examined.

In the following pages we discuss in turn, (1) the planning process and information needs, and (2) high altitude aircraft and spacecraft systems and data they can provide, including an account of the unique characteristics of satellite sensors with respect to area coverage, frequency of coverage, spatial resolution and data format.

The accuracy of the extracted information is then discussed, based on an image interpretation test given to several skilled interpreters. Satellite and aircraft data are then compared and contrasted for large area land cover analysis as well as more detailed regional land use surveys. The results provide an indication of the accuracy and detail of Skylab EREP photographic data for delineating regional land cover information in comparison to aircraft data.

2.0 REMOTE SENSING AND LAND USE PLANNING

The applications of remote sensing in land use planning are numerous. They include collection and analysis of land use data as well as information on the physical environment. The ways in which planners use land use and environmental data, and their needs for specific types of information are as varied as the jurisdictions and the individuals involved. There is a common trend, however, in the general process of planning, and in their major information needs, which indicates both limits and demands for remote sensing data. These may now be examined, along with the recent trends in land use planning which may lead to greater use of remote sensing by planners.

2.1 The Land Management/Planning Process

Land planning involves the allocation of land resources at a given time in response to a set of goals and objectives. Land planners and managers attempt to balance the diverse social, economic, psychological and physical needs of individuals and groups with the available environmental resources.

Land use planning typically is a government function, but may include private sector consulting and engineering organizations preparing plans for clients such as land developers, and small cities without planning departments. Public agency planners prepare plans that recognize the multifaceted goals of the general public. Public agencies involved in land use planning also have a distinct capability which other planning groups lack, namely the authority to regulate land use in compliance with policy goals and objectives.

In making a land use plan the planner first determines the goals and objectives through consulting a wide variety of public agencies and private organizations. He also uses information generated by public hearings, and independent studies and surveys.

The demand for information, the need to integrate and present information in various ways, and the need to update and revise this information continually is shown in the generalized planning process (Figure 1). Planning is by nature dynamic because of the flux and interplay between the public and private wills. Any plan will soon be outdated and erroneous as a guide to decisions of land use policy unless it is dynamic and responsive to changes in the natural and cultural environment. In order to maintain this responsiveness planners need to monitor these changes continuously and systematically.

Land use planning is conducted in both a current as well as future time frame. Current planning, known as plan administration, uses previously developed plans as guides to land use regulation through zoning and subdivision codes. Future or advanced planning analyzes private and public agency plans and coordinates them in preparation of a general land use plan. Agencies typically divide their efforts between these two functions, the proportion of which tends to remain similar at each level of the planning hierarchy: city, county, and state planning. Special purpose land use plans are developed by other governmental agencies for regions and districts defined in accordance with various types of mandates (i.e., legislation, compact, contract, etc.)

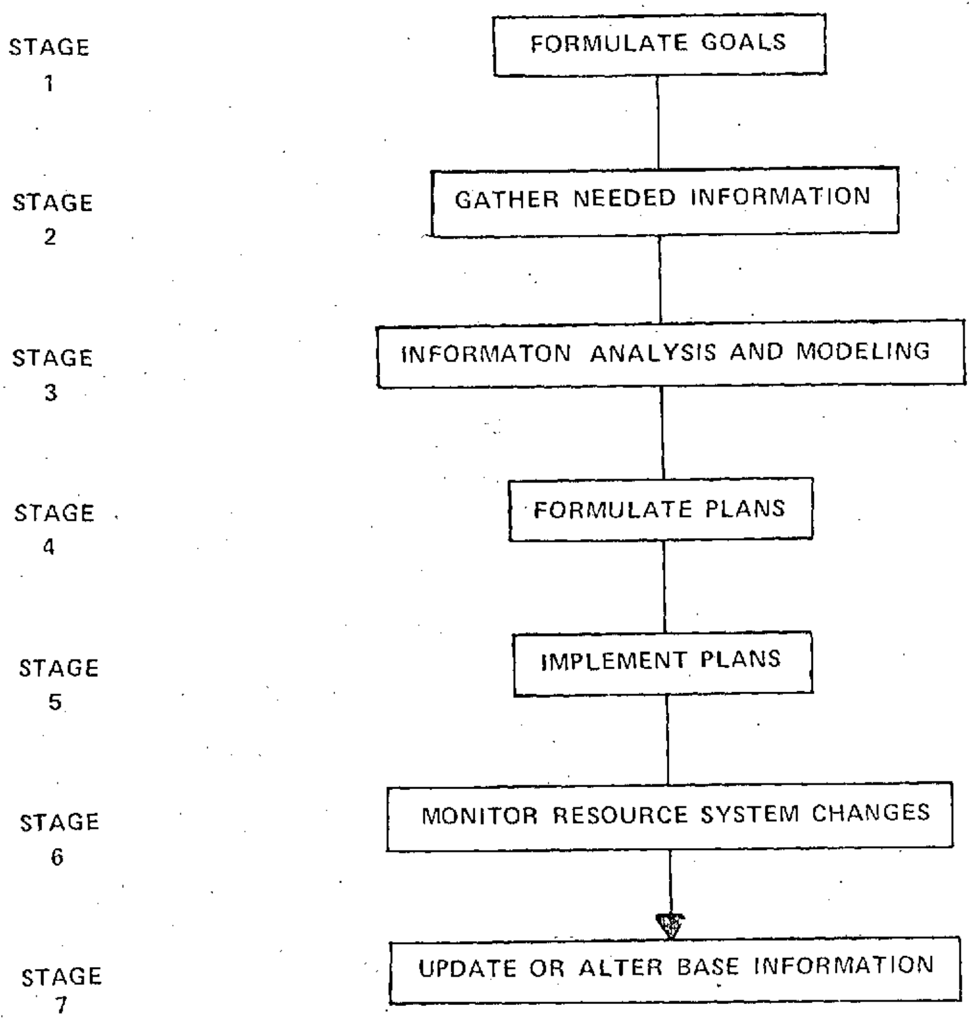


FIGURE 1 - GENERALIZED STAGES OF LAND RESOURCE PLANNING

2.2 Diversity of Planning Jurisdictions

Land use planning by public agencies can be divided into jurisdictional levels each with its own view of the planning function. Planning is also carried out by special purpose agencies at various levels which formulate specialized and often narrow land use plans. Each of these types of planning agencies is discussed below.

City planning: Land use planning at this level tends to reflect the particular goals of a city rather than goals of the constituents of an urban place, i.e., urban, suburban, and near-urban rural dwellers. The authority to plan and regulate land use is tied to the corporate city and its legislative power, not to its environs; there is little extraterritorial power among cities to plan the surrounding countryside. Specialized plans by the planning department may focus on specific land use problems, such as the renewal and rehabilitation of housing and the urban infrastructure, and generate a need for a comprehensive review of the previous general plan. Since revision of general plans in built-up areas tends to be controversial, the primary emphasis in land use planning for built-up areas is maintaining and administering the existing land use plan.

County planning: Land use planning at the county level tends to reflect the goals and objectives of a larger community of urban, suburban, and rural dwellers. County planning agencies generally are responsive to coordinating plans of local jurisdictions and plans of other county agencies that affect land use. In many cases, county planning agencies combine the functions of city and county levels of planning. County planners in predominantly rural areas may have simpler forms of planning, or a county may even lack land use planning of any type.

State planning: States were delegated power to regulate land use by the U.S. Federal Constitution. To make government responsive to local needs, however, the states generally have passed this power down to cities and counties. States have reserved land use planning functions which focus on state owned lands, location of state capital projects, development of policy guidelines for local planning agencies, and coordination of statewide plans, e.g., transportation including roads, highways, harbors, and airports, open space, etc. Similar plans are compiled by local jurisdictions and reviewed and combined with the state plans.

States have begun to retain regulatory power to control land use and development in critical areas, and to regulate specific land use problems including strip mining, power plant siting, and coastal zone activity. Although the primary impetus for expansion of statewide planning activities has been existing and pending Federal legislation, many states which are rapidly growing, and therefore are liable to serious environmental damage through unrestrained development, or are seeking to preserve and protect exceptional environmental amenities have recognized the need for developing statewide land use plans.

Land Resource Management Activites by Federal Agencies: Many Federal agencies are actively involved in the process of managing land resources. Federal involvement is characterized in several ways. These include: 1) direct land management as practiced by agencies such as the U.S. Forest Service, the Bureau of Land Management, or military agencies within the Department of Defense; 2) large scale site development such as water impoundments, bridge and highway construction, and 3) federal agencies are also charged with administering programs designed to provide funding and direction to state or local resource management programs. For example, the Environmental Protection Agency, the Department of Health, Education and Welfare and the Department of Housing and Urban Development administer legislation of this type.

Land use planning by other governmental agencies: Several types of agencies plan on an interregional level and involve mixtures of jurisdictions ranging from combinations of states and counties to regions defined by a specific problem, e.g., soil conservation and water districts. The concern of most agencies generally is to determine the effect of land usage on the primary subject of planning. One type of mixed jurisdictional agency, the Council of Governments (COG), has been established between the county and state level to coordinate a wide variety of activities, including land use planning, among cities and counties in urban regions.

2.3 Variation in Planning Jurisdiction Size and Authority

Two important determinants of planning needs are the size of a jurisdiction and the nature of an agency's legal basis for authority.

A primary criterion in determining the applicability of remote sensing to a planning problem is the areal extent of that problem. Budgetary considerations facing each jurisdiction necessitate cost-effective means of data collection. Jurisdictions of several levels may collect data of the same type in the same way because they occupy the same size range (Figure 2). Examples of such data collection would be cities which are vastly over-bounded, such as Oklahoma City, with substantial areas of rural land use within the corporate boundary. Information needs in the rural areas are normally more general than those for the built-up area proper which requires a more detailed classification system. Multi-level data requirements also apply to large counties, the largest of which occupy areas exceeding three of the smaller states. Thus there can be significant within-class as well as between-class variations in the demand for land use and environmental information which reflect the differing sizes of the jurisdictions.

Despite these caveats the size of the jurisdiction is a major factor governing the level of data detail required by planners. Levels of detail are appropriate to specific problems: site-oriented problems at the city level require fine grained data; site-oriented problems and regional problems at the county level depending on size (e.g., San Bernardino County, California, is 20,131 $mi.^2$) may require fine, moderate, and coarse grained data. Large states typically use all three types of data in varying proportions, while small states may use only fine and moderate grained data.

SIZE VS. AUTHORITY: SIZE LEVELS AT WHICH LAND PLANNING IS PERFORMED

JURISDICTION SIZE (IN SQUARE MILES)	JURISDICTION				MIXED JURISDICTION		
	NATIONAL	STATE	COUNTY	CITY	REGIONAL INTERSTATE	REGIONAL INTRASTATE	DISTRICT
>500,000	3,615,122 SQ. MILES	ALASKA 586,432 SQ. MILES			COLORADO RIVER COMPACT (SEVEN STATES)		
<500,000 TO >1000		TEXAS 267,339 SQ. MILES RHODE ISLAND 1,214 SQ. MILES	SAN BERNADINO CO., CA 20,131 SQ. MILES			VARIOUS COUNCIL OF GOVERNMENTS	WATER DISTRICTS SOIL CONSERVATION DISTRICTS
<1000 TO >100				LOS ANGELES, CA 463 SQ. MILES	WASHINGTON, D.C. AREA COUNCIL OF GOVERNMENTS		
<100			BRISTOL CO., R.I. 25 SQ. MILES	LIVONIA, MICH. 36 SQ. MILES			

EARTHSAT

Figure 2

Land use planning by agencies with a general responsibility for large geographic areas is more likely to be based in part on information collected by remote sensing systems. Agencies of smaller jurisdictions differ in terms of their planning function as dictated by law and have more precise information requirements. In one sense the dichotomy we are describing relates to the basic philosophical difference between site-oriented city or county planning, and spatially-oriented regional planning. That is not to say that these two types of planning are mutually exclusive or that the relationships implied are more than abstract generalizations, because in practice city and county planners consider spatial distributions as they seek to provide a rational order to local land use patterns by regulating activity at the parcel level. Regional planners consider site locations where activity or influence is so concentrated that it impacts the broad spatial arrangement of the landscape. This is particularly so with nodes and linkages of major intra-and extra-regional transportation patterns.

The scope of land planning or land management authority (type of legal mandate) determines whether information requirements should be broad or narrow. Figure 3 graphically illustrates variation in planning mandates, resource management responsibilities and possible responses as a function of jurisdictional level. Two trends are operative within state, county and municipal planning agencies: (1) planning at higher jurisdictional levels generally consists of coordinating plans of lower jurisdictions; and (2) land use planning at all levels tends to be functionally diffused, conducted by separate agencies over which the actual planning agency has varying influence.

Figure 3 ACTIVITIES AND REPRESENTATIVE AGENCIES INVOLVED IN LAND RESOURCE PLANNING

Authority, Problems, Actions / AGENCIES	AUTHORITY	PROBLEMS	ACTIONS
Federal USDA USDI DOD HUD EPA CEQ	Source: U.S. Constitution Acts of Federal Legislature Nature: (1) Plan and manage Federal lands (2) Allocate funds for land use planning to lower jurisdictions	• Comprehensive management of Federal lands • Allocation of Federal funds • Environmental impact assessment for all Federal construction projects • Regional water esource planning	• Management programs • Legal actions • Forcing compliance by withholding funding • Selective funding
State	Source: U.S. Constitution Nature: (1) Plan and manage state lands (2) Coordinate state line agencies in statewide plans (3) Allocate funds for land use plans to lower jurisdictions in state-wide plans	• Comprehensive management of state lands • Functional planning at the regional Level • Coordination of local activity • Enforcement of state legislation	• Management programs (Suitability/Capability Analysis) • Enforcement by legal actions • Taxation • Insures compliance by with-holding funding • Maintaining Information Sources
Council of Government	Source: Intergovernmental Cooperation Act (1968) Nature: Review Federally funded projects in urban areas (1) Review Federally funded projects in urban areas (2) Formulating land use policy	• Develop land use policy for urban regions • Coordination of activity within COG boundaries	• Review only (Very limited response)
County	Source: State Constitution Delegated powers from the state based on the Federal Constitution Nature: (1) Plan at county-wide level (2) Plan regions of the county (3) Manage county lands (4) Coordinate county agencies and lower jurisdictions in county plans (5) Administer plans	• Functional and comprehensive planning within jurisdiction (county boundaries) • Insuring environmental quality • Zoning regulation for unincorporated areas • Maintaining and providing services • Coordination of planning activities within county area	• Plan administration • Advance comprehensive and functional planning • Legal action • Taxation • Cooperative activities with higher jurisdictions
City or Municipality	Source: State Constitution Delegated power of the state based on the Federal Constitution Nature: (1) Plan at city-wide level (2) Plan districts of the city (3) Manage city lands (4) Coordinate city agencies in city plans (5) Administer plans	• Functional and comprehensive planning within the jurisdiction (municipal boundaries) • Insuring local environmental quality • Zoning regulations and parcel land use regu-lation • Maintaining and providing services	• Plan administration • Advance comprehensive and functional planning • Legal action • Taxation • Cooperative activities with higher jurisdictions

2.4 Information Needs of the Planning Community

Information needs of the planning community have evolved from changing social demands which have impacted and shaped the character of modern land use planning. In the last fifteen years, society has demanded greater consideration of environmental quality and has assigned part of this task to land use planners. The impact of this demand has created a greater need and use of traditional land use information, and information for determining the capability and suitability of land for various uses.

