E7.6-10.0.8 5.
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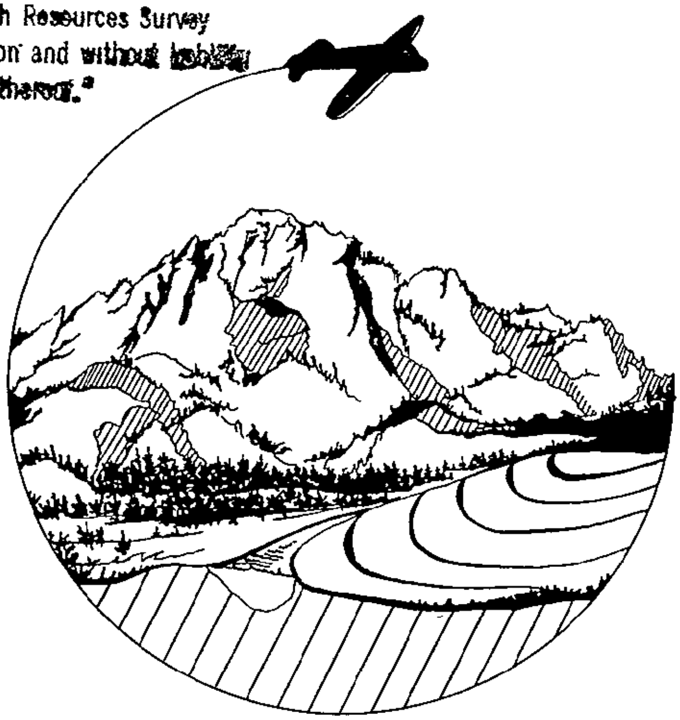

RESOURCE INFORMATION LABORATORY

ENHANCEMENT AND EVALUATION OF SKYLAB PHOTOGRAPHY FOR POTENTIAL LAND USE INVENTORIES

PART I

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DEPARTMENT OF NATURAL RESOURCES
NEW YORK STATE COLLEGE OF
AGRICULTURE AND LIFE SCIENCES
AT CORNELL UNIVERSITY

ENHANCEMENT AND EVALUATION OF SKYLAB PHOTOGRAPHY FOR POTENTIAL LAND USE INVENTORIES

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FINAL REPORT

July 1975

NASA Contract NAS 9-13364

Department of Natural Resources
New York State College of Agriculture & Life Sciences
a Statutory College of the State University at
Cornell University
Ithaca, New York

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PREFACE

This report covers the contract period from May 1, 1973 to July 31, 1975. It fulfills the requirements of the original and ammended Statements of Work and Article X concerning the reporting of work accomplished on NASA Contract NAS9-13364, "Evaluation of Satellite Imagery as an Information Service for Inventorying Land Use and Natural Resources. Due to delays in the receipt of data, actual work did not begin before September, 1973, with full staff committed by February, 1974. A major addition to the original Statement of Work included a User Needs Survey. This survey was conducted from August, 1974, to April, 1975. The remaining technical data and discussion contained herein pertains to the analysis of Skylab data and its utility for inventorying land use in New York State.

ACKNOWLEDGMENTS

During the course of any research effort, there are many individuals who make valuable contributions which are important in the successful completion of the project. Among those who contributed their professional skills to various investigative phases of the report, we gratefully acknowledge Debbie Stevens, Rodney Wulff, John Roebig, Mike Snowden, and Tom Orzel. We also would like to express our sincere appreciation to Ruth Lyon and Douglass Payne whose dedicated efforts and technical skills in the photo lab greatly contributed to the success of this project. Likewise, we would also like to express a special appreciation to Sherry Snyder for her dedication and forbearance in typing this report. Finally, a special thanks to all the New York State Extension CRD personnel, county extension agents, and to local, county and regional planners who cooperated with the staff in various phases of the work described herein.

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ABSTRACT

S190A and S190B Photography from the SL3 Skylab Mission was evaluated for possible applications in inventorying land use and updating an existing New York State land use inventory (LUNR). Three sites were evaluated: Finger Lakes-Tompkins County, Lower Hudson Valley-Newburgh, and Suffolk County-Long Island.

Special photo enhancement processes were developed to standardize the density range and contrast among S190A negatives. Enhanced black and white enlargements were converted to color by contact printing onto diazo film. A CIE Color Prediction Model was developed to automate the selection of color composites. This model related the density values on each spectral band for each category of land use to the spectral properties of the various diazo dyes. Combinations of spectral bands, diazo hues, and diazo exposures were selected so as to maximize the color contrast among land use categories being examined.

The S190A multispectral system proved to be almost as effective as the S190B high resolution camera for inventorying land use. Aggregate error for Level I averaged about 12 percent while Level II aggregate error averaged about 25 percent.

The S190A system proved to be much superior to LANDSAT (ERTS) in inventorying land use, primarily because of increased resolution. However, the S190A spectral information is not equal to LANDSAT in the infra-red bands. When the S190A is compared to the S192, the evidence suggests that carefully selected narrow spectral bands would be superior to the broader bands used on the S190A system.

A user needs survey was conducted to determine the land use information needs of various planning agencies in the state. Particular emphasis was placed on needs which might be filled by remote sensing systems,

including satellite data. Possible applications of satellite data at local, town, and county levels were limited; however, the number of potential applications and users increased considerably at the regional and state levels.

Final discussion centers on a need for greater concern in classification theory and how it relates to land use category definitions. Particular emphasis is also placed on the need for more technology transfer in the area of remote sensing and on the need for continued support of low cost analysis systems for evaluating satellite and other remote sensing data.

1.0 INTRODUCTION

1.1 Objectives and Scope of the Study

This study was undertaken to evaluate the use of Skylab EREP photography as a data source for updating existing land use inventories. Primary objectives included: the development of manual enhancement and interpretation procedures which are low in cost both in terms of capital investment and data analysis, and easily adaptable to situations requiring low technology. At the same time, information had to be produced with a high degree of accuracy formatted to meet the needs of most users.

Photographic data from the SL3 Mission was compared directly to the New York State Land Use and Natural Resources Inventory (LUNR This inventory was compiled from 1968, 1:24,000 scale, black and white air photos for up to 55 different land use classes. The LUNR data products included drafted maps with curvilinear boundaries circumscribing each land use. A Universal Transverse Mercator (UTM) grid system was then superimposed on these curvilinear figures which approximate polygons. The problem of updating such a detailed inventory was similar to trying to match polygons from two different data sources, each having a different set of parameters defining their respective polygons. These parameters included different sensor systems, scale and category definitions.

There are a number of difficulties encountered when attempts are made to duplicate previously designed classification systems. Most frequently, there is inadequate documentation of the procedures previously used to allow for accurate comparison. This was not a severe problem in the case of the LUNR inventory, as it was well documented, and a number of the technical staff from the LUNR project were available for work on this research project.

Duplicating a previously designed inventory is a very different procedure from the more usual time-lapse analysis approach used to measure changes in land use. In time-lapse analysis of air photos, the physical characteristics of the sensor is the same for each time period. Usually the analysis is in relation to specific types of changes with knowledge that both periods of photography will display the desired information.

When different sensor systems are used, as was the case for this research project, the classification must be modified in relation to the physical characteristics of the sensing devices. (Anderson, Hardy, Roach, 1972). Full recognition of the capability of the physical properties of a sensor is essential for any classification system. And in like manner, if two or more sensor systems are to be employed in relation to each other, the differences in their physical properties must be recognized as a factor in determining suitable classification systems to use. A more complete discussion of these relationships is found in Section 7 of this report.

Before final interpretation procedures were defined, special photographic enhancement steps were developed to balance the contrast and density range of the S190A multipsectral array. These steps were refinements of procedures developed by Phillips (1974) for processing LANDSAT (ERTS) data. In addition, a method was developed to standardize and automate the selection of color diazo film composites to enhance various land use categories. This method used a CIE Color Prediction Model which quantitatively related selected black and white density values from enlarged spectral bands to the spectral properties of the diazo films. It then chose combinations which maximize the color contrast among selected densities. In this way, colors on composites were related to various spectral categories.

Finally, an indepth survey was conducted to determine the information needs of various users of land use data of New York State. Both questionnaires and personal interviews were employed. Emphasis was placed on the kinds of data presently being used, requirements for new or updated information and the potential of satellite data to meet some of their needs.

1.2 Description of Test Site Areas

Three test sites were chosen in New York State to include very diverse land use patterns. The three test sites included: Tompkins County-the City of Ithaca in the Finger Lakes Region, the Lower Hudson Valley-the Cities of Newburgh and Kingston, and Suffolk County-Long Island.

The land use patterns in New York State are a patchwork mixture of urban, rural residential, agriculture, and forest. Except in major urban areas or very rural regions, there is little uniformity of land use. In addition, even agricultural patterns tend to be small with many fields of 10 acres interspersed with forest, brushland, or rural residential. This contrasts dramatically with land use patterns in the midwest and western United States where large, uniform expanses of a single land use are much more common.

1.2.1 Tompkins County-Ithaca

The 600 square kilometers which are in the Tompkins County test site are located between the UTM Lines 4690000m N. - 4720000m N. and 360000m E - 380000m E. This area is in the northwest corner of Tompkins County which includes the city of Ithaca and the southern tip of Cayuga Lake. The topography of the area has moderate relief with rolling hills in the upland areas and the Cayuga Lake basin in the valley. This region is shaped primarily by glacial action with some steep gorges, ravines, and hanging valleys.

The soils of this area are formed mostly from glacial till and the influences of the underlying bedrock. The depth to bedrock is generally shallow in the upland areas and consists of sedimentary rock such as, limestone, sandstone, and shale.

The climate is a humid continental type which is similar to the rest of New York State. The forest type is an upland northern hardwood which is mixed with coniferous species in the steep valleys. Most of the land was cleared for agriculture and much of it has returned to second and third growth woodlots. One of the main land uses is agricultural, especially dairy farming, even though the agricultural viability is from low to moderate. There are all stages of plant succession evident from fallow fields to emerging brushland and young forest regrowth. This is a reflection of the trend toward fewer active farms in the region.

The Ithaca city area has a population of approximately 30,000 with many small suburbs and villages in the surrounding region. The main industry of the city is education and research, although the area is generally a rural agricultural region.

1.2.2 Lower Hudson Valley-Newburgh

The 400 square kilometer Lower Hudson Valley test site is defined by UTM Lines 4590000m N.- 4610000m N. and 570000m E. - 590000m E. The area includes the city of Newburgh, Stewart Air Force Base and a portion of the Hudson River. The topography is of low relief and has underlying bedrock that varies from slate and schist to shale and sandstone. The soils and drainage offer only fair to poor agricultural viability but much of the land is used for dairy, fruit and some vegetable farming. A considerable amount of land is currently in different stages of regrowth from fallow fields to brushland and young forest woodlots, as this area shows a trend to fewer active farms.

The natural vegetation is a mixed northern hardwood forest with coniferous species included in the steep valley areas. The climate is similar to the rest of New York State's humid continental weather patterns.

The city of Newburgh has a population of approximately 30,000, which does not reflect all of the suburban developments around the city and near Stewart Air Force Base. The city is a small industrial area and the rural areas still maintain a fair amount of agriculture, particularly dairy.

