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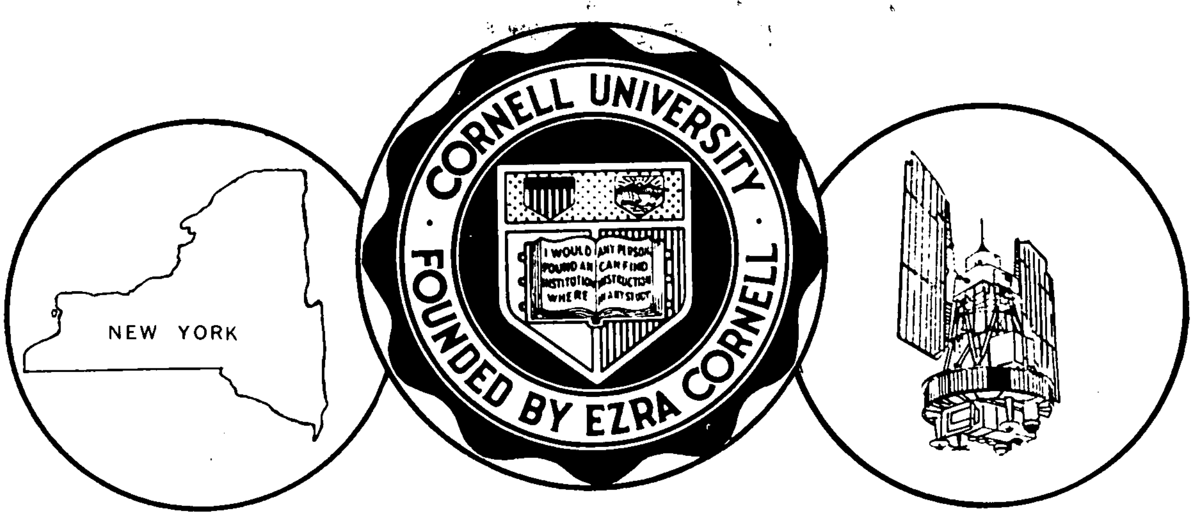

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Dear Sir:

Enclosed is a copy of our recently completed interim report sponsored by NASA contract NAS 5-21886. We would like to have you list the title and abstract in the NASA Earth Resources Survey Program Weekly Abstracts.

Thank you.

Sincerely yours,

James E. Skaley

James E. Skaley
Project Coordinator

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ERTS EVALUATION FOR LAND USE INVENTORY

Type II Report

December 13, 1972, to June 13, 1973

Contract #NAS5-21886

Agency: New York State College of Agriculture and Life Sciences
Department of Natural Resources
Cornell University
Ithaca, New York 14850

Principal Investigator	Dr. Ernest E. Hardy Senior Research Associate
Project Coordinator	James E. Skaley
Photo Consultant	E. S. Phillips
Computer Consultants	Robert Fisher Eric Siegel
Technical Staff:	Douglass Payne C. Selvarajah Linda Hunt Robert Barnes Chad Dawson
Secretary	Kathleen Manion

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PREFACE

This type II report covers the contract period from December 13, 1972, to June 13, 1973, and fulfills the requirements as outlined in Article II Item 4 for NASA Contract NAS 5-21886, "Evaluation of Satellite Sensed Information as a Source of Resource Inventory Information". The contents of this report are limited to the technical progress made during this period toward satisfying the objectives in the statement of work and as outlined in the Data Analysis Plan (DAP) approved on April 6, 1973. The data and methodology as reported is preliminary, and conclusions derived from the text should be treated as tentative.

[redacted]

ABSTRACT

The objective of this study was to evaluate the possibilities of using multispectral imagery from NASA's Earth Resource Technology Satellite for inventorying land use and updating existing inventories in the state of New York.

The feasibility of accomplishing a general inventory of any given region based on spectral categories from satellite data has been demonstrated in a pilot study for an area of 6300 square kilometers in Central New York State. This was accomplished by developing special processing techniques to improve and balance contrast and density for each spectral band of an image scene to compare with a standard range of density and contrast found to be acceptable for interpretation of the scene. Diazo film transparencies were made from enlarged black and white transparencies (scale 1:250,000) of each spectral band. Color composites were constructed from these diazo films in combinations of hue and spectral bands to enhance different spectral features in the scene. Interpretation and data takeoff was accomplished manually by translating interpreted areas onto an overlay to construct a spectral map. The eight spectral categories mapped were compared to equivalent categories in the Land Use and Natural Resources Inventory of New York State (LUNR). Field checking and sampling techniques were used to verify interpretation of the areas of different spectral categories and the accuracy with which these areas were geographically referenced to the Universal Transverse Mercator (UTM) ~~grid system.~~ The minimum area interpreted was 25 hectares. The minimum area geographically referenced was one square kilometer. The interpretation and referencing of data from ERTS ~~compared to LUNR~~ was found to be about 88% accurate for

Abstract (continued)

eight primary spectral categories.

A computer file system similar to that of LUNR is currently under development. Numerous other studies are also in progress relating to the effects of temporal change, interpretation of different geographical areas of the state, improving on photo processing techniques, and a prediction model to determine the type of spectral/hue combinations required to enhance different spectral categories specifically related to types of land use.

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INTRODUCTION

Classification Theory

It is not possible to gather all the information about the land use and resources of an area of the country without setting up some form of systematic approach to the organization of the information. By this means we are able to compress the whole truth into a workable mass of information. In doing this, we require a certain degree of "generalization", which in turn means we accept a small loss in detail for greater economy, maneuverability, and aggregation of usable data.

The kinds of information that are lost are not necessarily of great significance. We may have to settle for the knowledge that in a given area there are 50 dairy farms, using a total of 5,000 acres of land, while if we looked at more detailed information, we might find that ten of the fifty farms were large ones of over 200 acres, and the rest were much smaller, with less than 75 acres of land per farm.

Classification, as used in a project of this type, provides a means of getting large masses of data into a uniform format, and also allows us to organize the information into logical groupings that maintain an interrelationship with one another.

There is no one classification system that works well for all applications. But there have been many published efforts that have tried to foster the idea there should be one workable classification system for land use that would answer the needs of everyone. Classification systems are used or left unused according to the utility to the user of the information incorporated in the classification system. Therefore, the most logical decision-maker as to what should be in the classification system is the potential user. The user should look over his requirements for information, and then from needs he identifies, a classification system can be developed.

There is no limit to the number of possible classifications that can be defined. One user may wish information only on wetlands and bogs, so a system that maximized information about agriculture and urban land use would prove to be mostly wasted for that user.

The minimum classification system would have only two units in it, land and water. But this would be of little use to anyone.

The classification system is a working part of an inventory. It does not stand alone without the inventory, for the particular use or uses of the inventory will have determined the kind of classification that has been developed.

In all cases there are three qualities that must be supported by the classification. It must be: (1) comprehensive, (2) provide a unique description of each item, and (3) provide for discreet assignment of each item into only one class.

The requirement of comprehensiveness refers to complete coverage of all the land mass involved in the area being inventoried. This often calls for additional classes being added to provide appropriate places for certain kinds of land uses that perhaps are not of much interest to the potential users of the inventory. It also accounts for what are referred to as "wastebasket" categories, which allow the interpreter to put in one class a number of items that do not fit well anywhere else. It is possible, in this context, to have a very effective classification that requires only two map units. This is a single use classification that identifies the one item of interest and then lumps all other items into one category, often labeled "other". The more usual approach, however, is for the potential users to keep adding more and more units of items they will have use for, and the tendency is for such classifications to grow in number of map units rather than to decrease. To attain comprehensiveness, new class or map units may be needed. It is not always possible to predict all the kinds of land use that will be encountered in an inventory, and additional classes may have to be added to the system well after the start of the project.

Comprehensiveness is essential if we are to devise a means of measuring areas. Usually the best method is to work in terms of percentages of different land uses for a unit area. Without complete coverage of the area, this kind of measurement process becomes very difficult. There is one other situation that needs attention in terms of comprehensive coverage. It is possible to meet situations where it seems logical to count certain land areas twice. Such cases occur where we have caves, or underground mining operations, or large underground parking facilities. Since it is not possible to count such areas twice and maintain a true summary of the total land area, it is necessary to decide how such instances are to be handled, and then follow these rules in all cases.

A unique description of each item in the inventory classification is the major key to a successful inventory. By providing adequate descriptions, the interpreters and others preparing material and information for the inventory and the users of the inventory are provided with strong, accurate backup support for their decision-making process. A description of each item should be written as early in the inventory process as possible, and then changes made as needed.

The description process is best carried out by people who are very familiar with the items being described. And they should also be prepared on the basis of the source of information to be used in preparing the inventory. If information about an item (such as cemeteries) is to be taken from topographic maps, there may be very little description required. On the other hand, if the source of information is to be airphotos or some other form of remote sensing, the description should include the key indicators an interpreter would use in identifying the item.

The description is the most important written material of the inventory. It should be well enough written that someone unschooled in the project could read the description and know what was intended to be included in any particular class or map unit. The description should also include comments about the social, cultural, and technical practices that might have an effect on the identification of the item at present or in the future. The description phase of the write-up should be as wordy and lengthy as desired. One rule to follow is to ask if there is enough information in the description for someone to read it 20 years from now and still understand what you are trying to identify. For it is only through descriptions that we are able to continue this form of inventory over time. Without adequate description, it is not possible to make a subsequent inventory based on the same classification system.

There is another purpose served by the description, and that is to define the "cut-off" points or parameters for each classification unit. Most items in an inventory do not clearly identify themselves for the interpreter. Thus in most every instance, items occur in a continuous gradation. At first one thinks he knows what a junkyard is, but there is a lower limit that must be identified. There are people, very opposed to any kind of junk, who would insist one junked car creates a junkyard. It is obviously not practical to identify each junked car, but a decision must be made as to what the minimum size area or number of cars will be that can be recorded as a junkyard.

B

Discreet assignment refers to the fact that each item found in the area being inventoried can have only one legitimate classification within the classification system. Thus it should be impossible to register a large poultry farm as a factory operation one time and as a farm operation another. A cemetery is always a cemetery, etc. However, there are many cases where it is genuinely difficult to keep a land use or point type information under the same classification unit at all times.

THE CENTRAL CONCEPT

In all classification work, and in all things that appear in nature and that are influenced by man, there is a "range", or continuous scale of events that make it difficult to determine where limitations on various classification units should be assigned. Any item we wish to look at in the inventory system also displays this problem.

We are all certain we know what a farm is. But how small a unit shall we call a farm? If we arbitrarily select a size, say three acres, we may exclude some very intensively managed agricultural enterprises, such as the production of nursery stock, or specialized seedlings. If we go to even smaller areas, we soon get mixed in with those who simply enjoy a large garden, and then there is no end to the smallness of gardens. Obviously, a decision must be made.

Similar problems occur in all other classes. How small a trail should qualify as a road? We know where our more recent cemeteries are located, but how do we treat the ones of historic interest, or in more recent times, what do we do about pet cemeteries?

We have borrowed from the work of the soil scientists in trying to solve this problem. They perform their classification of soil units using a concept of the CENTRAL or IDEALISED unit as the basis for decisions. Between two different idealised soil profiles, referred to as benchmark profiles, there is a range of a variety of soils. As each soil is identified, it is classified in relation to the benchmark soil it most nearly matches. In this way, the classifier recognizes that not all soils with the same name are identical, but he can argue that they are all closely related to one benchmark soil. In fact, he can argue they are all more closely related to benchmark soil A than they possibly could be to any other soil.

In similar fashion, only with far less technical support, we have to select our "central concept" for each item in the inventory. As the areas we look at become more diverse in character we realize they are drifting from the original central concept, and a new unit or class will have to be used to cover the extremes of the unit.

Perhaps the problem is best illustrated by the use of crown cover density as a criteria for forest classification. We can select samples of each crown density that will represent our selected density classes. And we can keep samples of the crown cover density in front of us at all times. But trees grow at all heights, and with great diversity of numbers per acre. Consequently, we are still faced with the problem of deciding where, between two crown cover densities for which we have samples, we will make the decision to call any given area density A or density B. This is really an art. And in spite of the machinery that has been developed to help in making such decisions, it is still a matter for the individual doing the classifying to learn how to make such decisions. It is also a matter for the supervisor to have firm control over, for different individuals can make very different decisions from the same information, and each can justify his decision with conviction.

Recognizing and working with the central concept is the art of the trade. It calls heavily on the field knowledge of the interpreter, and the skill of the supervisor to keep decisions flowing in logical patterns of agreement. An accuracy level of 90 percent can be attained quite readily. A level of 95 percent is not too difficult for skilled and informed interpreters. But the last five percent of accuracy leading to perfection may be very expensive to acquire.

Supplemental information may often assist the interpreters greatly in unifying their decisions. Good topographic (topo) maps have a great wealth of information to incorporate into an inventory. Such things as travel brochures, maps of cities, campground directories, and business directories all offer help to the interpreter. He should use all the aids he can get, especially his own field travel. But a word of caution about secondary data is in order. Often many of the things shown on topo maps and in the other sources mentioned have changed in one way or another. Businesses become inactive, roads are relocated, and new buildings are produced and older ones torn down. It is always wise to check the supplemental information against what can be seen on the images for agreement. If differences are identified, then the interpreter must make his decision based on what he considers the best information.

A THEORY OF LOGICAL ASSOCIATION

There is little that can occur on the face of the earth, either through man's actions or through nature's ways, that cannot be identified and evaluated by airphoto interpretation. In natural settings we have floods that leave undercut bands and freshly gouged river channels, as well as large areas of fresh silt cover, where new plant growth may take a long time establishing itself. There are earth tremors that lead to numerous slides in mountainous areas. They leave scars visible for decades and longer. Earthquakes leave telltale fractures with uplifts, thrust faults, and disrupted cultural features. And fires, whether started by man or by natural means, leave scars that at first are visible by the lack of growth, and later are just as visible from the uniform, but different, type of growth that follows.

A background in geology, forestry, and other natural sciences will assist the interpreter in analyzing the logical association of events from the natural processes of nature that are visible on photos. That knowledge tells the interpreter that a braided stream denotes a high seasonal runoff, and perhaps flash floods. That large areas of silt loam will be associated with a mature meandering stream, often near the end of its run. And where there are well-drained soils, a certain combination of vegetative growth will be visible, depending on climatic features.

Surprisingly, perhaps, man is no less systematic or logical than nature in how he develops resources for his use, and in what he does in various ways to manage them for his own use. Consequently, we rarely see a dairy farm headquarters without some forage or cropland to go with it. Furthermore, the size of the stock sheds gives us a clue as to approximately how much land there should be connected with the operation. The trails in the range or crop area indicate how active the farm operation is, and we may judge its financial success from the visual condition of the residences associated with it, the number of cars in the driveway, the size of the main house, and the kind of maintenance it appears to receive.

As activity develops on the landscape, man takes the course of least resistance in many of his activities. Thus, while a foot traveler, man learned to stay near the water because it was level, but he also looked for the edges of drier gravel on which travel was easier. Now that we have machinery to transport us, and that allows us to adapt a wider variety of resources to our use, we still follow the same principles. Roads are usually along level and elevated routes if there is a choice. This means bridges are necessary to cross the great numbers of intersecting streams, and the size of the bridge and the size of the stream it crosses have a common factor of denomination. In like manner, the size of the road (two lanes, four lanes, single, etc.) gives us a strong indication of the amount of travel we should look for on any particular highway.

Land use classification systems are directed toward many areas--some research-oriented, some user-oriented. Some have been so carefully designed that they appeal to both groups and can be used almost universally. If a classification system is well-designed, then it is apparent that the designers have taken into consideration the capability of the system regardless of the interpretation techniques employed. When care is taken, illogical or contradictory situations can be avoided, for example, when the interpreter finds data points that do not clearly belong in any category. In such cases, the definitions for each category must be broadened or changed. This creates waste and at best inaccurate information. Admittedly, some revision is expected in any study. However, with proper preparation, fewer revisions will need to be made and more accurate information will be derived.

Planning the design of a classification system from remote sensors is no less complex. Several points should be considered in designing an inventory. The first is the classification system should fulfill the user's requests or he will not be able to use the system. The classification system must be basic so that every necessary item is included and there is no confusion due to overlap or underlap. An orchard that belongs in both fruit and forest is not useful to anyone. A gravel pit that does not belong anywhere is not useful. The user's needs must be coupled with the usefulness of each data item. If that is done, the system should be entirely workable.

> The inclusion of any data item in the classification should be justified on the basis of usefulness in decision-making, and classification should proceed by working backwards from the anticipated decisions to definition of data needs. In addition, each data item should be unbiased, uninterpreted (in a subjective sense), and as "basic" as possible.
>
> Shelton, Hardy, 1971.

Another point is the capability of the source. If the information source is only black and white aerial photographs at a scale of 1:200,000, a user could not request data on tree damage due to storms. Likewise, accurate information on marshlands could not be obtained during the summer of a two-year drought.

Another factor closely linked to capability is cost effectiveness. Most projects are limited to some extent by the amount of available funding. This explains why some rural projects do not undertake an inventory of wildlands within the study area. It also explains why other projects choose only the city core for intense study and simply list the housing areas as residential. Costs are associated with each data item and must be balanced against the usefulness of the item.

The fourth consideration is the input and retrieval processes. The decision must be made as to the form of the data going into the computer, and the form of the data to be received from the computer. This decision must be made before the data is ready to be inputed. The classification system is closely related to this form. The classification must be in a form agreeable to computer processes. The inventory itself must be applicable to the available computer output forms. Without this planning, an economic constraint will be placed on many projects and users who must pay for the product. Therefore, some time must be spent linking the classification system, cost effectiveness, and input and retrieval processes. The scope of the project is defined by the purpose, the potential users, the available funding, and the available computer processes of the project. These factors must be coordinated or the result will be an incomplete project or a non-operational system.

Another factor to consider is flexibility. Ideally, a category can be deleted and not affect the function of the rest of the system. We should also be able to expand the categories without affecting the internal processes of either the classification system or the retrieval process.

Repeatability is probably most important to anyone who wants to establish an on-going system with time-lapse analysis capabilities. If a study of cities is applicable only to Chicago, no other city will want to use it. If a study of a valley includes only the limited number of vegetation types prefaced by a locational word, no other valley will be able to use the same system. Every classification system should be designed so that it is universal. The time and effort put into a project should provide a product to be used by anyone.

A simple classification, if it adequately serves the needs of the user, is the better one. However, users are accustomed to asking for as much detail as the interpretation and data system is able to give them within budget constraints. Either the user can be convinced he needs less information than he asked for (improbable) or he can be given the detail he asks for (probable). Most decisions, planning decisions for example, are usually based on less than perfect information. The data may be biased unreasonably; it may be inappropriate for the decision to be made. But for security, decision makers would like to have 100% of any accurate information to support their decisions.

A classification system, therefore, needs to have detail or the possibility of adding detail. A classification with equal categories, and subcategories that can be expanded or aggregated as the need demands, is an ideal goal. In addition, the categories must be easy to understand. They must be well-defined and accurately described so that users of the system can comprehend what land use goes in each category. In summary, any classification system should (1) be comprehensive, (2) have categories uniquely described, and (3) allow discreet assignment of all items.

PATTERNS OF LAND USE

In many parts of the country, land use may be adequately identified simply by identifying one unique physical or time-oriented characteristic. Irrigated valley cropland surrounded by arid hill country presents little challenge to interpreters using visual techniques. Similarly, irrigated citrus groves in the arid southwestern states represent one of the most logical associations of management and use characteristics we can define. Neither of these cases should present more than a routine decision problem for an interpreter.

Complexity of land use patterns increases, however, as the humid east is approached. In the northeast, where historic boundary patterns are found combined with temporal, vegetational, and geomorphological variables, the most complex pattern of vegetative cover and land uses found in this country exists. There is very little irrigated land to be identified. None of it is found contrasted against an arid landscape.

Patterns do not, in themselves, become identifiers of land uses in the northeast. Therefore, due to the lack of rectilinear features, even in such standard features as road patterns, it is essential to look far beyond the readily visible features discernible in the imagery to generate useful classification systems. There are no clear cut distinctions. Urban areas grade into rural areas. Crops easily identified elsewhere in the United States are indistinguishable from forested real estate in the northeast. Detail, at the highest level possible, is the logical solution to this kind of problem.

Identification and geographic location of information is essential to production of a useful classification if it is to be applied at the local level. In the northeast, most decisions affecting resource management are made at the township, or private owner level. A township is usually about 30,000 to 40,000 acres in size. Private owners often influence decisions on parcels of less than five acres. To be effective, and provide usable information, satellite imagery must be interpreted to high levels of detail. To meet this need, attempts have been made to achieve a unit size of a few hectares. Subsequent efforts will be directed toward refinement of scale determination and information retrieval at those scales.

In choosing a classification system for this study based on what could actually be interpreted on the ERTS-1 imagery, it was decided that a broad classification system with a limited number of categories would be of the most use with the interpretation techniques to be employed. The first step was to search for and review as many operational classification systems as possible. After a group of systems had been identified and points of confusion cleared up by personal correspondence with the authors, the large group was classified into three smaller groups. They are identified as detailed, restrictive, and elemental. These different systems are listed below according to author and type.

*** Detailed**

Standard Land Use Coding Manual (U. S. Department of Commerce)

MacConnell Land Use (University of Massachusetts)

Poulton. A Preliminary Vegetational Resource Inventory and Symbolic Legend System for Tucson-Willcox-Fort Huachucha Triangle of Arizona (Oregon State Univ.)

Pettinger. Application of High Altitude Photography for Vegetation Resource Inventories in Southeastern Arizona (Univ. of California)

Land Use and Natural Resources Inventory for New York State (Cornell Univ.)