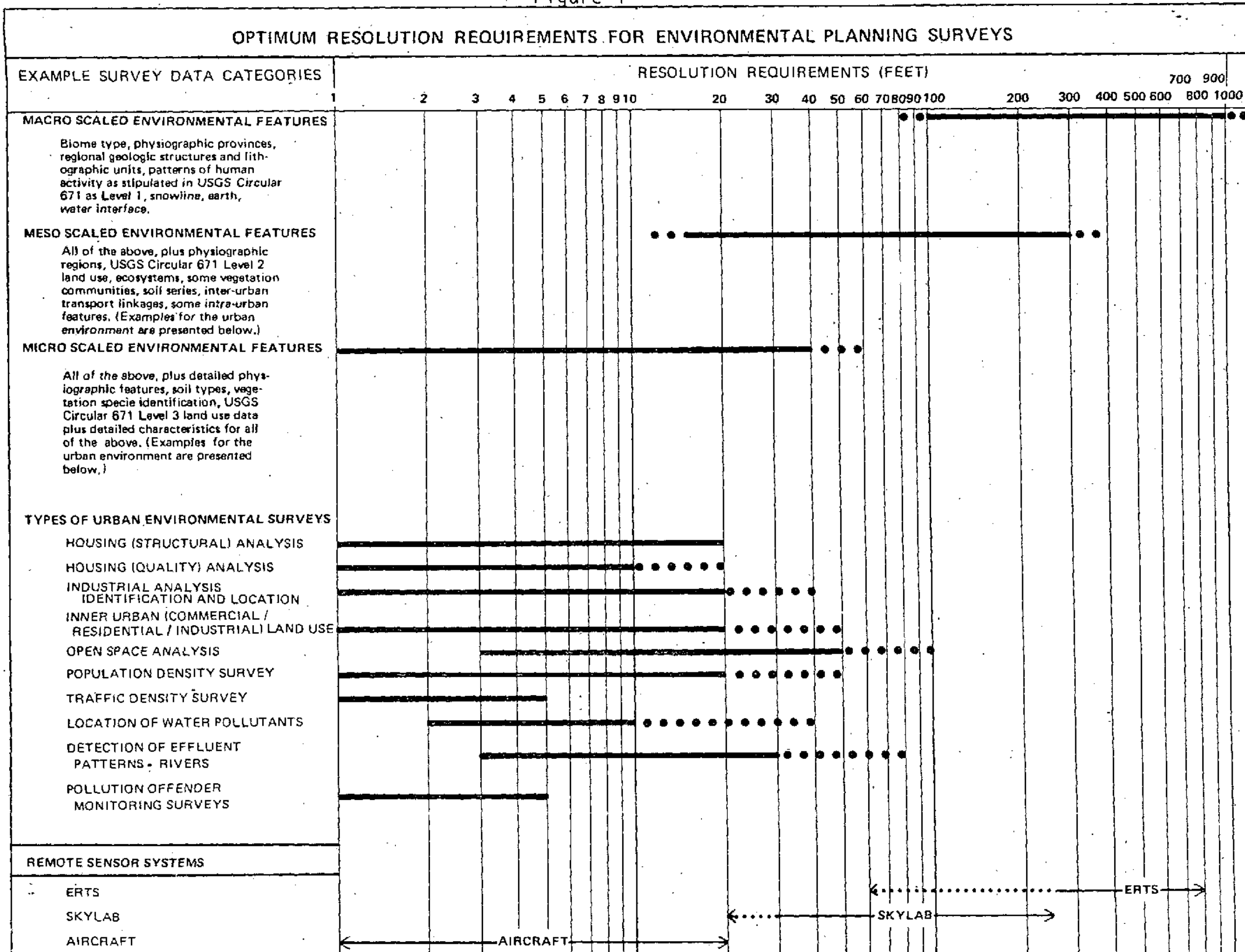
Information used by land use planners in making, analyzing, and administering land use plans varies over a wide spectrum, paralleling the breadth of governmental influence in human affairs. For this reason, no one type of information is unique to the planning community and it is only rarely collected and prepared for its sole use. A planner draws upon many types of information in a selective manner to meet his information needs. He is often forced to draw upon highly specialized information collected by functionally-specialized line agencies. Information requirements may thus range from site-specific to general within functional agencies, between agencies, and between jurisdictions all vested with authority to develop, administer and regulate land use plans.

The volume of data planners are expected to handle in the future will necessitate the use of conventional data and the use of remote sensing technology, standardized classification systems, and computer technology. Geobased information systems built and maintained with remotely sensed data, will allow planners to standardize data, to store and retrieve these data in various formats, and to display data as individual or combined themes, or as multi-themed displays comprised of several themes related to a set of decision rules or model. The use of remote sensing systems in meeting information demands of land use planners, urban or rural oriented, comprehensively focused or functionally specialized, depends on their ability to provide relevant data cost-effectively. In general, the cost of obtaining data and the volume of data collected are related. Many planning needs can be satisfied by an appropriate selection of imagery geared to a particular use. For example, high resolution systems provide volumes of data which are irrelevant to most purposes of state land use planners; the reverse of this situation applies to city planners. Figure 4 diagrams the resolution requirements appropriate to certain types of informaton used in the planning community. One fundamental decision in selecting the appropriate sensor is how many and what kind of levels of data can be obtained that are related to the planner's demand for information.

2.5 Remote Sensing Contributions to Planning

Remote sensing technology when viewed from a land resource planner's point of view is only one of many information sources to be utilized. Figure 5 sketches the major factors which must be considered in the process of transposing remotely sensed data to usable planning information. Within this diagram, lines represent systems outputs which include data and information plans as well as representations of conditions within the planning area (the resource

Figure 4



Sources. Some information modified from F. J. Wobber (1970) and D. S. Simonett (1969).

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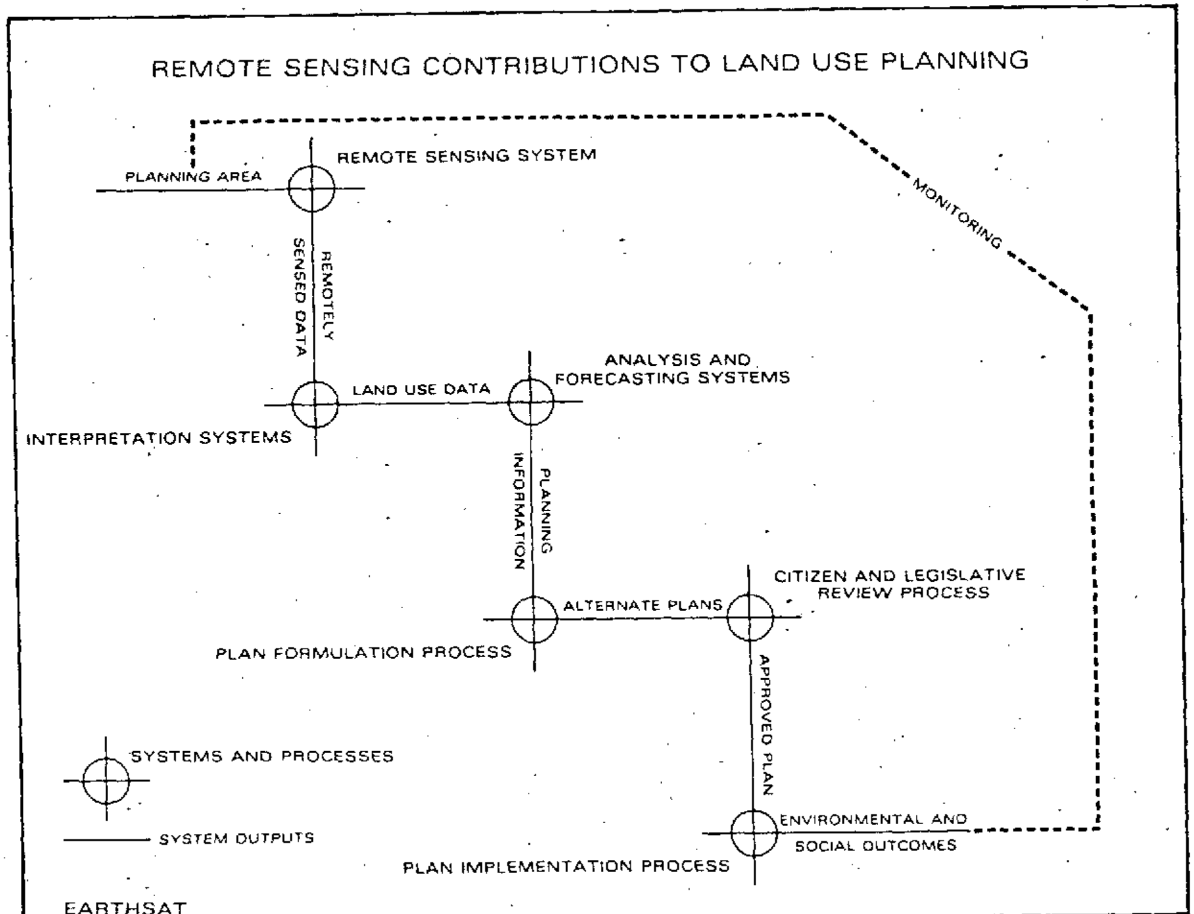

REMOTE SENSING CONTRIBUTIONS TO LAND USE PLANNING
PLANNING AREA
REMOTE SENSING SYSTEM
MONITORING
REMOTELY SENSED DATA
INTERPRETATION SYSTEMS
LAND USE DATA
ANALYSIS AND FORECASTING SYSTEMS
PLANNING INFORMATION
PLAN FORMULATION PROCESS
ALTERNATE PLANS
CITIZEN AND LEGISLATIVE REVIEW PROCESS
APPROVED PLAN
PLAN IMPLEMENTATION PROCESS
ENVIRONMENTAL AND SOCIAL OUTCOMES
SYSTEMS AND PROCESSES
SYSTEM OUTPUTS
EARTHSAT

Figure 5

being managed) both before and during the iterative planning process. One can assume that the components for various systems and processes will reflect the character of the environment being studied and perceived user information needs, as well as economic and social constraints (e.g., budgetary limitations, concerns for personal privacy) imposed by the cultural milieu in which the land planning process operates. All internal information flows and systems can be variably designed to provide the best information possible under constraints leveled by natural and social environments, and can be altered as goals or legislative mandates change.

Comprehensive reviews of the literature (See Branch 1971 and Westerlund 1972) and significant practical experience indicate that many land management situations utilize remote sensing. Remotely sensed data may provide primary information to assist in goal formulation and problem identification, or in more detail for inventories. Remotely sensed data during the analysis and forecasting process may be used either as a graphic base or for comparisons with analysis and modeling outputs. The heart of the planning process is where tentative plans are formulated and subjected to management and policy reviews prior to finalization. Imagery serves an important communication function in these stages, both as a graphic base (image map) for information from other sources and as a visual aid where spatial and environmental information are discussed during the policy formulation process. Remote sensing serves a valuable role in monitoring the outcomes of planning. During this stage monitoring of land use and other environmental changes serve as the basis for continual plan and policy adjustments. Thus, remote sensing data can be used as an initial information source, a communications aid either as an image map or in visual presentations, and for monitoring changes in the resource base over time.

3.0 REMOTE SENSING SYSTEMS

Since planners are increasingly faced with the need for state and region wide land use and related data to develop and monitor land use plans, many ways of acquiring needed data are being examined. High altitude aircraft data and, more recently, ERTS-1 and Skylab data are of particular interest to planners. These latter systems may now be examined (see Colvocoresses, 1974 for an in-depth discussion).

3.1 ERTS-1

The ERTS-1 System provides planners with highly repetitive low resolution imagery in four discrete wavelength bands -- green, red, near infrared and infrared portions of the spectrum. The ability to acquire synoptic imagery and map primary land cover over large regions has been demonstrated by numerous investigators (see Thomas et al. 1974, Simpson et al. 1974, Bale and Bowden, 1973, and Krumpe 1974). Research has also shown that digital processing of ERTS-1 imagery can often provide accurate land use data to a secondary level of detail, eg., residential, commercial, etc. (see Wray et al. 1973, and Baumgardner et al. 1974). Such imagery provides planners the perspective of their jurisdictional area often needed for briefings and formulation of goals and objectives. Although the low resolution of ERTS-1 imagery will preclude its use for mapping highly detailed land use features, such imagery is useful for monitoring trends in regional land use change and to focus attention on areas of most rapid change requiring more intensive study. Investigators have reported in some cases satisfactory recognition and mapping of Level 2 land use categories (USGS Circular 671). Although few investigators have placed information extracted from ERTS data into an information management system, this is a resonable expectation of future processing capabilities. Given picture element coordinates of known ground control points, the ERTS-1 digital data can be registered in a geobase information system to within 1 or 2 picture elements. This provides a unique capability to planners not heretofore available. That is, the ERTS data provides a means of monitoring change in land use and will in the future provide a direct means for updating land use information systems (Thomas, et al. 1974). Although the present ERTS-1 system has limited resolution and thus limited application for consistent identification and mapping of detailed Level 2 and Level 3 land use classes, techniques being developed to handle the present data will enhance the utility of higher resolution systems of the future. The Skylab EREP package is truly an experimental package and when analyzed thoroughly will not only provide data immediately useful to planners and resource managers, but will also provide guidelines for designing future satellite systems and their increasing role in earth resource management.