1.2.3 Suffolk County-Long Island

The 600 square kilometer test site in Suffolk County, Long Island is located between UTM Lines 4510000m N. - 4540000m N. and 680000m E. - 700000m E. This area is a cross section of the island, which includes the city of Riverhead and several smaller residential communities on the south shore of the island. The topography is a very low relief formation of the Atlantic Coastal Plain, with two sandy morraines running the length of the island. These unconsolidated sands and gravels are shaped on the south shore into the characteristic barrier beaches, sand bars and bay areas.

The soils have good drainage and respond well to both fertilization and irrigation. The coastal climate, which has adequate precipitation and a long growing season, provides a potential for two crops per year. These characteristics and close proximity to the New York City market promote intensive and very specialized vegetable, fruit, and sod farms.

The natural vegetation includes regions of mixed hardwood-oak forests, pitch pine-oak forests, and the low brushland species characteristic of the sand dune habitat.

Although the area is largely a residential and recreational suburb of New York City, there is still a fair amount of land which is intensively managed for agricultural uses. Two large airfields are also evident in this area: Suffolk County Air Force Base and Grumman Aircraft Engineering Corporation airfield.

2.0 METHODOLOGY

The development of the methods described in this section began after the completion of the Final Report - "ERTS Evaluation for Land Use Inventory," (Hardy, Skaley, Dawson, Stevens, 1974) NASA Contract #NAS5-21886.* This report outlined in detail a two-step enlargement process necessary to produce multispectral enhancement on the low contrast ERTS imagery. The SL3-S190A photographic products were of a higher contrast and a one-step photographic process proved more efficient and effective for a multispectral enhancement system. The following sections will explain in detail the procedure by which a one-step enhancement system is constructed for operation in a conventional darkroom.

A further consideration for the SL3-S190A enhancement was to choose a scale of photographic enlargement which would be inexpensive, easy to handle and repeatable. The S190A photographic products were enlarged to the 1:250,000 scale to minimize the cost of the photographic procedure, as it would cost 16 times more in materials to go directly to the 1:62,500 scale. Also, the logistics of processing and handling dictated the use of a smaller scale and a projection technique to enlarge the color composites to the desired scale (1:62,500). The overhead projector and backlighted screen technique proved very adaptable to testing various scales and enlarging the other original S190A and S190B products.

The development of these techniques and the color composite selection process will be elaborated upon in the following sections. Some mention will also be made of tests on the S190B film products and subsequent enlargement procedures.

The following three tables and one figure state the specifications of the S190A, S190B, and S192 sensor systems for reference to discussions in the following sections.

*Agency: Cornell University, Department of Natural Resources, New York State College of Agriculture and Life Sciences. Available as a NATIONAL TECHNICAL INFORMATION SERVICE Publication #N7327248.

TABLE 2.0.1 - All S190A photographic products usable over New York State are from the SL3 Mission at scales of 1:2,850,000 and approximately 1:712,500, a 4X enlargement

S190A Station	Filter	Filter, Band Pass Micrometers	Film Type Eastman-Kodak Company
1	CC	0.7 - 0.8	EK 2424 (B&W infra-red)
2	DD	0.8 - 0.9	EK 2424 (B&W infra-red)
3	EE	0.5 - 0.88	EK 2443 (Color infra-red)
4	FF	0.4 - 0.7	SO 356 (Hi resolution color)
5	BB	0.6 - 0.7	SO 022 (Panatomic-X B&W)
6	AA	0.5 - 0.6	SO 022 (Panatomic-X B&W)

TABLE 2.0.2 - All S190B photographic products usable over New York State are from the SL3 Mission at scales of 1:950,000 and approximately 1:475,000, a 2X enlargement.

S190B

Film Type Eastman-Kodak Company	Wratten Filter	Filter, Band Pass Micrometers
SO 242 (Hi resolution color)	None	0.4 - 0.7
EK 3414 (Hi resolution B&W)	#12	0.5 - 0.7
EK 3443 (Infra-red color)	#12	0.5 - 0.88

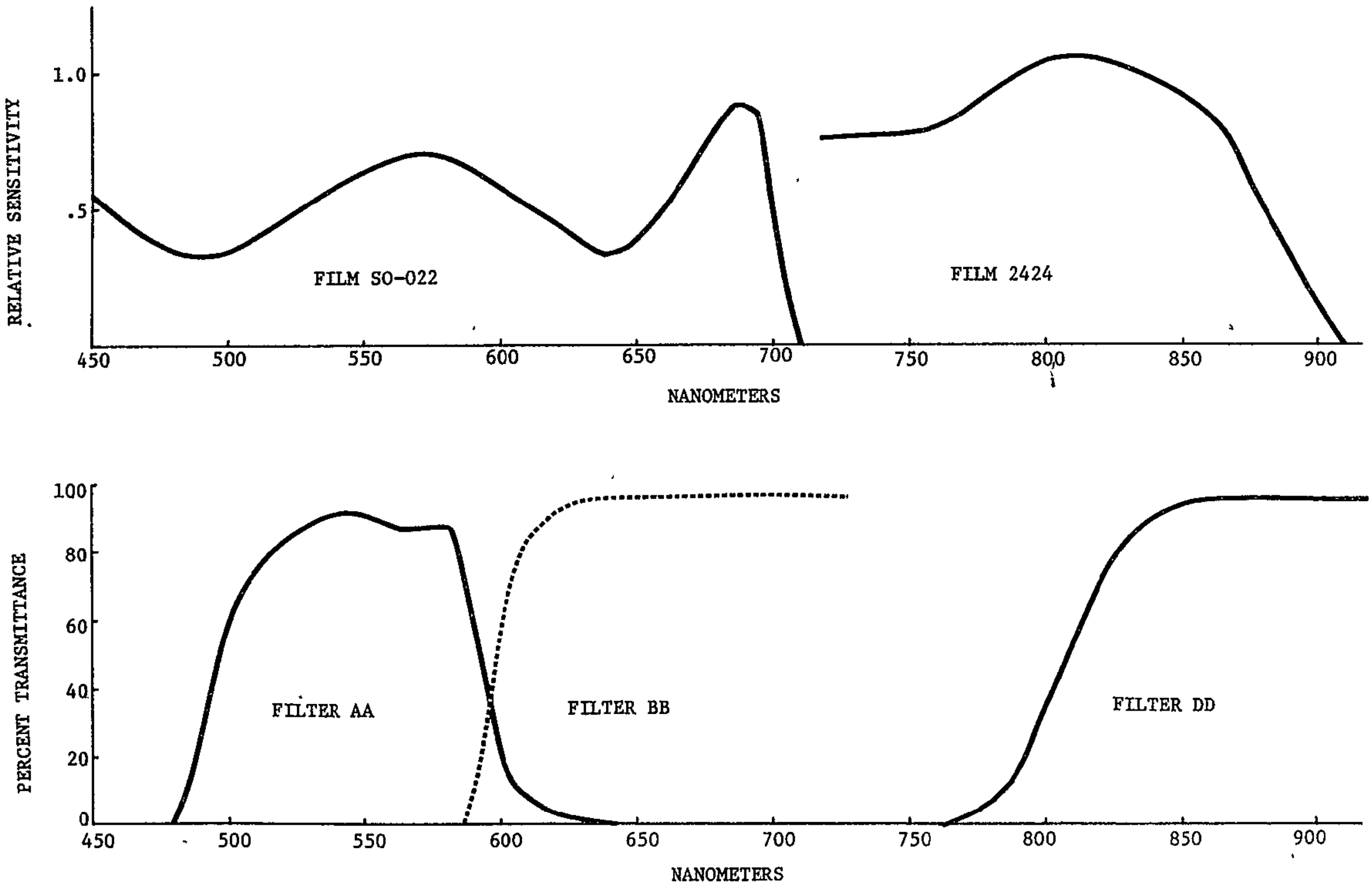


FIGURE 2.0.1 S190A film sensitivity and filter transmittance.

TABLE 2.0.3 - S192 Multispectral Scanner Configuration

S192

Band Number	Wavelength Micrometers
1	0.41 - 0.45
2	0.44 - 0.52
3	0.49 - 0.56
4	0.53 - 0.61
5	0.59 - 0.67
6	0.64 - 0.76
7	0.75 - 0.90
8	0.90 - 1.08
9	1.00 - 1.24
10	1.10 - 1.35
11	1.48 - 1.85
12	2.00 - 2.43
13	10.20 -12.50

2.1 Photo Enhancement and Processing of S190A Photography

The photographic processing procedures for the S190A are outlined briefly with the flow diagram in Figure 2.1.1. This one-step enlargement process from the original 70 mm negative film (scale of 1:2,850,000) to a film positive (scale of 1:250,000) involves a test procedure to determine the density range of the original. From the experimental data, the correct film, developer and development time can be calculated to bring each spectral band (Filters AA, BB and DD) to the same density range. This desired density range is determined by the Log exposure range of the color diazo film, so that the resulting color composite will contain the largest possible density range for the best color separation. The density range of the contact negative film (scale of 1:250,000) is the same as the positive but in a nearly reciprocal relationship. These three spectral bands, both negative and positive, are then duplicated in contact with the direct positive-forming diazo films of cyan, magenta and yellow. The three subtractive color films of cyan, magenta, and yellow can be combined from various spectral bands (positive and negative) to form a wide range of possible colors.

GAF diazo film was compared to three other manufactured films and was selected on the basis of the spectral curves of the dyes for cyan, magenta and yellow. The Log exposure range equals approximately 1.0 for all three films. Therefore, the black and white film which is contact printed onto the diazo film should have a density range of 1.0 (excluding clouds). This will maximize the density range on the color diazo film by using the straight line portion of the characteristic curve (density vs. Log exposure). A quadrant diagram illustrates the relationships between the characteristic curve of the contrast corrected black and white film, the characteristic curve of the diazo film, and the color reproduction (see Figure 2.1.2).

It is, therefore, necessary to be able to correctly choose a film, developer, and development time that will result in an enlarged positive film with a density range of 1.0 for each of the three spectral bands.