Scheme for Study by Association of American Geographers (J. Anderson, American Geographers)

Canada Land Inventory (Canadian Government)

Minnesota Land Information System (Univ. of Minnesota)

*** Restrictive**

Aldrich. Space Photos for Land Use and Forestry. (USDA Forest Service)

Krumpe. A Regional Approach to Wildland Resource Distributional Analysis Utilizing High Altitude and Earth Orbital Imagery (University of California)

Simpson. Urban Field Land Use of Southern New England: A First Look (Dartmouth College)

Simonett. Susceptibility of Environments to Low Resolution Imaging for Land Use Mapping (University of Sydney, Australia)

*** Elemental**

Anderson. A Land Use Classification System for Use With Remote Sensor Data (USGS)

Rudd. Macro Land Use Mapping with Simulated Space Photos (Oregon State University)

Landgrebe. A Study of the Utilization of ERTS-A Data from the Wabash River Basin. An Early Analysis of ERTS-1 Data (Purdue University)

*See Appendix A for detailed explanation.

DETAILED

The classification systems in this category usually have more than ten major categories (first order division) and at least one entry in a subcategory (second order division). A few of the systems in this group have seven or eight first order divisions. However, if there were third order divisions within each of the second order divisions, the system was defined as detailed. An example of this could be found in a classification with only a few first order categories but which included distinctions at the third order levels between woodland grazing, productive woodland, and nonproductive woodlands. These distinctions were made to emphasize a certain user's needs, or to reflect the professional orientation of the taxonomist. Because of this emphasis, these types of systems do eliminate themselves from possible consideration for first phase applications using satellite imagery.

Most of these systems were developed for and used with conventional aerial photography. For the most part, they incorporated a large number of categories and subcategories. Most of these systems had also been used on very large land areas. Therefore, many categories were needed to cover the different land uses and natural resources found in the area. Also, most of them needed the extra detail to satisfy many different types of users. However, by accumulating so much detail, their transposition to satellite data is unworkable at this time. But at this time what is really needed is a fairly broad classification system with a limited number of categories. As a consequence, it would not be possible to accomplish more than a small portion of the detailed inventories using only satellite imagery.

RESTRICTIVE

Restrictive classification systems enbrace those groups that show extreme detail in one area of a particular interest in one area of land use or natural resources. Two examples of this type would be "Space Photos for Land Use and Forestry" (Aldrich, 1971) and "A Regional Approach to Wildland Resource Distributional Analysis Utilizing High Altitude and

Earth Orbital Imagery" (Krumpe, 1973).

This group has an advantage in that it includes systems developed from simulated and actual satellite imagery. In some instances satellite imagery can supply the needed data. However, the Aldrich study is of southern forests using only color infrared photographs. The basic objective of the study was to measure forest volume using Apollo 9 photographs for prediction. The study was completed and produced forest volume predictions. However, the classification system was not transferable. Some agricultural terms were included but no urban features were included due to the interest of the researchers. This limited the classification system to accommodate only forested areas.

The Krumpe study deals in vegetation and terrain features. This is very detailed and deals mainly with western United States' land features. This study is not transferable to other geographical areas in that the information is appropriate for only the western parts of the United States in terms of vegetation and terrain.

Both of these examples and the others in the group do not deal with land use in total. They deal only in selected types of land use, e. g. land use in forestry, land use in vegetation types, etc. Focusing on one area may well have fulfilled their area of interest or their particular user's needs, but it severely limited the scope of their classification. As a consequence, rather than attempt to adapt any of the above systems to use for this project, a system based on total land use concepts was developed.

ELEMENTAL

The elemental group appears most suited for use with satellite data.

Most of these classification systems were constructed in levels and based upon information retrievable from satellite imagery. When one level was found to be completely interpretable, then a subsequent level was introduced. In the systems reviewed, there exists at this time only two levels of data. Examples of this type of system would be: A Land Use Classification System for Use With Remote Sensor Data (Anderson, Hardy, and Roach, 1972), and Macro Land Use Mapping with Simulated Space Photos (Rudd, 1971).

Members of the elemental group of classifications define only a few major categories. Anderson calls for nine categories at the first level while Rudd suggests only four. Anderson's was designed to satisfy land use classification (based on satellite imagery) for all 50 states. Therefore, tundra, and permanent snow and ice fields, had to be included in the classification. Consequently, Anderson developed a system with six major classifiable categories that account for most land use on the continental United States and Alaska.

The classification system currently in use on this project was developed mainly from the two examples cited above. However, it is more closely aligned with Anderson's. The concept of using first order levels of interpretation seemed most appropriate initially. As interpretation techniques are refined, more categories can be added.

DESCRIPTION OF PILOT STUDY AREA

The pilot study area is comprised of a rectangular area of 6300 sq. kilometers in four adjacent counties in west central New York State, including Cayuga, Onondaga, Cortland, and Tompkins counties. This area includes parts of the Lake Ontario basin, the Finger Lakes Central Plain, and the foothills of the Appalachian Plateau (Figure 1).

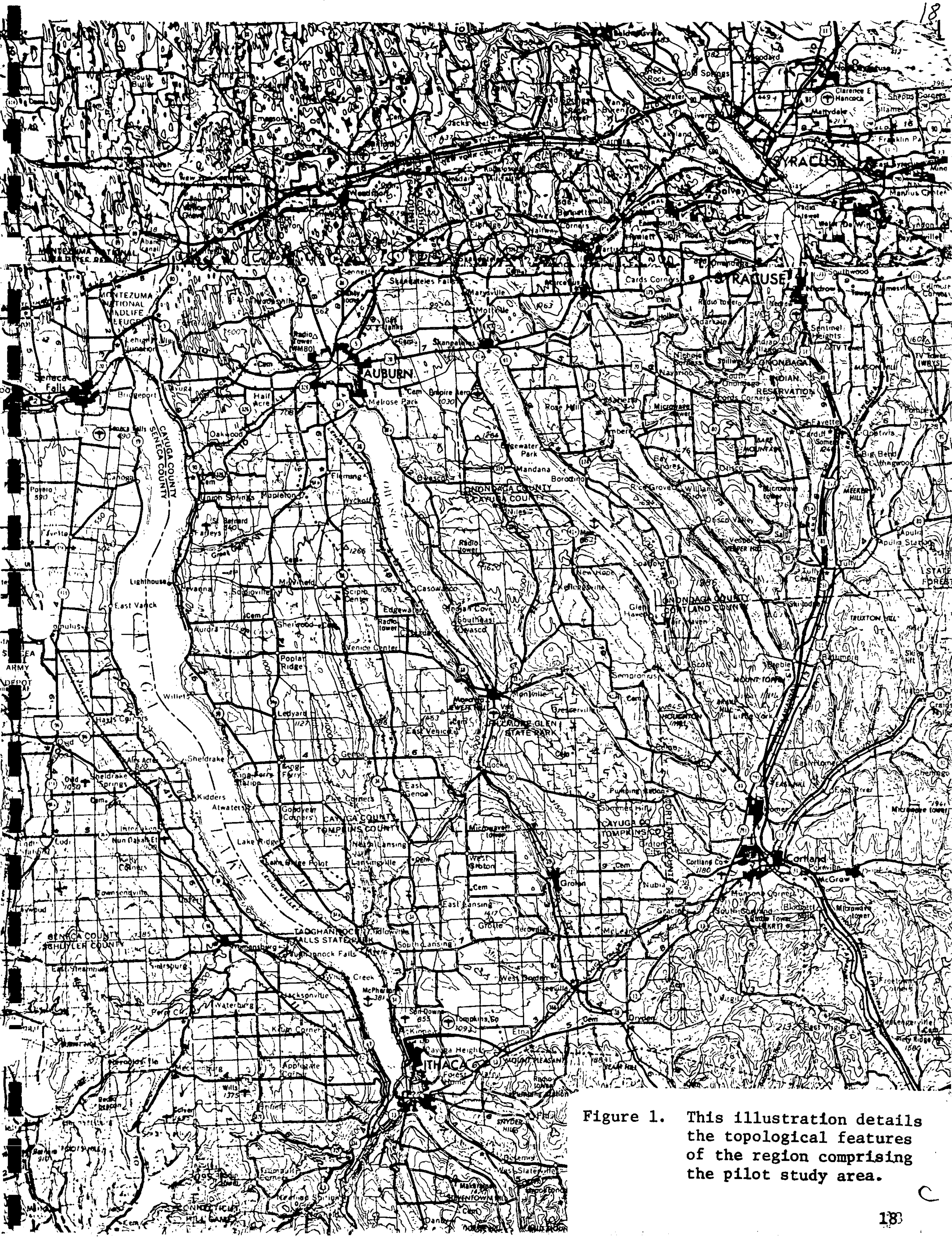


Figure 1. This illustration details the topological features of the region comprising the pilot study area.

Geologically, the area is comprised of sedimentation from paleozoic seas deposited in the form of shales, sandstone, and limestone which comprised most of the bedrock formations of the area. These formations are tilted to produce a dip to the south. Glacial activity retrenched some of the bedrock formation forming the Finger Lakes area and also developed extensive glacial till deposits. These deposits are uniquely evidenced by drumlins north and west of Syracuse, New York, and moraines and gravelly till soil throughout the rest of the area. Soils range from limy to acid, depending on the occurance of limestone in the underlying deposits, with soil texture related to the type of deposition.

The general climate of the area is humid and temperate, with January temperatures averaging below freezing and July temperatures averaging around 68°F. Precipitation averages approximately 40 inches per year. Frost-free days range from 100-150 days in the south to 150-180 days in the northern part of the area. Weather changes occur frequently and rapidly and are heavily influenced by the topography and proximity of the Great Lakes and the several large Finger Lakes. This situation results in approximately 80 percent cloudy conditions.

The pilot area is almost entirely drained to the north by the Oswego River Basin except for the southeastern part of Cortland County, which is drained by part of the Susquehanna River Basin. The Oswego basin includes the Oswego and Seneca Rivers with primary outflow from lakes Oneida, Onondaga, and the Finger Lakes from Lake Seneca east to Lake Otisco. This region covers about 5000 sq. mi. and has an annual average discharge of 6,532 cfs.

Throughout the pilot area forests are spotty, restricted in part to farm woodlots and a few large holdings such as Game Management Areas and state reforestation projects. The common forest types include northern mixes of hardwoods and soft pine/spruce plantations. Well-drained soils generally support a beech-sugar maple mix and wetter soils support elm and red maple. The average farm woodlot is 20 acres. Within recent years, the occurance of forest plantations has also been on the increase as marginal farmland and brushland areas are replanted to trees.

Agriculture is a mix of dairying on the rolling uplands and vegetable, fruit, and grain crops on the more fertile, well-drained flatland areas. Other farmland consists of dairy support crops or specialty farms such as horses, mink, etc.

Extractive industry occurs in the form of salt wells, sand and gravel, limestone and shale quarries. The largest and most visible of these is the Jamesville Quarry, which provides limestone for industrial and commercial uses.

Syracuse is the predominant urban center within the area. The cities of Auburn, Cortland, and Ithaca form secondary centers of urban activity. Within the Syracuse area are major crossings for transportation routes including the New York State Thruway east and west and U. S. Highway 81 going north and south. In addition, Syracuse has a major barge terminal connecting the Finger Lakes region to the Great Lakes port facilities and an international airport with major east-west and north-south trunk lines. Outlying residential and commercial strip areas of the city have been expanding at a rapid pace in the past decade. This rapid growth has generated a certain amount of urban sprawl conditions.

The area is highly diversified in terms of land use and topological features. This diversity makes for a complicated scene of many small geographical data units. This complicated mix of land use categories is probably typical for the whole northeastern part of the United States. In contrast, regions of the midwest and west have generally far less complicated mixes of land use.

IMAGERY FILE SYSTEM

After the images are received from NASA, each set is geographically located on a mylar overlay of a USGS index sheet for New York State for easy reference. Latitude and longitude are used to locate the frame. Upon locating each set geographically, each individual 70mm film chip is given an identification number. In addition, a master index card is made for each film chip. Information on the master card includes the type (millimeter size and positive or negative), accession number (or observation ID number as it is referred to by NASA), the band number, the geographic area of New York State, and the date the image was scanned. Also found on this card is a number assigned to that film chip. The chips are assigned consecutive numbers as received starting with number one.

Each film chip is also cross-referenced by date, geographic area, and spectral band. The subject is at the top of each card. For example, the date card has the date at the top. All the other information from the master card is listed underneath the subject line. This enables a user to search for a chip by month if he is doing a time analysis. He also can locate all available images by geographic location if he is studying a certain area. The band card is useful if he is studying the quality of all images from a given band over a period of time. The master card categorized by the numerical accession number is useful if the Earth Resources Technology Satellite Standard Catalogue is used to find the images.

Each chip is placed in a negative file envelope with its number stamped on the outside and is then filed by consecutive numbers. The index cards are first organized by subject, but within each subject area the cards are organized as to NASA accession number.

METHODOLOGY

Photo Techniques:

Analysis of the bands recorded led to the immediate conclusion that color transparencies could be used to produce results that would approximate Kodak's "false color" or as experimentation progressed to assign arbitrary colors to the different bands to glean specific information. Additive color was discarded as a possibility because of the need for specialized equipment and because additive color (without electronic equipment) is, in general, less efficient than subtractive color.

Additive color was synthesized as early as the mid-1800's by Clark Maxwell when he photographed colored ribbon through three cameras using colored liquids as filters (1). Red, green, and blue light, therefore, produced a latent image on the individual films. These negatives were developed (2) and printed on glass plates to make positive transparencies (3). The transparencies, when projected through the same cameras and filters, produced a superimposed image on a screen that created a reasonable facsimile of the original ribbon (Figure 2).

Figure 3 illustrates the subtractive color theory and practice (in original Kodachrome) which depends on three selectively sensitive layers of film that correspond in sensitivity to the three primary colors (red, green, blue) (Baines, 1958). Without filters, the film is exposed to an original object and developed (4). The film is then treated to remove

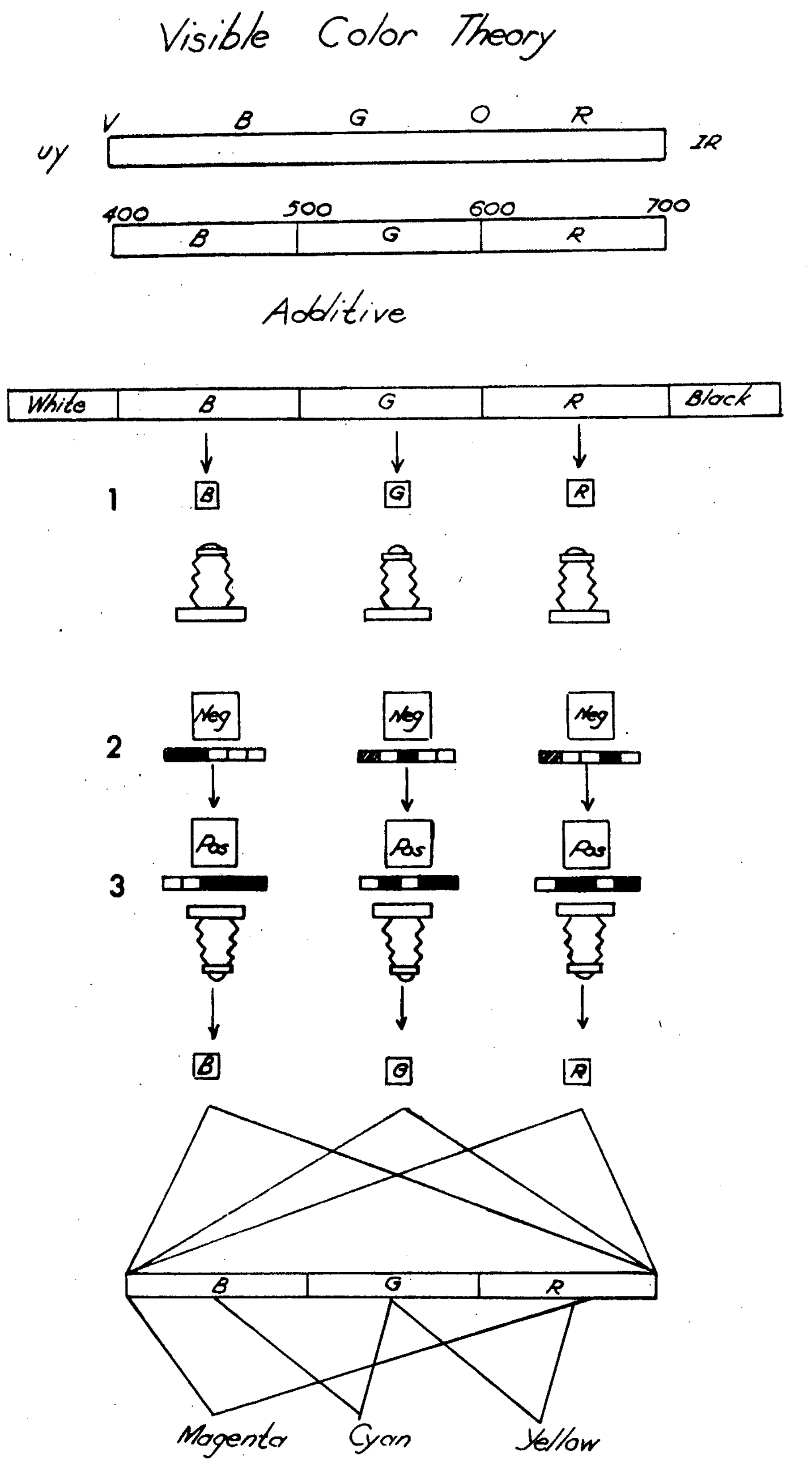


Figure 2. This illustrates the additive color process as originally discovered by Clark Maxwell (see text for explanation).

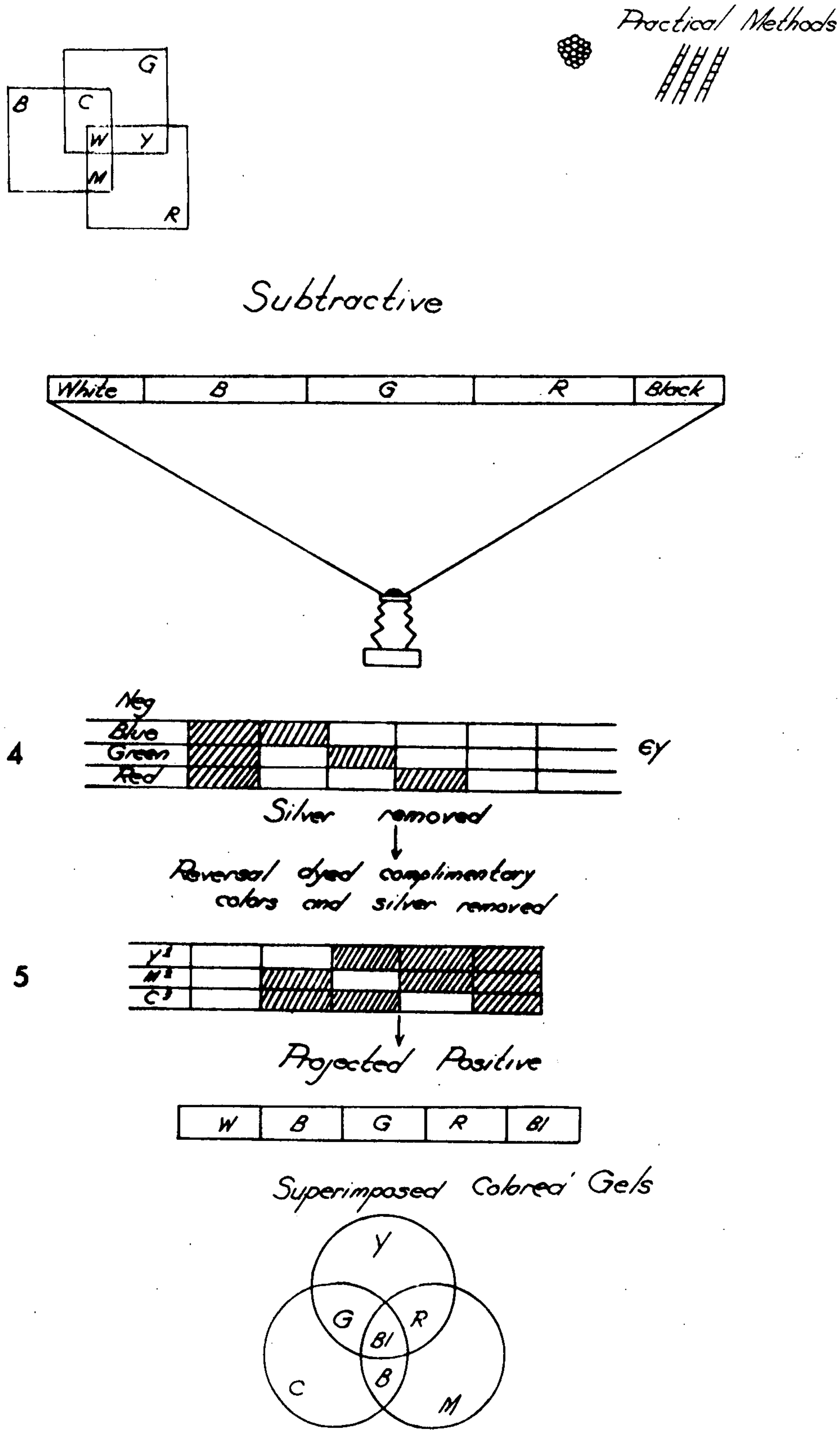


Figure 3. This illustrates the subtractive color theory and actual practice defined in the manufacture and processing of color reversal film (see text for further explanation).

the developed silver and reexposed and redeveloped with dye couplers that dye each layer selectively with the secondary colors (5). Thus, the blue layer is dyed yellow, the green sensitive layer is dyed magenta, and the red sensitive layer is dyed cyan. Dye deposits in proportion to the silver in the reversal process when the silver is removed, the dyes remain. A further explanation of the method of projecting the final positive image is best understood by thinking of what each layer absorbs in the reversal process (Figure 3). Where the original is white, no dye exists in the processed film and all the light from the projecting light source reaches the screen. Where one or more layers absorb primary light, the following takes place:

	blue object	green	red	black
		- blue*	- blue	- blue
Light ↓	- green		- green	- green
	- red	- red		- red
remaining light to screen →	blue	green	red	no light black

NOTE: - = minus

Fractional absorbing in the different layers produces color other than the primaries.