3.2 Skylab EREP

The Skylab EREP package has provided imagery over extensive regions of the United States. Three sensors are of particular interest to resource planners and remote sensing scientists. These are the S-190A multispectral photographic camera, S-190B earth terrain camera and the S-192 multispectral scanner. The configuration of these sensors is shown in Tables 1, 2 and 3. Each of the

Table 1. S-190A Multispectral Photographic Camera Configuration

- Lenses - Six (6) F/2.8 15.24cm. Focal Length (21.2° FOV)

- Coverage - 163 km square (26585 square km)

Film	Spectral Coverage	Expected Ground Resolution
B&W I.R. (EK2424)	0.7 to 0.8 μm	68 Meters
B&W I.R. (EK2424)	0.8 to 0.9 μm	68 Meters
Color I.R. (EK 2443)	0.5 to 0.88 μm	57 Meters
Hi Res Color (SO-356)	0.4 to 0.7 μm	23.8 Meters
B&W Pan-X (SO-022)	0.6 to 0.8 μm	27.8 Meters
B&W Pan-X (SO-022)	0.5 to 0.6 μm	30 Meters

Table 2. S-190B Earth Terrain Camera Configuration

- Lens - F/4 18" Focal Length
- Coverage - 109 km Square (11950 square km)

Film	Spectral Coverage	Expected Ground Resolution
Hi Res Color (SO-242)	0.4 - 0.7 μm	15 Meters
B&W High Definition (EK3414)	0.5 - 0.7 μm	15 Meters
Color I.R. (EK3443)	0.5 - 0.88 μm	30 Meters

Table 3. S-192 Multispectral Scanner Configuration

- IFOV - 79.3 Meter Square Ground Coverage
- Swath Width - 68.5 km.

Band	Description	Spectral Range
1	Violet	0.41 - 0.46 μm
2	Violet-Blue	0.46 - 0.51 μm
3	Blue-Green	0.52 - 0.56 μm
4	Green-Yellow	0.56 - 0.61 μm
5	Orange-Red	0.62 - 0.67 μm
6	Red	0.68 - 0.76 μm
7	Near infrared	0.78 - 0.88 μm
8	Near infrared	0.98 - 1.08 μm
9	Near infrared	1.09 - 1.19 μm
10	Mid infrared	1.20 - 1.30 μm
11	Mid infrared	1.55 - 1.75 μm
12	Mid infrared	2.10 - 2.35 μm
13	Thermal infrared	10.2 - 12.5 μm

three systems produces different data with potential for different uses. The high resolution of the S-190A and particularly S-190B systems are of considerable interest to investigators (see Colwell et al. 1974). The S-190B data are useful for preparation of detailed regional land use maps. Although Skylab will not provide repetitive coverage of the United States, it has provided an extensive recent data base which can be used to efficiently complete or update resource inventories. The repetitive coverage with ERTS satellites by contrast will emphasize monitoring of change and provide for updating information systems. The EREP package provides research scientists with photographic data of high spatial resolution and scanner records of spectral bands which are narrower than ERTS MSS bands. Thus analyses of S-190A and S-190B data will provide indications of improved capabilities to extract information with data of higher spatial resolutions than that presently available from ERTS. The S-192 scanner data will later permit more detailed analysis of optimum data channels for discrimination of land use classes. Some combinations of channels will provide a better basis for discriminating between land use classes than others. Coggeshall and Hoffer (1973), working with aircraft data, demonstrated that five channels of data including one thermal band and a mid-infrared band yielded the best test class performance in discriminating deciduous forest, evergreen forest, water and agricultural classes. Optimum spectral bands for discriminating various land use classes from aircraft data have been reported by many authors (Coggeshall and Hoffer, 1973; Weber and Polcyn, 1972; Driscoll and Spencer, 1972; Weber et al. 1972; and Rohde and

Olsen, 1972) Results from continued analyses of Skylab EREP data will provide scientists with insights which will be valuable in planning systems such as EOS or Space Shuttle and in anticipating the contributions such systems may make in land use planning and other resource management activities.

4.0 EVALUATION OF SATELLITE AND AIRCRAFT DATA

The following discussion focuses on an evaluation of Skylab S-190B photography and attempts to compare those results with results achieved through an analysis of ERTS-1 data and high altitude aircraft data. The techniques which were used include: 1) an image intepretation test; 2) comparative land cover mapping at 1:120,000 scale; and 3) comparative land use mapping at 1:60,000 scale.

4.1 Image Interpretation Test

Imagery acquired from the S-190B Earth Terrain Camera was expected to provide data with approximately 15 meter resolution. Welch (1974) reports an estimated resolution of 25 meters for second generation S-190B color transparencies. These resolutions are a substantial improvement over ERTS-1, but are coarse when compared with aircraft imagery. Because Skylab data have not been evaluated previously, an image interpretation test was conducted to determine to what level of detail and to what accuracy interpreters could identify various categories of land use from S-190B photography. The results from this test are compared with interpreters results from high altitude photography of the same areas to provide an indication of the comparability of the two systems.

4.1.1 Interpreters Test Design

S-190B color transparencies and high altitude color infrared transparencies were used in this test. The Skylab S-190B imagery and aircraft imagery was acquired on 5 August 1973 and 12 June 1973, respectively. All images were enlarged to a common scale of 1:126,720 (2 miles to one inch).

Ground truth data acquired earlier and our personal knowledge of the test area provided the basis for selecting examples of land use classes. All test classes were defined according to the land use classification scheme shown in Appendix A. Table 4 gives the number of test identifications in each land use class.

Although test examples were not selected for each category of land use shown in Appendix A, enough were selected at each level within the five major classes to provide a representative sample.

Five interpreters, experienced in land use mapping with ERTS-1 and high altitude imagery, and who were equally familiar with the test areas were asked to identify each test class to the greatest level of detail possible. All test classes were interpreted first on S-190B imagery and then aircraft imagery. This minimized the possibility of biasing the interpretation of the S-190B imagery by learning or memory.

After all interpreters had completed testing, results were tabulated by grading the interpreter's results in a hierarchical manner. Thus, an interpreter could incorrectly identify a particular land class at one level of detail and at a higher level of detail he could be correct. For example, consider an urban single family residential (111) test example. If an interpreter identified this test class as urban multifamily residential (112), he would be graded as incorrect at the third level of detail and correct at the second and first levels of detail.

TABLE 4 - NUMBER OF TEST CLASSES WITHIN EACH LAND USE TYPE

LAND USE CLASS	LEVEL OF DETAIL	NUMBER OF TEST CLASSES
URBAN	1	72
	2	72
	3	72
	4	14
AGRICULTURAL	1	68
	2	68
	3	68
FOREST	1	87
	2	87
WATER	1	10
	2	10
	3	7
BARREN	1	6
	2	6

4.1.2 Interpreters Test Results and Analysis

Results from this interpretation test were tabulated for each interpreter. The average percent correct for all interpreters was also calculated for each level within major land use categories for each film type. These results are shown in Table 5.

Although the results in Table 5 are not definitive, several observations regarding the ability to identify land use classes from satellite imagery can be made. First, however, several comments regarding the test design are in order.

It was not the intention in this test to evaluate all EREP film filter combinations with aircraft photography. Rather, it was to evaluate the comparability of the S-190B photography to aircraft photography. High altitude color infrared photographs were used because they provide the best overall capability to accurately identify all classes of land use, particularly at Levels 2 and 3 within the agriculture and forest land use classes. Similarly, color infrared photographs provide excellent identification of water bodies. Thus it was expected that all the interpreters -- highly experienced in land use mapping from high altitude aircraft data -- would achieve high accuracy levels for identification of land use type. On aircraft photography, accuracy levels greater than 90 percent were achieved for all levels of land use tested except Level 3 agricultural classes where 85.3 percent were correctly identified.

TABLE 5. IMAGE INTERPRETATION TEST ACCURACY (PERCENT CORRECT) OF LAND USE CLASSIFICATION BY INTERPRETERS AND IMAGE TYPE

SENSING SYSTEM	INTERPRETER	LAND USE TYPE 1/ URBAN LEVELS 1	URBAN LEVELS 2	URBAN LEVELS 3	URBAN LEVELS 4	AGRICULTURAL 1	AGRICULTURAL 2	AGRICULTURAL 3	FOREST 1	FOREST 2	WATER 1	WATER 2	WATER 3	BARREN 1	BARREN 2
HIGH ALTITUDE AIRCRAFT	1	100	97.2	95.8	92.9	97	97	78	97.7	90.8	100	100	100	100	100
	2	97.2	94.4	94.4	100	100	100	83.8	98.9	82.8	100	100	100	83.3	83.3
	3	100	95.8	93.1	100	98.5	98.5	80.9	97.7	89.7	100	100	100	100	100
	4	100	97.2	97.2	100	98.5	98.5	97.1	100	96.6	100	100	100	100	100
	5	100	95.8	94.4	92.9	98.5	98.5	86.8	94.3	90.8	100	100	100	100	100
	MEAN	99.4	96.1	95.0	97.2	98.5	98.5	85.3	97.7	90.1	100	100	100	96.7	96.7
SKYLAB S-190B	1	95.8	83.3	76.4	28.6	88.2	88.2	86.2	86.2	05.7	80	70	85.7	66.7	66.7
	2	93.1	84.7	79.2	35.7	98.5	98.5	87.4	87.4	20.7	80	70	85.7	66.7	66.7
	3	91.7	83.3	81.9	35.7	97.1	97.1	90.8	90.8	06.9	30	30	71.4	66.7	66.7
	4	95.8	87.5	87.5	71.4	89.7	89.7	90.8	90.8	52.9	80	80	85.7	66.7	66.7
	5	94.4	83.3	81.9	50	89.7	89.7	85.1	85.1	02.3	70	40	85.7	66.7	66.7
	MEAN	94.2	84.4	81.4	44.3	92.6	92.6	88.1	88.1	17.7	68	58	82.8	66.7	66.7

1/ THE NUMBER OF TEST CLASSES WITHIN EACH CATEGORY AND LEVEL OF LAND USE IS SHOWN IN TABLE 4.

Table 5 shows that interpretation accuracies from S-190B photography were lower than from aircraft photography. The errors are a function of both the spatial resolution and the spectral coverage provided by the S-190B film. Accuracy of identification of Level 1 urban land is acceptable. The reduction in accuracy at Levels 2 and 3 urban categories appears to be principally a function of the moderate spatial resolution. At Level 2, residential categories were consistently identified accurately whereas commercial and industrial classes were misidentified creating numerous errors. At Level 3 consistent separation of single family residential classes from multi-family residential classes was not possible, particularly when such classes covered small areas. Also, older residential areas with established mature trees were often confused with open land or forest categories. Similarly, apparent breaks within a typical subdivision of single family homes were often misclassified as either schools or parks. It should be remembered that if a particular land class was misclassified at one level of detail it would subsequently be misclassified at all more detailed levels of classification. This certainly has contributed to the lower accuracy associated with Level 4 urban land use classes. The lower accuracy of identification of Level 4 urban classes can also be attributed to spatial resolution in that many errors were made in distinguishing housing density, particularly in older neighborhoods. Increased spatial resolution would permit improved detection of buildings thus increasing the probability of correct interpretation of housing density. Also, with increased spatial resolution school facilities would be more readily discernable thus reducing errors associated with schools and open and other, parks, and golf courses. The latter errors would also be expected to be minimized if color infrared photography were employed. In practice, these errors could be minimized by correlation of interpretation of S-190B photographs with S-190A color infrared imagery where appropriate. Golf courses, parks and athletic fields associated with schools tend to have relatively distinctive spectral signatures on color infrared film. The results achieved with the higher resolution color infrared aircraft photography support the above arguments.

Levels 1 and 2 agricultural land use classes were consistently identified at acceptably high levels of accuracy on the S-190B photographs. The low accuracy at Level 3 arose from misclassification of cropland and pasture. This would be expected particularly where croplands are dominated by continuous cover crops. Increased spatial resolution would not likely improve identification accuracies significantly at Level 3. Croplands with continuous cover crops and pasture land tend to have similar spectral responses on conventional color films. However, improvement in accuracy could be expected if color infrared imagery were used. Cattle trails, feeding areas and other livestock activities associated with pasture land creates distinctive spectral responses on color infrared photography as compared to a more uniform homogeneous signature from croplands with continuous cover crops. In some cases misclassifications were associated with pasture, cropland and upland brush categories. Although high error rates can be expected on normal color films, the ability to detect major vegetation structural differences and relative vigor with color infrared film would tend to minimize errors of this type. Again, the results achieved on color infrared aircraft photography within the agricultural land use classes support this argument.

Accuracy of identification of forest lands (Level 1) on S-190B photography was at an acceptably high level, although significantly lower than on aircraft photography. Results at Level 2 were extremely poor. Level 1 errors resulted from confusion of forest land with continuous cover crops on agricultural land. Level 2 errors resulted from an inability to consistently separate deciduous, evergreen, and mixed forest types. This type of error would be expected on small scale normal color films. As is evident from the results achieved with aircraft photography, these errors would be minimized with color infrared films.

Unacceptable accuracy levels were achieved within the barren land and most water land use classes. The low contrast between water surfaces and adjacent terrain classes on normal color film results in many errors which would be minimized with color infrared film because of the high contrast between water bodies and adjacent terrain features.

The primary error within barren land use classes was associated with the misclassification of disturbed land as cropland. This error was quite common in suburban fringe areas encroaching on rural farmland. Because of the dynamic nature of land cover associated with active cropland, temporal data would undoubtedly reduce misclassification errors of barren-disturbed land.