S190A PROCESSING PROCEDURES

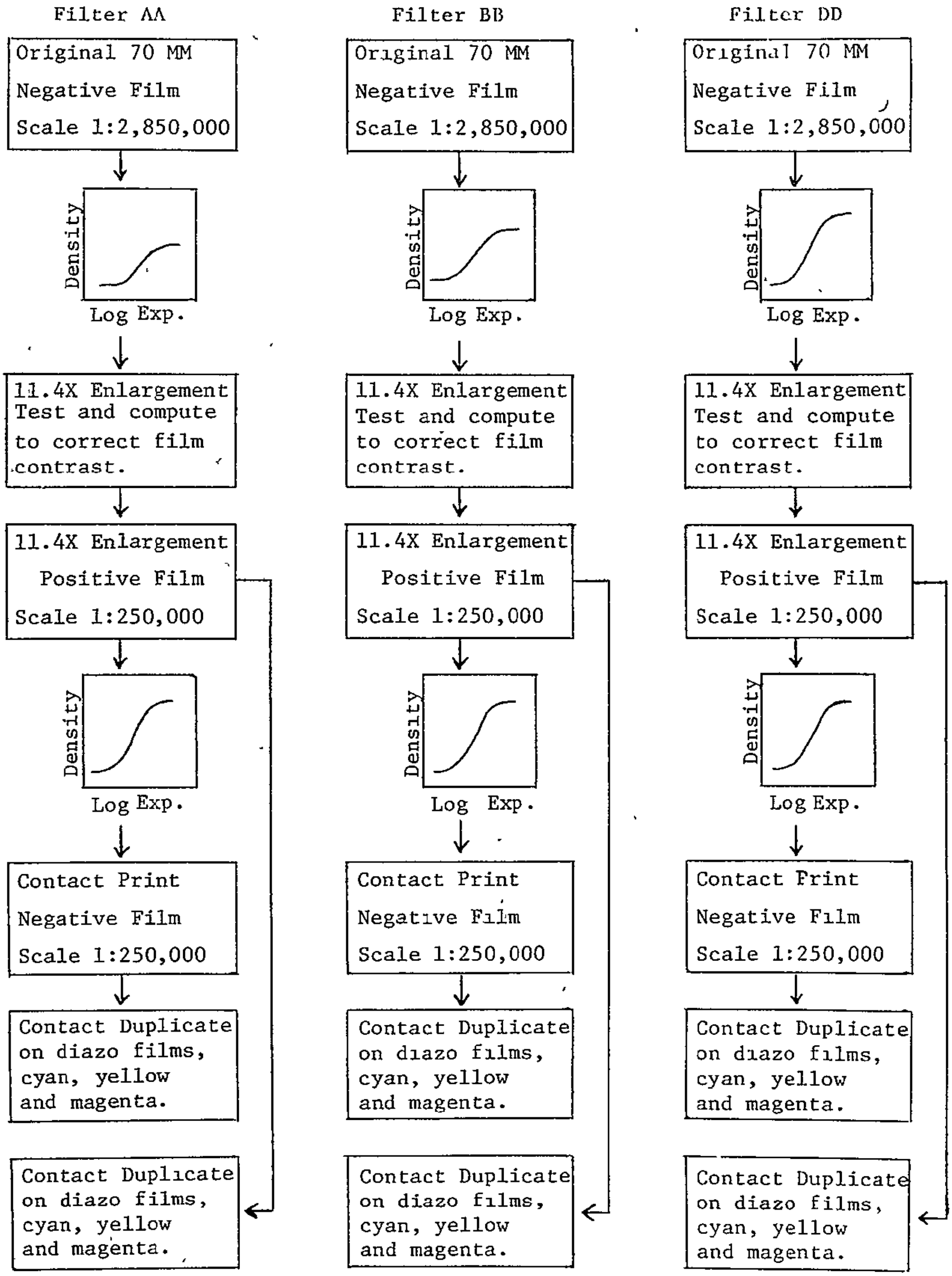


FIGURE 2.1.1

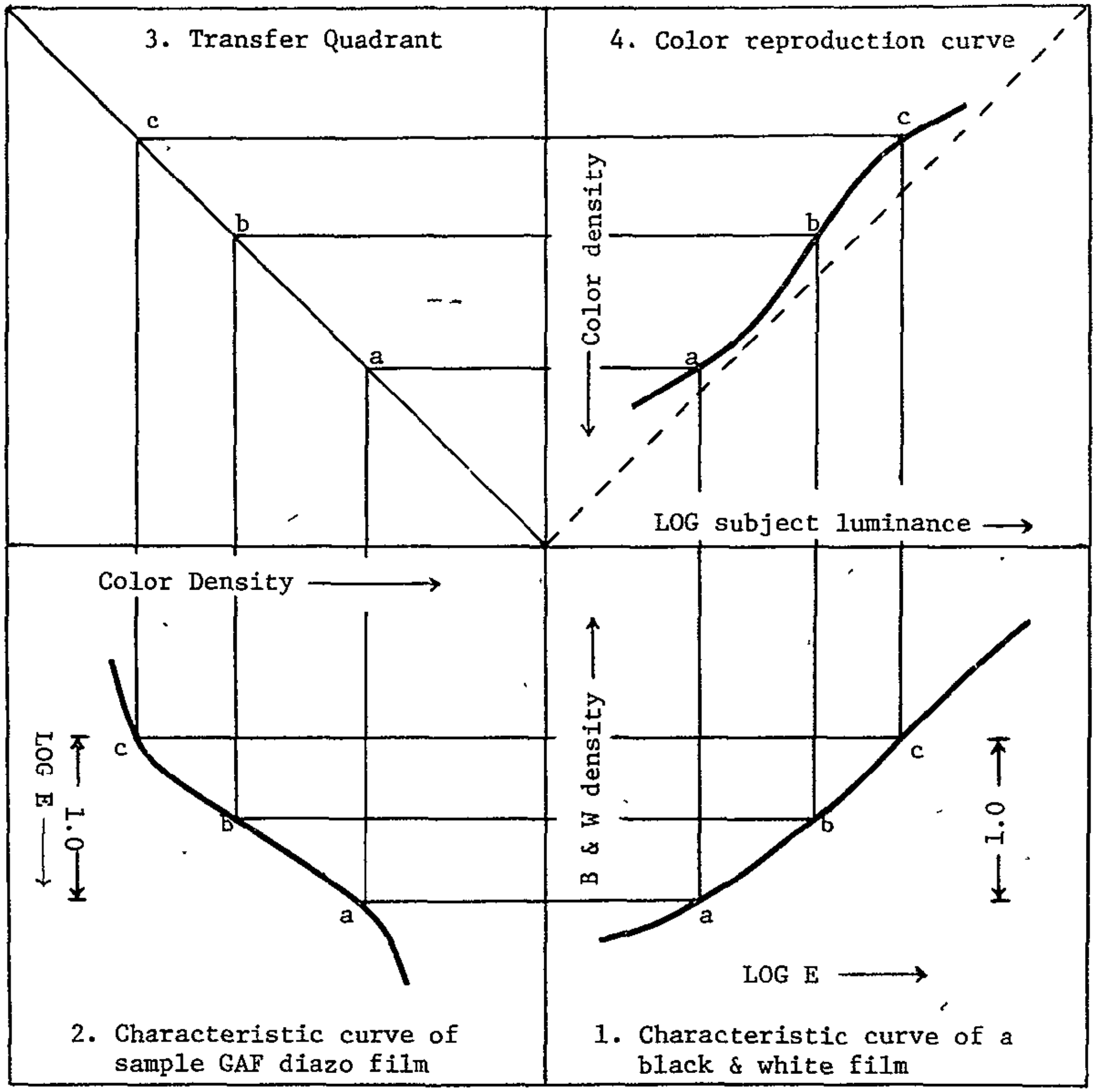


Figure 2.1.2 The quadrant diagram indicates the relationship between an original black and white film and the color diazo reproduction.

The first step is to determine the density range of each spectral band negative. This can be done by direct diffuse densitometer measurement if the areas are of sufficient size to accurately measure, or experimentally by projection printing on Kodak Polycontrast paper. Use any polycontrast filter necessary to achieve a "normal" print, which contains detail in the "shadow" and "highlight" areas. As indicated in the quadrant diagram, a "normal" print results when the density range of the original is approximately equal to the Log exposure range of the paper. Therefore, when we have a "normal" print, we can use the known polycontrast filter Log exposure range to approximate the density range of the original. For example, if we find that a Polycontrast #3 filter produces a "normal" print and the Log exposure range is 0.85 (see Table 2.1.1), then the original can be assumed to contain a density range of approximately 0.85 for that particular spectral band.

TABLE 2.1.1 -- The contrast paper necessary to make a normal print indicates the Log exposure range of the film that is required for a density range of 1.00.

KODAK GLOSSY POLYCONTRAST PAPER WITH PC FILTERS	KODAK GLOSSY CONTRAST GRADE PAPERS	LOG EXPOSURE RANGE OF KODAK PAPERS	LOG EXPOSURE RANGE REQUIRED TO PRODUCE FILM OF 1.00 DENSITY RANGE
	0	1.50	1.50
PC 1	1	1.25	1.25
PC 1½		1.15	1.15
PC 2	2	1.05	1.05
PC 2½		0.95	0.95
PC 3	3	0.85	0.85
PC 3½		0.75	0.75
PC 4	4	0.70	0.70
	5	0.55	0.55

This information can be used to determine the film, developer and development time by matching the Log exposure range of the paper (or density range of the original) to the Log exposure range of a black and white film. As a first step, however, it was necessary to experimentally determine the characteristic curves of several films, developers and development times by exposing a #2 Kodak density step wedge in contact with a film and then develop it for a standard time. This procedure is continued on the same film type while varying the development time and developers for subsequent test strips. Several films and developers were tested to produce a wide selection of Log exposure ranges for different situations. The densities of the step wedge (Log exposure range) were plotted vs. the film densities and a series of characteristic curves are illustrated in Figure 2.1.3.

Each characteristic curve was measured to determine the Log exposure range between the film densities of 0.30 and 1.30 (see Figure 2.1.4). This was done to keep the enlarged film densities on the lower straight line portion of the curve and to avoid compressing information on the "toe" of the curve. This data was condensed into a graph of Log exposure range vs. development time, such that each film type has a family of curves for each developer tested (see Figure 2.1.5).

From the above described system, the Log exposure range necessary for a "normal" print can be determined for a negative of unknown density range. This same Log exposure range indicates the film, developer and development time necessary to produce a positive film with a density range of 1.0, between 0.3 and 1.3. The black and white positive film (1.00 density range) is then contact printed into a negative film format. However, the test procedure is not necessary because the negative film, developer and development time can be chosen knowing that the positive film has a 1.00 Log exposure range (1.00 density). This will produce a negative with a 1.00 density range and a nearly reciprocal relationship to the positive film.

The following example contains the data necessary to produce Figure 2.1.6.