Experimental Processing Techniques:

Bands in ERTS imagery approximate the sensitivity of Kodak's Infrared Aerographic film with an added IR band. Briefly, the steps used at Cornell to develop processing techniques for the ERTS data were as follows:

figure 19
in folder

1. Using ERTS positives (70mm), negatives are made on lantern slide plates. These may be made 1 to 1 or enlarged.

2. Enlarged transparencies (positive) are made on Kodak commercial film.

3. For "false color" transparencies, diazo tri-color films are used (yellow, magenta, cyan by GAF). Band 4 is exposed to the yellow, band 5 to magenta, and usually band 7 to the cyan.

4. If the film is exposed and developed properly from balanced positives, a close approximation to Kodak's Infrared Aerographic film is possible.

Several variables make the process more complex than the above brief description. They include:

1. Atmosphere conditions on earth are not uniform and by the day and season produce dissimilar imagery. The bands react differentially to atmospheric changes with the maximum effect on band 4 and minimum variation in band 7. These differences exclude the influence of clouds which is so self-evident that it seems unworthy of mention.

   Because of NASA bulk processing (and partially due to the differences inherent in the different wavelengths) the density ranges of the different bands is critically influenced by these atmospheric conditions. Thus, it seemed evident that under adverse recording conditions the negatives from each band may need different treatment.

   To more accurately determine the extent to which imagery would have to be enhanced, three sets of positives were chosen. One with bad atmospheric conditions, one with fairly acceptable conditions, and one with clear atmospheric conditions. Procedures with each will be discussed later.

2. Variations (shading effect) in the gain control of the scanner system showed on some imagery as much as a .5 density difference in a west to east orientation.

3. The absence of some sizable area of neutral color precluded comparative densitometric measurements of the different bands and thus left several areas in which human judgment is essential. The choice of 70mm imagery was also a factor. Clouds and shadows help in this judgment, and in some cases actual measurements are possible, for the visible bands. However, bands 6 and 7 were measured less exactly.

To outline in detail the steps followed with the three sets of imagery mentioned above, the clear atmosphere set will be discussed first with variations for the remaining two experiments added when they are discussed.

"Clear Atmosphere" Experiment

1. Simultaneous contact images were made from NASA positives on Kodak Polycontrast F Rapid Enlarging Paper. The exposing light was from the Omega D-3V enlarger with 211 bulb at 120 v. ac. The lens was an 80mm Schneider Componan purposely adjusted "out of focus". The film plane of the enlarger was 20" from the paper to be exposed. The lens setting was f-11. This assures approximately parallel light. A sandwich is made of (from the bottom up) enlarging paper, positives, and near-optical glass. This assures good contact of positives and paper.

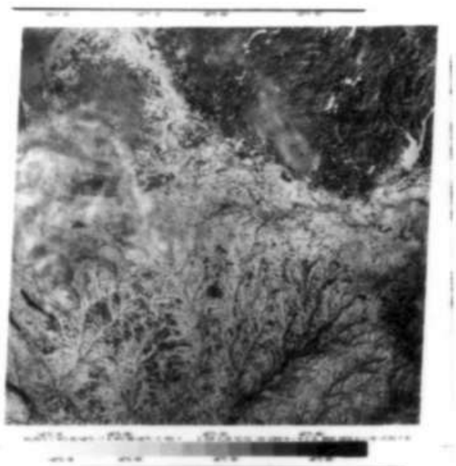
   Exposure time was 12 seconds and the enlarging paper developed for 1 1/2 minutes in Dektol diluted 2 to 1.

2. All four negatives (as viewed on the paper) appeared to be closely in balance with respect to both density and density range (contrast) (Figure 4).

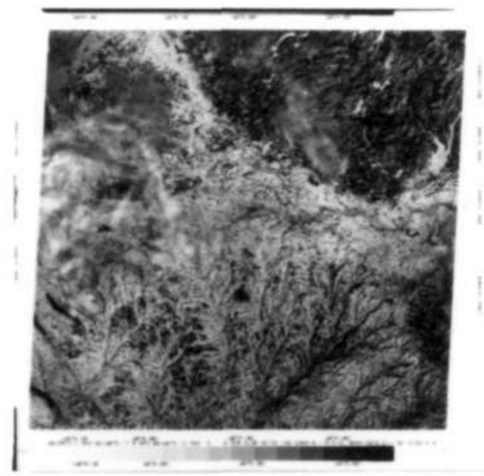
3. Band 5 (NASA) positive was next exposed as was the paper except that Kodak's grey scale with .3 increments was placed along one edge. Initial trials showed that an exposure approximately 2/3 that for the Polycontrast paper appeared adequate. 1 1/2 minutes development in Dektol 2 to 1 gave normal contrasts.

   NOTE: To greatly enlarge some portion of the NASA imagery, projected negatives would be made to replace the contact negatives described above. This procedure is followed in producing imagery for interpretation.

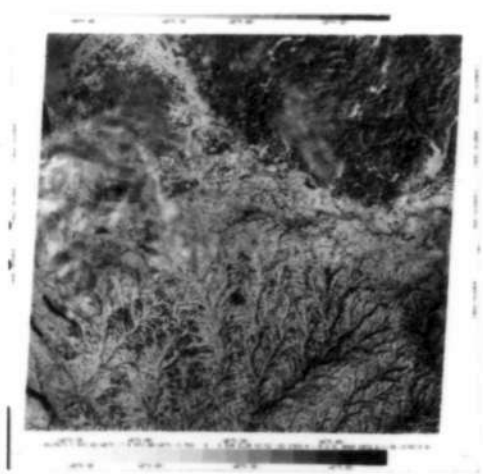
   The lantern slide plates are washed for 30 seconds, treated with Permawash for 30 seconds, and washed for one minute. The plates are sponged on the sides, back, and emulsion surface with a viscous sponge treated lightly with diluted Kodak Photo Flow 200. Force drying was the usual rule merely to save time between development and that of reading the grey scale to ascertain the perfection (or lack of it) of the glass negative. To avoid error, the clear edge of the plate was marked with two figures from a black indelible marking pen. The first figure would be the exposure time in seconds, and the second figure the time of development in minutes. After the plate is dry, the negative number is added to any clear area.



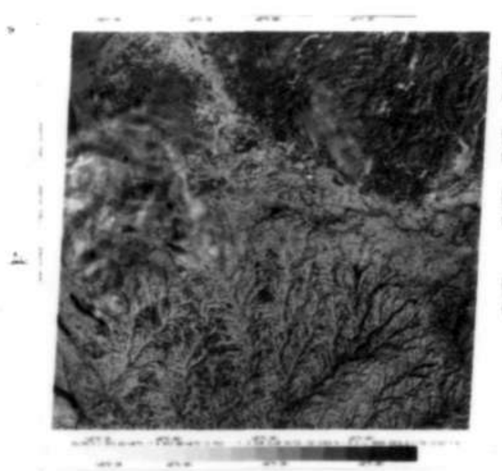
Band 4 (.5-.6u)
NASA Acc # 1170-15182-4



Band 5 (.6-.7u)
NASA Acc # 1170-15182-5



Band 6 (.7-.8u)
NASA Acc # 1170-15182-6



Band 7 (.8-1.1u)
NASA Acc # 1170-15182-7

Figure 4. These four bands of a single scene were taken on January 9, 1973. This scene represents very clear atmospheric conditions with maximum contrast between snow fields and other cultural and natural features.

4. The remaining bands were exposed and developed as was band 5.

5. The density differences within bands 4, 5, and 6 were approximately 1.0. However, band 7 was only .75. Grey scales measured the same but an assumed highlight and shadow <u>within</u> the picture area of band 7 gave the lower density difference.

6. 8 X 10" test print on Polycontrast paper showed that an exposure of f-11 would be 15 seconds. (The area chosen was nearly the full width of the 70mm imagery). Paper was developed 1 minute and 15 seconds.

7. Bands 4, 5, and 7 were exposed at f-11 on Kodak Commercial film #4127 for 1/10 the polycontrast exposure i. e. 1.5 seconds. Development was in DK 50 for three minutes.

8. When dry, rough register marks were added to the commercial positives to facilitate assembly of the color diazo transparencies.

9. Identical exposures for each band were made on the diazo material.

   Band 4 - printed yellow
   Band 5 - " magenta
   Band 7 - " cyan

10. The result was a relatively colorless transparency typical of early winter. Its chief asset appears to be watershed analysis (See Figure 7).

<u>"Moderately Clear Atmosphere" Experiment</u>

These images pose an entirely different problem. Cursory examination shows positives with a high background fog (in all clear parts of the film) and a marked density difference from west to east. Measured, the difference is about .5. Fog measured .58.

Individual bands show:

Band 4 - Fairly dense but extremely low in contrast (density difference)

Band 5 - Much more dense than band 4 but with a more acceptable contrast

Band 7 - Least dense of all. Its contrast poses a problem. If one judges contrast of band 7 as the difference between maximum density as recorded by water and the least density from vegetative areas, this must be rated as the positive with the greatest density range. Measured on vegetative areas alone, the reverse would be true.

1. To verify judgment on density and contrast, a composite print of all three positives was made on Polycontrast paper as outlined in the previous experiment (Figure 5).

2. By reading both transmitted and reflected (of the print) densities, an exposure ratio as follows was derived:

   Band 5 - Normal
   Band 4 - 1/4 to 1/2 normal
   Band 7 - 1/10 normal

   NOTE: Since the first experiment, a Honeywell Spotomatic meter was used at 1° of arc to verify the densitometric readings. Because of the possibility of throwing areas of the small positive "out of focus" these readings were essentially the same as those from the densitometer.

3. To check these results composite prints were made as in #1 but with the exposure correction found in #2. Band 7 seemed low in exposure and was doubled. The final results:

   Band 5 - 20 seconds (Rates - 1)
   Band 4 - 10 seconds (" 1/2)
   Band 7 - 4 seconds (" 1/5)

   NOTE: It should be pointed out that the timer is a Heathkit and shows an inconsistency of as much as 10%.

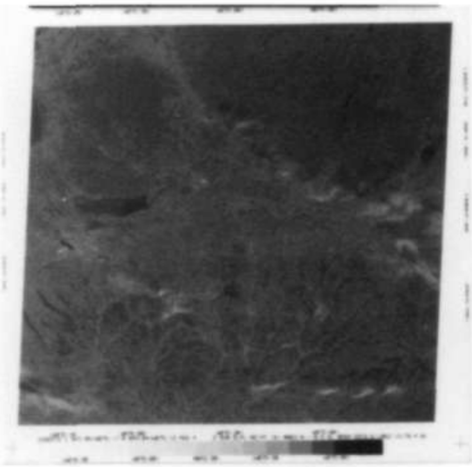
4. Contrast correction posed a problem. No attempt has at this point been made to derive the family of gamma curves with time and dilution. Thus, some healthy guesses were used.

   NOTE: D-11 developer was tried but found too high in contrast for these negatives. Final exposure and development in Dektol (2 - 1).

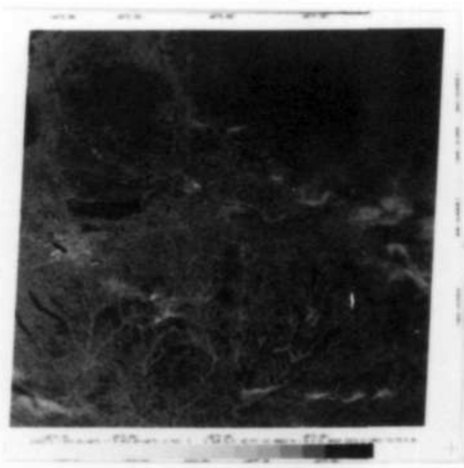
   Band 5 - 20 sec. - 1 1/4 min. Dev. (Dektol 4-1 in this one only)
   Band 4 - 4 sec. - 5 min. Dev. (Dektol 2 - 1)
   Band 7 - 1.6 sec. - 4 min. Dev. " "

5. The above negatives appeared reasonable in tone and contrast but a lateral density difference needed correction. A medium lantern slide plate was differentially fogged and developed to achieve a wedge of densities that ranged from about .7 to 0. This gave approximately a .5 difference over the negative area. When dry, this plate was separated from the negative emulsion by approximately 1/8". The dense area of the wedge was adjusted over the low density area of the negative so that the final projection gave uniform readings.

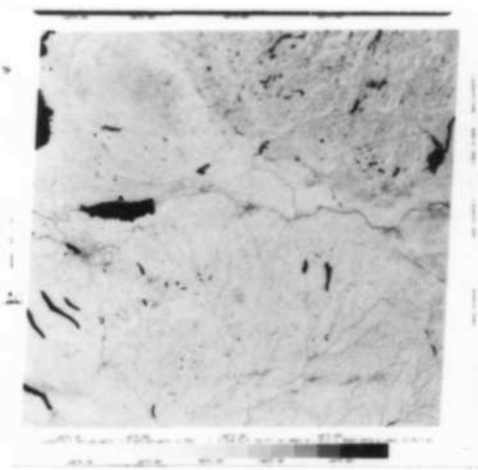
6. 8" X 10" commercial film was exposed from the above negatives.



Band 4 (.5-.6u)
NASA Acc # 1062-15175-4



Band 5 (.6-.7u)
NASA Acc # 1062-15175-5



Band 7 (.8-1.1u)
NASA Acc # 1062-15175-7

Figure 5 . These three bands are of the same scene depicted in Figure 4 , but this one was taken on September 23, 1972. Atmospheric conditions were moderately hazy. These conditions mostly affected band 4; however, land detail on band 7 was also washed out. Band 6 was not received for this scene.

Band 5 - 5.0 seconds and 2 minutes development
Band 4 - 2.5 seconds and 5 minutes development
Band 7 - 3.0 seconds and 3 minutes development

NOTE: The advantages offered by two areas for correction are now self-evident. When errors occur in making negatives, there is still room for correction with the enlarged positives. When time permits more sensitometric data, these errors would be greatly minimized.

7. The resulting density ranges of the different bands (measured on the commercial positives) are as follows:

Band	Range	Difference
4	.3 - 1.0	.7
5	.2 - 9.0	.7
7	.38 - 1.25	.87

8. Ozalid prints from the above positives look good (See Figure 7).

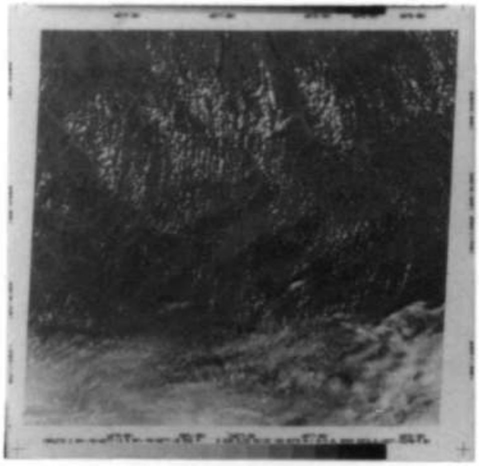
"Heavy Haze Atmosphere" Experiment

The NASA positives reflect the influence of atmosphere more in this set than in any so far (Figure 6). Band 4 showed an extremely low density range .4 between cloud and shadow. Overall density of the positive appeared to be higher than desirable. Bands 6 and 7 were also dense and reflected the lack of spectral diversity in the reflectance from land forms and cultural features that are charactrristic in the infrared regions. Band 5 was judged a normal positive.

After considerable experimentation with both medium and contrast lantern slide plates, Dektol, and D-11 developers, the final result was:

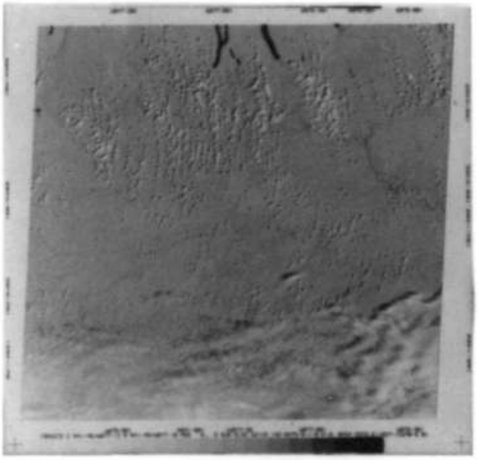
Band 4 -	2.5 seconds - 3 minutes Dektol	Contrast plate
Band 5	4.5 seconds - 2 minutes Dektol	Medium plate
Band 7	2.0 seconds - 2.5 minutes Dektol	Contrast plate

The commercial film was all developed in DK 50.

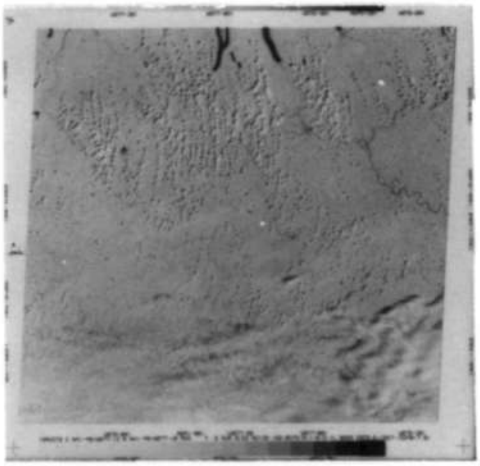


Band 4 (.5-.6u)
NASA Acc # 1027-15240-4

Band 5 (.6-.7u)
NASA Acc # 1027-15240-5

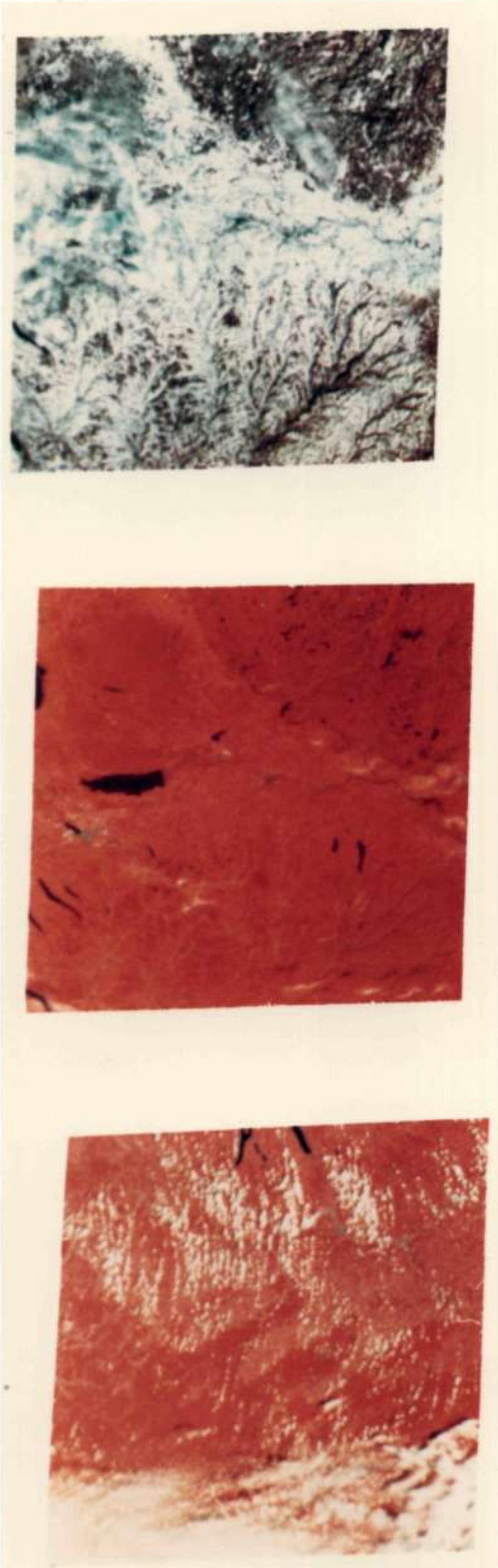


Band 6 (.7-.8u)
NASA Acc # 1027-15240-6



Band 7 (.8-1.1u)
NASA Acc # 1027-15240-7

Figure 4 . These four bands are of a scene taken on August 19, 1972. Atmospheric conditions appeared to be heavy haze with scattered clouds. Bands 4, 6, and 7 were affected the most.



Clear Atmosphere Experiment

A color IR reproduction of a winter scene in central New York (January 29, 1973). Snow cover is evident producing high contrast conditions within the scene.

Moderately Clear Atmosphere Experiment

The same color IR scene as above, but taken on September 23, 1972. The area was heavily vegetated producing a more uniform scene, but the density and contrast balance within the scene is similar to that above.

Heavy Haze Atmosphere Experiment

This scene is in southern New York and northern Pennsylvania taken on August 19, 1972. The original NASA positives were badly balanced in terms of density and contrast. The result is a well-balanced scene similar to those above.

Figure 7 . The above three images represent simulated color infrared reproductions using the diazo process for each of the specially produced scenes discussed in the text.

Band	Exposure	Development
4	0.8 seconds	5 minutes
5	1.5 seconds	3 minutes
6	2.5 seconds	3 minutes
7	2.5 seconds	3 minutes

The diazo prints received approximately the same exposure time for the final composite (Figure 7).