4.1.3 Conclusions

Results from this image interpretation test show that the best overall accuracy of identification for all land use classes tested was achieved with the aircraft color infrared photography. Although the S-190B photography did not provide consistently high accuracy levels at all levels of detail, Levels 1, 2, and 3 urban classes and Levels 1 and 2 agricultural classes were identified with acceptable accuracies. Only Level 1 forest land classes were identified at acceptable accuracy levels on the S-190B photography. Although spatial resolution was a limiting factor, image date and spectral coverage appeared to be major factors influencing the accuracy of land use identification. This type of error could be easily minimized through registration of S-190A color infrared data with the higher spatial resolution of the S-190B data.

It should be obvious that although the overall results achieved with the S-190B photography were not as good as those achieved with the aircraft photography, the S-190B data when supplemented appropriately with color infrared photography, e.g., S-190A color infrared, can provide data of acceptable accuracy for regional land use mapping.

Results from this test should also be interpreted with respect to capabilities with future satellite systems. Basically, future operational satellite systems which provide systematic-repetitive coverage will acquire imagery with multispectral scanner systems rather than photographic film systems, although Space Shuttle will provide some photographic data. In expectation of future scanner systems, results achieved here indicate the value of near infrared data for accurate identification of detailed land use classes. It is certainly conceivable that future orbiting multispectral scanner systems with spatial resolution similar to that obtained with S-190B imagery and spectral coverage of near infrared, red, green and blue spectral regions will enable accurate identification and mapping of land use data. Such data when merged with developing electronic data processing techniques and geobased information systems will permit timely and efficient acquisition, interpretation and analysis of land use related data.

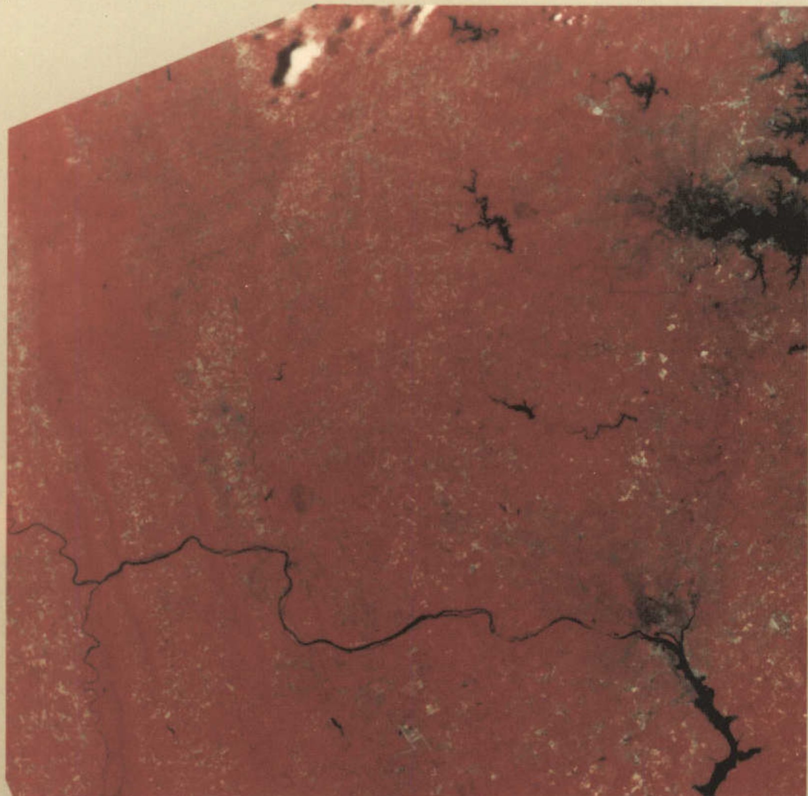
4.2 Land Cover Mapping

In Section 2 two trends in current land planning were identified. Both the tendency toward increasing planning activity at higher jurisdictions (State and Federal level) and the trend toward environmental planning have similar effects upon planning information needs. Progressive Federal and State legislation has forced land planners to consider the total resources under their control both from the standpoint of area and comprehensiveness of data. Experiments with satellite remote sensing have shown that useful environmental data of interest to planners can be obtained from satellite data. The graphic format of ERTS-1 imagery for example contains a synoptic record previously unavailable for an entire planning region. In the next comparative mapping exercise the utility of satellite data as a source of regional information is examined along with the differences between data records and information acquired from ERTS-1 and Skylab (Figure 6).

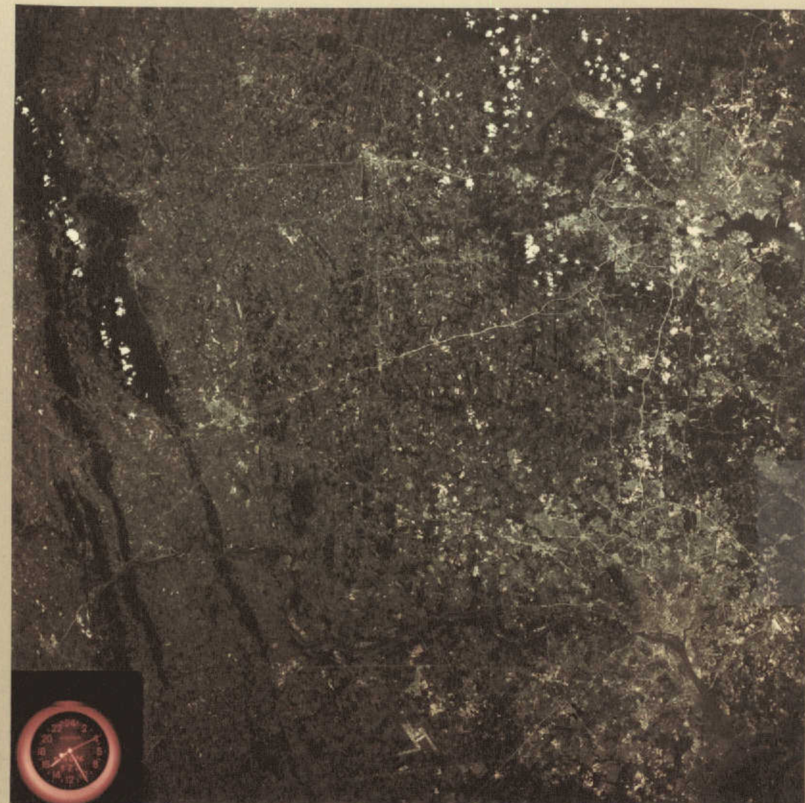
The exercise was designed to provide control among the variables affecting the character of the final information file (Land Cover Maps). The results obtained from analysis and comparison of the regional land cover products will therefore be mostly a result of differences in the remote sensing systems themselves. Variables considered in our attempt to control map comparison included scale, area coverage, image format, interpreter, mapping techniques, minimum mapping areas and classification scheme. Variation between finished maps can then be considered on the basis of information character, costs of mapping and ease of mapping. These differences related to the two systems will form the basis of a discussion of the appropriateness of each as sources of planning information.

A full frame Skylab S-190B color photograph and portion of an ERTS-1 MSS color composite image which covered the same areas were used. Both were centered on west central Maryland and covered over

REGIONAL SYNOPTIC VIEW FROM EARTH RESOURCE SATELLITE SYSTEMS



ERTS-MSS, JUNE 1973



SKYLAB S-190B, AUGUST 1973

5 0 5 10 15 20 MILES

EARTH RESOURCE SATELLITE SYSTEMS PROVIDE REGIONAL INFORMATION FOR LAND PLANNING AND MANAGEMENT.

SATELLITE IMAGES PROVIDE PLANNERS A REGIONAL PERSPECTIVE OF THEIR ENVIRONMENTAL SETTING AND ABILITY TO MONITOR POTENTIAL REGION-WIDE IMPACTS OF LAND USE CHANGE.

EARTH SATELLITE CORPORATION

Figure 6

1,000 square miles. The area included the Baltimore, Md.-Washington, D.C. metropolitan areas as well as parts of the ridge and valley province of the Appalachian Mountains. The S-190B photo acquired in August, 1973 and the ERTS MSS image acquired in July, 1973 were enlarged to 1:250,000 prints. Figure 6 presents both images at a much reduced scale.

An interpreter was chosen who was familiar with the areas to be mapped and who had previously worked with both ERTS and Skylab data. Use of one interpreter insures that the classification scheme would be applied in a similar manner in each mapping exercise. Using two interpreters, even if they had similar disciplinary backgrounds, would have resulted in additional differences in the maps due to variations in individual perceptions, though often a single interpreter does not agree with himself when using moderate and coarse resolution data. Familiarity with the area was necessary to minimize variation in the final mapping as a result of learning. Familiarity with both data sources also helps reduce the variation in mapping which can result from the striking differences in both spectral and spatial resolution of the two images.

Interpretation and mapping was accomplished at image scale. Each photo positive was placed on a light table and land cover information was transferred to a frosted acetate overlay. The paper prints were relatively translucent and allowed sufficient light through to facilitate interpretation. A strict time record was kept of each mapping effort. Once complete, both maps were copied using a color plate separation process to produce the products as presented in Figures 7, 8 and 9.

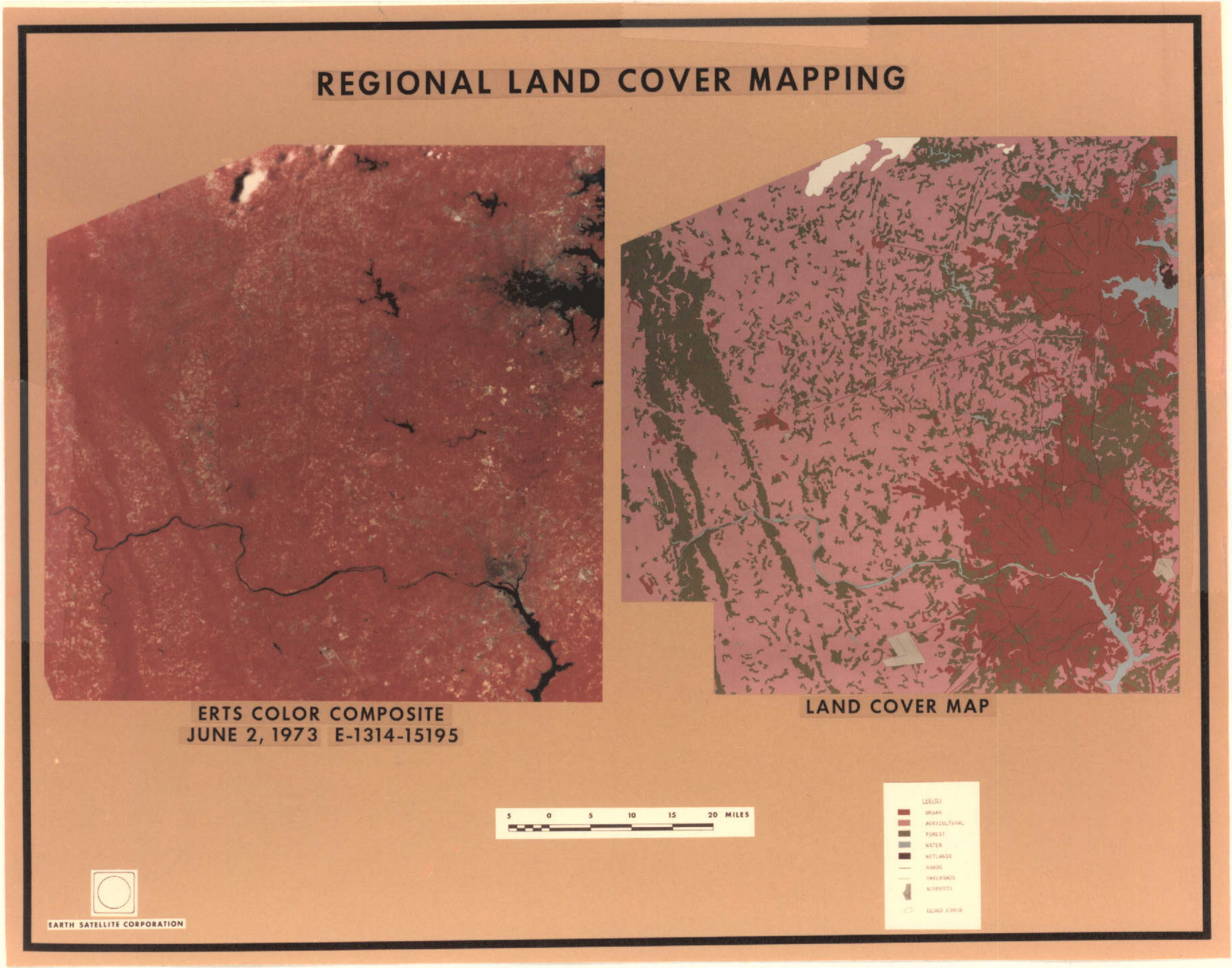
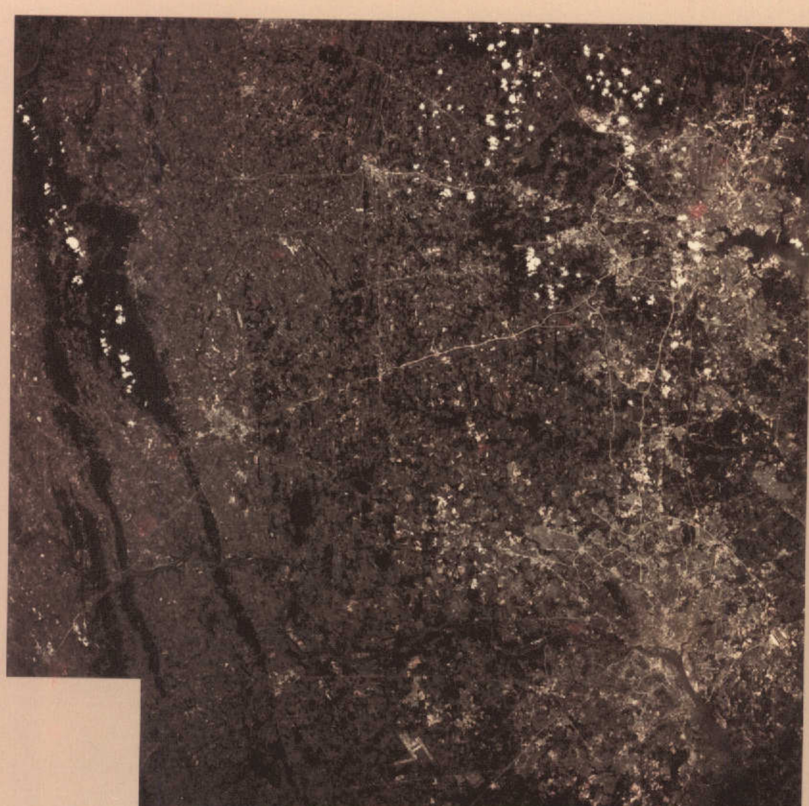