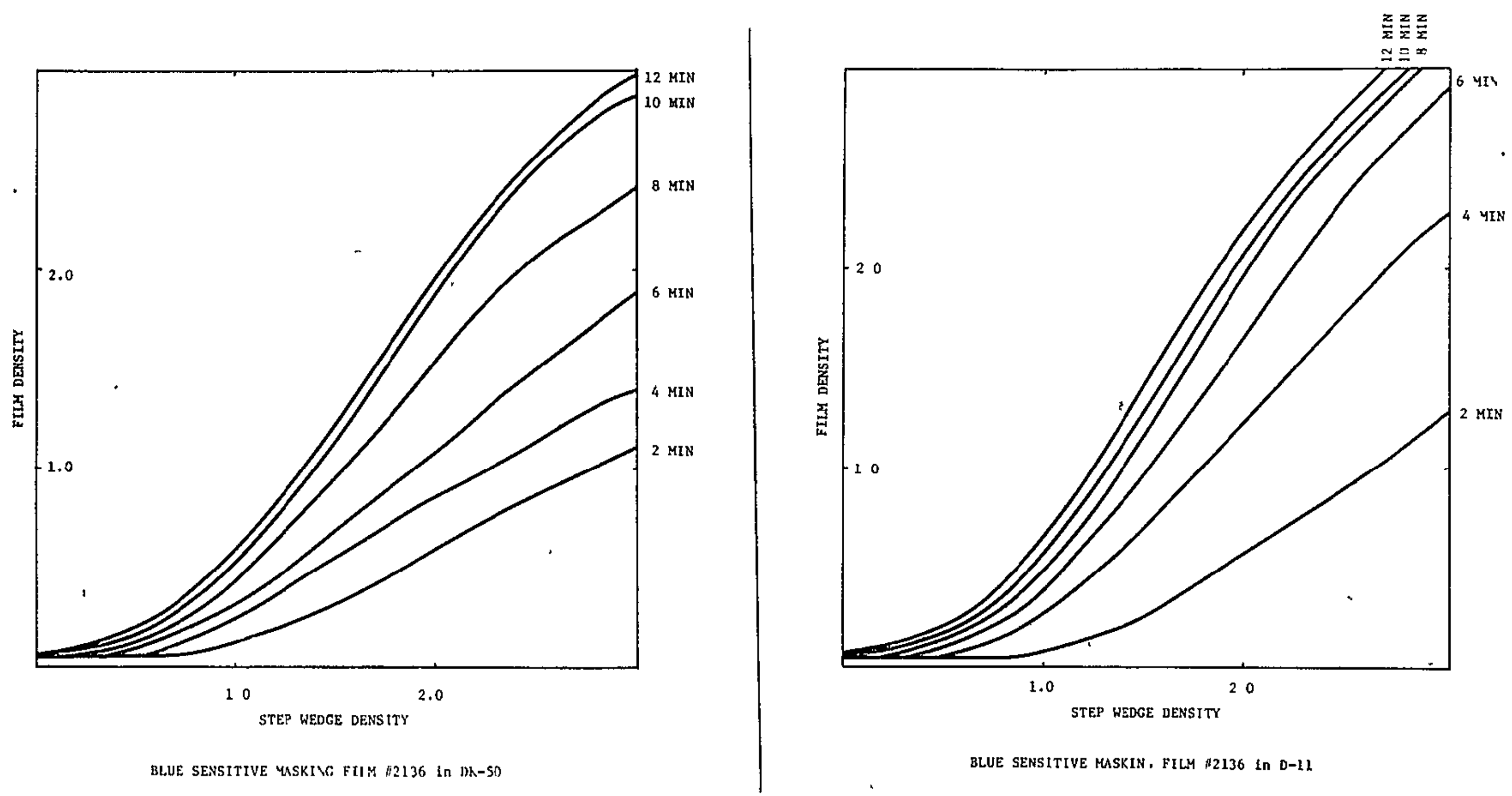


FIGURE 2.1.3 Characteristic curves for Blue Sensitive Masking Film #2136 in two different developers.

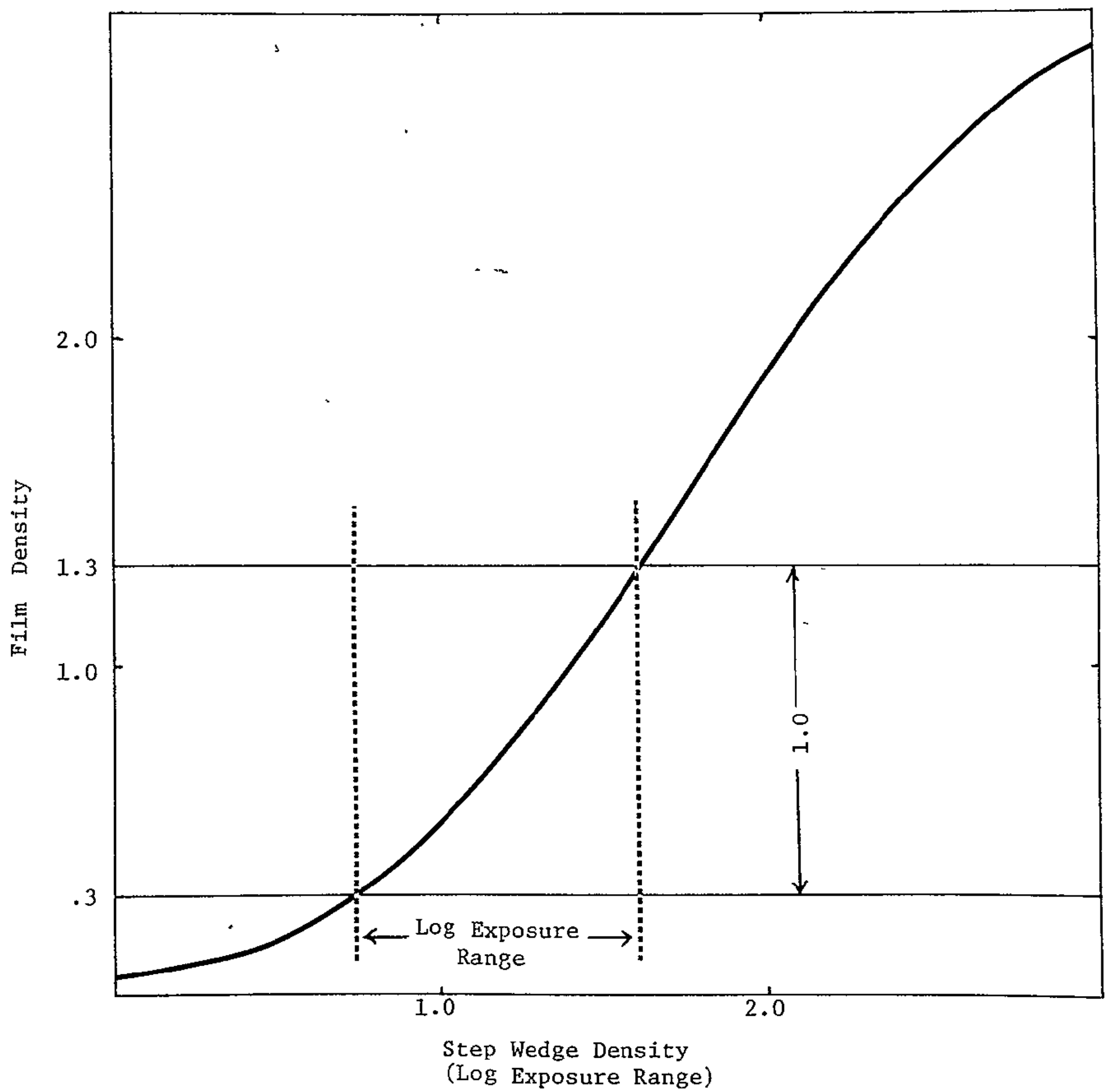
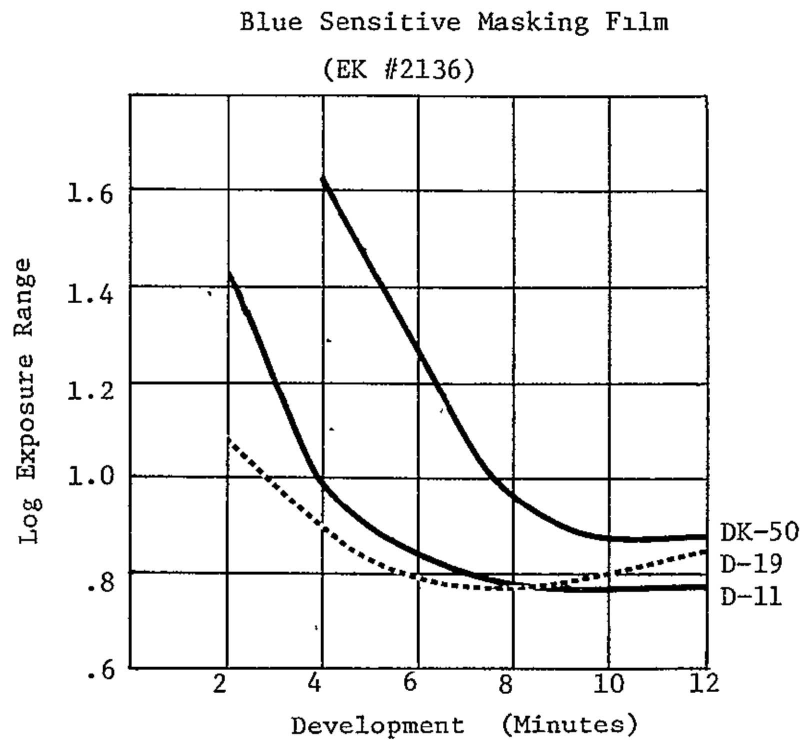


Figure 2.1.4 Measure the Log exposure range of a film from the characteristic curve.



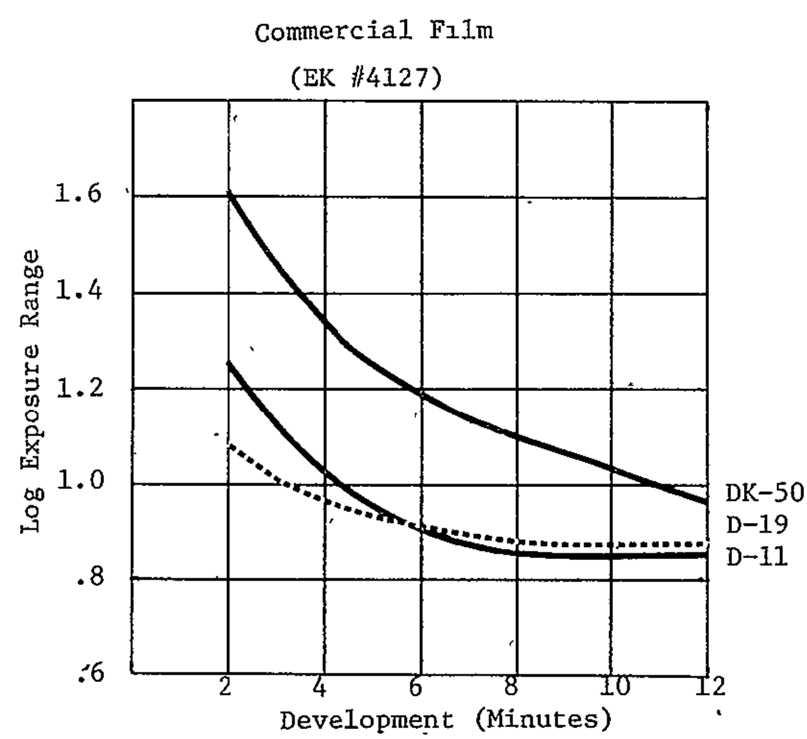


Figure 2.1.5 Graphs of the Log exposure range vs. development time for two films and three developers.

	FILTER AA NEGATIVE	FILTER BB NEGATIVE	FILTER DD NEGATIVE
Polycontrast Filter ("normal" print)	PC 3½	PC 3	PC 2
Log Exposure Range	.75	.85	1.05
Film	Blue Sensitive Masking Film #2136		
Developer	D-11	D-11	D-11
Development Time	8 min.	6 min.	3½ min.

The resulting positive films (1.00 density range) are all contact printed onto Blue Sensitive Masking Film and developed in D-11 for 4 minutes to produce reciprocal negatives. It is important to note that test prints (and films) never match in individual areas exactly because of different spectral information. However, the prints should "match" in the sense that each print overall has the same density range (see Figure 2.1.6). Data represented in the preceeding discussion are from experimental tests with Kodak films, papers and chemicals.

It is necessary to calibrate the system for each darkroom because of differences in chemical batches, film lots, processing conditions, agitation methods, enlarger optical contrast, and even such variables as water quality can produce significant variations from the specific data shown above. The above tests were carried out using a Leitz enlarger with a Focotar Leitz 1:4.5/50 lens at f11. All development was performed in trays at 70°F with continuous agitation and fresh developer.

It is entirely possible and feasible to use other products of known quality and characteristics to produce the data for this system. This would be desirable for imagery or photos that have inherently low contrast and require a higher contrast than the Polycontrast system offers. The other possibility for a very low contrast spectral band would be to repeat the above procedure in two steps to achieve the desired density range of 1.0 (0.3 - 1.3).