The final result appeared satisfactory.

NOTE: Much work remains to be doen to solidify the parameters and acquire sufficient base data so that replication is possible. Much more work is needed to experiment on very small areas--grain size, added enhancement, and other techniques must be investigated to finally determine what level of information is ultimately derivable from the 70mm filter chips.

<u>Processing Procedures to a Scale of 1:250,000</u>

Upon the completion of the experimental processing steps, imagery was processed according to an enlarged scale of 1:250,000 (13.5 X). This required the two-step process as described above but with allowances for increased exposure due to the 3X enlargement at the first step and a 4.5X enlargement to the commercial film 4127.

Parts of two scenes that covered all or most of the four-county study area were selected for interpretation. The first was taken on August 19, 1972, and was considerably affected by heavy haze conditions such as in Figure 6. The second scene was taken on October 11, 1972, with clear atmosphere such as in Figure 4.

The processing steps were as follows:

Heavy haze: August 19, 1972

70mm positives to lantern slides 3X enlargement with an 80mm Schneider lens, an Omega 211 bulb, and a 3 1/2" condensor.

Band		Exposure f-11
4	contrast plate	8 seconds
5	medium plate	10 seconds
6	contrast plate	4 seconds
7	contrast plate	4 seconds

All the slides were developed in Dektol 2:1 dilution for 2 minutes. All procedures were performed as described above.

Lantern slide negatives to 8" X 10" commercial film (4127) transparencies. 4.5X enlargement with a 135mm Kodak enlarging lens, an Omega 211 bulb, and a 6" condensor.

Band	Exposure f-11
4	3 seconds
5	2 seconds
6	2.6 seconds
7	2.6 seconds

All transparencies were developed in DK 50 for 3 minutes.

Clear atmosphere: October 11, 1972; equipment, scale, and procedures identical to that above.

70mm positive to lantern slide 3X enlargement.

Band		Exposure f-11
4	contrast plate	50 seconds
5	medium plate	80 seconds
6	medium plate	25 seconds
7	medium plate	15 seconds

Developed in Dektol 2:1 diluted for 2 minutes.

Lantern negative slides to 8 X 10 transparencies 4.5X enlargement.

Band	Exposure f-11
4	4 seconds
5	4 seconds
6	4 seconds
7	4 seconds

Developed in DK 50 for 3 minutes

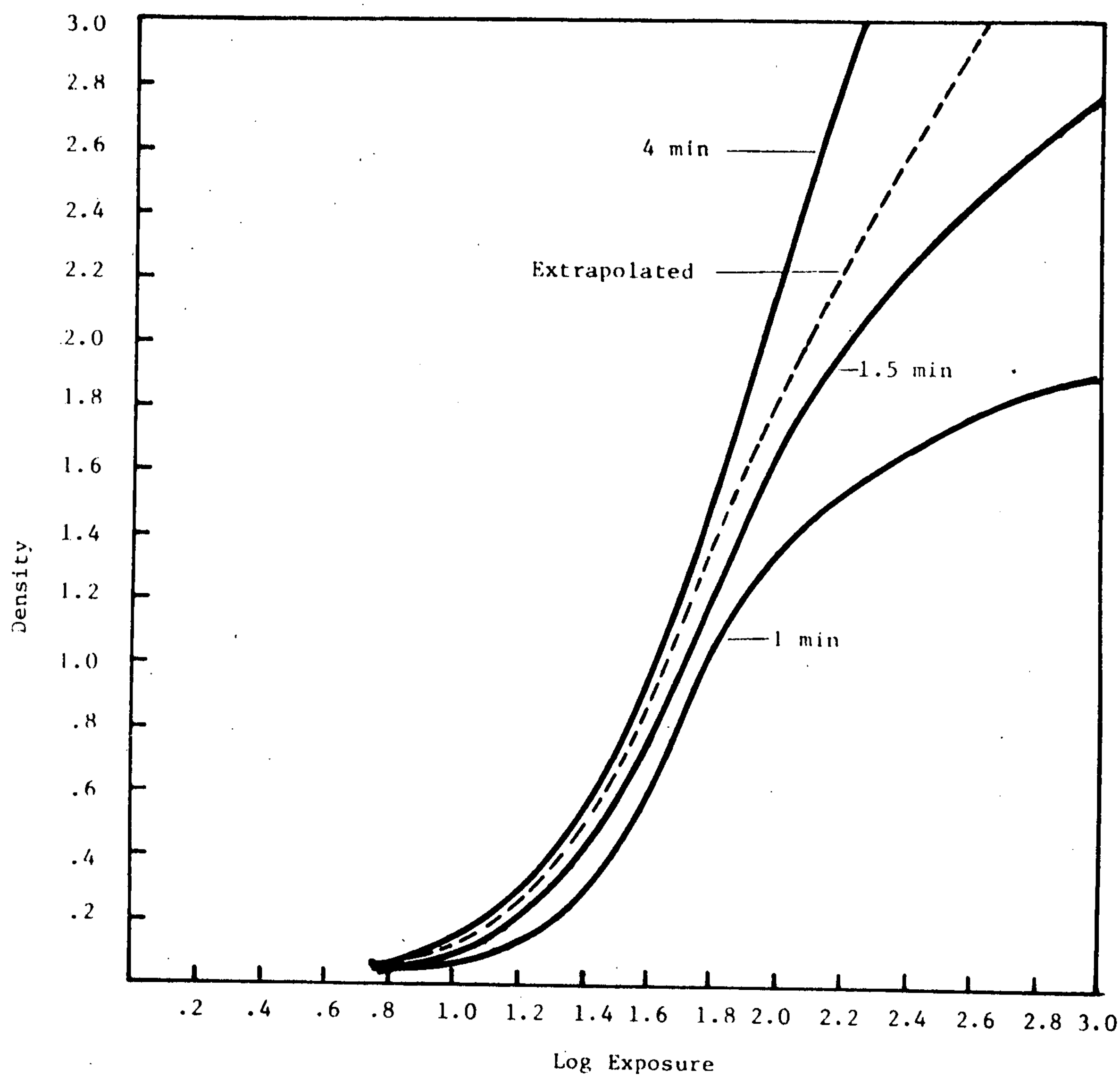
Contact negative transparencies were made from the 8" X 10" transparencies produced above. Exposure was accomplished in the enlarger. The distance from the lens to the easel was 33", and the f-stop was f-22. Exposure time was 8 seconds for all transparencies and development time was 3 minutes in DK 50.

Figures 8, 9, 10, and 11 give the log exposure curve for the contrast lantern slide plate, medium slide plate (in two different developers), and the commercial film #4127.

The techniques described above have produced very satisfactory results as evidenced by the final products. However, efforts will continue to make the procedure more systematic and consistant. This will be accomplished by correlating average density measurements from the original NASA positives to the necessary processing steps for various atmospheric conditions and interpretation requirements. In this way, any results which we obtain photographically should be able to be duplicated with a minimum of effort and time.

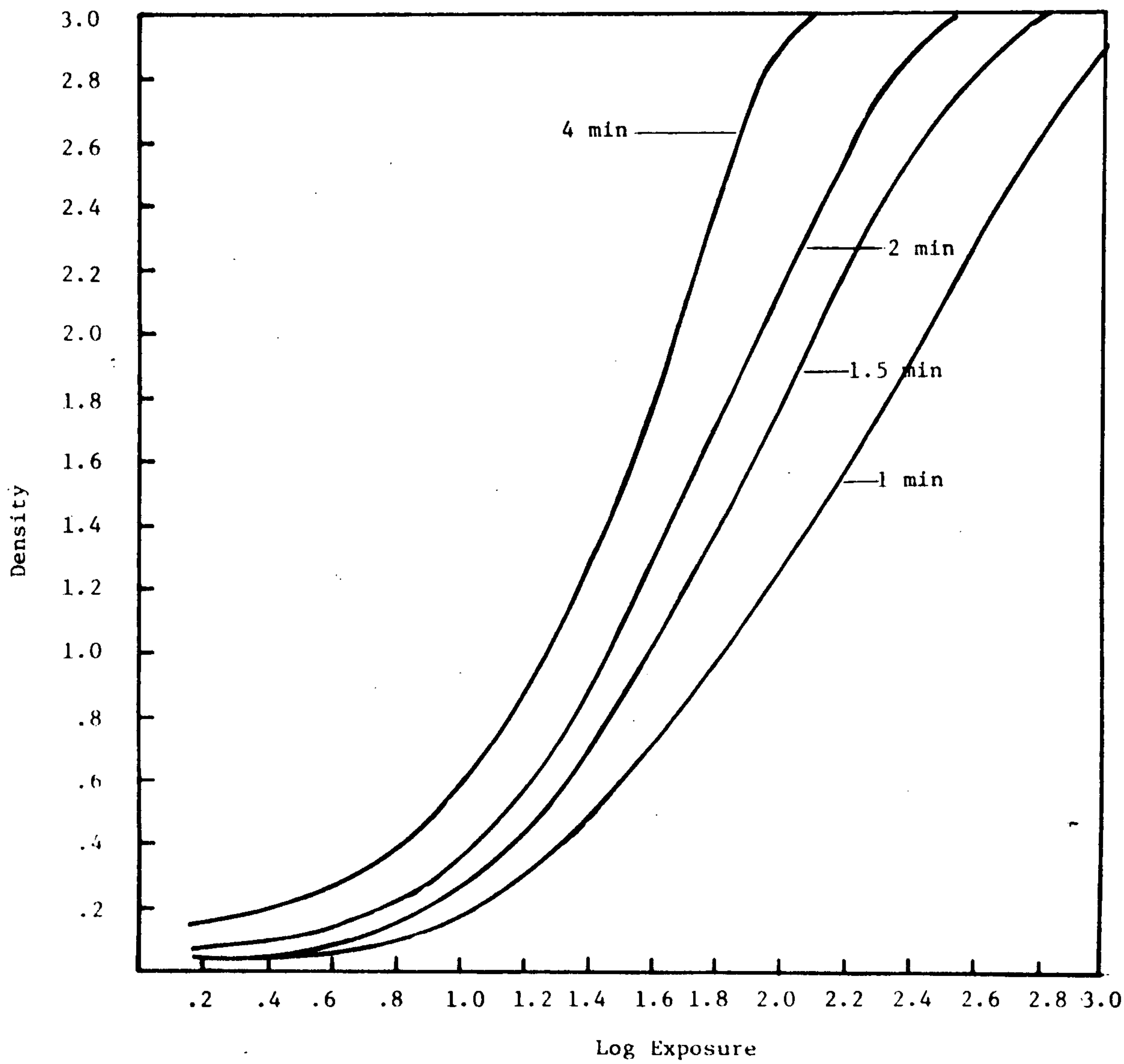
Diazo Process:

The diazo process is a two-step process that allows one to make contact positive prints or transparency reproductions in color or black and white originals. This is accomplished by combining special diazo light sensitive



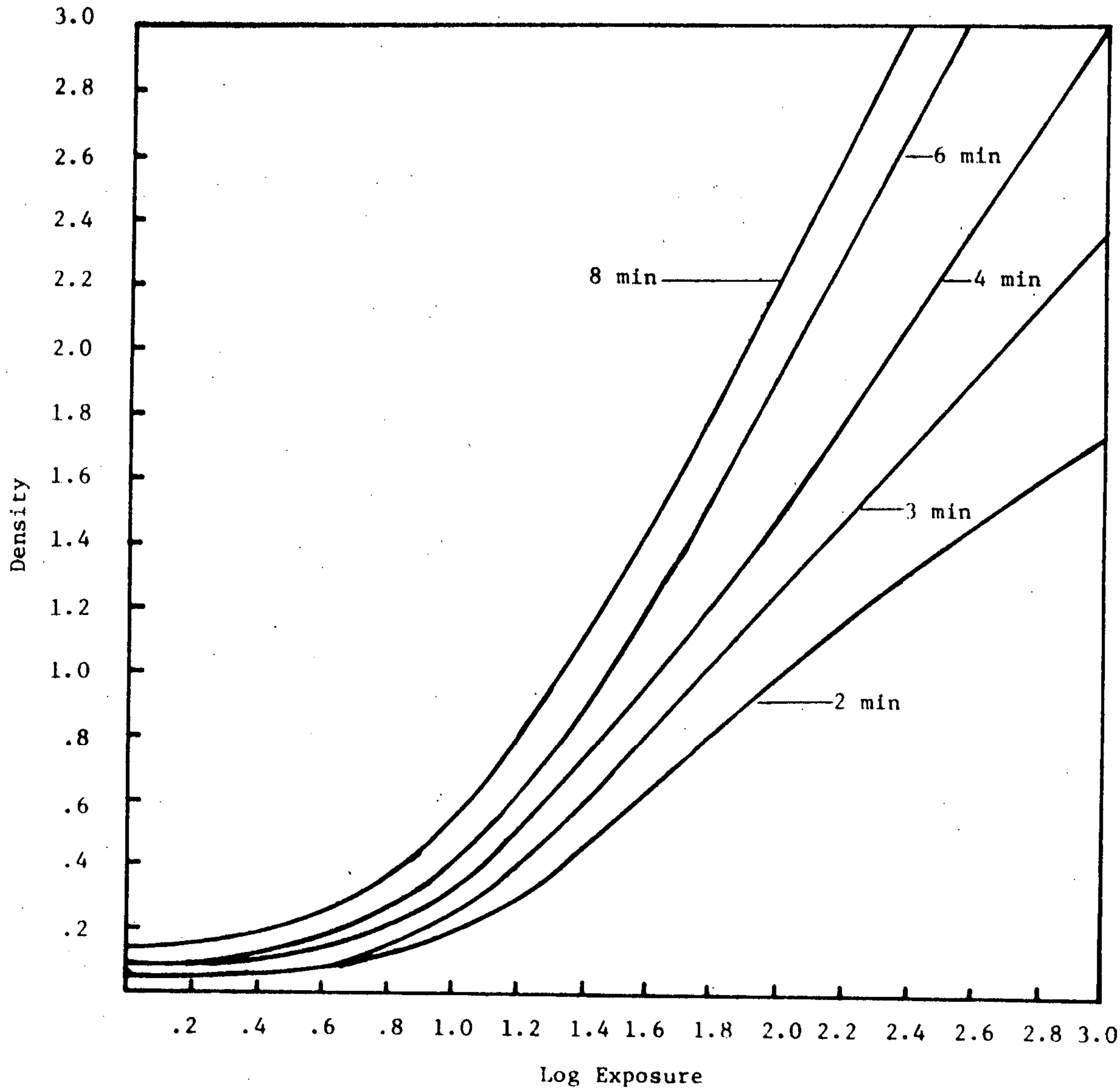
FILM:	Contrast LS Plate				
DEVELOPER:	Dektol 2-1				
TIME:	1.0	1.5	(2.0)	4.0	minutes
TEMP:	70°				
GAMMA:	1.9	2.2	(-)	3.0	

Figure 8.



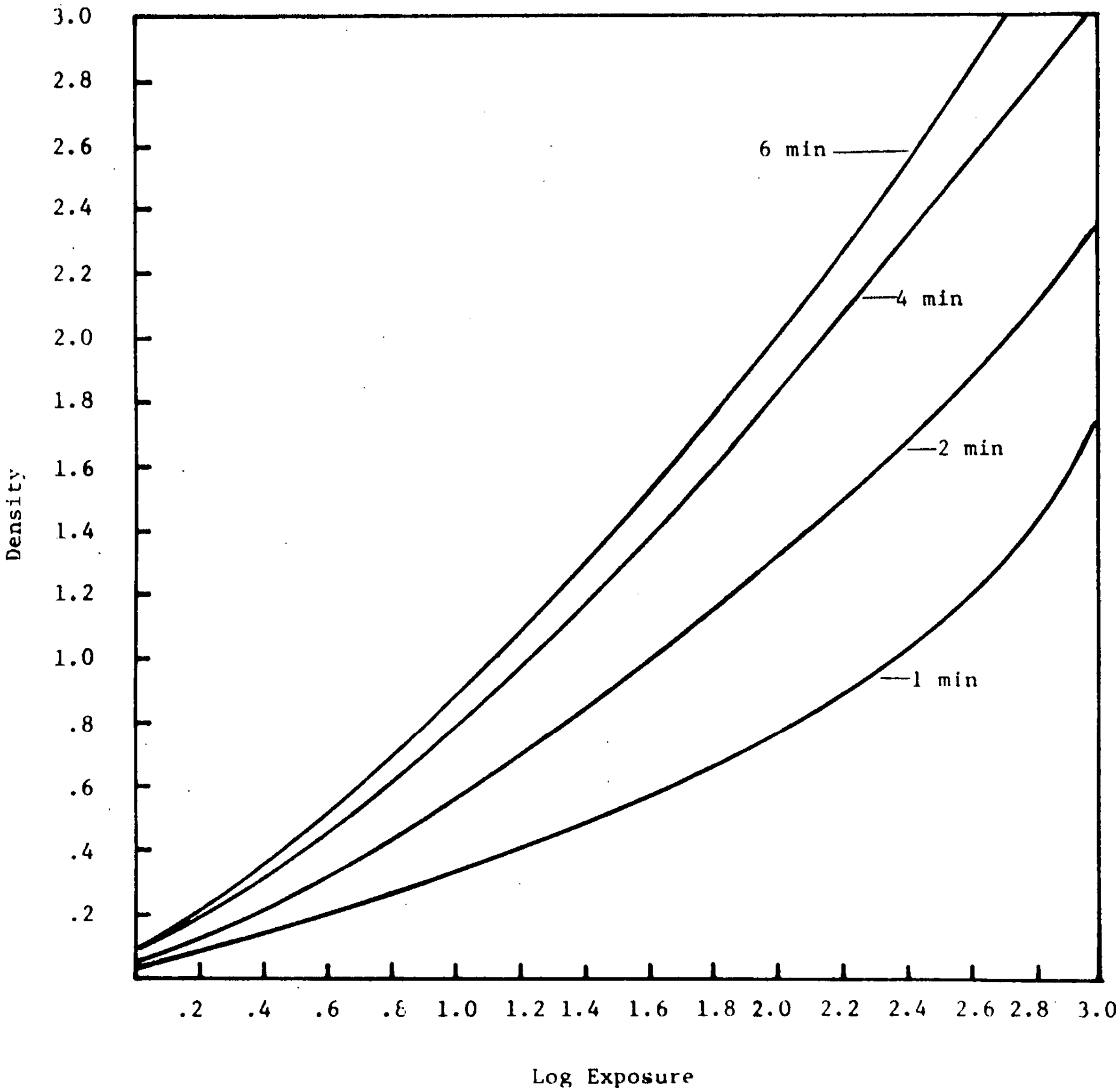
FILM:	Medium LS Plate				
DEVELOPER:	Dektol 2-1				
TIME:	1.0	1.5	2.0	4.0	minutes
TEMP:	70°				
GAMMA:	1.3	1.8	2.3	2.8	

Figure 9.



FILM:	Medium LS Plate
DEVELOPER:	D-76 (full strength)
TIME:	2 4 6 8 minutes
TEMP:	70°
GAMMA:	.85 1.45 1.8 1.8

Figure 10.



FILM:	Commercial
DEVELOPER:	DK 50
TIME:	1 2 4 6 minutes
TEMP:	70°
GAMMA:	-- .85 1.2 1.3

Figure 11.

salts and couples imbedded in the reproduction material, which may be acetate or paper. When these salts and couples are exposed by a mercury vapor lamp and then processed by heated aqua ammonia vapors, a positive reproduction of the original results (Ozalid, 1950).

By varying the exposure time, changes in density may be produced relative to that on the original. This is advantageous in that aside from making it possible to closely match the density of the original, it is also possible to increase detail in areas of low density by increasing the exposure time. This, however, results in a loss of information in the dense areas of the image.

This process has been effectively applied to the processing and interpretation of ERTS-1 imagery. The enlarged black and white transparencies are used to expose diazo material producing cyan, magenta, and yellow reproductions of the black and white image. All three colored transparencies are produced for each spectral band from both positive and negative transparencies. This yields 24 different diazo film transparencies, three each for each of the four spectral bands in both positive and negative modes.

These diazo transparencies are produced on a GAF Model #240 with a modified control knob having 60 calibrations as opposed to the normal 45. In addition, a special voltage regulator has been installed on the machine to insure a constant voltage source. Standard procedures are followed in exposing and processing the diazo film. Based on the average density of the original black and white transparencies, an exposure setting of seven on the expanded scale was generally found to yield the best overall density when color composites were put together. However, by increasing or decreasing the exposure time, light or dark areas in the image can be selectively examined to pull out the maximum amount of information in the scene.

Color Composites:

Color composites of selected scenes have been constructed to enhance, spectrally, the general types of categories of materials in the scene. For instance, urban and cultural features were noted to reflect most intensely in the red portion of the spectrum (band 5). Water detail and wetlands were most evident in the infrared (bands 6 and 7), and vegetation patterns were indicated most strongly in bands 4 and 5.

The task was to find combinations of spectral bands and contrasting hues to clearly demarcate the boundaries of the different major spectral zones. To accomplish this, imagery from August 19 and October 11 was used to construct the composites. The rationale for selecting these two times was partly fortuitous in that only limited coverage had been obtained at the time the decision had been made to select a test site. On the other hand, August and October represented a significant spectral change in terms of deciduous forests and agricultural lands. By comparing the two periods, it was reasoned that spectral boundaries might be more easily delineated.

At first, only positive images were combined. This did produce some interesting spectral breakouts, but for the most part no sharp consistant spectral delineations were produced. Two exceptions were a false color combination and a near true color (minus blue) composite 5_c, 4_y, 7_m. As the photo processing techniques improved, negative transparencies were made from which diazo films were exposed. It was quickly noted that by using both positive and negative combinations of a scene together much sharper spectral delineations were possible. Unfortunately, this expanded the number of possible combinations beyond a manageable level.