REGIONAL LAND COVER MAPPING
ERTS COLOR COMPOSITE
JUNE 2, 1973 E-1314-15195
LAND COVER MAP
5 0 5 10 15 20 MILES
LEGEND
URBAN
AGRICULTURAL
FOREST
WATER
WETLANDS
ROADS
RAILROADS
AIRPORTS
CLOUD COVER
EARTH SATELLITE CORPORATION

Figure 7

REGIONAL LAND COVER MAPPING



S-190B, AUGUST 1973

LAND COVER MAP

5 0 5 10 15 20 MILES

EARTH SATELLITE CORPORATION

Figure 8

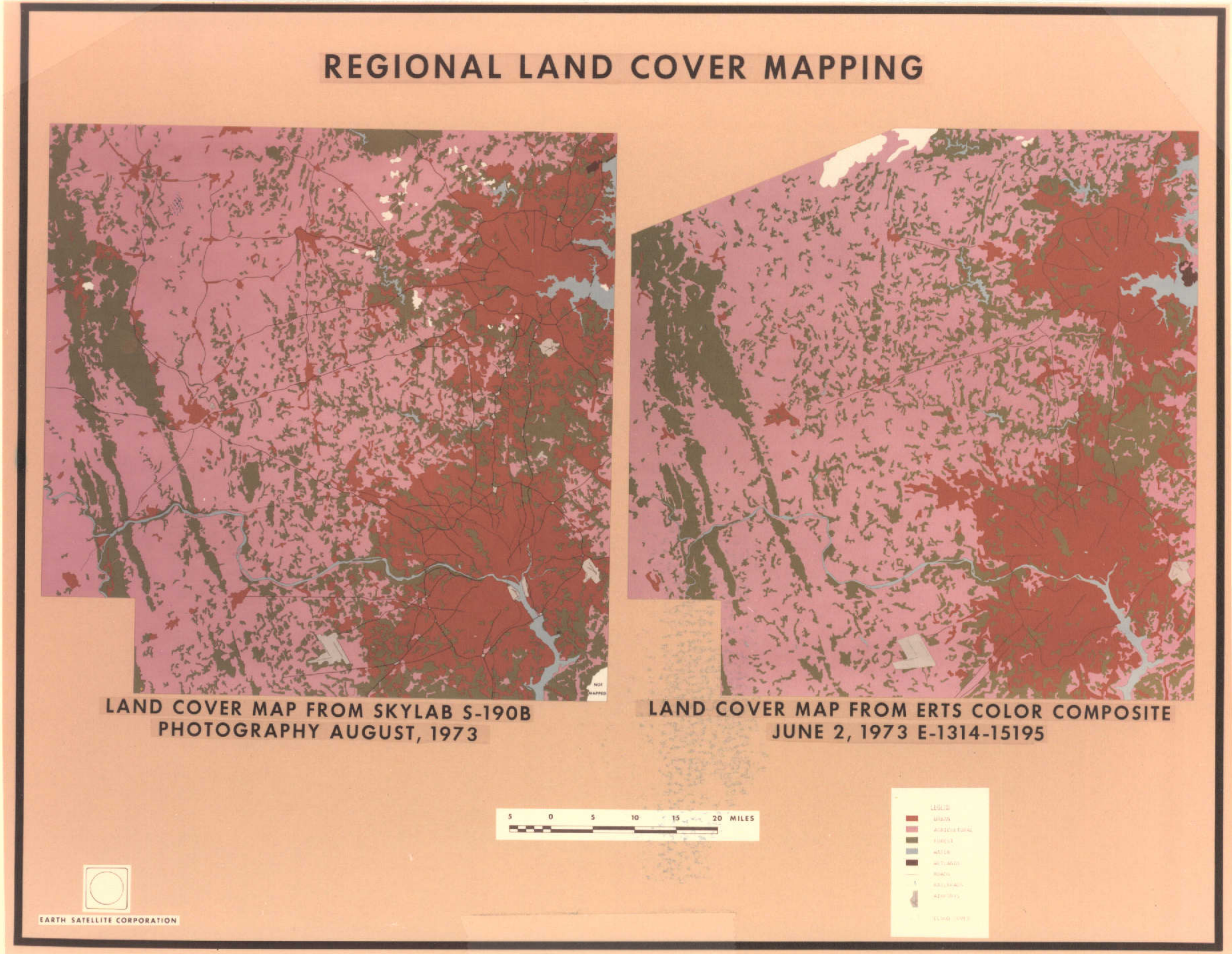

REGIONAL LAND COVER MAPPING
LAND COVER MAP FROM SKYLAB S-190B
PHOTOGRAPHY AUGUST, 1973
LAND COVER MAP FROM ERTS COLOR COMPOSITE
JUNE 2, 1973 E-1314-15195
5 0 5 10 15 20 MILES
EARTH SATELLITE CORPORATION

Figure 9

In order to control variability a common classification scheme was also used. Several good schemes exist; the Level 1 legend given in USGS Circular 671 was chosen. A standard classification scheme was necessary if the results were to be comparable.

Visual comparison of the mapped land cover by categories shows that some of the differences between systems (i.e., platform, data format, data resolution, etc.) are directly reflected in the mapped products. Figure 6 shows that the extent of urban areas is easier to recognize on the Skylab image while location and shape of waterbodies can more easily be ascertained from ERTS. The following tables are designed to illustrate variations in the interpreter's ability to separate categories on both images. In these tables the relative ease of separation between categories in terms of identification and delineation are ranked nominally either as 1 (good), 2 (fair) or 3 (poor). Because of the subjectivity of the assessment some caution is advised in the interpretation of the rankings as presented in Table 6.

As in all situations where nominal scales are employed, no absolute values are intended for the intervals between classes. The rankings are the qualitative estimates of the investigators. The reasons for the results of this ranking can be seen by comparing the ERTS color composite to the Skylab S-190B color photograph. Urban features are more easily discernible and seem to occupy a greater area on the Skylab image in spite of the fact that core areas are equally visible on each. The S-190B's superiority as a data source for the urban category becomes increasingly apparent as one progresses toward the urban fringe where the

TABLE 6 - CATEGORY SEPARATION MATRICES FOR 1: 250,000 SCALE

LAND COVER MAPPING EXERCISE

ERTS - 1 FALSE COLOR COMPOSITE (MSS 4,5,7)	URBAN	TRANSPORTATION	AGRICULTURE	FOREST	WATER
TRANSPORTATION	2				
AGRICULTURE	3	3			
FOREST	2	2	2		
WATER	1	1	1	1	
WETLANDS	1	1	1	1	1

SKYLAB S-190B COLOR PHOTOGRAPHY	URBAN	TRANSPORTATION	AGRICULTURE	FOREST	WATER
TRANSPORTATION	2				
AGRICULTURE	1	1			
FOREST	1	1	1		
WATER	1	1	2	3	
WETLANDS	3	3	3	3	3

RANKINGS OF 1 = GOOD; 2 = FAIR; AND 3 = POOR, WERE ASSIGNED BY THE INVESTIGATORS ON A COMPARATIVE BASIS THROUGH SEVERAL ITERATIONS.

character of the category changes and the increase in amounts of vegetation (e.g., trees, lawns and parks in residential areas) results in a signature which is easily confused with both agricultural and forest cover categories. Economic patterns common to urban expansion at the rural-urban fringe further complicate the landscape patterns and render the false color ERTS composite less useful especially where disinvested agricultural lands, urban residential uses, active agriculture, tree covered parks and woodlots are intermixed. The spectral characteristics of the S-190B photography results in high color and tonal contrast between vegetation and urban land cover categories. Also because the spatial resolution of the S-190B photography is adequate for detection of roads and houses (or groups of houses) the separation between urban and vegetation categories, even for the confused landscape at the rural urban fringe, is facilitated.

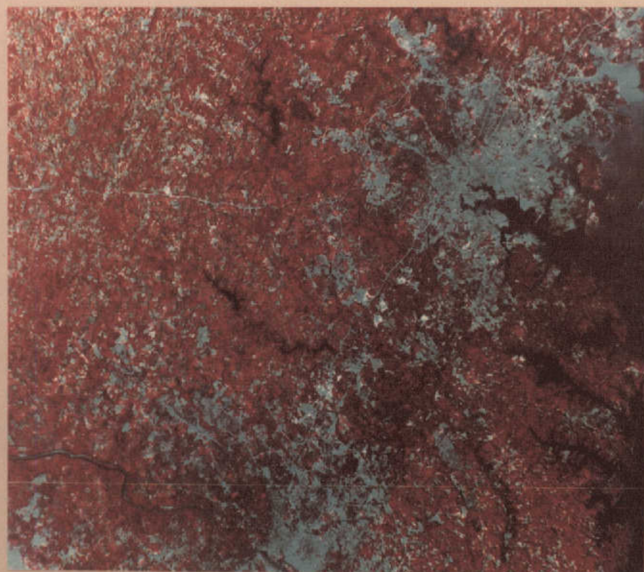
Mapping when accomplished from low resolution imagery is an exercise in delineating broad areas which appear to be similar on the photographic copy. Recognition of types of human activity is based on the textures, patterns, location and spectral characteristics of these various areas.

Table 6 indicates further differences in the ease of identification and delineating vegetation categories between the two satellite systems. Skylab S-190B photography, because of its superior spatial resolution, is a preferable data source for information concerning the distribution of agricultural and forested land in rural Maryland. Considerations such as the time of year that the ERTS image was acquired and the use of standard photographic products (rather than original digital tapes) result in a relatively inferior photographic rendition of our ERTS scene. This photographic product contains significantly less information than the digitally enhanced image shown in Figure 10. Working with original data and utilizing appropriate digital processing techniques one could produce a more interpretable data record and thereby a better land cover map than has been prepared during this exercise.

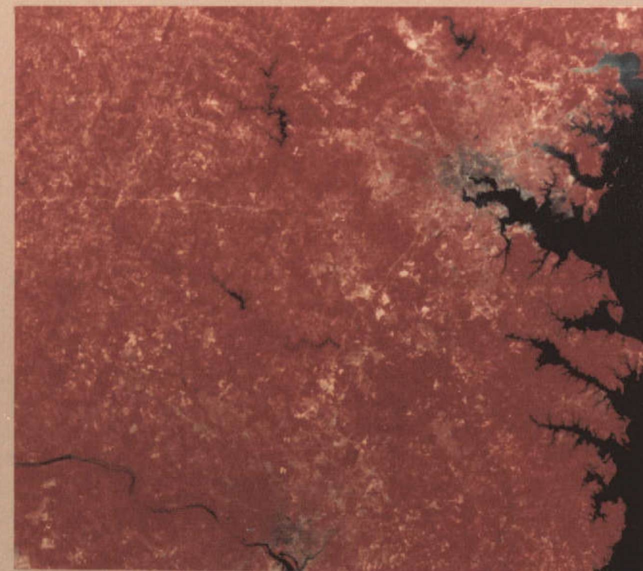
The remaining category where there are significant differences in interpretability is the surface water category. For this category the spectral characteristics and format of the ERTS image proved most satisfactory even though Skylab imagery has superior resolution. The lack of color contrast between dark water bodies and dark forested areas makes the interpretation of water features difficult on S-190B photographs. However, where water adjoins light toned urban areas, its extent can be easily mapped. Contrasts in color and brightness are important to the ease with which a land cover category can be mapped.

In order to rate the value of a remote sensing system to land management and planning information on the ease of mapping and time and costs are also necessary. Mapping time utilizing the Skylab image was just in excess of two working days (18 hrs.). The ERTS-1 land cover map was produced in a little more than four working days (35 hours). The marked difference in time needed to produce each map was related to the variations in spatial resolution and color formats of the two products. Mapping with the ERTS image was slower due to: 1) the coarser spatial resolution; 2) the lack of sharp color contrast between agricultural fields and small forested

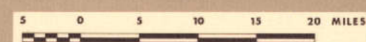
ERTS DIGITAL IMAGE PROCESSING



ERTS DIGITAL IMAGE COMPOSITE, JULY 1973



ERTS COLOR COMPOSITE, JULY 1973



BALTIMORE, MD. - WASHINGTON, D.C.

DIGITAL ENHANCEMENT OF ERTS IMAGERY IMPROVES DEFINITION AND INTERPRETABILITY. THE DIGITAL IMAGE IS A COMPOSITE OF MSS BANDS 4, 5, AND 7. EACH BAND WAS DIGITALLY ENHANCED TO EQUALIZE THE SPECTRAL DENSITY HISTOGRAMS AND PRINTED ON A DIGITAL FILM RECORDER. ADDITIONAL PROCESSING MAY BE USED TO ENHANCE SELECTED LANDSCAPE FEATURES.

EARTH SATELLITE CORPORATION

Figure 10

wood lots; and 3) the lack of color and tonal contrast in the complex urban fringe environment, which collectively led to much time lost in attempting separations. It should be pointed out that although mapping was more expensive using ERTS the repetitive data collection capability engineered into the ERTS system is a significant attribute which renders the overall costs (including acquisition) less expensive.

A detailed analysis of the two systems can not be attempted here because of the amount of necessary information which is not available to the investigators. However, it appears that the two systems, ERTS and Skylab, both have roles to play in the collection of resource management data.