SL3 - S190A - FRAME 36 - ROLLS 42, 41 AND 38

Filter AA | Filter BB | Filter DD

Original Negative
Scale 1:2,850,000

Original Negative
Scale 1:2,850,000

Original Negative
Scale 1:2,850,000

Corrected Positive
11.4X Enlargement
Scale 1:250,000

Corrected Positive
11.4X Enlargement
Scale 1:250,000

Corrected Positive
11.4X Enlargement
Scale 1:250,000

Contact Negative
Scale 1:250,000

Contact Negative
Scale 1:250,000

Contact Negative
Scale 1:250,000

FIGURE 2.1.6

When a set of spectral bands are being enlarged into several black and white films, all from the same original negatives, it is only necessary to test each band once. Then all enlarged sections will have the same processing procedure and the resulting color composites will maintain continuity from one area to another.

2.2 Comparative Processing of ERTS-1 and Skylab Multispectral Photography

An attempted comparison between Skylab S190A and ERTS-1 imagery of the same area on the Hudson River was performed using images collected within 21 days of one another. The ERTS imagery,including Bands 4, 5, and 7, was taken on August 30, 1973 (Accession No. 1403-15120). The general procedures followed included a two-step enlargement process as described in the Final Report - "ERTS Evaluation for Land Use Inventory," (Resource Information Laboratory), 1974, NASA Contract #NAS5-21886. This two-step process allowed the generally low contrast ERTS imagery to be corrected to an acceptable contrast and density range for diazo composite printing. The processing followed the one-step procedure previously described. The original S190A negatives were collected by SL3 Mission on Rolls 44, 47 and 48, Frame 236 from September 19, 1973.

The resulting S190A color composite showed a remarkably close correlation to the ERTS composite of the same area, as can be seen in the simulated color IR scenes protrayed in color photo Figure 2.2.1. To obtain the desired color balance, it was necessary to "match" all test prints between spectral bands, as previously described, and also band to band between S190A and ERTS-1 imagery to insure equivalent results.

The ERTS-1 and Skylab S190A comparison, as represented in color Figure 2.2.1,consist of all positive films in the combination of Filter AA (band 4) in yellow, Filter BB (band 5) in magenta, and Filter DD (band 7) in cyan. The Skylab S190A composite includes a cloud and shadow which is not present in the ERTS-1 scene.

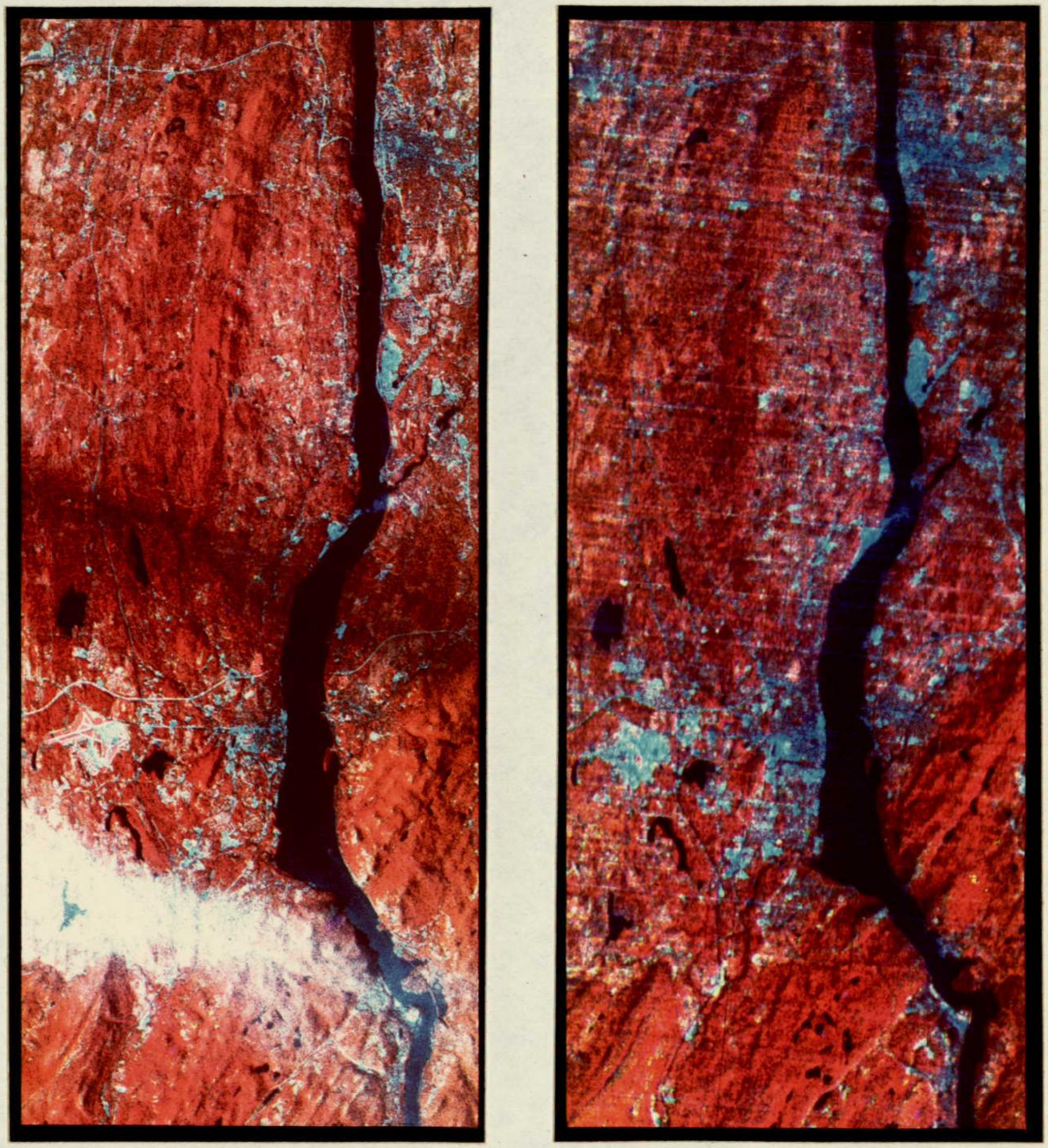


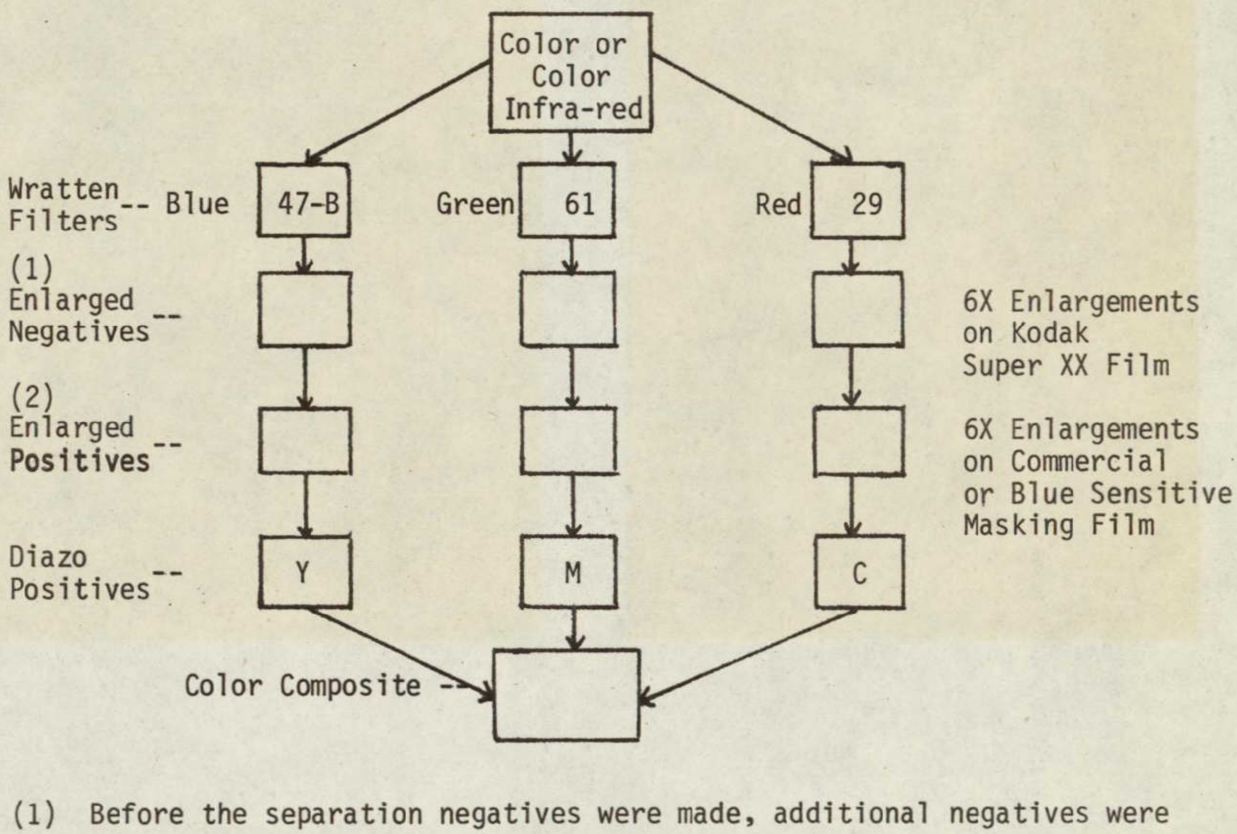
FIGURE 2.2.1 A comparison of Skylab S190A and ERTS-1 color composites for the Lower Hudson Valley, New York at a scale of 1:250,000.

2.3 Comparative Enlargement Techniques for S190B Photographic Products

2.3.1 Color Separation Techniques on Color and Color IR Films. Color separation techniques were conducted to produce low cost color enlargements and test diazo films for color separation materials. Several experiments were conducted using 1) NASA supplied duplicates from the High Resolution Color Film (Roll 88, Frame 277) and 2) NASA supplied duplicates from the Infra-red Color Film (Roll 87, Frame 299).

Portions of the duplicates were selected and enlarged to a scale of 1:24,000 (and later to 1:48,000). The steps discussed below were the same for both Color and Color Infra-red Films and no photographic masking techniques were used on either film.

The procedure is best outlined diagramatically:



(1) Before the separation negatives were made, additional negatives were projection printed with a gray scale through each filter to determine the

correct exposure and development time for the individual negatives.

(2) Before printing the enlarged positives, test prints were made on Polycontrast Rapid paper with no filter to check the final exposure balance needed. In general, Kodak Commercial or Blue Masking Film was used.

Current results indicate that 1:24,000 enlargements from the furnished color materials falls short of the sharpness desired for easy interpretation. However, 1:48,000 enlargements produced the same way were usable.

In an attempt to correct the color imbalances found in the magenta dye used in the diazo process and at the same time to give modest control of the contrasts in the original, further experiments were conducted with a single mask over the original before the separation negatives were made. The transparencies were mounted in a printing frame in contact with Kodak Pan Masking film and exposed with light from the enlarger through filters #33 and #81EF. "Unsharp" masks were produced using Kodak's .003 inch Kodapak Diffusion sheet. (Emulsion and diffusion layer always faced the light source). Maximum density of the mask was .45.

No trouble was encountered with registration. The results produced a slight improvement in the final composites but were deemed too slight for the additional steps involved. However, if strong enhancement of small areas on color enlargements is desired in the future, the single masking procedure holds considerable promise. Further enhancement by means of Highlight Masks and Multiple Color Masking may hold additional promise.

Figure 2.3.1 compares the False Color IR color composite (scale of 1:48,000),from the above described method, with a S190A color composite of the same area (Hudson Valley, New York) at a scale of 1:250,000.