A systematic approach was used to rapidly assess the various combinations to prevent repetition and also allow for a division of labor in discovering the best combinations to use. Several hundred combinations were examined combining both positive and negative images as well as interleaving August and October imagery. From the combinations tried, four were selected as best delineating the major spectral boundaries in the scene.

Data Take-Off

Upon selecting the various color composites to spectrally break out different features, decisions were made on how best to transfer the data from the composite to something that would produce some sort of usable map product. It was quickly decided that some sort of grid system correlated to an existing scale for a United States Geological Survey map would be necessary. Since the LUNR inventory already employed the UTM grid system with one square kilometer grid cells, it was decided to employ something similar to minimize the problems in correlating the ERTS interpretation to the LUNR categories.

A 1:250,000 USGS sectional map for the study area was selected as the map base to which our ERTS interpretation would correspond. Major features of the map, such as lake boundaries for Cayuga Lake and other Finger Lakes falling into the test site, were lined in on a 10 Km square matte finished acetate overlay. A 10 Km square grid size was selected for two reasons: 1) It is a large enough area to quickly reference at a scale of 1:250,000 and 2) It allows for a further breakdown to a 1 Km square grid, which correlates to the LUNR computerized data output. In addition, data from each primary cell (10 Km square) can be broken down according to percentiles for each spectral category interpreted within that area. Figure 12 illustrates the line map and grid combination used. Making use of the UTM coordinate system also allows one to quickly geographically reference any single point. This is critical in terms of setting up a usable classification system (see discussion above on classification theory).

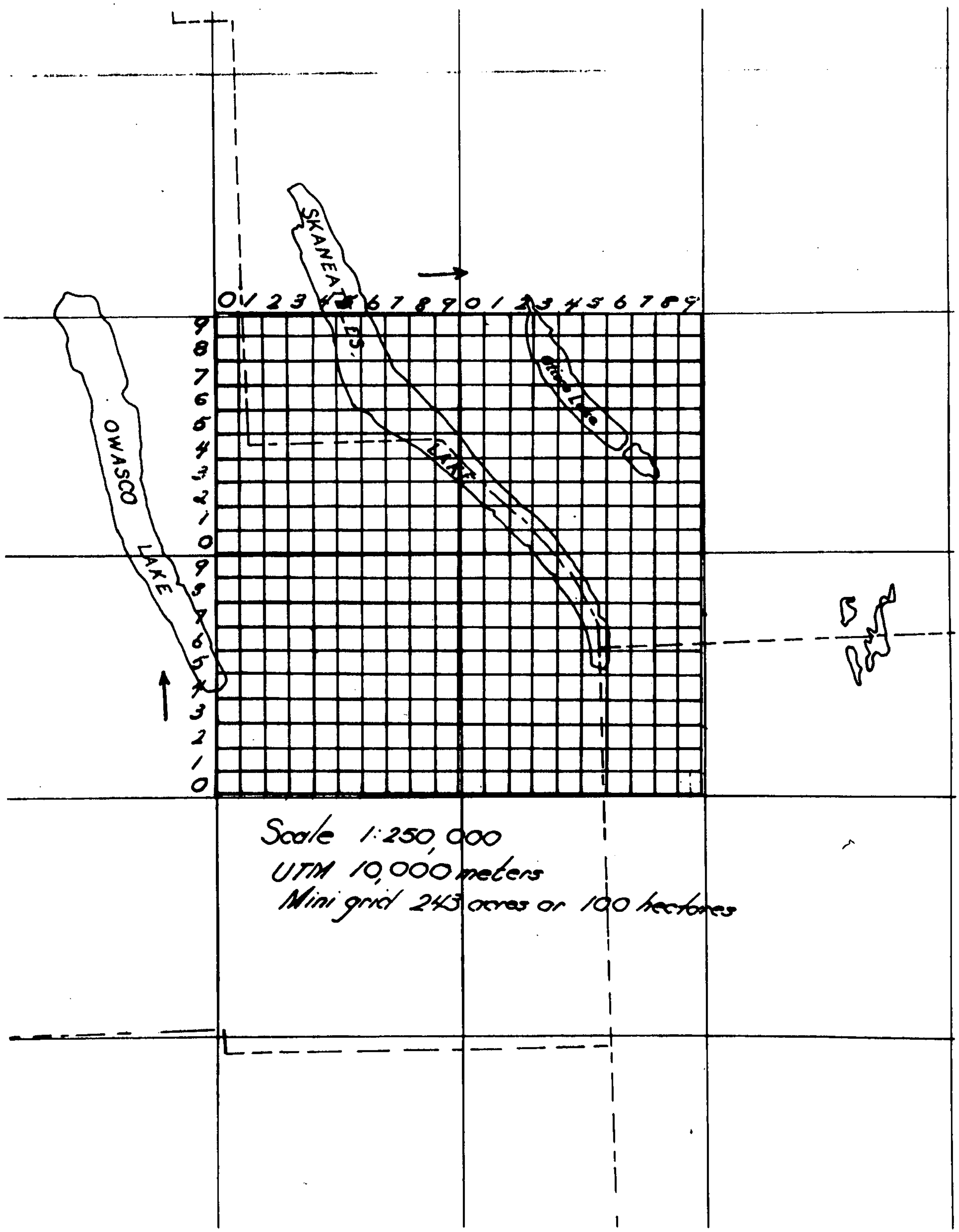


Figure 12. This shows part of the two grid systems employed in the data take off process. The larger grid cell is 10Km square, and the smaller one is 1Km square. The numbers on the smaller grid are part of the UTM coordinate system which reads up and across starting with the lower left hand corner.

It became obvious at the first interpretation attempts that there would have to be some minimal interpretable element beyond which attempt would be made to translate that unit to a map. After a number of field checks to confirm some of the results, it was decided that 25 hectares would be a useful areal size both in terms of interpreting the ERTS data and translating this data to spectral maps. In addition, it became quite difficult to physically locate most areal units that were less than 25 hectares. The basic 25-hectare unit also allowed for some spectral boundary breakout within each 1 Km grid cell, thereby further refining the ERTS data to the point where it would directly correlate to the 1 Km grid on the computerized LUNR output.

The interpretation process consisted of defining the spectral boundaries determined by changes in hue on each of the different color composites. A composite at a scale of 1:250,000 would be mounted on a light table with the gridded line map matte finished overlay on top of it. The color composites were used in a set sequence to systematically construct a spectral base map from which the data could be broken down into separate categories while maintaining both map registration and scale. From each composite, spectral boundaries were simply traced onto the acetate overlay with pencil. At first, colored pencils were used so that the different spectral categories could be easily identified. But while this most effectively visually separates the mapped information, it proved to be a problem in final reproduction of the base map data in a black and white format. Therefore, a compromise had to be made, limiting the visual effect of the color separating the mapped categories for a numbered reference system. In this way, each category was assigned a reference number, which limited confusion in producing different overlays as well as permitting final reproduction in black and white.

In parts of the scene where there was a complicated mix of small areas of different spectral features together with many sharp linear features (e. g. urban areas), it was desirable to enlarge this part of the composite to better break out these spectral features. For these special cases, the composite transparency was placed on an overhead projector and projected onto a screen to a scale of 1:24,000. The desired type of overhead projector for this purpose should have the following features: good optics, a strong light source (750-1000 watt lamp), sufficient cooling including a heat shield to minimize the distortion resulting from the acetate being heated by the projection lamp, and the elimination of the freznel lens. Whereas, the last feature is not a major point of concern with the projector design, eliminating the resulting concentric circles from the projected scene makes the scene easier to interpret.

Placing grids on the projected image increases the ease of data take-off and involves the accuracy of locating the different points in a scene for translating the information to a map overlay. Figures 13 and 14 summarize the data take-off process starting with the original NASA 70mm film chip to translating the data in the scene onto a map overlay.

INTERPRETATION OF THE FOUR-COUNTY TEST SITE

The entire test site was interpreted from diazo color composites as described above. Four composites were used to delineate seven major spectral categories of information and in addition two categories were created for anomalous features. The latter two categories included those terrain features which could not be placed in any single category but could be expected to have a relatively uniform spectral response. This category was named undefined and with field checks it was found to

Figure 13. This illustrates the intermediate and final products in the processing steps to obtain diazo color composites. On the left column is a NASA bulk processed 70 mm film chip (top), a glass lantern negative slide and a contact positive image. In the middle is an enlarged 1:250,000 scale positive B&W transparency and on the right a diazo color composite produced from combinations of different spectral bands and diazo film.

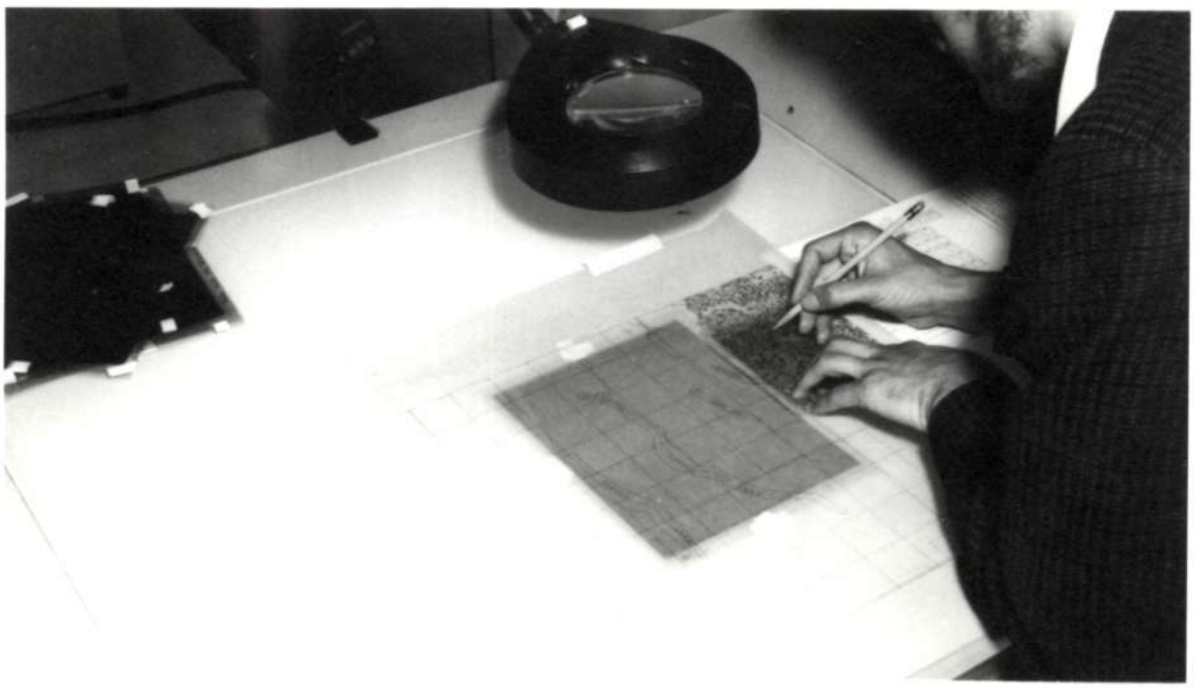


Figure 14. Shown here is a data take off step determining percentiles of an area for each of several interpreted categories of information. These categories were interpreted directly from the diazo color composites and transferred to a 10 km square grid overlay. The percentiles are taken by using a 1 km square grid.

include generally recreation areas such as golf courses or parks and also cemeteries and inactive type land in non-forested areas not having agricultural or some cultural use. The other category included clouds and cloud shadows.

In the interpretation process the first step is to identify the location on the gridded overlay of clouds and cloud shadows. If this is done first, these areas will not be misinterpreted later and placed into another category simply because the hues might appear similar. A cyan diazo reproduction from a positive black and white transparency from either of the two infrared bands will quickly delineate the areas of clouds and cloud shadows.

Upon having identified the cloudy region of the scene, it is then most helpful to devise a systematic approach to the interpretation and delineation of the remaining spectral categories. In this way, the entire area on the composite is interpreted for only a single spectral category at a time. This accomplishes two things: (1) it speeds up the process of interpretation and (2) the interpreter does not get confused as easily between the different hues and tones that would depict other spectral categories. In addition, it cannot be assumed that a single composite can reliably be used for several categories. Often it is true that two or three categories will easily break out on a single composite, but care should be taken to choose the composite which will yield the sharpest and most consistent color contrasts for the category of interest. In addition, the accurate interpretation of some categories may be affected as a result of temporal changes. For instance, vegetational zones will shift with the seasons and, as such, vegetation changes may shift the spectral boundaries of different regions within urban core and residential areas. Therefore, some thought must be taken into the category being interpreted and what types of spectral combinations and temporal effects will result in the best interpretation of that area.

Before it can be determined that major categories of interest can be easily interpreted from the scene, a few spot checks using airphotos, maps, or field checks is appropriate to assume for initial interpretation efforts that a particular hue has some consistance in delineating a certain spectral boundary. In this way, different hues on different composites can be associated with some major uniform spectral category.

One should be advised, however, that it is not appropriate to use maps, airphotos, and other collateral data on a cell-by-cell basis when interpreting the ERTS-1 imagery. Such interpretation practices, when employed in a research effort to evaluate the effectiveness of satellite data for defining land use information, can only "doctor" the data. In such cases, it would not be clear whether interpretation is accomplished from the airphoto and maps or from the ERTS-1 imagery. Reference to maps or airphotos in this interpretation effort is sharply curtailed to a few spot checks when some unusual anomaly is detected.

At present, the selection of hue and spectral combinations to break out different categories is done on an "educated" trial and error basis. Some categories such as water are going to be enhanced by concentrating on combinations heavily skewed to include mostly infrared bands, etc. After a certain amount of practice one tends to get a "feel" for putting combinations together which will produce the type of contrast desired for a part of the scene which is of interest.

To remove some of the trial and error in the construction of color composites, a project is being undertaken to attempt some prediction of the combination of spectral bands and color hues which will yield the best composite for a particular spectral category. At this writing, there are no results to report. However, emphasis will be placed on obtaining a model to make predictions on the basis of density measures on the different black and white transparencies for each spectral band and to correlate these densities to color contrasts that could be produced by mixing the densities and hues.

When the major spectral categories have been determined, there are some necessary correlations and checks that must be made to assure the accuracy of the interpretation and to determine the types of land use categories which may fall into a single spectral category. For each spectral category, there must be preferably no more than two spectral composites which delineate the boundaries for that category. Within each composite, decisions must be made to fix the amount of variance in hue, tone, and shape configurations that will be determined as valid for that category. If several different interpreters are working on one spectral map of an area, it might be advisable to produce a color key for each spectral category to minimize the amount of variation which is naturally going to be evident with independent decisions being made as to what variation in hue represent what category. These hues must initially be confirmed as having some inherent homogeneity in terms of the spectral characteristics of the material they represent. For instance, because of similar material composition, pavement, concrete buildings, sandy beaches, and stone quarries should have very similar spectral responses although they fall into very different land use categories. This field confirmation should be done with on-site field checks as well as with any existing airphotos or maps. Using airphotos and maps will firmly place in perspective reasons for homogeneity or lack of it in the areas surveyed. This can be illustrated by an example. In field checking parts of Syracuse, New York, which were classified as high density residential areas, (i. e. areas where lot frontage on the street side did not exceed 50 feet as defined by the LUNR inventory) it was determined that there was a difference spectrally between two high density residential areas as indicated by a distinct change in hue from orange to cyan. The orange area had been initially interpreted as an urban core type spectral zone whereas the cyan areas were classed as simply residential. Upon inspection, of 1:24,000 scale B&W aerial photographs, it was quickly determined that there was a difference in the size of the vegetation zones within each area. The area that approximated urban core type actually had a higher housing density than did the area interpreted as residential. To confirm this, blocks of 300 hectares each were sampled in both the urban core type area and the residential type area. In the former, the vegetated zone comprised 25 hectares (approximately 8%) whereas, in the other area about 100 hectares (33%) of the area was vegetated. Use of the airphotos quickly cleared up a possible confusion cuased by a failure to correlate spectral interpretation to site checking, since from the city street level little overt differences were discernible between the two areas.

After these field checks have confirmed a consistance in the hues defining the general spectral category, a second correlation should be made which identifies the type of materials and the general terrain features which fall into that spectral category. Finally, these materials and features may be correlated to and identified as specific types of land use which have a defined spectral response.

The following summarizes the interpretation steps which should be followed:

Determine spectral category. → Determine best color composite to delineate the spectral category. → Fix limits of variation for hue, tone, and shape, which define the category. →

Make an initial field check at several different locations to determine homogeneity for the spectral response and associated hue. → Identify the different materials and terrain features which made up this spectral category. → Correlate these different spectrally-related materials and terrain features to the different types of land uses which might occur.

Table 1 details these steps for the different categories defined in the pilot study area. Figures 15, 16, 17, and 18 are color prints of the four composites that were used in the interpretation of the major spectral categories defined in Table 1. In Figure 17 a yellow diazo film of a negative transparency from August was included with the color composite to increase the contrast and so aid in differentiating the residential type zones from the urban core type areas.

The sequence that was followed in the interpretation of the spectral categories within the study area started with urban core type features and road transportation networks. These features were determined and traced directly onto the gridded overlay. These two categories were interpreted from composite #2 (Figure 16). This composite is comprised of bands 5^+ cyan (August), 5^+ cyan (October), 5^-magenta (October), and 7^+ yellow (October). (+ and - refer to positive or negative images). The dates refer to the scene from which the diazo overlay was made.

The reason for starting with urban core type and transportation was due to the prominance of the Syracuse metropolitan area on the part of the study area that was initially interpreted. The sequence in which spectral categories are interpreted and mapped would seem to be governed

Table 1. Correlation and Interpretation of Spectral Combinations to Land Use Categories

Level I Categories	Spectral Combinations and Color Combinations	Hue, Tone, and Shape Configuration	Primary Association of Delineated Areas With Spectral Characteristics of the Material in the Area - (Field Checking, Collateral Data)	Secondary Association - Identification of General Reflectance and Spectral Features of a Bounded Area	Correlation of And Identification of Land Use
Agriculture	Composite #3 band 5+ yellow (October) band 5- cyan (October) band 7+ magenta (October)	Light blue, dark blue, and subtractive process with rectangular type pattern	Bare soil, monotypic plant growth less that six feet tall, rural hamlets	Bare soil, monotypic plant growth less than six feet tall	Rural non-forest/non-brushland, non/wetland/water Minimum area - 25 square hectares
Forest	Composite #4 band 4+ yellow (October) band 5- magenta (August) band 6- cyan (August)	Light green	Plant growth over six feet tall both monotypic and mixed	Plant growth over six feet tall both monotypic and mixes	Aggregations of deciduous, coniferous trees and brush-scrub land Minimum area - 25 square hectares
Water	Composite #1 band 7- cyan (October) band 7- cyan (August) band 7+ magenta (August) band 5+ yellow (August)	Bright orange	Water	Open water	Standing open water (lakes and ponds) Flowing water Minimum area - lakes 1-2 hectares Minimum width - streams 22-30 meters
Wetlands	Composite #1 band 7- cyan (October) band 7- cyan (August) band 7+ magenta (August) band 5+ yellow (August)	Yellowish green	Vegetation and water	Vegetated water area	Standing water with mixed vegetation (grasses, shrubs, and trees) Minimum area - 25 hectares
Urban core type	Composite #2 band 5- magenta (October) band 5+ cyan (October) band 7+ yellow (October) band 5+ cyan (August)	Bright orange	Concrete, asphalt, bare rock and earth, buildings, and rooftops	Concrete, asphalt, bare rock and earth	Core - concrete/pavement, concentrated buildings (office and commercial) lack of vegetation Ind/Extractive - tailings, quarries settling ponds, tank farms
Residential type	Composite #3 band 5+ yellow (October) band 5- cyan (October) band 7+ magenta (October)	Burnt orange and light cyan	Concrete, asphalt, and vegetation	Concrete, asphalt, and vegetation	Residential - lesser amount of pavement, rooftop areas, small trees, grass (single family and small apartment complexes
Linear transportation	Composite #2 (same as above)	Bright orange	Concrete and asphalt	Concrete and asphalt	Urban/rural interface - residential/light commercial intermixed with agricultural/forest Transportation - road networks, airports

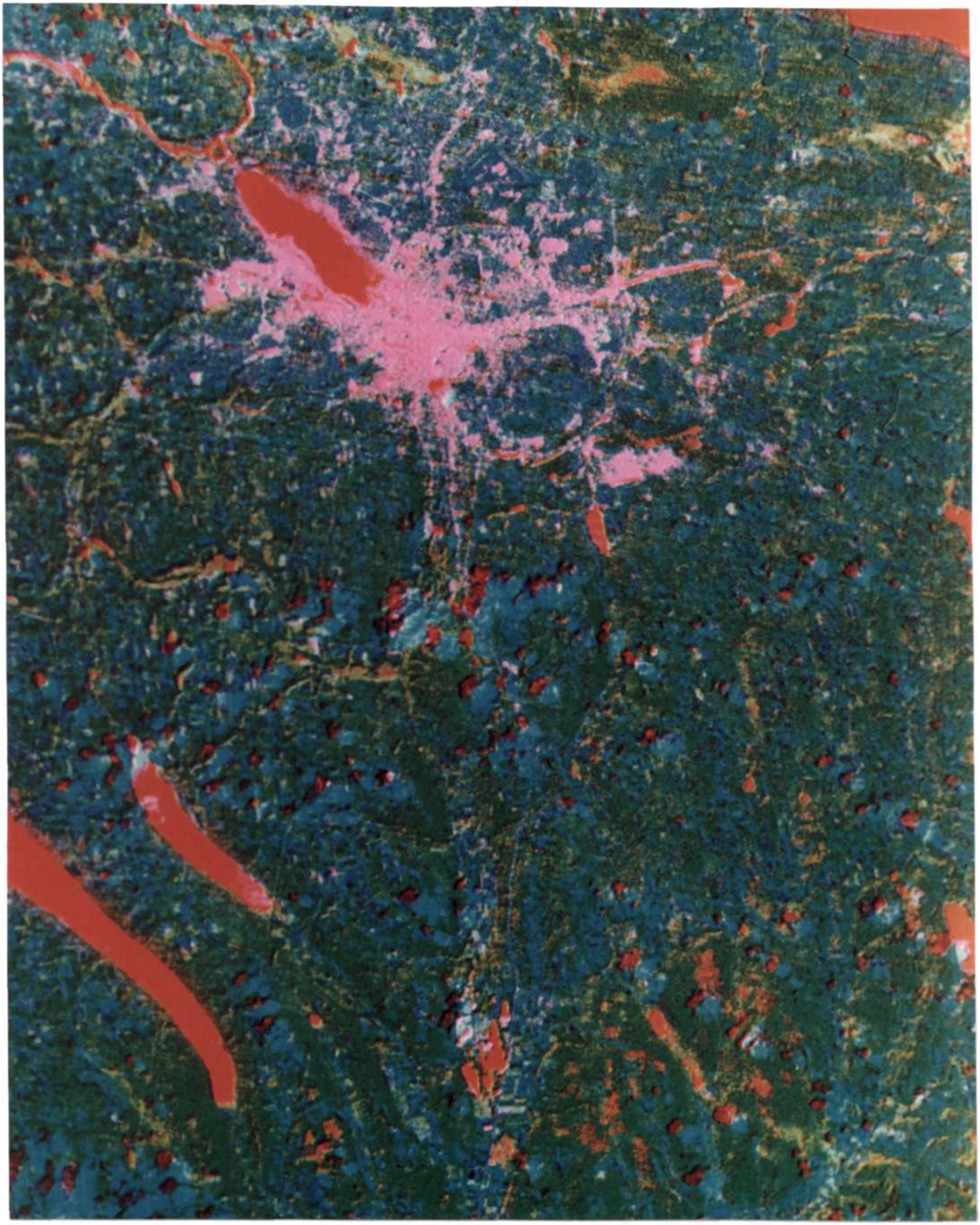


Figure 15 . Color Composite #1.