4.3 Land Use Mapping

This exercise was designed in an attempt to determine whether or not Skylab S-190B data could be used as a base for land use mapping. It differs from the regional mapping exercise described earlier in that much more detail is extracted from the imagery in the hope that the resulting information would be comparable to that desired by state planners. The Skylab interpretation was compared to the land use map made with high altitude aircraft imagery and which satisfied the information demands of state planners in Maryland. The classification scheme is more detailed than that used in the regional land cover mapping comparison. Since the classification breaks the urban category as to differences in economic activity and residential density it is referred to here as land use rather than land cover. This exercise represents a relatively uncontrolled test because different photo interpreters made each map. However, it is valuable in testing potential applications of Skylab EREP data in an operational sense.

Two areas in Maryland were chosen because of their diverse landscapes. The first area, Rockville, Maryland, is a compactly organized suburb of Washington. The second area, Columbia, Maryland, is a new town and a satellite community to both Washington, D.C. and Baltimore, Maryland.

Standard manual overlay interpretation was used in preparing all four maps. The comparison maps belonging to Maryland Department of State Planning were originally interpreted using both black and white chronoflex enlargements and original color infrared high flight imagery obtained by NASA. The mapping scale of the enlargements was 1:60,000. Skylab S-190B EREP data was enlarged to 1:60,000 and printed in photopositive color. Mapping for comparison was done directly from the photopositive format with back lighting.

4.3.1 Rockville, Maryland Test Site

Figure 11 shows the area covered in the Rockville test site. The high altitude aerial photograph taken in June of 1973 covers 317 square miles. Portions of the Washington Beltway can be seen in the southern portion of the image. Radial transportation arteries running from the center of Washington can be seen trending generally north to south. The easternmost of these is Connecticut Avenue, to the west is Wisconsin Avenue and its extension Rockville Pike and along

SATELLITE PHOTOGRAPHY PROVIDES REGIONAL LAND PLANNING INFORMATION IN A HIGHLY COMPACT FORMAT

HIGH ALTITUDE AERIAL PHOTOGRAPH, JUNE 1973

SKYLAB S-190B PHOTOGRAPH, AUGUST 1973

1 0 1 2 MILES

URBAN AND REGIONAL PLANNERS ARE PROVIDED DETAILED LAND USE INFORMATION, SUCH AS RESIDENTIAL DENSITIES, COMMERCIAL, INDUSTRIAL, AND INSTITUTIONAL ACTIVITIES BY TYPE. A FULL FRAME AT 1:126,000 COVERS APPROX. 325 SQUARE MILES.

STATE AND REGIONAL PLANNERS ARE PROVIDED USEFUL LAND USE INFORMATION SUCH AS RESIDENTIAL TYPES, COMMERCIAL AND INDUSTRIAL ACTIVITY CENTERS, AND INTENSITY OF DEVELOPMENT ALONG TRANSPORTATION ROUTES. A FULL FRAME COVERS APPROX. 4,290 SQUARE MILES.

EARTH SATELLITE CORPORATION

Figure 11

the far western edge of the image is Interstate 70-S. These north-south transportation radials are the focus of commercial development and most of the area between the arteries is dedicated to residential and associated urban land uses. Small amounts of agricultural activity can be found along the northern edge of the frame.

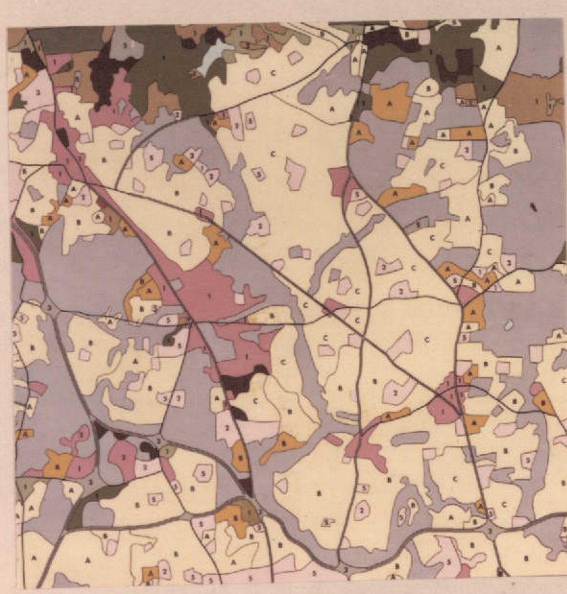
Spatial resolution on the RC-10 photograph is fine enough so that individual dwelling units can be identified and, where contrast is sufficient, individual vehicles can be identified on the freeways. Color infrared imagery aids in the separation and identification of water bodies, various agricultural uses and deciduous and evergreen forests (Figure 12). Excellent detail is also provided in the commercial areas where subsequent analyses of the imagery might provide information as to the number and location of shoppers, types of commercial services and types of uses isolated within and associated with large residential tracts. There is thus a level of detail in such imagery which exceeds that needed to produce the land use map in Figure 12.

The Skylab S-190B photograph covering the same area contains a less complete data record for several reasons (Figure 13). Spatial resolution is roughly five times poorer than that of the high altitude aerial imagery. Secondly, the spectral characteristics of the color image do not allow one to easily identify and differentiate water bodies, different kinds of agricultural activity or differences between evergreen

REGIONAL LAND USE MAPPING FROM AERIAL PHOTOGRAPHY

ROCKVILLE, MARYLAND

HIGH ALTITUDE AERIAL PHOTOGRAPH, JUNE 1973



LAND USE INTERPRETATION MAP

1 0 1 2 MILES

LEGEND

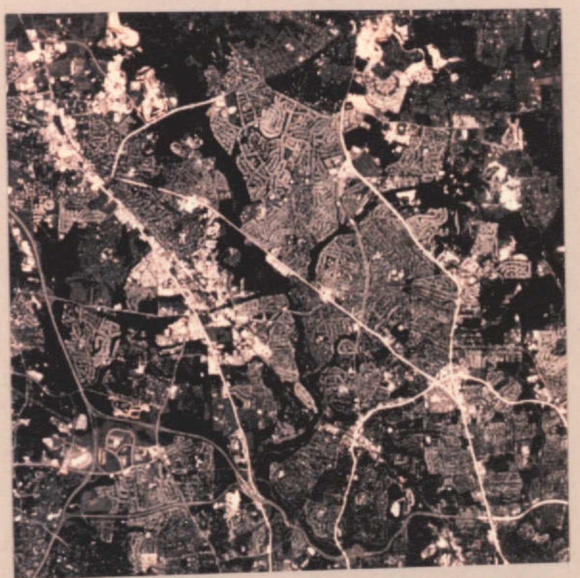
110 RESIDENTIAL
111A SINGLE UNIT, LOW SUR DENSITY
111B SINGLE UNIT, MEDIUM SUR DENSITY
111C SINGLE UNIT, HIGH SUR DENSITY
112A MULTI-UNIT LOW MUR DENSITY
112B MULTI-UNIT HIGH MUR DENSITY
113 MOBILE HOME AND TRAILER PARKS
120 RETAIL AND WHOLESALE SERVICES
121 RETAIL SALES AND SERVICES (COMMERCIAL)
122 WHOLESALE AND SERVICES AND LIGHT INDUSTRIES
130 INDUSTRIAL
131 HEAVY INDUSTRIES HEAT PROCESSING
132 HEAVY INDUSTRIES METAL PROCESSING
133 HEAVY INDUSTRIES CHEMICAL PROCESSING
140 EXTRACTION
141 COAL (SURFACES MINES)
142 OTHER QUARRIES AND PITS
150 TRANSPORTATION, COMMUNICATIONS AND UTILITIES
151 AIRPORTS AND ASSOCIATED AREAS
152 RAILROADS, INCLUDING YARDS AND TERMINALS
153 FREEWAYS, HIGHWAYS, ETC.
154 MARINE TERMINALS
155 COMMUNICATIONS AND UTILITIES
160 INSTITUTIONAL
161 ELEMENTARY SCHOOLS
162 SECONDARY SCHOOLS
163 COLLEGE AND UNIVERSITY
164 MILITARY FACILITIES
165 OTHER INSTITUTIONAL
170 STRIP AND CLUSTERED
190 OPEN AND OTHER (URBAN)
210 CROP AND PASTURE LAND
211 CROP LAND
212 PASTURE LAND
220 ORCHARDS
230 FEEDING OPERATIONS
410 DECIDUOUS FOREST
411 UPLAND DECIDUOUS FOREST
412 LOWLAND DECIDUOUS FOREST
420 EVERGREEN FOREST
421 UPLAND EVERGREEN FOREST
422 LOWLAND EVERGREEN FOREST
430 MIXED FOREST
431 UPLAND MIXED FOREST
432 LOWLAND MIXED FOREST
440 UPLAND BRUSH
530 RESERVOIRS

EARTH SATELLITE CORPORATION

Figure 12

REGIONAL LAND USE MAPPING FROM SKYLAB S-190B PHOTOGRAPHY

ROCKVILLE, MARYLAND



SKYLAB S-190B PHOTOGRAPHY, AUGUST 1973

LAND USE INTERPRETATION MAP

EARTH SATELLITE CORPORATION

Figure 13

and deciduous forests. Individual single family residences can barely be delineated and determinations of specific commercial activities within large areas of commercial land uses can only be accomplished by analyzing their location with respect to their surroundings (i.e., other land uses and the types of available transportation). In addition, institutional uses associated with residential subdivision including schools and churches cannot be identified with any degree of certainty. There is, however, sufficient information with the advertised ground resolution of approximately 25 meters for the production of the map as seen in Figure 13. Figure 14 presents a comparison of the two maps. In comparison it appears that the level of detail in each is approximately equal. Boundaries of the various activity areas are similar and identifications are for the most part quite consistent. The largest difference in category identification was introduced because different interpreters produced the two maps. As a result the areas of parks which separate residential subdivisions by following stream valleys within the urban area carry different category identifications. On the land use map made from RC-10 CIR photography these parks are identified as open and other urban uses. On the land use map made from the S-190B Skylab photography most of these areas have been identified as forest lands and only the cleared area within the wooded sections have been given a park designation.

REGIONAL LAND USE MAPPING FROM AIRCRAFT AND SKYLAB S-190B PHOTOGRAPHY

ROCKVILLE, MARYLAND

LAND USE MAP FROM RC-10 CIR PHOTOGRAPHY, JUNE 1973

LAND USE MAP FROM S-190B PHOTOGRAPHY, AUGUST 1973

110 RESIDENTIAL
111A SINGLE UNIT, LOW SUR DENSITY
111B SINGLE UNIT, MEDIUM SUR DENSITY
111C SINGLE UNIT, HIGH SUR DENSITY
112A MULTI-UNIT LOW MUR DENSITY
112B MULTI-UNIT HIGH MUR DENSITY
113 MOBILE HOME AND TRAILER PARKS
120 RETAIL AND WHOLESALE SERVICES
121 RETAIL SALES AND SERVICES (COMMERCIAL)
122 WHOLESALE AND SERVICES AND LIGHT INDUSTRIES
130 INDUSTRIAL
131 HEAVY INDUSTRIES HEAT PROCESSING
132 HEAVY INDUSTRIES METAL PROCESSING
133 HEAVY INDUSTRIES CHEMICAL PROCESSING
140 EXTRACTION
141 COAL (SURFACES MINES)
142 OTHER QUARRIES AND PITS
150 TRANSPORTATION, COMMUNICATIONS AND UTILITIES
151 AIRPORTS AND ASSOCIATED AREAS
152 RAILROADS, INCLUDING YARDS AND TERMINALS
153 FREEWAYS, HIGHWAYS, ETC.
154 MARINE TERMINALS
155 COMMUNICATIONS AND UTILITIES
160 INSTITUTIONAL
161 ELEMENTARY SCHOOLS
162 SECONDARY SCHOOLS
163 COLLEGE AND UNIVERSITY
164 MILITARY FACILITIES
165 OTHER INSTITUTIONAL
170 STRIP AND CLUSTERED
190 OPEN AND OTHER (URBAN)
210 CROP AND PASTURE LAND
211 CROP LAND
212 PASTURE LAND
220 ORCHARDS
230 FEEDING OPERATIONS
410 DECIDUOUS FOREST
411 UPLAND DECIDUOUS FOREST
412 LOWLAND DECIDUOUS FOREST
420 EVERGREEN FOREST
421 UPLAND EVERGREEN FOREST
422 LOWLAND EVERGREEN FOREST
430 MIXED FOREST
431 UPLAND MIXED FOREST
432 LOWLAND MIXED FOREST
440 UPLAND BRUSH
530 RESERVOIRS

1 0 1 2 MILES

EARTH SATELLITE CORPORATION

Figure 14

Further discrepancies are apparent in the northern region of the test site where specific activities have been identified on the RC-10 color infrared photography which have not been identified on the Skylab photo. Also a small reservoir was easily identified on the color infrared aerial photography and was not mapped from the Skylab image.

4.3.2 Columbia, Maryland Test Site

The Columbia, Maryland area presents many of the varied land uses in the Baltimore/Washington corridor (Figure 15). The test site focuses on Interstate Highway I-95 which stretches between Baltimore and Washington, D.C. and bisects the test site diagonally from the northeast to the southwest. The community of Columbia, Maryland is located in the northern and western corner of the image. The residential area associated with Laurel, Maryland is located south and east of Highway I-95. College Park, Maryland is the community in the far southern portion of the test site. This corridor area between the two major metropolitan areas is the focus of extremely rapid urbanization and land use change.