2.3.2 Experiments Using Agfa Contour Film. Because a few other experimenters had reported some success with Agfa Contour Film, it was deemed advisable to investigate the possibility of this unique film's usefulness in conjunction with the diazo process. The experiments were

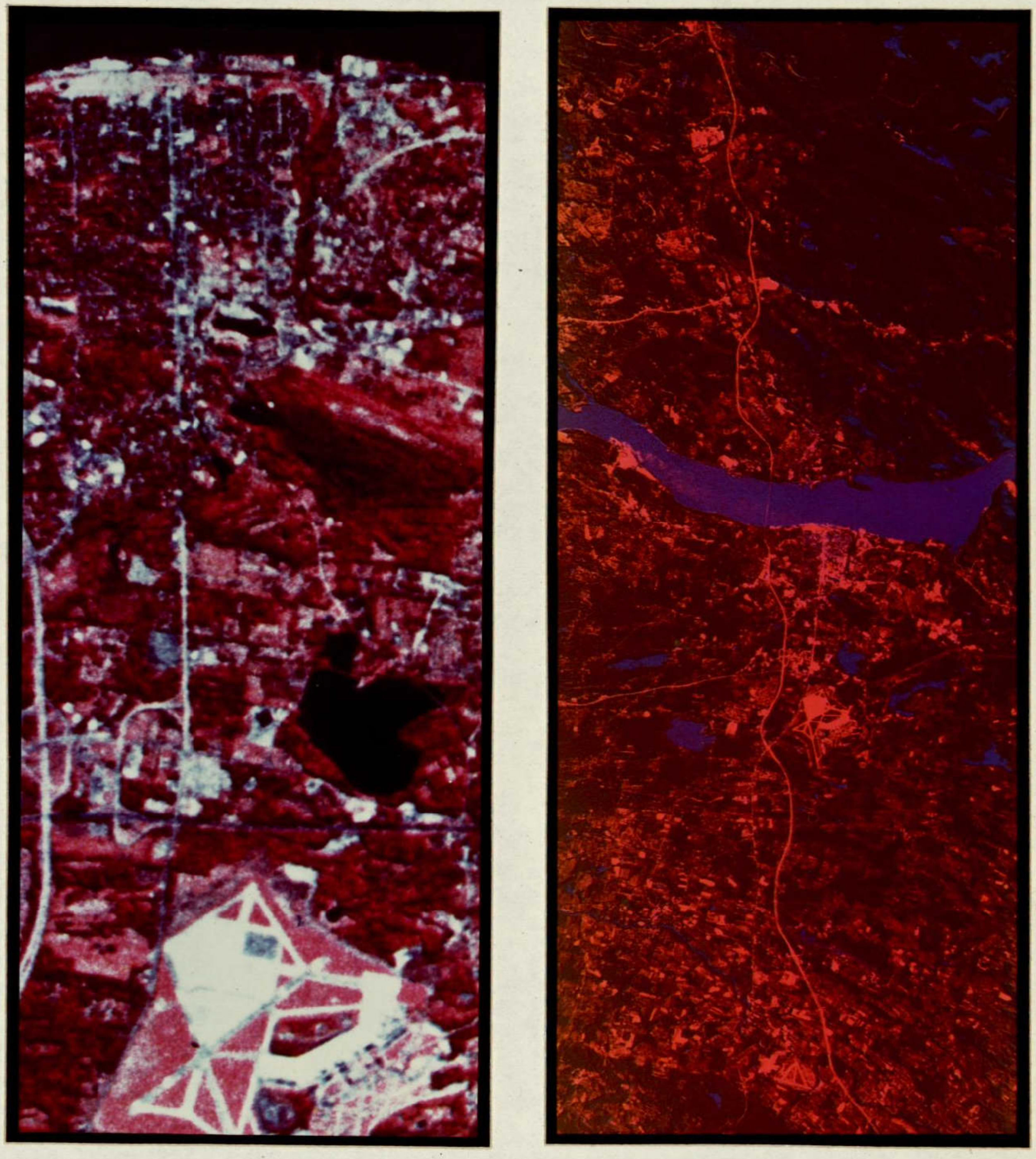


FIGURE 2.3.1 False Color IR color composite (S190B), at a scale of 1:48,000, compared to the S190A color composite at a scale of 1:250,000, for the same area around Newburgh, New York. The S190A composite consists of band BB+ cyan, band BB- magenta, and band DD- yellow.

carried out using both the positive and negative black and white duplicates from the 5" x 5" High Resolution camera, Roll 85, Frame 345. A small section of the area (at the north end of Cayuga Lake - including Montezuma muck area) was chosen and reciprocal 3" x 5" transparencies were made. These in turn were mounted together with a small gray scale and given a series of exposures - each of which doubled the preceding one. The resulting contour film was printed both on diazo and on 3-M Color films.

The results show that although the final color composites are startling and brilliant, their usefulness is limited by a number of factors:

1) Edge definition is poor, as is common to high contrast film and high density differences. (Edge, Eberhard, and Kostinsky effects).
2) There is no assurance that because a portion of the negatives has the same density, it represents the same type of objects. Only on very limited areas could one hope for such marked delineation.
3) The long exposure times needed to properly expose the contour film negated our objective of easily and quickly obtaining "hard copy proofs." The only way the time could be reduced was to use electronic flash equipment and compute the 2-1 exposure differences on the basis of the inverse square law.
4) Direct use of the NASA material was unpredictable because of the inherently yellow color of the duplicating film used. In some cases, this may be a factor of 4 or 5 over a neutral gray scale. The Agfa Contour film characteristic curve changes with shifts in the color of the exposing light (or filters).
5) It was also judged that second or third generation derivations from the contour film might produce better results - but again, the time factor is involved. Therefore, further experiments on this film were not pursued.

2.3.3. S190B Black and White Enlargements. The S190B black and white film was photographically enlarged in a direct two-step enlargement to a scale of 1:24,000. The only photographic correction involved an increase in contrast of the final image to offset the apparent low contrast due to the extreme enlargement. A small portion of Roll 85, Frame 345 was enlarged to a scale of 1:24,000 over Ithaca, New York, and the resulting detail can be clearly seen in Figure 2.3.2.

2.3.4. Ektachrome Duplicating Film 6120. Direct enlarged duplicates were made with existing equipment from both color and color IR 2X enlargements of the Newburgh, New York area. Because time was a factor, complete calibration of our equipment was not possible. However, the color temperature reading of the enlarger appeared reasonable (3000° K). The #211 enlarging bulb was changed to a #212 with approximately twice the output, the voltage read a constant 122, and a "black tunnel" was built to reduce reflected flare light from the enlarger support and surrounding objects.

The Ektachrome Duplicating Film (6120) used called for a 10 second exposure with filter additions of CC 30 Y and CC 20 M. Unfortunately, the only filters available for immediate use were CC 25 Y and CC 25 M. Since it often takes some time to secure CC filters, the exposures were made with the existing ones. Thus, we are short .05 Y and plus .05 M. (Were such duplicates to be included regularly in the scheme of operations it would be highly desirable to secure a complete compliment of CC filters and make more refined tests on the total operation.)

Some observations concerning the photographic enlargements shown in Figure 2.3.3 include: 1) Definition of the "true color" film is considerably greater than that of the "color IR" film; 2) exposure differences of 2-1 on the duplicating film are still sufficiently accurate for interpretation because of the long "straight line" portion of the curve; 3) remarkably close correlation with the standard diazo process resulted. This close correlation partially verifies the accuracy of the diazo procedure employed. It further points to the need for close controls in every step of the color separation technique, including the final diazo

FIGURE 2.3.2

Ithaca, New York at a scale of 1:24,000 from an enlargement of the Black and White Film SL3-S190B, Roll 85, Frame 345.

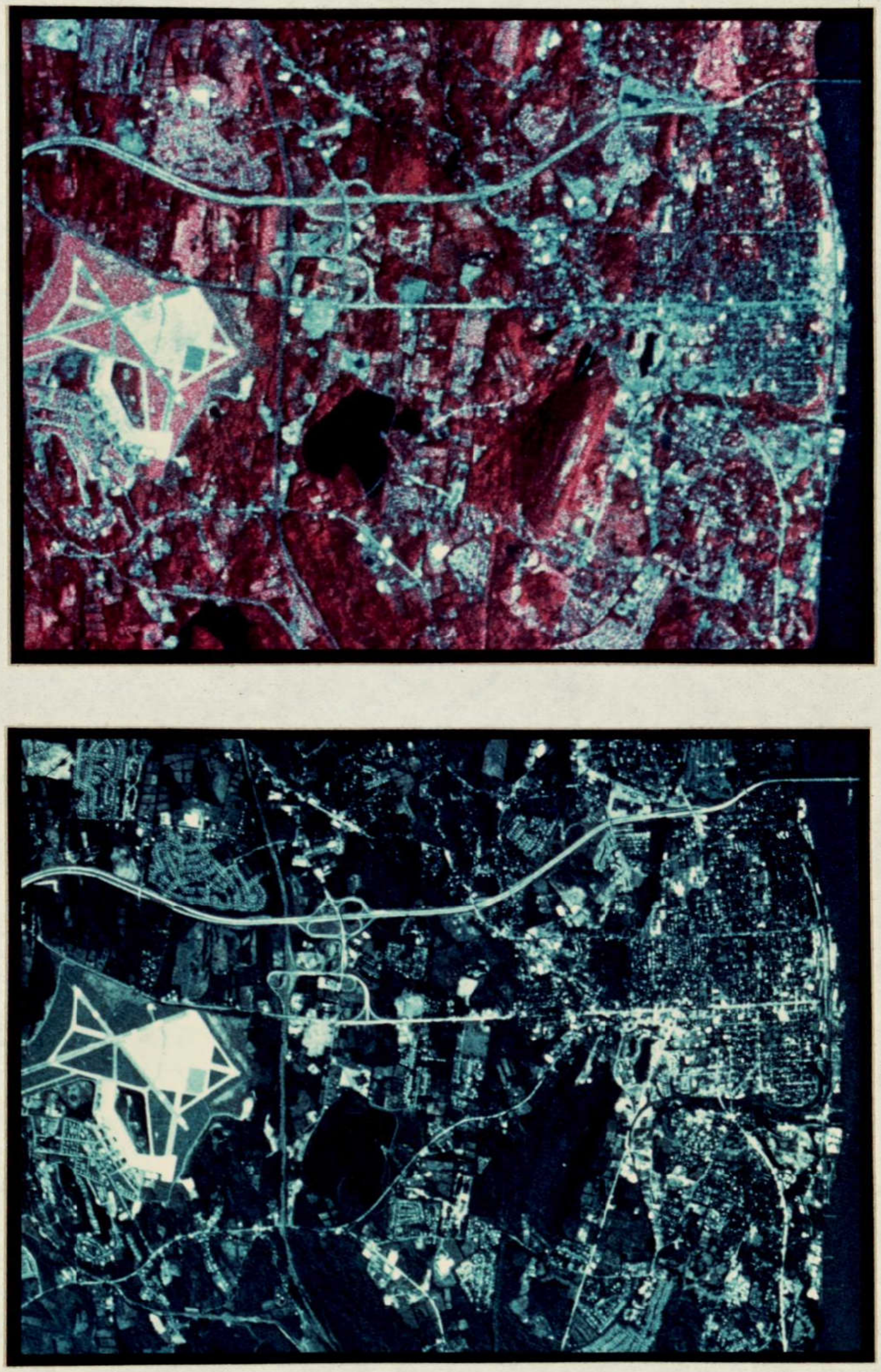


FIGURE 2.3.3 Comparison of SL3-S190B color and color IR film enlargements at a scale of 1:80,000 near Newburgh, New York.

composite. Errors in contrast and density range are particularly degrading. Careful registration of properly prepared diazos (Figure 2.3.1) results in a composite that compares favorably with the single-shot duplicates on Ektachrome Duplicating film. Figure 2.3.3 compares S190B-SL3 True Color, Roll 88, Frame 274 with False Color IR, Roll 87, Frame 299 at a scale of 1:80,000.