This composite is useful in defining water bodies (bright orange) and wetlands (yellowish green). Brownish areas are cloud shadows within the scene. Area comprises approximately 1500 square kilometers in the Syracuse, New York, area (pink region). Scale approximately 1:250,000.

Figure 16. Color Composite #2.

This composite is useful for defining spectrally related features similar to urban core having a high reflectance, particularly in band 5 (pavement, buildings, rooftops, quarries, and bare gravelly soil). These features appear bright orange in this scene. Major transportation routes also fall into this category. (Syracuse, New York, scale approximately 1:250,000).

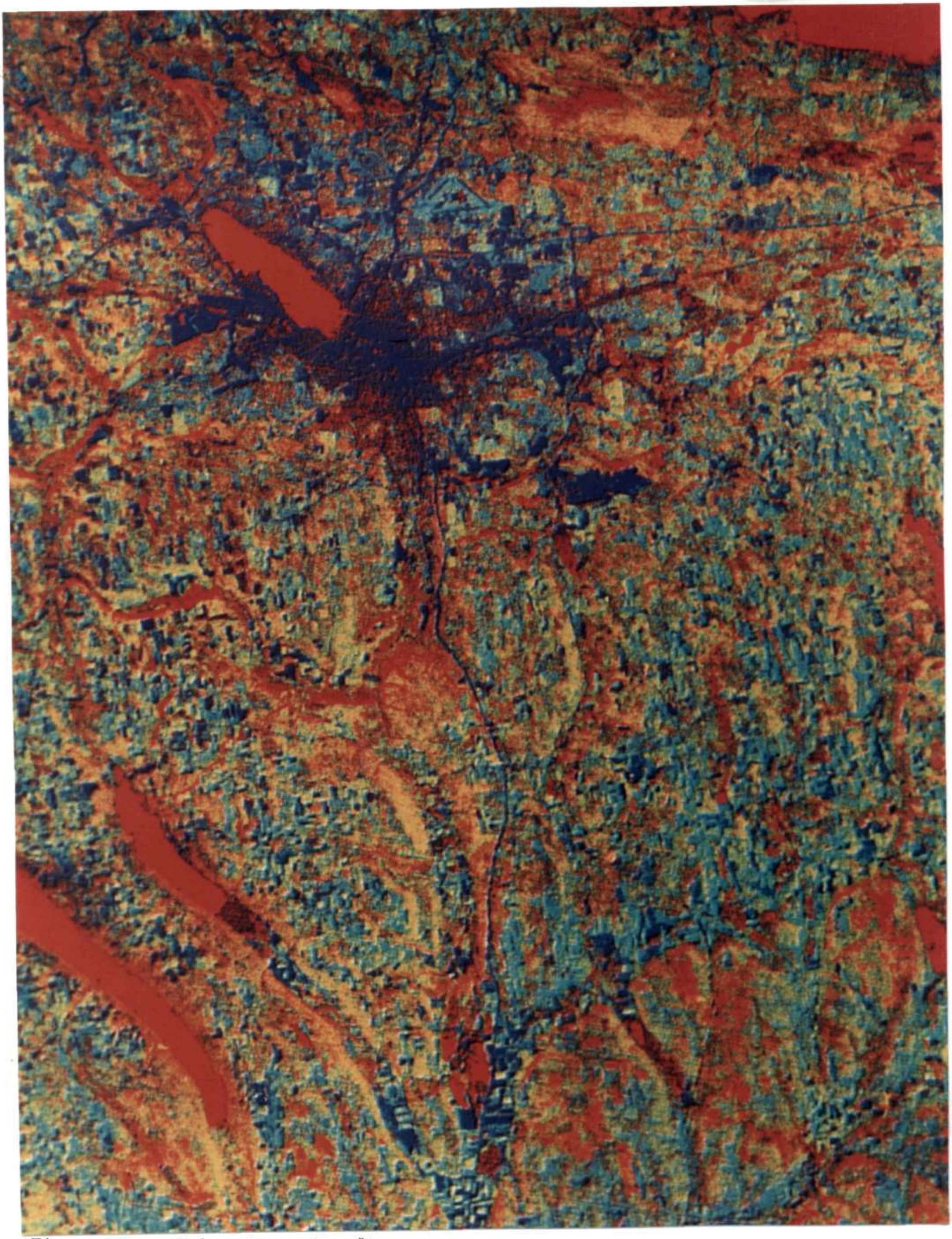


Figure 17 . Color Composite #3.

This composite is useful in defining the residential (burnt orange and light cyan) and agricultural zones. These zones were not interpreted only on the basis of hue, but by a subtractive process (see text for explanation).

Figure 18 . Color Composite #4.

This composite is used to define forested areas (light green). It also clearly shows turbidity characteristics (magenta) in the water bodies (yellow).

by the prominent features within the scene and the homogeneity of the spectral response within each spectral category. Categories such as agriculture have a great diversity of possible spectral responses depending on seasonal changes as well as farming practices in the region. Such categories are very difficult to interpret and map; therefore, they are better left for the latter part of the sequence. It should be pointed out, however, that the actual placement of different composites in the interpretation sequence is of no importance. It is important, however, to maintain the sequence throughout the interpretation to minimize problems of confusing areas of one spectral category with another.

Composite #4 (Figure 18) was used next to delineate the forested areas. This composite consists of bands 4^+ yellow (October), 5^- magenta (August), and 6^- cyan (August). By defining the forest category areas it was felt that residential types and agricultural categories could be more easily defined, especially around the urban/rural interface.

Third in the sequence was composite #1 (Figure 15) which was used to define the open bodies of water and wetland areas. This composite was composed of bands 7^- cyan (October), 5^+ yellow (August), 7^- cyan (August), and 7^+ magenta (August).

Finally, composite #3 (Figure 17) was used to define the residential type areas and also the undefined areas within the metropolitan regions of Syracuse and outlying districts. The undefined category includes all the spectral anomalies that failed to fall into any of the broad general categories. Composite #3 was comprised of bands 5^+ yellow (October), 5^- cyan (October), 7^+ magenta (October), and 5^- yellow (August). The last yellow film was added to block out the urban core regions to make the residential zones stand out better. This composite could also be used for delineating agriculture. But within this interpretation sequence, agriculture was the last spectral category to be defined with boundaries, so it effectively comprised all the remaining area not already defined by their heterogeneous make up and the more or less rectalinear patterns produced by the cultivated fields.

All of the August data was taken from a single scene NASA Accession #1027-15233, and the October scene was NASA Accession #1080-15180. Unfortunately, the August and October scenes were from adjacent orbital tracks with the overlap area covering the eastern half of the test area. The western half of the test area was only interpreted with composites constructed from August imagery although the same combinations were used with August overlays being substituted for the October ones. Fortunately, the effect was minimal on the interpretation.

The interpretation product for the major spectral categories is illustrated in Figure 19 (back pocket). Since this is only a spectral map of the region, each of the spectral zones must be correlated to land use categories. This was accomplished on a sample basis by means of field checks and correlations to the LUNR data. A discussion of these checks and results follows below.

VERIFICATION AND CORRELATION OF ERTS DATA TO LUNR

Initially, two 10 Km grid cells were carefully field checked to determine how close the ERTS interpretation came to classifying spectrally the different categories of land use in each area. The one area comprises a large section of the city of Syracuse, New York, which includes both central core and different residential zones. The second cell was deliberately chosen from a rural area in and around Tully, New York. This area is substantially a mix of agriculture and forest zones with some small waterbodies and a few wetlands.

From these two cells it was felt that we could obtain a good representation of the different categories we would hope to extract from the ERTS data. Within each cell there were 100 square kilometers or 10,000 hectares. The minimum area interpreted on ERTS for this study was approximately 25 hectares.

Checking commenced by obtaining a LUNR Datalist for each of the cells. This datalist lists all the different categories within each square kilometer by the number of hectares for each type of land use. These different LUNR land use designations were lumped into groupings thought to be similar in their probable response. Table 2 compares the spectral categories of ERTS to the groupings in land use categories in LUNR. With this data in hand together with the ERTS interpretation, these two cells were carefully field checked with two considerations in mind: (1) whether the grouping of the LUNR land use categories appeared to be spectrally similar, and (2) how close the ERTS interpretation came to accurately delineating the different spectral zones in the two cells.

The urban cell included extensive commercial and residential areas in Syracuse. It also included parts of primary highway interchanges, some large and small industry, and a part of Onondaga Lake. As areas were field checked, each square kilometer that had significant discrepancies was marked for further examination.

The cells with discrepancies were checked again to determine whether the LUNR designation had been spectrally grouped in the wrong category or if there was a problem with the ERTS interpretation. One cell included the state fairgrounds. These grounds in LUNR are given a land use desig-

Table 2.

ERTS Spectral Categories	LUNR Land Use Categories
1. Urban core type Gravelly fields High density residential with 3% backyard area per 300 hectare block.	Urban core Limited access highways Urban inactive Heavy industry Shopping centers Commercial sites Gravel and sand pits Stone quarry. Railroad yards High density residential with 3% backyard area per block.
2. Residential Type	High density residential with 33% backyard area per 300 hectare block. Medium density residential Low density residential Rural hamlet Residential strip Light industry
3. Undefined	Airports Public facilities Outdoor recreation Barge canal terminal Underground mining (oil and gas storage tanks, waste beds)
4. Forest	Forest lands Forest brushlands Forest plantations Orchards Shoreline development (lakeside cottages)
5. Water	Natural ponds and lakes Artificial ponds, lakes, and reservoirs Streams and rivers

Table 2 (continued).

ERTS Spectral Categories	LUNR Land Use Categories
6. Agriculture	Active cropland and cropland pasture Pasture High intensity cropland Specialty farms Inactive agriculture lands
7. Linear transportation	
8. Wetlands	Wooded wetlands Marshes, shrub wetlands, and bogs

nation of outdoor recreation. However, a large part of the area is covered by large buildings with expanses of open grassy or base areas. Spectrally, the large buildings might appear as urban core type which they, in fact, did on the ERTS interpretation. The remainder of the area was classed as undetermined by the ERTS interpretation. Other LUNR designations that caused problems included those land use categories marked public which included public utilities, parks, cemeteries, etc., high density residential areas, and light industrial zones.

The public areas were mostly comprised of different types of buildings or storage areas such as schools, churches, hospitals, sewage and water treatment plants, etc. These sites were generally small in area and spectrally they were not distinct from the immediate areas surrounding them. Therefore, these areas were designated as part of either urban core type or residential type on ERTS, depending on the relative location of the site. Parks and cemeteries were generally spectrally distinct if they were large enough and they were not located near the urban/rural interface. Small parks were mostly grouped as residential type areas. The larger parks and cemeteries were classed as undetermined on ERTS because of their obvious distinctness from the immediate areas surrounding them. One large park, however, was mistakenly interpreted on ERTS as residential type. Spectrally, it did not break out clearly from the residential type even though field checks failed to show much difference from other large parks in the Syracuse area. With further work on developing color composites and photo techniques, it is hoped that these undetermined spectral categories within the urban areas will break out into separately defined spectral classes.

Residential zones were generally interpreted correctly from the

ERTS data with two general exceptions. In the one case, part of an area designated high residential by LUNR spectrally was interpreted as urban covertype; whereas, the other part of the area was correctly classified as residential type. As previously mentioned, the urban core had only 8% of its area in vegetation and the surrounding residential areas had 33% vegetation, which produced a spectral distinction between the two areas.

Another misinterpretation of residential type on ERTS appears at the other extreme. Outlying areas on the very fringes of the urban area where housing density is very sparse were spectrally grouped with agriculture. In addition, small rural hamlets that would normally have a residential classification in LUNR for the most part were misclassified on ERTS as either agriculture or forest. In many cases, the housing in these communities was substantially marked by large groups of trees. Better composites and refined techniques may yield some subtle differences which will make up a new category to include these rural communities.

Light industrial areas had been expected to appear similar to commercial strip development with spectral similarities to urban core types. However, in all but one instance, these areas were grouped with residential type. Field checks indicated that these light industries were grouped into industrial parks with adequate amounts of tended grass and trees to dull or mask the impact of the buildings and parking lots. The one exception was an area classed as light industry that was a complex of old buildings with extensive areas of bare ground and litter scattered about. This complex was spectrally interpreted as urban core.

Land that was classified as urban inactive by LUNR was interpreted as both urban core type and residential type on the ERTS imagery. In some outlying residential areas, which had urban inactive, this land was spectrally identified as agriculture which field checks proved to be misclassified.

The other 10 Km grid cell that was intensively field checked was predominantly rural with only a couple of small rural hamlets in the area. On the ERTS interpretation, the area was classified into four spectral categories: forest, agriculture, water, and wetlands. Field checks confirmed the general accuracy of this interpretation. On the initial interpretation of the ERTS imagery, several small isolated areas or urban core type appeared in the middle of extensive agricultural areas. Before field checking it was assumed that these may be areas of excavation or gravel pits. The area is predominantly glacial till and outwash and it does have a number of gravel pit operations. Field checking did confirm the identification of several of the gravel pits, but the interpreter had overestimated the number of operations in the region. Instead, what was found were large fields plowed for winter wheat. The soil in the region is very gravelly and rocky, and it is possible that its spectral reflectance may be quite similar to pavement under certain conditions or at least it may have a similar spectral response in band 5 of the ERTS array.

When the 25-hectare criteria was applied to these urban core type areas, they failed to be of sufficient size to be included on the spectral map even though they could be easily interpreted. Further work may provide methods to more accurately identify the components of the complex spectral response generated by agricultural areas. This will be a specific objective of a temporal change study which will attempt to determine spectral change in different areas according to seasonal conditions. Agricultural and forested areas will be two spectral categories that should exhibit specific changes which may yield clues for a further break out of subcategories.

Having determined on the basis of checking 20 square kilometers that the ERTS interpretation was yielding promising results, eight additional 10 Km cells were chosen at random from the remaining 61 cells in the study area. This represented a sample size of 100,000 hectares. Datalists of each of the 100 square kilometers were obtained from the LUNR inventory, and each kilometer cell was cross-checked with the ERTS interpretation. Totals for each category were compiled and compared. Table 3 is a summary of this sample. Since areas of 25 hectares or less were not spectrally mapped, but were contained in the LUNR totals, some adjustments were made to compensate for that bias. For each of the 1000 kilometer grids, land use areas less than 25 hectares were located and recorded together with the surrounding predominant land use. These totals were subtracted from each LUNR category in which they fell and then added to the predominant category surrounding it. In this way, a correction was obtained which would closely approximate the possible interpretation that would be obtained from the ERTS data. This correction accounted for a shift of 16.3% of the total hectares sampled for all of the categories combined.

Some explanation for the discrepancies between the totals for LUNR and ERTS can be readily generated. Only half of the study areas was interpreted with composites which included both August and October imagery. There is a noticeable increase in area for urban core type when predominantly October imagery is used as opposed to August. Therefore, the interpreter is not likely to have identified as much urban core type for the cities of Ithaca and Auburn which had only August coverage.

There may also be some discrepancies in the way LUNR land use categories were grouped spectrally so that comparisons could be made to ERTS. With

Table 3.

LAND USE COMPARISONS

Category	ERTS (hectares)	LUNR* (hectares)
1. Urban core	3,629	7,319
2. Residential	10,191	9,595
3. Undetermined	2,076	2,832
4. Forest	24,197	21,799
5. Water	5,696	5,809
6. Agriculture	51,128	49,261
7. Linear transportation	0	0
8. Wetlands	710	3,231
9. Cloud cover	2,273	0
Total	100,000	99,846+

*Land use totals of areas greater than 25 hectares

+This total equals less than 100,000 hectares because some minor LUNR classifications were intentionally left out of the groups formed to compare with ERTS categories.

regard to wetlands, agriculture and forest categories, LUNR data was based on interpretations of spring aerial photographs. ERTS data was taken from late summer and fall. This seasonal difference is probably more important to the wetlands category than the other two. In addition, areas designated by LUNR as forested wetlands would likely have sufficient canopy to shield most of the spectral reflectance obtained from the water. Therefore, it is likely these areas could have been included in the forest category on ERTS. A quick glance at Table 3 will show that the amount of overestimation of forest areas for ERTS compared to LUNR will very closely make up the difference between the two wetland categories. It should be kept in mind, however, any shifting of figures in such manner falls more in the realm of conjecture and should be viewed with skepticism for the present.

In summary, over all the categories excluding cloud cover, the ERTS interpretation correctly included approximately 88% of the LUNR classifications in proper geographical reference. This fails to consider differences particularly around urban fringe areas where considerable land use change has occurred in the past five years since the LUNR inventory was completed.

A survey is in progress to determine the amount of land use change that has occurred in Cortland County which includes nearly a quarter of the test site area. Whereas no figures are available as of yet, several trends appear to be evident: (1) land use boundaries do not apparently change much with a change in land use, (2) most change has occurred near urban areas, (3) marginal farmland is going into reforestation, and (4) there is a large amount of interchange between active agriculture areas, inactive agriculture areas, and active pasture area. Some types of land use categories appear to expand in areal extent with time. These include gravel pits, reforestation projects, and cluster type residential developments.

Upon completion, the updated LUNR information will provide data on land use change since 1968, an estimate of the amount of error intrinsic to the LUNR survey and trends in the changing land use picture for the county. This updated information will also serve in determining accuracy levels for the ERTS interpretation.

COMPUTER FILE AND RETRIEVAL SYSTEM

Work is progressing on designing a computer file and retrieval system to incorporate both the ERTS data and the LUNR file structure. At this time, the system is not ready to receive data. When completed, it will be able to automatically correlate ERTS data with the LUNR data to determine accuracy measures for the ERTS interpretation or identify regions where land use change has occurred. In this way, it may be possible to demonstrate how existing land use inventories may be updated with the satellite data.

In addition to simple comparisons at the 1 Km grid cell level, studies are being undertaken to allow for expansion of the ERTS file structure to hectare units. At this level, soil and geological map data can be inputed in the file for limited size areas probably the areal extent of a county. Correlations then could be made with the spectral associations produced by ERTS for land use or terrain cover to soils and geological data.

A number of other possible applications for the file structure have been considered, but they are as yet preliminary in conceptual design and may be presented if feasible in later reports.

SURVEY TO DETERMINE USER INFORMATION NEEDS

A questionnaire was conceived as a means of measuring the public needs in the area of mapping. As much information as could be gathered was desired from the survey. Therefore, it seemed unwise to direct questions only in terms of satellite processes. Too often a user might decide that "a satellite cannot see that, so no point in including it." To avoid this reaction, the questionnaire was directed to map information in general.

Each question was included for a specific purpose. The first question about scales was included first to see which was the most used scale and second to see if anyone objected to small scale maps (See Appendix B).

The second question on types of maps was included to develop some ideas about possible uses for maps and types of maps that could be generated. This could include entirely new applications, or it might involve compilations of data from other sources into one map form.

The third question involves listing the map forms already in use. This question was included to determine what maps or aerial photos are commonly used.

The fourth question arose from the possibility of updating information every 18 days by ERTS. It was necessary to determine if anyone could use information updated semimonthly. The question also helps to determine the oldest possible data for usable information. This question was included because of some response from users that LUNR was becoming outdated. It was necessary to determine if this was actually happening on a large scale or if it was applicable only to certain areas.

Tables 4A-E (Appendix B) present a percentage breakdown of the results. The percent totals may exceed 100 percent in that for each question, the potential user could mark as many areas of interest as he wished. Therefore, some measure of interest could be assessed on the part of the user.