Comparison of land use maps prepared from aircraft and Skylab S-190B data again shows a remarkable similarity in both identification of land use types and boundary placement (Figure 16). However, detail is again not available on the Skylab image in forested and agricultural areas. The large reservoir in the west central portion of the test site is also

REGIONAL LAND USE MAPPING FROM SKYLAB PHOTOGRAPHY

WASHINGTON, D.C. - BALTIMORE, MD. CORRIDOR

S-190B
5 AUGUST 1973

LEGEND

110 RESIDENTIAL
111A SINGLE UNIT, LOW SUR DENSITY
111B SINGLE UNIT, MEDIUM SUR DENSITY
111C SINGLE UNIT, HIGH SUR DENSITY
112A MULTI-UNIT LOW MUR DENSITY
112B MULTI-UNIT HIGH MUR DENSITY
113 MOBILE HOME AND TRAILER PARKS
120 RETAIL AND WHOLESALE SERVICES
121 RETAIL SALES AND SERVICES (COMMERCIAL)
122 WHOLESALE AND SERVICES AND LIGHT INDUSTRIES
130 INDUSTRIAL
131 HEAVY INDUSTRIES HEAT PROCESSING
132 HEAVY INDUSTRIES METAL PROCESSING
133 HEAVY INDUSTRIES CHEMICAL PROCESSING
140 EXTRACTION
141 COAL (SURFACES MINES)
142 OTHER QUARRIES AND PITS
150 TRANSPORTATION, COMMUNICATIONS AND UTILITIES
151 AIRPORTS AND ASSOCIATED AREAS
152 RAILROADS, INCLUDING YARDS AND TERMINALS
153 FREEWAYS, HIGHWAYS, ETC.
154 MARINE TERMINALS
155 COMMUNICATIONS AND UTILITIES
160 INSTITUTIONAL
161 ELEMENTARY SCHOOLS
162 SECONDARY SCHOOLS
163 COLLEGE AND UNIVERSITY
164 MILITARY FACILITIES
165 OTHER INSTITUTIONAL
170 STRIP AND CLUSTERED
190 OPEN AND OTHER (URBAN)
210 CROP AND PASTURE LAND
211 CROP LAND
212 PASTURE LAND
220 ORCHARDS
230 FEEDING OPERATIONS
410 DECIDUOUS FOREST
411 UPLAND DECIDUOUS FOREST
412 LOWLAND DECIDUOUS FOREST
420 EVERGREEN FOREST
421 UPLAND EVERGREEN FOREST
422 LOWLAND EVERGREEN FOREST
430 MIXED FOREST
431 UPLAND MIXED FOREST
432 LOWLAND MIXED FOREST
440 UPLAND BRUSH
530 RESERVOIRS

LAND USE
INTERPRETATION MAP

1 0 1 2 3 4 5 MILES

SATELLITE IMAGERY PROVIDES A HIGHLY COMPACTED DATA SOURCE FROM WHICH ACCURATE AND DETAILED REGIONAL LAND USE MAPS CAN BE PREPARED. THE LARGE AREA COVERAGE AND DETAILED DATA APPARENT IN SUCH IMAGERY IS VALUABLE TO LAND PLANNERS. HIGH RESOLUTION IMAGERY PERMITS ANALYSIS OF LAND USE CHANGE PREVIOUSLY DETECTED ON REPETITIVE LOW RESOLUTION ERTS IMAGERY. SUCH ANALYSIS OFTEN REVEALS POTENTIAL NEGATIVE ENVIRONMENTAL IMPACTS RESULTING FROM CONSTRUCTION, DEFORESTATION, OR CONVERSION OF LAND FROM RURAL TO URBAN USES.

EARTH SATELLITE CORPORATION

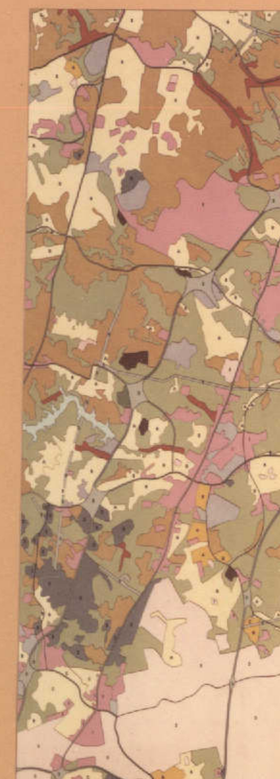
Figure 15

COMPARATIVE LAND USE MAPPING FROM AIRCRAFT AND SKYLAB

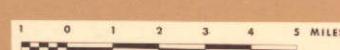
AIRCRAFT INTERPRETATION MAP

LEGEND

- 110 RESIDENTIAL
  - 111A SINGLE UNIT, LOW SUR DENSITY
  - 111B SINGLE UNIT, MEDIUM SUR DENSITY
  - 111C SINGLE UNIT, HIGH SUR DENSITY
  - 112A MULTI-UNIT LOW MUR DENSITY
  - 112B MULTI-UNIT HIGH MUR DENSITY
  - 113 MOBILE HOME AND TRAILER PARKS
- 120 RETAIL AND WHOLESALE SERVICES
  - 121 RETAIL SALES AND SERVICES (COMMERCIAL)
  - 122 WHOLESALE AND SERVICES AND LIGHT INDUSTRIES
- 130 INDUSTRIAL
  - 131 HEAVY INDUSTRIES HEAT PROCESSING
  - 132 HEAVY INDUSTRIES METAL PROCESSING
  - 133 HEAVY INDUSTRIES CHEMICAL PROCESSING
- 140 EXTRACTION
  - 141 COAL (SURFACES MINES)
  - 142 OTHER QUARRIES AND PITS
- 150 TRANSPORTATION, COMMUNICATIONS AND UTILITIES
  - 151 AIRPORTS AND ASSOCIATED AREAS
  - 152 RAILROADS, INCLUDING YARDS AND TERMINALS
  - 153 FREEWAYS, HIGHWAYS, ETC.
  - 154 MARINE TERMINALS
  - 155 COMMUNICATIONS AND UTILITIES
- 160 INSTITUTIONAL
  - 161 ELEMENTARY SCHOOLS
  - 162 SECONDARY SCHOOLS
  - 163 COLLEGE AND UNIVERSITY
  - 164 MILITARY FACILITIES
  - 165 OTHER INSTITUTIONAL
- 170 STRIP AND CLUSTERED
- 190 OPEN AND OTHER (URBAN)
- 210 CROP AND PASTURE LAND
  - 211 CROP LAND
  - 212 PASTURE LAND
- 220 ORCHARDS
- 230 FEEDING OPERATIONS
- 410 DECIDUOUS FOREST
  - 411 UPLAND DECIDUOUS FOREST
  - 412 LOWLAND DECIDUOUS FOREST
- 420 EVERGREEN FOREST
  - 421 UPLAND EVERGREEN FOREST
  - 422 LOWLAND EVERGREEN FOREST
- 430 MIXED FOREST
  - 431 UPLAND MIXED FOREST
  - 432 LOWLAND MIXED FOREST
- 440 UPLAND BRUSH
- 530 RESERVOIRS



SKYLAB INTERPRETATION MAP



BALTIMORE,MD.-WASHINGTON,D.C. CORRIDOR

HIGH RESOLUTION SATELLITE IMAGERY SIMILAR TO S-190B IMAGERY CAN PROVIDE DATA FOR LAND USE INTERPRETATION OFTEN COMPARABLE TO THAT AVAILABLE FROM HIGH ALTITUDE AIRCRAFT. SKYLAB PHOTOGRAPHY'S COMPACT DATA FORMAT PROVIDES A MORE EFFICIENT MAPPING BASE THAN DOES CONVENTIONAL HIGH ALTITUDE PHOTOGRAPHY.

EARTH SATELLITE CORPORATION

Figure 16

somewhat differently delineated on both maps. This is a further example of the difficulty one faces in separating water bodies from forested areas in the color format of the Skylab image. Other variations between the maps again result principally from the differential application of the land use classification scheme by interpreters who are trained in different disciplines. Much of the area classified as either urban residential or as retail and wholesale services in the aircraft image were classified as strip and cluster in the Skylab image. This was due in part to the orientation of these activities along transportation routes and also because the spatial resolution of the Skylab photography did not allow for a specific identification or separation between urban and commercial uses in these areas. Once again, however, the map produced from the Skylab photograph presents a sufficiently detailed information record to serve as a needed input to regional land use planning at the state level.

4.3.3 Conclusions

The preceeding qualitative discussions provide sufficient information for a more structured comparison of the two data sources and the products derived from them. The following two tables (Tables 7 and 8) present first a complete comparison of the two sets of photography and the variables associated with the mapping that could impact the character of the land use map products and second a category by category

TABLE 7 - SKYLAB S-190B, HIGH ALTITUDE AIRCRAFT LAND USE MAPPING COMPARISON

REMOTE SENSING SYSTEM / VARIABLE CHARACTERISTICS		SKYLAB EREP S-190B COLOR PHOTOGRAPHY	HIGH ALTITUDE AIRCRAFT (CIR) FALSE COLOR PHOTOGRAPHY
SPATIAL RESOLUTION		25 METERS	2 METERS
SPECTRAL CHARACTERISTICS		VISIBLE	ULTRA VIOLET, VISIBLE, INFRARED
SCALE	ACQUISITION	1:2,867,000	1: 130,000
	MAPPING	1: 60,000	1: 60,000
CLASSIFICATION SCHEME		MODIFIED USGS LEVEL 2	MODIFIED USGS LEVEL 2
INTERPRETATION TECHNIQUES		DIRECT OVERLAY FROM A POSITIVE PRODUCT	DIRECT OVERLAY AND TRANSFER FROM POSITIVE TRANSPARENCY PRODUCT
INTERPRETERS		DIFFERENT	DIFFERENT
LANDSCAPE		SAME	SAME
ESTIMATED TIME		16 HOURS	12 HOURS (EST.)
COST SQUARE MILE		$1/SQUARE MILE	$.75/SQUARE MILE (EST.)
RESIDUAL INFORMATION		1 FACTOR	5 FACTOR
INFORMATION PRODUCT		SIMILAR	SIMILAR

Table 8. Land Use category separation matrix for maps produced from S-190B photos.

Qualitative Rankings*

1 = good separability
2 = fair separability
3 = poor separability

	Residential	Retail & Wholesale	Industrial	Extraction	Transportation	Institutional (etc)	Strip & Clustered	Open & Other Urban	Crop & Pasture Land	Orchards	Deciduous Forests	Evergreen Forests	Mixed Forests	Upland Brush
Retail & Wholesale	1													
Industrial	1	3												
Extraction	1	1	2											
Transportation	1	1	2	1										
Institutional (etc)	2	2	1	1	1									
Strip & Clustered	1	1	1	1	1	1								
Open & Other Urban	1	1	1	1	1	1	1							
Crop & Pasture Land	1	1	1	1	1	1	1	2						
Orchards	1	1	1	1	1	1	1	2	2					
Deciduous Forest	1	1	1	1	1	1	1	2	2	3				
Evergreen Forest	1	1	1	1	1	1	1	2	2	3	3			
Mixed Forest	1	1	1	1	1	1	1	2	2	3	3	3		
Upland Brush	1	1	1	1	1	1	1	2	3	3	3	3	3	
Reservoirs	1	1	1	1	1	1	1	2	2	2	2	2	2	2

* Rankings were assigned on a qualititative basis through iterative process by the investigators.

comparison which assesses the relative ease of distinguishing between categories. Information presented in both tables provides the basis for the concluding assessments of both systems and their potential use as sources of regional planning information.

The direct comparison of the two data sources in this exercise provides some interesting information as to the utility of the two systems as a source of land use data. The major differences between the two data sources in land use mapping lie in the variations between their spatial resolution and spectral characteristics. The impact of these variations can be found in both the time costs and estimated ease of mapping and in the estimated residual information content of the imagery. Mapping was accomplished somewhat more quickly and easily from the high altitude photography because legend categories could be quickly recognized without employing secondary locational or contextual clues in identification.

Residual information, the amount of information contained in the data record that is in excess of the amount needed to produce the map, is estimated to be four or five times greater on the high altitude aerial photography than on the Skylab image. This might indicate that although the data content of the Skylab image is sufficient for purposes of mapping land use at the given scale (1:60,000), other uses of the data which would require finer data resolution could not be accommodated. Such other uses might include use of images as visual catalysts in policy planning situations, and as a means of communicating abstract ideas and concepts during the analysis and review phases of planning (see Section 2).

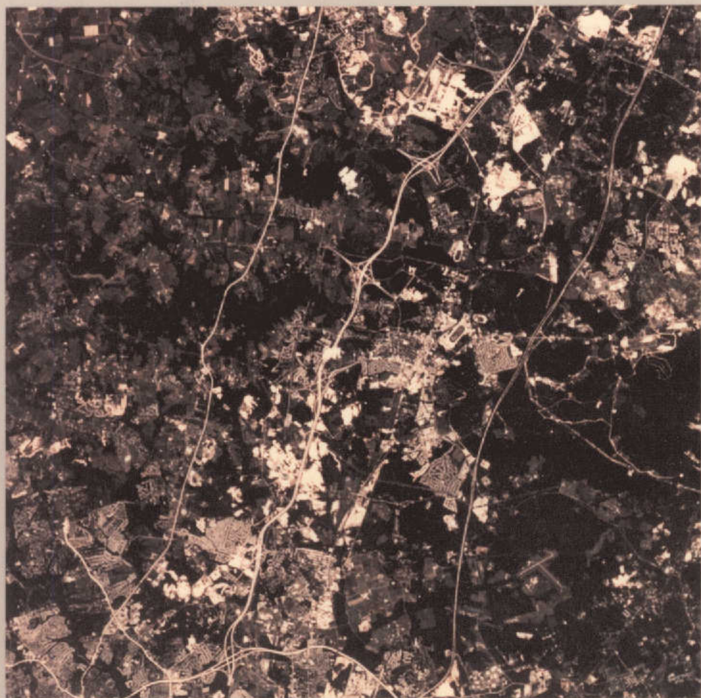
Table 8 is a category separation matrix in which all mapped land uses are ranked on the ease with which they may be distinguished from other categories. Only the Skylab EREP maps are considered in the matrix because all the separations can be accomplished at the "good" level using the RC-10 photography.

Fair and poor separation capability assignments for categories in the mapping exercise utilizing the S-190B data base are localized in two areas on the matrix. First, the failure to separate categories within the urban sector is a function of the spatial resolution of the photography. The organization and scale characteristics of activity patterns in an urban setting require a level of detail not available in the S-190B photography. In general the resolutions needed to make detailed land use or economic activity determinations range from less than one meter to 10 meters, and the EREP photography barely accommodates the upper end of that range.