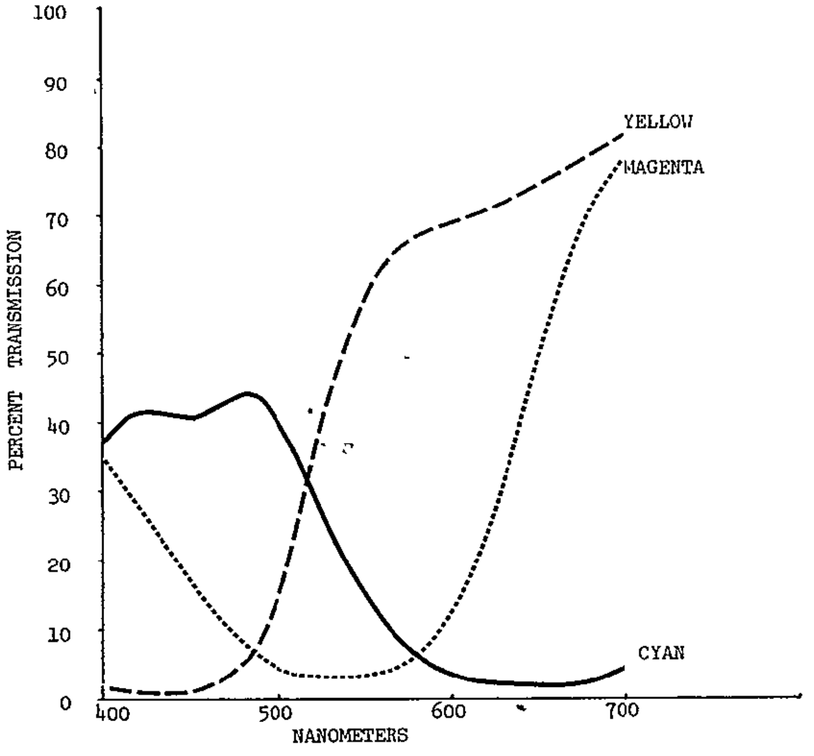
2.4 Spectral Characteristics and Processing of Diazo Film

The diazo film process is a two-step process of exposure and development which allows a black and white film to be contact duplicated as a color film. This is accomplished by the manufacturing of special diazo light sensitive salts and couplers imbedded in a base material, which is in this case clear acetate sheets 8½" x 11". The salts and couplers produce a positive contact image when exposed to a UV mercury vapor lamp and developed by heated aqua ammonia vapors.

The diazo processing machine used was a GAF Model #240 with a modified control knob having 60 calibrations, as opposed to the normal 45. The machine included a special voltage regulator to provide constant voltage, particularly important to the exposing mercury vapor lamp output. Standard procedures involve a recommended operating temperature and double development at a low speed to completely saturate the film for color density standardization.

The diazo films selected were the subtractive photographic colors of cyan, magenta and yellow. Several manufacturers products were tested and the GAF products were selected on a basis of the color density range and relative color purity. Figure 2.4.1 indicates some GAF films sampled and the relative purity. Also evident are some variations in dye color purity between film lots.

Diazo films are manufactured for line drawing reproduction and, as such, they are inexpensive to purchase and process but were never intended



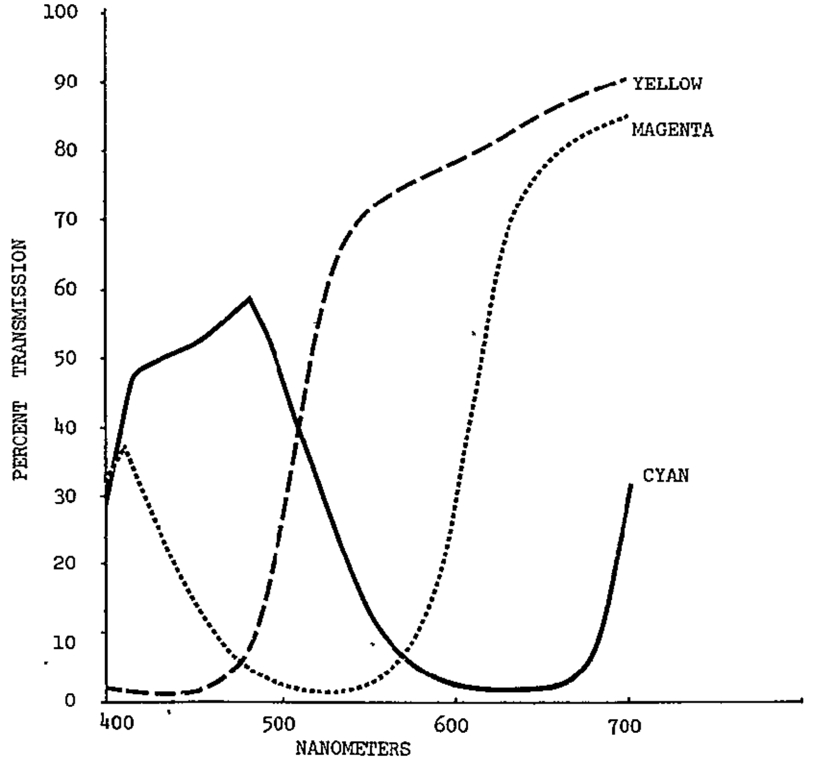


Figure 2.4.1 The transmission characteristics of three GAF diazo films measured at 10 nanometer intervals for two samples of different film batches.

to match the quality control evident in the color films available in the silver process. Therefore, this section will attempt to indicate the characteristics of diazo film for continuous tone reproductions of satellite imagery.

The variation from package to package and among different consignments may be due to a number of factors, including but not necessarily limited to: quality control in the manufacturing process, the dye characteristics, overall shelf life in each dye and the age of the product prior to shipment. So as to minimize further variation and to preserve shelf life, all film shipments when received were immediately frozen. Twenty-four hours prior to use, the film was thawed. All opened film packages were carefully resealed to prevent condensation and refrigerated. All refrigerated film was allowed to remain at room temperature eight hours before exposure and development.

The diazo film Log exposure range was determined from an average characteristic curve of over 50 samples of each color film. The Log exposure range was calculated from the charactertistic curve (see Figure 2.4.2) over the entire color density range and was determined to be approximately 1.00 for all three films. This is the reason why the black and white enlarged S190A films need a density range of 1.00 to make full use of the diazo film range.

Figure 2.4.2 was generated from film samples over an eight-month period and all tests were conducted at a standard machine speed and with standard processing procedures. The GAF diazo films of magenta, yellow and cyan were printed with a #2 Kodak step wedge on one film from each package of film used, then the densities were measured and recorded. The GAF film manufacturers stated in a personal communication that a ± 10% density variation was allowable in film manufacturing. The results of 63 yellow film samples showed a ± 10% density variation, 53 cyan film samples showed a ± 14% density variation, and 54 magenta samples showed a ± 16% density variation. There is less variation in packages from the same film lot than packages of different film lots, but what percent is

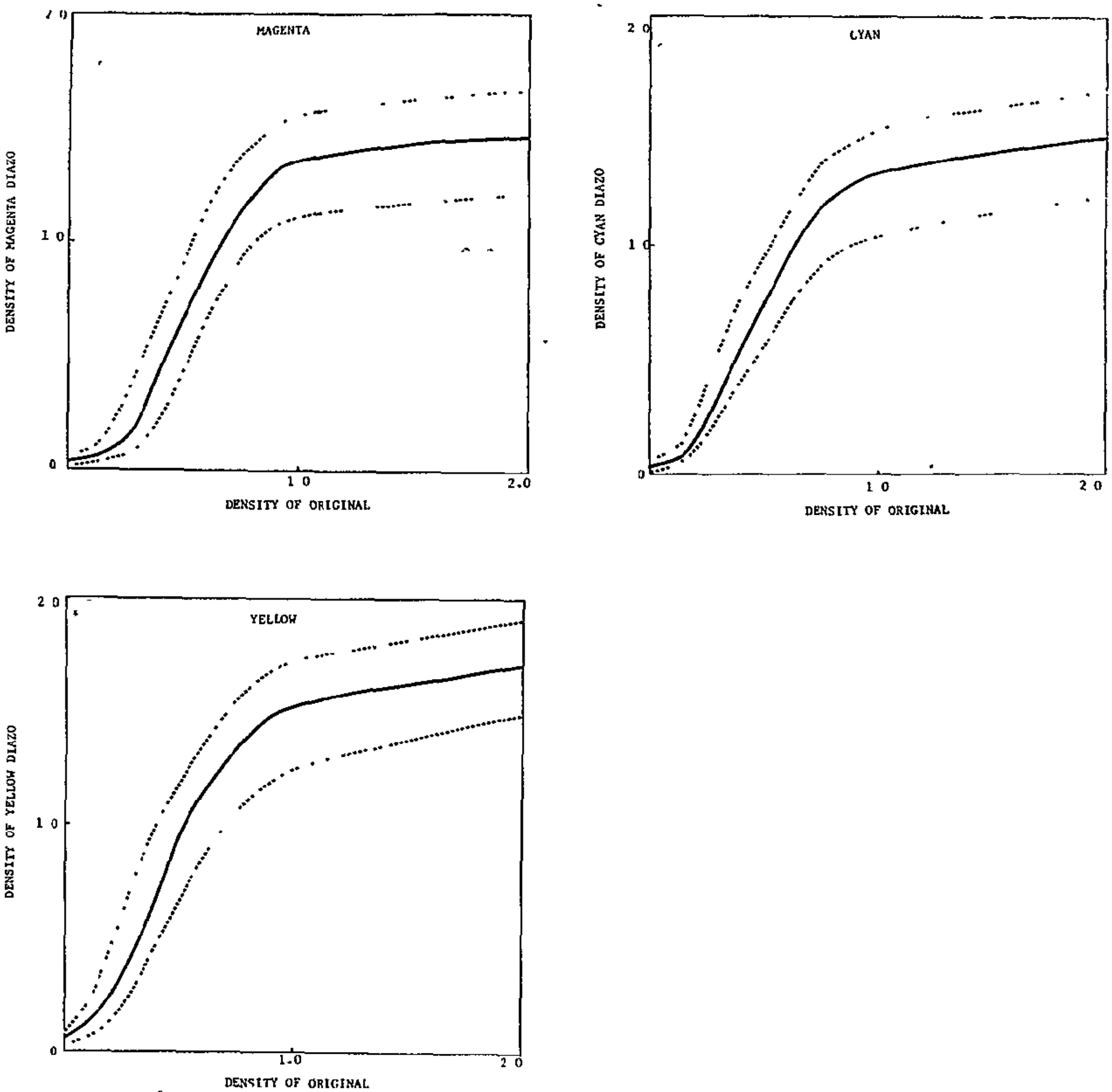


Figure 2.4.2 The average density range (solid line) of each diazo film is plotted against the density range of the black and white step wedge. The dotted lines indicate the total range of variation measured from over 50 samples of each film.

due to film variations and what percent is due to variations in the diazo printer is not known.