THE SAMPLE

Four groups of potential users were approached to answer the questionnaire. The first group was the Cooperative Extension, Cornell University, State University of New York. Agents working at the county level were interviewed. These people worked actively with the residents in the county in several areas of specialty relating to agriculture. The second group were staff members of the New York State Department of Environmental Conservation. This group contained specialists in the areas of forestry, fish and game, wildlife management, and environmental impact statements. Their work was at a regional level. The third group included planners at the city and county levels. Some of the counties were mainly agricultural with a small to medium-size city somewhere in the county. Therefore, the city planning department and the county planning department reflected the urban-rural land use patterns within the same topographic area. The fourth group was the academic counterpart of the three previously described groups. Some of the faculty members of Cornell University in fields corresponding to those of people working in the community were interviewed. These faculty members were included to determine if any differences lay between the academic research at the university and the projects of the people in the field. There was no apparent difference. The university personnel were usually involved with many of the field projects. For the most part, the faculty interviewed were not involved in theoretical studies but in projects having a current impact in the public sector.

The samples included 23 persons. Although this is a small sample number, it may reflect the types of potential users for map products. Since the study sample was selected rather than a random sample, the results are indicative of the immediate needs of potential users who have an interest in obtaining the information that may be available.

THE SCALE

The first question deals with map ratios. The most popular map scale is 1:25,000. This is approximately the same scale as the USGS 7 1/2 minute topographic maps, the LUNR maps, and some available airphotos. The availability of the map seems to dictate the most popular scale since the most used map is the 1:24,000 USGS series. Therefore, decisions are likely made by what source data is available rather than what is needed.

A number of other scales were mentioned as of use. The use of maps or airphotos at the various scales of 1:10,000; 1:12,000; 1:15,000; 1:16,000; and 1:20,000 seemed to be entirely reliant on what airphotos could be obtained. No one requested a scale of 1:15,000 in preference to 1:16,000. The choice was made entirely by the cost of the materials and how readily available the airphotos were.

The second preference in map scales is 1:125,000. This scale is used on county road maps, which often include much more than transportation routes. Some include forest plantations, suburban areas, and recreation areas. Some are accurate enough to be used as a base map.

Most of the maps and aerial photos mentioned in this section are used as base maps. A planner, for example, uses a USGS topo sheet as the base for locating and mapping all areas actively involved in lumbering operations. The USGS is probably preferred because it is readily available and has more printed information on it than some of the other maps.

An important point of consideration was the unfamiliarity of most users with map scales. The use of ratios such as 1:25,000 was hardly ever used. More often, the user referenced a map that was scaled at 1 inch = 2,000 feet. Often a phone call to a subordinate was needed to determine the scale, or a map had to be retrieved and examined to find the scale. The interviews included both people in administrative positions and in staff positions. Therefore, it was evident that the users would have to be educated as to the correlation of scale and information if certain scales are to be promoted, or if user inputs are to be used in deciding on scales for mapped data products. This subject of scale was one of the most difficult questions for the user to answer. He essentially used whatever maps and airphotos he could find without much concern or reference to scale.

The currentness of the maps also affected their use. The USGS series dated after 1966 are used extensively by people in areas where they are available. An area such as Cortland, last mapped in 1955, relies on county maps, airphotos made available for tax mapping, and the Niagara Mohawk Power maps. The problem of keeping current materials available is sometimes the biggest problem.

MAP APPLICATIONS

This question applies to what data is in map form now and what is needed to be put in map form. Most information needed is in some map form, but these maps are not necessarily published, as are those sold by the United States Geological Survey or the New York Office of Planning Services. Most of the information is on county maps or maps produced by the staffs of planning offices and conservation offices. These maps are developed as a product of one particular project but may be used for successive projects.

The following is a summary of each subject defined by the importance it has to the user. Where correlations could be drawn between subjects, they are included:

Recreation - In this context recreation is slightly different than usually defined. When asked to explain what was needed in the area of recreation mapping, users cited several needs: locational maps to hand out to the public, areas for potential development, naturally occurring grassy places, and current recreation sites and their land uses. These broad requirements apparently existed because the users could not consolidate different types of recreation activity to make a clear definition of what constituted recreational map.

Transportation - Transportation routes include existing transportation routes as well as planning corridors for proposed roads. One person was also interested in abandoned railroad routes to be included as part of new state parks.

Forest growth or forest decrease - The main response to this question came from users in urban areas who were concerned with keeping green belts near the cities. In some areas, the land was reverting to forest; in other areas, timber was being felled for construction. Some interest in lumbering was evidenced, but the major interest was in forest areas as it related to urban and suburban development. More of the interest was in forest growth rather than forest decrease.

Strip development - This group encompasses commercial development as well as housing along transportation routes. The interest here lies in knowing what presently exists and in developing a technique for keeping track of new development. There seems to be no interest in the curtailing of strip development, only in keeping track of it.

Existing farmland areas - The interest in this category is paramount at this time because of the organization of agricultural districts in New York State. This law is designed to encourage continuance of a strong agricultural industry in the state and to discourage urban dispersion into good farm areas (Linton, 1971). The information required to form these agricultural districts is presently obtained from the farmers of the area. Within the next few years the total area of existing farmlands will be mapped. There seems to be little interest in different categories of farmland, e. g. no one showed particular interest in differentiating pasture from active fields or inactive fields. The differentiation between pasture and inactive fields had been a particularly difficult task in the inventory. It is now apparent that such distinctions may have only limited use.

City growth, existing urban sprawl - These two groups need to be examined together. City growth means expansion or new growth within the city boundaries. Urban sprawl involves the suburban development. The difference in interest should be noted. The suburban areas attract almost 30% more interest than the city areas. But the urban areas may be considered already committed to certain land uses while the suburban areas offer opportunity to effectuate land use planning in what is considered open country. However, urban renewal programs may increase the need for land use planning in the central urban core.

Extractive industry - This involves sand and gravel operations as there is no mining in the four-county area except for some salt wells. These operations are also applicable to some urban areas where gravel is stored or extracted for new construction.

Wetlands - The interest in wetlands is high now because of the New York Environmental Quality Bond Act of 1972. A project is now underway to inventory and preserve the wetlands in New York State. Some counties are not waiting for an official inventory but are going ahead on their own to buy wetlands now. This is happening in the Syracuse area. Onondaga County has a high water table and is easily affected by drainage from new transportation routes and land fill for new housing developments. The need to keep the water table and the wetlands in a constant state is imperative in this area.

Wetlands were also mentioned in connection with transportation routes. If new routes could be built avoiding both existing wetlands and new ones formed from the construction, the cost of building the route could be reduced. The cost of land fill and asphalt drainage ditches could also be eliminated by avoiding these areas.

Drainage - Drainage includes mapping the complete watershed, single river basins, and run-off from fields or wetlands. This was of interest to most people in contact with wetlands studies.

There is much concern about any kind of development in the headwaters areas. For example, Cortland County is the headwaters of six watersheds. Any construction that disrupts the water tables or existing run-off patterns is of concern to the county planners. They could use a map of all six watersheds, including volume data for each of the contributory streams so they can keep the flow constant and still develop some areas of the county.

Drainage patterns and wetlands are of interest to many planners because of the floods caused by Hurricane Agnes in June, 1972. Some of the interest is in flood protection; some in flood damage. Flood damage includes the extent of damage to all properties including those not on a flood plain, as well as damage to riverbanks and animal habitats. Many of the items in this area are better done by ground survey than remote sensing. The Water Resources section covered earlier mentions several projects that used remote sensing for watershed management.

Industrial development - Development is probably not the proper word to explain the interest in this subject. Most of those interviewed were not interested in attracting new industries to their areas. They were more interested in expanding present industries, or keeping what is present by improving transportation routes. There was some interest in monitoring suburban expansion. That is, an industry may start out in an eastern suburb, open another branch in a northern suburb, and have the branch offices in a southern suburb. None objected to this expansion; the wish was only to monitor it.

Most of the industry in this area is light industry. If the people interviewed reflect the public interest, there apparently is little concern with industrial park growth in the suburbs. The theory of keeping industry in the urban core is not practiced in this area.

Soils - Soil surveys, accurate to 25-acre plots, have been developed from soil association maps and are being made available for all counties in New York State. Therefore, a general soil map is available to anyone who needs it. Because general information is available, interest in this area is in intensive studies for smaller areas. Developers sometimes request detailed studies of an area they plan to develop. Since New

York State was greatly affected by glacial actions, soils cannot be accurately categorized in smaller than 25-acre parcels. There are always inconsistancies within the 25-acre area. These inconsistancies may make a difference in location of a septic tank, or for that matter the foundation of the building. The soil texture and permeability would be useful to these developers. They were most concerned with how the soil reacted to different uses.

Water quality - The major interest in this area was in water pollution. Chemical pollution is of the most concern. Some interest in turbidity, agricultural pollution, and pollution from construction was also shown, as well as siltation in lakes. Ground water measurements and quality were discussed, as well as some measure of ground water potential. Some users wanted information on water demand by industry to be compared with waste water produced by industry. In this context, the possibility of a nuclear power plant to be built on Cayuga Lake was mentioned often. However, generally speaking, few really knew what kind of water quality data they required.

Slope - The concern here was for development purposes and for farming interests. The available contour intervals on USGS maps are 20 feet. This is not adequate for many users. An interval of five or ten was more to their interests.

CORRELATIONS

Many of these categories are interrelated. When cities were first settled, they depended on the drainage patterns of the area for their water and transportation. Later, the roads took over in importance for transportation. A good road and water network meant industrial development and urban growth. The soils and their capabilities affected the areas to be farmed. Forest volume affected what the houses would be made of. Slope affected both farming and urban growth. As the city grew, strip development and continuing urban growth became a major concern. Wetlands became not something to get around but something to get over, build on, and dump on. Wetlands appeared where there were none before from increased urban and transportation growth. The relationships that dictated the settlement of an area are still present in an established city.

The relationships are evidenced in studying the percent of interest in the different categories grouped under water quality. For instance, 60.86% of the interest is in water pollution. The other 60% is interest in pollution from construction, siltation of water, nuclear power stations, flood damage, ground water potential, group water quality, chlorophyll content of lakes, and similar subjects.

County agents and some county planning departments were not particularly interested in water quality. However, people working with soils, water resources, and city planning usually added several categories to the listing.

Water quality is related to all other subjects in this survey. The potential user would like to maintain or improve water quality while continuing development and farming activities. There are some studies on the quality of water in the Finger Lakes. However, chemical levels may go up and down without anyone knowing why. Most of the interest is in knowing the sources of pollution and then understanding the effects of pollution on ground water and other environmental factors.

Interest in existing farmland areas, soils, and wetlands amounted to

74%. These three are related by land use patterns. Soil quality affects the viability of farming, dictating which areas should remain in farming and which areas are better suited to transportation routes and urban development. Wetlands sometimes result from soil type, sometimes from poor drainage, and sometimes from construction.

Soil properties may significantly affect the land use of the area. For example, they determine the economic viability of farmland for a given area. In New York, farm viability is a primary consideration in the establishment of agricultural districts. These districts are not open to development or speculation. Members of an agricultural district must maintain their farm operation for a period of eight years with an option to renew at the end of that period. Therefore, soil characteristics may indirectly influence the boundary areas of these agricultural districts.

Because of the Environmental Quality Bond Act, most of the major wetlands will also be unavailable for development and speculation. The power of the Act will reach outside the wetlands itself. Any construction or change in land use patterns that will affect the wetlands will have to be reviewed to determine if the wetland will be affected adversely.

Recreation, forest growth, existing urban sprawl, drainage patterns, and water pollution ranked third (61%) in interest and are directly or indirectly related. Some recreation areas are dependent on forested areas. Some campgrounds, ski slopes, hiking trails, and mountain climbing areas also need forested areas. Since urban areas require intensive recreation areas, small parks, swimming pools, picnic areas, and fishing spots are of great interest to the inhabitants of the area. Many cities are interested in preserving or establishing large grassy and forested tracts within the urban area for recreation purposes. Knowing the extent of available open areas is necessary to establish these parks.

Drainage, whether it is watershed areas, streams near industry, or reservoir management, is closely linked to water quality. If the quality is to be kept high, then the drainage patterns must be mapped and monitored. Changes could be made if necessary, and the option to leave the land natural would also be avilable. Drainage patterns and water quality, as well as access to open water and grassy areas, affect the development of good recreation areas. Lakes downstream from a chemical plant will not be acceptable as a fishing or swimming area. Recreation sites are usually found near some form of water. Therefore, if the area is subject to water pollution, the benefits of the outdoor recreation area are lost.

The subjects ranking fourth with 57% interest are transportation routes and strip development. As transportation routes are built or widened, the road frontage is quickly accessed for commercial sites, multiple family housing, and, in cases of lax zoning laws, single family units. This happens most frequently at the edge of the suburbs or where one suburb meets another. Existing strip development is of use to the planner in determining in which direction the city is expanding.

MOST COMMONLY USED MAP SERIES

Many different types of maps are used. Some methods are available for all parts of the state such as USGS topo maps, LUNR overlays, and New York OPS base maps. Others, such as soil surveys and tax maps, are presently available for some of the counties. Generally, anything that is available is used.

UPDATING

This question was introduced as a result of the sequential coverage supplied by ERTS. The prospect of coverage every 18 days has been an advantage of this particular satellite. This question was posed to determine if anyone would need sequential coverage and, if they did, at what interval it would be useful. There was also considerable concern as to the perishability of information which could be extracted from remote sensors. Some users of LUNR (now four years old) have noted that certain areas need to be updated. These categories or geographical areas have to be determined to be able to predict what types of land use are undergoing the most change. To get this information would require frequent sampling and aerial or satellite coverage of a region.

This problem of information perishability was a difficult question on which to elicit answers since some data is almost static and could be measured once every 20 years. Foresters often mentioned that their needs did not come on a monthly or yearly basis, but in ten-year blocks. Most potential users, however, felt that one year or one to five years would be an ideal time span. It was mentioned that not all areas would need to be updated but only the areas of greatest change.

AGE OF INFORMATION

This question was included to determine the age at which inventory information becomes outdated. One of the biggest problems with a data bank is keeping the information up-to-date. However, the time that it is no longer considered to be up-to-date needs to be measured. If the user complains that his information is out-of-date, reevaluations must be done immediately. Setting up the evaluation takes time; locating funds to update the project takes time. If the update time can be determined at the time of the initial proposal, an effective updating plan can be achieved. This will alleviate complaints on the part of the user for the product he receives.

If an updating plan is achieved, an effective date can be placed on each product. This extra notation will reassure the use that his information can be used for the rest of the year in other projects he may undertake.

There was not much call for monthly updating. Each person interviewed spent time deciding whether one year made more difference than two and if two made more difference than five. The most natural choice, then, was for one year, thus assuring the user that his data would always be up-to-date with few lapses.

Seventeen percent chose ten years. Ten years was viewed as an excellent base area. Areas and kinds of change could be measured if ten years was used as the base. Some areas, such as forested areas and farmlands, were not expected to change substantially in ten years, but rural/urban interfaces could undergo dramatic change.

In summary, the obvious benefits of a questionnaire include the opportunity for more complete understanding of the user's needs. Most agencies seem to be progressing in the same direction as research programs, although by different and sometimes circuitous routes.

As the questionnaire was tabulated, areas of need became apparent. It appears that data from ERTS can fulfill many of the land use needs of these users. Combined with data from other projects such as water quality studies, very effective use can be made of this data by a very large percentage of planning agencies.

Although the 18-day coverage does not now seem necessary, yearly coverage does. Yearly airphoto coverage is out of the question in terms of cost. Therefore, satellites such as ERTS that can withstand years in space would be a great help in supplying this data to potential users.

DETERMINING LAND USE PLANNING

One research endeavor of this project is proceeding somewhat independently of the larger technical investigations. We are attempting to explore the status of land use planning in the several states and at the federal level in an attempt to determine the potential value of satellite-sensed data in developing the inventories that either precede or are developed concurrently with the ongoing planning process.

Representatives of many of the states and the Council of State Governments have expressed concern in response to our inquiries regarding states' abilities to meet the planning requirements that they expect to be imposed upon them by legislation currently pending in the Congress. One aspect of this concern, as expressed to us, might be characterized as a feeling that ERTS data is neither available to planners in a truly usable form, nor at a reasonable cost in materials, personnel, or equipment.

Therefore, we are engaging in dialogue with state and federal officials regarding the type of information they require to implement policy or write legislation. Such needs are mandated by statewide land use plans, shoreline protection measures, and bond issues such as in New York and Florida which require the acquisition of those areas of "critical state concern".

These perceived needs are communicated back to the technical operation, and attempts are continually being made to adjust the methodology in such a way as to make it a more valuable tool for later generations of such information or information systems. We are now scheduling working sessions with decision makers to apprise them of the potential value of the Cornell ERTS data system for land use planning and to get yet further insights into their needs.

In the course of these investigations to date, we have been struck by existing and potential difficulties faced by planners in communicating with one another in a coherent fashion, not only between states or between states and the federal government, but among jurisdictions within states as well. We are coming to recognize the absence of consistency in inventory definition as a significant planning problem in and of itself.

We are, therefore, exploring the structural and political potential for acceptance of either a nationwide or a nationally compatible system of land use classification based on the capabilities of ERTS and the information systems it generates. We are not here attempting to propose or evaluate classification systems (Anderson, et al, 1972); rather, we are attempting to explore the reaction of decision makers to such a proposition, and speculate on the range of implications inherent in the adoption of such a system.

While it is too soon to draw conclusions or confidently speculate on these matters, we can confess to encouragement, based in large measure on preliminary response by decision makers. They have indicated that they feel, as we do, that the information we expect to generate will be of considerable value to them in designing planning operations.

PROJECTED ACTIVITIES

The second half of this contract period will concentrate on building on the preliminary findings detailed in this interim report. It is felt that the basic methodology relating to photo processing techniques, interpretation, and data takeoff has been worked out. Therefore, efforts will be concentrated on refining these techniques and trying to determine to the extent possible in the time remaining how much information can he extracted from the ERTS data by manual methods and in what context might this data be applied.

Studies will continue on the four-county test site using the information already gathered as a base. One study will assess the effects of temporal change on the spectral response of an area and how this change will influence the interpretation process. Some indication exists from the preliminary interpretation that certain categories of land use are best interpreted with respect to a certain season.

Preliminary interpretation data for the test site will also serve as the initial input to the ERTS computerized storage and retrieval system. In this system, data from ERTS will be stored together with the LUNR data bank. In this way, both land use categories and spectral categories can be correlated, updated, and corrected as the case may be. Other types of information will also be inputted on a trial basis. Such data might include soils and geology map data and wetlands data. A special effort would be made to correlate these types of data to existing land use and spectral categories for the same area or for areas nearby with the intent to see if such correlations would be of use to regional land use planners.

Work is continuing on refining some of the photo processing techniques. Special emphasis is being placed on enhancing small areas to determine what some of the possible limits might be on extracting information from a part of the scene. One attempt will concentrate on pulling out more detail from large urban areas, and another will concentrate on part of an agricultural area. In addition, the processing loop will be completed so that average densitometric values for a given 70mm film chip as received can be matched to a specific type of processing to maximize the information content in the frame and to maintain contrast and density balance across the four bands for each scene.

In addition, a study is going to be undertaken to determine if a computerized model can be constructed to predict the combinations of spectral bands and diazo color film which will produce the best color contrast for the spectral categories of interest. The parameters for this study have not been worked out yet.

Finally, several different regions of the state are to be selected for interpretation from the ERTS data received. These interpretations will be compared to that finished for the four-county test site to determine if spectral categories maintain uniformity from one topological region of the state to another. In addition, it is hoped that data from these other regions will provide information on types of land change with respect to a region.

APPENDIX A

DESCRIPTIONS

A brief review of several classification systems follows. The information for this analysis was derived from classification systems published in journals, symposia notes, appendices, and other reports; consequently, some studies may not be represented here.

Each study was investigated according to certain criteria. When available, the objectives and the background of the project are explained. If the project is now an ongoing service, the products are listed. Most of the emphasis is on the classification system and its categories.

The important aspects of repeatability and transferability, discussed earlier, are evaluated for each system. In some cases, an attempt was made to see if a potential user had taken part in the formulation of the classification categories. This often helped to explain the direction of some of the more detailed studies. The successful, ongoing inventories all displayed evidence of having relied on contributions of potential users in development of the classification. But in many other cases, it was obvious no potential user inputs had been incorporated.

Emphasis was restricted to systems developed for use in the United States using both conventional aerial photography as well as orbital photography and imagery, with the exception of the Canada Land Inventory.

DETAILED INVENTORIES

Standard Land Use Coding Manual

The Standard Land Use Coding Manual was released jointly by the Urban Renewal Administration and Bureau of Public Roads in 1965. This manual provides a four-digit categorization of land use developed mainly for use in urban and suburban areas in the United States. This scheme was not designed especially for airphoto interpretation or any other remote sensing techniques. Ground observation and data collection provide the information necessary for land use classification for this scheme. This system would not lend itself to a large scale inventory because of the manpower cost, vast amounts of data, and the need for continual updating to keep the inventory fairly accurate.

This system evidently has been used or referred to widely. But even if aerial photography is used, there is a high reliance on ground observation. For example, if the Residential category is examined, the differentiation of a residential hotel from a household unit is very difficult using aerial photographic interpretation. Ground surveys are required to verify such difference. Many times the user cannot really justify his need to make such a distinction. It seems like an interesting fact to know. Therefore, it is included.

Some have suggested that the Standard Land Use Coding Manual (SLUCM) could lend itself to the fourth level of the USGS classification (Circular 671, Anderson, et al, 1972). But at this level aerial photography could not be the main source of information simply because of the cost factor. The combined cost of ground surveys and the detail required on aerial photographs would make a large inventory prohibitively expensive. Therefore, this classification system would be better used on a small inventory with heavy reliance on ground surveys.