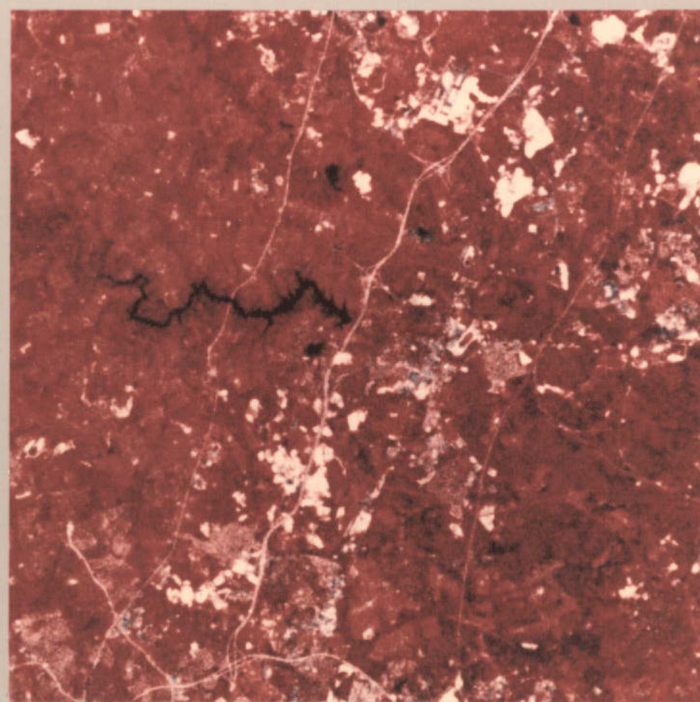
Problems encountered in the separation of agricultural, forest and reservoir categories at the other end of the matrix are more a result of the spectral character of the S-190B photography than the spatial resolution. With the color format alone, as noted in the preceeding analyses, no internal differentiation could be accomplished within either the forest or agriculture categories. In addition, several water bodies were poorly delineated on one map and were not recognized on the other. The problem faced with recognition of water bodies is a function of contrast as well as similar spectral response between water and vegetation. Confusion due to spectral and contrast characteristics are not an insurmountable problem when one considers the total sensor array of the Skylab platform. This experiment explored the utility of high resolution S-190B color photography as a source of land use information in regional planning. Joint use of S-190A color infrared imagery and S-190B images for the same test sites would improve mapping of water bodies and vegetation categories (Figure 17).

On the basis of this comparison one can safely assume that Skylab EREP data could serve as a valuable data source for most state planning organizations. However, because planning at this level can involve a number of highly variable land management activities this type of imagery is only one of many information sources which state agencies will employ. Specifically, Skylab photography could replace high altitude aircraft data where information requirements stipulate regional or generalized products (i.e., statewide or multi-county maps with greater levels of detail than that provided by land cover maps). Without significant improvements in spatial resolution EREP data can not provide more than a regional overview or a sense of spatial context for localized agencies concerned with land use regulation at the parcel level. Since part of the state planning function includes supporting and coordinating the efforts of local jurisdictions, efforts in these areas can only slightly benefit from the Skylab imagery.

SPATIAL AND SPECTRAL CHARACTERISTIC DIFFERENCES OF S-190B AND S-190A SKYLAB IMAGERY



SKYLAB S-190B, AUGUST 1973



SKYLAB S-190A CIR, AUGUST 1973

1 0 1 2 3 4 5 MILES

VARIATION IN SPATIAL RESOLUTION AND SPECTRAL SENSITIVITIES BETWEEN PHOTOGRAPHIC SYSTEMS ON SKYLAB ENHANCES PARTICULAR LAND USE TYPES. FOR EXAMPLE, URBAN DETAIL IS CLEARLY VISIBLE ON THE S-190B PHOTOGRAPHY. EXCELLENT ENHANCEMENT OF WATER FEATURES AND IMPROVED DISCRIMINATION WITHIN FORESTED LANDS IS PROVIDED BY S-190A COLOR INFRARED PHOTOGRAPHY.

EARTH SATELLITE CORPORATION

Figure 17

5.0 SUMMARY AND CONCLUSIONS: UTILITY OF SKYLAB EREP DATA IN LAND MANAGEMENT ACTIVITIES

One may summarize the utility of Skylab EREP data by first reviewing the data needs of those agencies identified in Section 2 of this report and comparing those needs with the results demonstrated in Section 4. The variable output of all three remote sensing systems (Aircraft, Skylab and ERTS) can then be compared in terms of the characteristics of both data and derived information.

5.1 Review of Data Needs

The specific characteristics of planning agencies -- such as the type of mandate, its size and variety of environmental problems -- are the principal factors which help to determine information needs. Land use planners associated with urban areas are less likely to employ high altitude aircraft and satellite remote sensing data than are regional planners and land resource managers associated with county, state and Federal agencies. In addition, two trends which will impact the orientation and direction of future land management efforts were identified. These included both the trend towards planning for larger areas with a regional perspective and the trend towards comprehensive environmental consideration in all land resource management actions.

5.2 Quality of the Land Use/Cover Information

Results from the image interpretation test indicated that good quality informaton products (maps) could be expected from Skylab S-190B imagery at both Level I and Level II as defined by U.S. Geological Survey Circular 671. Variations in test results at finer levels of classification were organized in such a way to suggest that the combined spectral characteristics of S-190A and S-190B photography are needed for accurate identification and mapping in forest and agricultural classes. In addition significant variations in category identification can occur because of differences in the training and experience of the participating interpreters.

The land cover mapping exercise could only be assessed in qualitative terms due to the level of abstraction dictated by mapping scale and the resolution limitation of the ERTS photographic product. For the area over which the mapping comparison was completed the Skylab-based product is markedly superior. S-190B imagery contains more information than the ERTS products. However, the differences between the two systems and the differing results reported by ERTS investigators for different landscapes dictate that for some larger area extensive planning programs require information needs which can only be supplied by ERTS data.

Comparative land use mapping in the Rockville area and the Baltimore-Washington corridor of Maryland suggest that land use products may be developed from Skylab S-190B photography which are similar to high altitude aircraft land use maps currently used by regional planning agencies. Because most regional planning agencies (especially states) are charged with supporting and coordinating the activities of local agencies within their jurisdictions and with setting regional land resource planning policies, functions requiring additional information obtainable only from high and medium altitude aircraft imagery. S-190B imagery cannot acceptably substitute for all uses of aircraft data.

5.3 Systems Comparison and Conclusions

Our methodology has focused upon comparing the data record provided by Skylab S-190B photography with both higher and lower resolution systems. Table 9 displays the comparison of the data and information characteristics of all three systems. Skylab data and the informaton derived from it is intermediate in almost every respect between high altitude aircraft and ERTS. Clearly, the versatility of ERTS in frequency of coverage and its consistency of timing are important aspects which were not examined closely in this study. The intermediate resolutions of Skylab imagery are indicative of the value of future satellite systems which will combine greater spatial, spectral and temporal resolutions.

TABLE 9 - SYSTEMS COMPARISON

SYSTEM / CHARACTERISTICS	ERTS - 1 FALSE COLOR COMPOSITE MSS 4, 5, AND 7	SKYLAB S - 190B COLOR PHOTOGRAPHY	HIGH ALTITUDE AIRCRAFT FALSE COLOR (CIR) PHOTOGRAPHY
FRAME DIMENSIONS	7.25 " x 7 "	4.5 " x 4.5 "	9 " x 9 "
SCALE	1:1,000,000	1: 961,485	(APPROX.) 1: 130,000
AREA COVERAGE	(APPROX.) 13,250 SQ. MILES	(APPROX.) 11,356 SQ. MILES	(APPROX.) 317 SQ. MILES
SPATIAL RESOLUTION	< 79 METERS	< 25 METERS	< 2 METERS
SPECTRAL CHARACTERISTICS	.5 TO .7 AND .8 TO 1.1 MICROMETERS	.4 TO .7 MICROMETERS	
COVERAGE REPETITION	EVERY 18 DAYS	REPETITIVE, BUT INTERMITTENTLY SO AT HIGH COST	REPETITIVE, BUT INTERMITTENTLY SO AT MODERATE COST
DATA DETAIL (SEE FIGURE 3)	MACRO SCALE, SOME MESO SCALE	SOME MACRO SCALE MESO SCALE, SOME MICRO SCALE	SOME MESO SCALE, MOST MICRO SCALE

APPENDIX A

LAND USE CLASSIFICATION SYSTEM

LAND USE CLASSIFICATION SYSTEM

(Adapted from USGS Circular 171 and USGS proposed Level III land use classification scheme)

Number and Category

1. Urban and Built-up Land

    1.1 Residential

        1.1.1 Single-family household units

        1.1.2 Multi-family household units

        1.1.3 Group quarters (such as rooming and boarding houses, membership lodgings, retirement homes and orphanages, work quarters (labor camps) and other group quarters

        1.1.4 Residential hotels

        1.1.5 Mobile home parks or courts

        1.1.6 Transient lodging (motels, tourist courts, and non-residential hotels) (Placed under residential in accord with the Standard Land Use Coding Manual)

        1.1.9 Other

    1.2 Commercial and Services

        1.2.1 Wholesale Trade Areas

        1.2.2 Retail Trade Areas (Central Business District, Shopping Centers, Strip Commercial and Other Retail Trade Areas)

        1.2.3 Business, Professional, Personnel Services (except those included in the institutional category)

        1.2.4 Cultural, Entertainment, and Recreational Facilities

        1.2.9 Other

    1.3 Industrial

        1.3.1 Mechanical processing (textile mill products, apparel, and other finished products, lumber and wood products, furniture and fixtures, stone, clay, and glass products)

1.3.2 Heat processing (primary metal industries, electric power generation)

1.3.3 Chemical processing (paper and allied products, petroleum refining, and related industries)

1.3.4 Fabrication and assembly (fabricated metal products, professional, scientific and controlling instruments; photographic and optical)

1.3.5 Food processing

1.3.6 Other

1.4 <u>Extractive</u>

1.4.1 Stone quarries

1.4.2 Sand and gravel pits

1.4.3 Open pit or strip mining

1.4.4 Oil, gas, sulphur, salt and other wells

1.4.5 Shaft mining

1.4.9 Other

1.5 <u>Transportation, Communications, and Utilities</u>

1.5.1 Highways, auto parking, bus terminals, motor freight, and other facilities

1.5.2 Railroads and associated facilities

1.5.3 Airports and associated facilities

1.5.4 Marine craft facilities

1.5.5 Telecommunications, radio, and television facilities

1.5.6 Electric, gas, water, sewage disposal, solid waste, and other utilities

1.5.9 Other

1.6 <u>Institutional</u>

1.6.1 Educational Facilities

1.6.2 Medical and Health Facilities

1.6.3 Religious facilities

1.6.4 Military areas

1.6.5 Correctional

1.6.6 Government and Admin. Offices

1.6.7 Civic, Social, and Fraternal Organizations (YMCA, Scouting Groups, etc.)

1.6.9 Other

1.7 <u>Strip and Clustered Settlement</u>

(No further breakdown recommended at Level III)

1.8 <u>Mixed</u>

(No further breakdown recommended at Level III)

1.9 <u>Open and Other</u>

1.9.1 Improved

1.9.2 Unimproved

1.9.9 Other

2. <u>Agricultural Land</u>

2.1 <u>Cropland and Pasture</u>

2.1.1 Active Cropland

2.1.2 Idle Cropland

2.1.4 Pasture

2.1.9 Other

2.2 <u>Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas</u>

2.2.1 Fruit and Nut Trees

2.2.2 Bush Fruit

2.2.3 Vineyard

2.2.4 Nurseries and floricultural areas

2.2.9 Other

2.3 Feeding Operations

2.3.1 Cattle feed lots (including holding lots for dairy animals)

2.3.2 Poultry and egg houses

2.3.3 Hog feed lots

2.3.9 Other

3. Rangeland

3.1 Grass

(No further breakdown at Level III required for the study area)

3.2 Savannas (Palmetto prairies)

(No further breakdown at Level III required for the study area)

3.3 Desert Shrub

(No further breakdown required at Level III for the study area)

4. Forestland

4.1 Deciduous

4.1.1 Red oak

4.1.2 White oak

4.1.3 Chestnut oak

4.1.4 Scrub oak

4.1.5 Cypress

4.1.6 Aspen - pen cherry

4.1.7 Riverbirch - Sycamore

4.1.8 Cove Hardwoods

4.1.9 Northern Hardwoods

4.1.10 Bottom land Hardwoods

4.1.11 Red gum - yellow poplar

4.2 Evergreen Forest

4.2.1 White pine

4.2.2 Loblolly pine

4.2.3 Oak - White pine

4.2.4 S. White cedar

4.2.5 Hord pines

4.3 Mixed Forest

4.3.1 Northern Hardwoods - White pine

4.3.2 White pine - Northern Hardwoods

4.3.3 Oak - White pine

4.3.4 Hard pine - oak

4.3.5 Oak - Hard pine

4.3.6 Loblolly pine - Hardwoods

4.3.7 Hardwoods - Loblolly pine

4.4 Upland Brush

4.5 Lowland Brush

5. Water

5.1 Streams and Waterways

5.1.1 Natural (rivers and creeks)

5.1.2 Man-Made (canals, ditches, and aquaducts)

5.2 Lake

5.2.1 Natural Lakes and Ponds

5.2.2 Man-Made Lakes and Ponds

5.3 Reservoirs

(No further breakdown at Level III required for the CARETS area)

5.4 Bays and Estuaries

5.4.1 Bays

5.4.2 Estuaries

5.6 Ocean

5.9 Other

6. Nonforested Wetlands

6.1 Vegetated

6.1.1 Brackish marsh

6.1.2 Fresh water marsh

6.1.3 Brush covered wetlands

6.1.9 Other

6.2 Bare

6.2.1 Brackish bare areas

6.2.9 Other

7. Barren Land

7.1 Salt Flats

(No further breakdown at Level III required for study area)

7.2 Beaches

7.2.1 Sandy beaches

7.2.2 Gravelly, rocky beaches

7.2.3 Mud shorelines

7.3 Sand other than Beaches

(No futher breakdown at Level III required for study area)

7.4 Bare Exposed Rock

(No further breakdown at Level III required for study area)

7.5 Disturbed Land

(This consists of areas under construction, etc., where the vegetation cover has been removed by mechanical means)

7.9 Other

8. Tundra

(No further breakdown recommended at this time)

9. Permanent Snow and Icefields

(No further breakdown recommended at this time)

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