The SLUCM offers a firm advantage to planners of classification systems. It provides an excellent checklist of classification items to be considered by those preparing comprehensive classifications. As the SLUCM approach is hierarchical, any satisfactory level of refinement may be selected.

MacConnell's Land Use System Used by New England River Basin Commission - The state of Massachusetts was studied at an earlier date and resurveyed for this project. The source of information was 1971 aerial photography at a scale of 1:20,000 with a product scale of 1:24,000 to coincide with the 7 1/2 minute USGS quadrangle sheets. Manual interpretation techniques were used. The original land use classification had 99 categories, but for this study they were aggregated to 14. The overlay method was used for a final product prepared by photographically reducing the overlays (W. MacConnell, personal communication).

Although this inventory includes only 14 categories with no subcategories, it is still included in the detailed group because of distinctions made in certain areas. Instead of being one category, residential is two categories incorporating two housing densities. Agriculture appears as two distinct categories--cropland and pasture. This approach excludes fruit industries, intensive agriculture, specialized noncrop-based operations, and relegates inactive agricultural land to open land. One of the categories was Institutional; another Open Space Outdoor Recreation. The latter two reflect activity-oriented categories rather than a vegetative or covertype category. There was no indication of how these were identified from airphotos without supplemental information. The combination of the two is difficult to coordinate in one inventory. The activity on a parcel of land does not always coincide with its cover type, but cover is usually the best initial indicator of land use. An inventory is more readily understood if the classification is all one or the other, though this is rarely attained completely. This inventory was meant to be used with low altitude photography as some identifiers for categories such as Institutional and Open Space Outdoor Recreation would not transfer well, or perhaps not at all, to high altitude or satellite imagery.

The above categories reflect the needs of the user and the land uses in the New England area. Several of the categories are not applicable to rural areas, and several features common in the eastern United States are not included. The inventory was designed specifically for a designated area, and, therefore, is not transferrable to other sites.

A Preliminary Vegetation Resource Inventory and Symbolic Legend System for the Tucson-Willcox-Fort Huachucha Triangle of Arizona - The topography of this study site includes river basins, desert, forested areas, grassy plains. Apollo 9, Apollo 6, and high altitude color and infrared photography were used for interpretation information.

The authors have attempted to build levels of interpretability into the classification system. However, the differences are displayed by numbers and decimals in a numerator/denominator symbol format. Each numeral is a code number representing a level of occurance. This may be entirely workable to someone who is used to the system or is well-versed in arithmetic displays. However, it might prove dismaying for the user who just wants the answers.

The amount of detail developed through this study seems unnecessary and operationally beyond the capability of the sensors used. If the purpose of the project was to locate all the land features, they were successful. However, this system is not readily transferable to any other region of the United States. The main groupings are definitely slanted toward southwestern terrain features, and the subcategories are even more oriented to the subject area. If there is a need for all the features of an ecosystem to be displayed on two computer lines, this system could be used. For typical user interests, however, the level of detail appeared greater than what is usually required.

The Application of High Altitude Photography for Vegetation Resource Inventories in Southeastern Arizona - This classification system includes information on land use, barren lands, water resources, crops, agricultural facilities, and urban areas. The study was done with high altitude (1:24,000) and space photography. The staff of this project seems particularly expert at organizing the interpreters and testing their interpreting capabilities. The products of the project are done well. But in designing the classification system many decisions seem to have been made without consideration for the needs of the final product. An attempt was made to combine three classification systems from the same project into one. This was accomplished, but one system involves land use, another vegetation types, and the last agricultural products. This system is designed to give county planners a rapid idea of the type of land use conversions taking place (Pettinger, 1970). On the surface this seems an excellent idea. But the project seems to lack basic classification design because three complete classification systems were developed and mapped on the same photo mosaic before any attempt was made to simplify or combine them.

The classification system for this project closely follows the Land Use Coding Manual (previously stated as being an unwise choice for a large scale inventory because it was not designed for use with remote sensors). The choice of following the Standard Land Use Coding Manual severely limits the usefulness of the classification system of this project. So much ground checking is needed that on a large scale, even with the careful route planning done by Pettinger, field checking would be an economic constraint.

In the researcher's attempt to show that a great deal can be seen by a satellite, they lost sight of the design of their project. This study might have been quite enlightening but as it stands it is a fine example of a project limited because too much detail was attempted without adequate design. One must question the ability of even experienced interpreters to identify accurately most of the detailed classification units presented, especially when using high altitude and space photography. At least a great amount of inferential interpretation would be essential. For example, identifying species of small fruits from the altitudes and scales described without strong back-up data and inferential concepts seems unrealistic.

Land Use and Natural Resources Inventory for New York State (LUNR) - The New York State Department of Conservation and Cornell University staff members arranged a plan to institute a land use and natural resources inventory. Responsibility for establishing the inventory was later assumed by the Office of Planning Coordination (now reorganized as the Office of Planning Services).

The statewide aerial photography was obtained through an existing proposal jointly proposed by OPS for base mapping projects and the Department of Public Works for transportation needs. This system is designed to be done primarily by manual airphoto interpretation. The user overlay product is coordinated with the USGS 7 1/2 quadrangle map. Computer graphic maps and tabular printed outputs are also available (Belcher, Shelton, and Hardy, 1971).

The LUNR classification system lends itself to small or large area classification. Areas as small as an acre can be mapped. The classification includes natural resources as well as land use practices. There is also supplementary information such as depth to bedrock, soil associations, agricultural viability that is available through computer processes.

The aerial photography was keyed to the scale of 1:24,000, the scale of existing topographic maps for most of New York State. This makes the data more easily understood by the user. The classification was aimed toward potential users and was limited by the main source of information--the aerial photographs. That is to say, a user might like to know where all the hunting preserves are located. But an area where hunting takes place might better be classified as forest. LUNR classifies the area as covertype, forest, rather than its activity hunting. This project is now an ongoing service. The materials are maintained and distributed by LUNR Users Service.

LUNR is included in the detailed group because it has a total of 150 categories not including the supplemental data, i. e. depth to bedrock. Since the smallest area unit mapped was approximately an acre, it was necessary to make distinctions between types of airports, types of housing, and so forth. These distinctions would be difficult to eliminate from the system. Adapting a design is sometimes harder than constructing a new one. In this case, it would be difficult to adapt the design without time consuming reorganization. Although LUNR categories are still valid, workable items (as are others of this group) they are better suited for a detailed inventory and are not easily adaptable to a broad classification system of 6 or 7 major categories.

It is possible to consider aggregation of the land use classification units to be used with information from satellite sources. The LUNR system can be aggregated to 10 major units. There is a recognized problem, however, in identifying the component parts of each major group from satellite imagery. Many could not be discreetly identified. This is as expected as the original classification was designed for use with 1:24,000 imagery.

Association of American Geographers - This scheme was developed by asking a potential user (Association of American Geographers) what information would be important to their studies. This study is done in levels similar to Anderson, 1972, and was, in fact, used by him in planning his scheme. However, there is far more detail. This classification scheme is designed for use with satellite imagery as well as some use of ground observation and enumeration.

The system was tested in a pilot study in the Phoenix, Arizona, area. The scale of the product is 1:250,000. Conventional color and color infrared photography from Apollo 9 and from high altitude aircraft were used. This information was supplemented by black and white photography at a scale of 1:62,500.

The first order categories can be used with smaller scale imagery. The second and third levels would be more appropriate with aerial photography or ground observation. In fact, the second and third levels of this system could be incorporated as the third and fourth levels of USGS Circular 671 (Anderson, et al, 1972). Some areas such as Mountain Oriented Recreational Activities are of questionable value because of their activity orientation. But other areas of the classification system would answer the need for detail that so many users have become accustomed to asking for.

This scheme was presented to a conference in Washington, D. C., in June of 1971, and served as a basis for discussion for the conference. The concensus of the conference formulated the Level I categories of the classification now presented in USGS Circular 671 (Anderson, et al).

Canada Land Inventory - The Canada Land Inventory (CLI) was developed in

1963, after formal consideration of the plan under the Agriculture Rehabilitation and Development Act (ARDA) of 1961 took place. The CLI is a joint effort of federal and provincial government. Many universities, provincial governments, organizations, and companies were initially involved in the formulation of the project.

The basis of the information comes from the Soil Survey organization of Canada. Their data on classifying and mapping soils along with their published maps and reports provided much fundamental information on the soils of Canada. Federal and provincial Departments of Forestry, Parks and Recreation, and Wildlife have carried out studies relating land capability to productivity. Land use classification was developed from aerial photo techniques used by the Department of Energy, Mines, and Resources, and other technical experts. Other agencies contributed statistical information on social and economic factors of land use (Department of Regional Economic Expansion, 1970).

The CLI is a study of land capability and use designed to provide a basis for resource and land use planning. It is to be used primarily for planning rather than management. Only settled portions of rural Canada and some of the adjoining areas that affect income and employment are included in the inventory. These areas were facing the problem of choosing between alternative land uses in rural development. The inventory provides for information on land capability for agriculture, forestry, recreation, wildlife, present land use, and a pilot land use planning project in each province.

The information is available for parts of Canada by computer mapping techniques. Planning can be done at the provincial or federal levels. It is not designed for management of particular parcels of land such as a particular pasture or a woodlot.

The CLI is included in the detailed category because of its emphasis on land capability. It could be equally well identified as a member of the elemental group. The data of soil types and land use can be determined by interpretation techniques. But the land capability is a subjective decision. If the decision is made to define the study by the capabilities of the present system, the number of subjective decisions that need to be made should be severely limited.

Minnesota Land Management Information System - The Minnesota Land Management Information System (MLMIS) developed from a series of lakeshore studies. The primary goal of MLMIS is to improve the quality of public- and private-sector decisions about the environment (Orning, 1972). MLMIS is doing this by providing extensive information on present land use, economic, and social conditions.

This system is very close to the elemental studies. Its landscape classification is very general. MLMIS has attempted to find only dominant land use for each forty-acre parcel. However, it is included in the detailed category because of its additional information such as acres of all land per person, acres of private land per person, market value of land and buildings, and so forth.

The basic information was black and white aerial photography at a scale of 1:90,000. Additional information was added from government agencies and university projects. The product is computer graphic maps. As with all such projects, the main problem is to make the information known and available to anyone who needs it. This project is a good example of the type of information that would be useful on a regional level.

The MLMIS is transferable to other areas. However, it is not just a land use inventory. As its name suggests, it is a management tool.

RESTRICTIVE GROUP

Space Photos for Land Use and Forestry - This project attempts to answer the question: "Can forest be separated from other land uses and how?" (Aldrich, 1971). The source of information was color photography from Apollo 9. The multiband photographs were studied by machinery to rate the four films by their value for forest interpretation. Automated as well as manual interpretation was used for areas in Mississippi and Georgia. Additional information was gathered by photography available from aircraft. Ground observation was extensive with some information being gathered tree by tree.

The study did answer its question. However, the inventory is transferable only within the Forest Service and related agencies. This information is needed at times. But instead of constructing an inventory for each project, a better approach might be to include forestry categories in a larger, more universal system. Then a user primarily concerned with forestry could use only the forest categories and the meaning of the results would be universally understood for anyone who is familiar with the system.

The high reliance on aerial photography and ground observation raises some questions as to the repeatability of the project results. If one area had been studied extensively and then the other location had been studied by only orbital photography, the repeatability of the results might be more easily determined. If ground observation is a large part of the data collection for an inventory, then the manpower costs must be examined. On a large scale, the manpower costs for this study would be prohibitive.

Urban Field Land Use of Southern New England: A First Look - The Purpose of this project is to investigate urban sprawl. The northeast megalopolis is the scope of the study with the focal point being the Narrangansett Bay-Rhode Island area. The source of information is color composites from ERTS-1 with some back-up data from RB-57 imagery. This is one of many NASA-sponsored research projects. The information available was not a final report. Therefore, there will probably be some changes in the investigation between the time of this report and the end of the project.

The project is included in the restrictive category for only one reason. The classification system is oriented toward housing, particularly urban housing. This is logical since the project is focused on an urban area. However, this limits its repeatibility to only urban projects. The classification system has been developed by studying the imagery first. This is a direction only a few projects take. However, because of its urban emphasis, it is not practical for a large scale inventory without reorganization.

Susceptibility of Environments to Low Resolution Imaging for Land Use Mapping - This study considers the effectiveness of low resolution images to collect information in areas of different spatial complexity in 106 county sites representing environments spread throughout the United States (Simonett, 1971). The project was sponsored by the United States Geological Survey in connection with the then upcoming launch of the Earth Resources Technological Satellite (ERTS).

Simulation of 800, 400, 200, and 100 foot resolution cells was accomplished by using transparent overlays. These were used in connection with aerial photos at the scale of 1:20,000. The purpose of the simulations was to estimate the capabilities of ERTS images.

The sites were grouped according to complexity. Then the sites were clustered by computers and by humans. After this process was completed, their interpretability was rated. It was decided that ERTS would be most effective in areas where humans did not make land changes, or where the ground cover is nearly all the same over a large area.

The needs of the research reflect greatly in this classification system. This is understandable. The categories included would be relevant in judging the interpretability of low resolution imagery. However, the system is not transferable to any other type of project. The eight major categories are very general and, therefore, could be used at the first level nearly anywhere in the United States. But at the second levels the emphasis changes from general to specialized areas. The categories at the second level are not of equal value, and there are many land uses that are not included. Grassland is separated into pastures and naturally occurring grassy areas. Woodland has only one level but is differentiated into species at some undetermined time. Settlement is broken into four categories: urban areas of all sizes, farmsteads with trees and stockpens, all roads within a cell, and other transportation lines. There is no provision for urban features that occur outside an urban area. This discrepancy at the second level makes this system non-transferable and, therefore, places it in the restrictive category.

A Regional Approach to Wildland Resource Distributional Analysis Utilizing High Altitude and Earth Orbital Imagery - The source of information for this study is ERTS-1 imagery, RB-57 small scale photography, ground observation, and some large scale aerial photographs. The interpretation is done manually. The testing of manual interpretation procedures and development of interpretation aids are some of the objectives of this study (Krumpe, 1973). The testing of the interpreters has proved they can interpret validly the major areas of the inventory. Krumpe states that a large amount of ground observation will be needed. If this is true, perhaps the use of automated devices or a less detailed classification system is needed.

This project, as far as could be determined, did not take requests from potential users. That is not to say that this inventory may not be valid. However, the extra time it would take to contact potential users would be justified to insure acceptance by these users.

This project is a vegetation inventory and includes land use only after identification through vegetative classification. As it stands, the vegetation inventory is valuable to anyone studying or living in the western United States. However, it is localized and is not transferable to other areas. Most places in the United States cannot be interested solely in vegetation types even if the major interest is wildland area. Data on urban structures and other man-influenced sites would need to be expanded into more than one category.

This classification is an illustration of a system suitable for application to a highly localized situation. Some of the units are identified by geographic reference to a given stream or watershed. Because of this, it would be essentially impractical to transfer it to any other location.

ELEMENTAL GROUP

United States Geological Survey Circular 671. A Land Use Classification System for Use With Remote Sensor Data - This system was developed at the request of the Department of the Interior. With the use of space platforms and the rapid development of remote sensing technology, more and more agencies and groups are turning to remote sensors for information. The need became apparent for a universal classification system to satsify the needs of federal agencies and still maintain uniformity in formatting similar data to be used by several agencies. This system had to be up-to-date and applicable to any area of the country. The basis for recording inventory data also needed to be uniform in data, scale, and categorization at the first and second classification levels (Anderson, et al, 1972).

This classification is open-ended, so that any state or local agency can develop a more detailed land use classification by adding more levels. As a result of the needs of the federal agencies, the Land Use Classification Scheme for Use With Remote Sensor Data is being applied. In particular, this system is being used extensively in research connected with the NASA contracts for ERTS-1 studies.

The system is developed to the first and second levels only. There is an option to expand it to third and fourth levels, and both would be applicable to fairly detailed studies. However, before levels three and four are developed, the first two categories must be deemed accurate. As a result of extensive use of the existing system, an acceptable, revised system should ensue.

Macro- Land Use Mapping With Simulated Space Photos - This research project was carried on under the auspices of the United States Geological Survey.

The purpose of the study was to investigate the limitations of land use mapping that may result from the small scale of ERTS-1 and other satellite imagery (Rudd, 1971). No Apollo 9 photos were available for the Pacific Northwest. Therefore, a photomosaic at a scale of 1:400,000 was developed for northwest Oregon and southwest Washington.

The project was carried out as a three-stage effort. First, a general classification was developed. This was later proved inaccurate because the categories did not match what could be seen. This is a fairly common occurrance as the project designers attempt to "outguess" their sensor systems.

After the initial mapping experience had defined what could be interpreted a new classification system was created. The classification system was built in levels similar to the USGS scheme. According to Rudd, the subdivisions under the major categories in his system were not equal but they could be adjusted to be made more equivalent.

The last stage was to verify the results. This was done through the use of aerial photographs at the scale of 1:30,000. The interpretation was done manually. There was little reliance on ground observation, even though the aerial photos used were flown in 1953.

Rudd's category definitions are explained by signature notations. The attempt to find signatures needs to be tested. The signatures may be valid for high altitude black and white photography. But such signatures would not likely transfer to multiband scanner imagery. The great difference in the physical makeup, resolution, and optical concepts between photographic and scanner images would require a thorough analysis before transferring the concepts of this system to studies.

A Study of the Utilization of ERTS-1 Data From the Wabash River Basin; An Analysis of ERTS-1 Data - This project is one of several ERTS projects at the Laboratory for Applications of Remote Sensing. The study uses automatic data handling techniques. The classification system is limited by the capabilities of the hardware and software. That is not to say automated processes do not work. They do, but categories sometimes are selected because they are easily distinguishable rather than because they are of high potential benefit to a user.

The classification system has been developed and expanded over a long period of time, even prior to the original listing in the NASA Earth Resources Survey Program weekly abstracts published by the Department of Commerce. At first, the classification system dealt with agriculture and forest. Now it has expanded (J. B. Peterson, personal communication) so that it closely resembles the USGS scheme. Because it has six general categories without subunits, it is included in the elemental grouping. It is uncertain if any time has been spent on dividing the information into levels of categories. The level system would seem to lend itself to automated data handling techniques, but obviously will be limited by the capabilities of the hardware used in the system, and, in some cases, the software that is available.

APPENDIX B

NEW YORK STATE COLLEGE OF AGRICULTURE AND LIFE SCIENCES

CORNELL UNIVERSITY

RESOURCE INVENTORIES SURVEY

NAME ______________________________

AGENCY______________________________

DATE ______________________________

I. Choose the best scale for you. Number them in order of preference:

1:500,000__________

1:250,000__________

1:125,000__________

1: 25,000__________

Other______________

II. This list of possible applications was made by interviewing only two people. Check any of these you could use. Please list as many others as possible.

recreation______________________

transportation routes____________

forest growth___________________

forest decrease_________________

strip development_______________

existing farmland areas__________

city growth_____________________

existing urban sprawl____________

extractive industry______________

wetlands________________________

drainage patterns________________

industrial development___________

soils____________________________

water pollution patterns__________

others:

____

____

____

____

____

____

____

____

____

____

III. How do you get information at the present time?

USGS topo maps_____________

county road maps___________

memory_____________________

others:

____

____

____

____

IV. If the possibility of continually updated material would be of the most value to you, please fill out these two sections.

A. I would like my information updated every:

two months___________

six months___________

other

B. I could not use information that was older than:

three months__________

six months____________

one year______________

other_________________

COMMENTS:____

____

____

____

____

____

Scale Size	Percent Utilization
1:500,000	4.34
1:250,000	13.04
1:125,000	34.78
1:25,000	78.26
1:1000	8.69
1:2000	8.69
1:6000	8.69
1:62,000	8.69
1:12,000	8.69
Other	39.06

Table 4A. Reference Question #1 on survey. These are compiled results in terms of percentiles of relative use and preference for different map scales.

Subject	Percent Requested
Water quality	121.52
Existing farmland areas	73.91
Wetlands	73.91
Soils	73.91
Recreation	60.86
Forest growth	60.86
Existing urban sprawl	60.86
Drainage patterns	60.86
Transportation routes	56.52
Strip development	56.52
Forest decrease	39.31
City growth	34.78
Industrial development	34.78
Extractive industry	30.43
Slope	8.69

*This subject has a percentage of over 100 percent because users, in addition to checking water quality, added related subjects to the listing. The subjects were then grouped with water quality, inflating the percentage.

Table 4B. These are results of Question #2 giving in percentiles the possible applications for inventory surveys in which interviewees were interested.

Map Series	Percent Utilization
USGS	82.60
County road maps	69.56
Aerial photography	69.56
Memory	26.08
Soil surveys	26.08
LUNR products	21.73
OPS base maps	17.39
New York Department of Transportation	8.69
Ground survey	8.69
Niagara Mohawk power maps	4.34
Historical search	4.34
Geology surveys	4.34
Sanborn maps	4.34
Tax maps	4.34

Table 4C. Results of Question #3 on how interviewees currently obtain geographical and inventory information.

Oldest Usable Age	Percent Requested
Six months	4.34
One year	21.73
Two years	8.69
Three years	8.69
Five years	13.04
Ten years	17.39
Other	4.34
Not applicable	17.39

Table 4D. Results of Question #4 on the age of information at which time on update would be required.

Information to be Updated Every:	Percent Requested
Two months	4.34
Six months	8.69
One year	39.13
Two years	4.34
Ten years	8.69
One to five years	13.02
Other	8.69
Not applicable	17.39

Table 4E. Results of Question #5 depicting how frequently an update of an inventory would be desired.

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