The GAF Model #240 diazo printer was tested to determine what changes in exposure speed would produce in the characteristic curve. The exposure speed (transport belt speed) was varied from 1 to 10 and each test used a diazo film in contact with a #2 Kodak step wedge. The resulting characteristic curves are shown in Figure 2.4.3 and form the basis to predict the correct diazo exposure when compared to the density range of the black and white film to be contact printed. Table 2.4.1 was generated from the data in Figure 2.4.3 and indicates the correct diazo exposure for each spectral band when the lower density value is known. For example, if the enlarged black and white film (Filter AA) has a lower limit of .35, then the printing speed for magenta is 6, yellow is 4, and cyan is 6. It is advisable to exclude clouds and water from these density measurements, since variations in the land use categories are of primary interest. When an original negative is enlarged into several black and white sections, it is necessary to find the lower density value for each spectral band among the several enlarged films, and then process each spectral band according to that value for the entire area. This method will maintain color continuity over the entire study area.

The above described method will maintain the color density separation of black and white film densities if in the 1.0 density range. However, for purposes of enhancing different spectral categories, it is desirable to "overexpose" or "underexpose" the diazo film and emphasize the high or low section of the black and white density range. This will compress the density separation on one section and expand the density separation on the other section for more specific enhancement tasks. For example, if a black and white film has been determined to need a #6 setting for magenta film but it is run at a speed of #10, then the lighter black and white densities will be reproduced in the middle of the charactersitic curve and the darker black and white densities will be compressed on the "shoulder" of the characteristic curve; the higher the diazo setting, the less exposure. Conversely, if the same black and white film is run

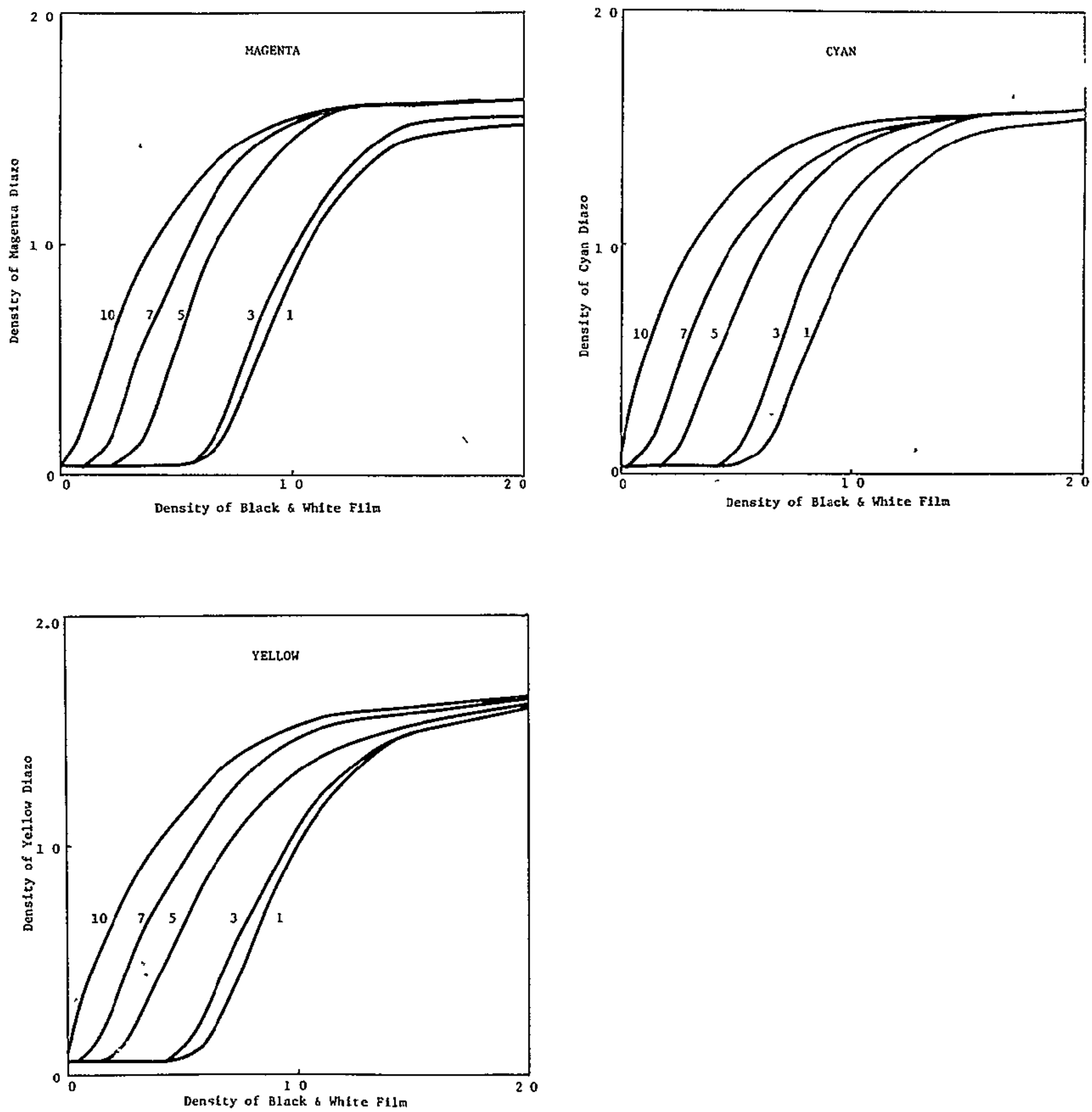


Figure 2.4.3 The characteristic curve for each diazo film changes with respect to the GAF #240 exposure speed, as shown for five settings from 1 - 10.

TABLE 2.4.1 Chart to Determine the Diazo Exposure for a Normal Color Composite

LOWER LIMIT OF B&W FILM 1.00 DENSITY RANGE	DIAZO SETTING
<u>Magenta</u>	
$D > .72$	3
$.71 > D > .58$	4
$.57 > D > .42$	5
$.41 > D > .34$	6
$.33 > D > .26$	7
$.25 > D > .00$	8
<u>Yellow</u>	
$D > .40$	3
$.39 > D > .32$	4
$.31 > D > .22$	5
$.21 > D > .00$	6
<u>Cyan</u>	
$D > .60$	3
$.59 > D > .52$	4
$.51 > D > .44$	5
$.43 > D > .32$	6
$.31 > D > .18$	7
$.17 > D > .00$	8

The lower limit of B&W 1.00 density range determines the diazo film exposure to correctly match the B&W film to the diazo film characteristic curve. (See text for explanation).

at a speed of #2, then the darker black ahd white densities will be on the middle of the characteristic curve and the lighter black and white densities will be compressed on the "toe" of the characteristic curve or possibly eliminated entirely. These relationships have been exploited for color enhancement of different spectral categories as discussed in Section 2.5

Diazo film has produced acceptable results when the procedures are standardized and can be calibrated to a particular film batch lot number to further minimize possible variations. The low expense of this process, both for materials and processing, makes this rapid, hard-copy method a useful tool for either direct interpretation or further projection enlargement for interpretation on a front- or back-lighted screen. Possibly with increased awareness on the part of manufacturers as to potential applications of thèir product for this kind of analysis, improvements could be made in the diazo films and printers.

2.5 CIE Color Prediction Model to Construct Color Composites

In working with multispectral imagery, the photo interpreter has generally been at a decided disadvantage with respect to sorting out intermediate variations in tone among several spectral bands. As a result, a great deal of the quantitative work in multispectral analysis has been accomplished by automated computer processing techniques.

However, as discussed above, one aid has been in the use of diazo materials to convert black and white densities on the film to different hues, varying in saturation and brightness in relation to densities of the original black and white film. Combining these diazo products in different ways (independently varying the spectral band, diazo hue, and diazo exposure) can result in various color tones representing the summation of densities from the combined spectral bands, point by point, across the scene. This methodology has been very useful as an inexpensive, straight forward way of analyzing various kinds of multispectral satellite and aircraft data. Unfortunately, it often lacks any quantitative color reference to which one can relate the combined densities of two, three or more spectral bands. The color composites, with the exception of simulated color infra-red, are constructed on a more or less trial and error basis until particular kinds of information are contrasted with the background to the satisfaction of the interpreter. Needless to say, this is a time consuming and frequently frustrating process.

While working on ERTS-1 imagery and Skylab S190A photography, it quickly became apparent that it was difficult, if not impossible, to extract all the information from the various bands by using conventional techniques employed with black and white photo processing and diazo film. The number of possible permutations rapidly exceeded the possible mechanical manipulations that a photo interpreter would have the patience to endure.

Therefore, it was with the intent of finding some mechanism to automate the selection process for color composites that this study was begun. The task broke into three areas: 1) identifying a standard quantitative reference, 2) determining the spectral properties of the various diazo materials, and 3) constructing algorithms to relate the black and white film densities to the spectral components of the various diazo materials, so as to maximize the color contrast among selected densities.

A review of color theory quickly identified the Commission Internationale de l'Eclairage (CIE) color coordinate system as a logical standard reference within which all colors would have a fixed reference based on quantitative measurements of the materials being examined. Using a series of equations developed by Hardy (1936) and the OSA Committee on Colorimetry (Billmeyer and Saltzman, 1966), tristimulus values for red, green, and blue can be calculated, which define the relationships of hue, saturation, and brightness. These tristimulus values are derived from a summation over visual wavelengths of the color matching coefficients as defined by a standard observer times the spectral energy distribution times the percent transmittance of a sample at a particular wavelength expressed in nanometers. Equations 1, 2, and 3 summarize these operations:

$$1)\quad X = \Sigma_{\lambda}(E_{D5,000}\bar{X})T, \quad Y = \Sigma_{\lambda}(E_{D5,000}\bar{Y})T, \quad Z = \Sigma_{\lambda}(E_{D5,000}\bar{Z})T$$

where X, Y, and Z represent the tristimulus values of red, green, and blue; $E_{D5,000}$ is the spectral energy distribution of a standard light source*, $\bar{X}$, $\bar{Y}$, and $\bar{Z}$ represent standard observer coefficients, and T is the percent transmittance of the sample material at a particular wavelength.

Dividing each tristimulus value by the combined sum of X, Y, and Z yields the chromaticity coordinates:

$$2)\quad X_{D5,000} = \frac{X}{X+Y+Z}, \quad Y_{D5,000} = \frac{Y}{X+Y+Z}, \quad Z_{D5,000} = \frac{Z}{X+Y+Z}$$

X and Y values are plotted on the abscissa and ordinate axes.

Brightness is expressed as the Y% and is plotted on the Z axis, where:

$$3)\quad Y\% = \frac{Y}{\Sigma_{\lambda}(E_{D5,000}\ \bar{Y})100}\ (100)$$

From these equations, a series of coordinates representing the possible variations in hue, saturation, and brightness can be derived for the visible portion of the spectrum. These CIE Coordinates form the fixed reference by which it is possible to relate different color values in Euclidean space with respect to the distance from one reference point to another. Figure 2.5.1 is a chromaticity diagram which also shows the relative shifts in hue, saturation, and brightness with changes in the CIE Coordinates.

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*Values obtained from Table 16.4, p. 892, SPSE Handbook of Photographic Science and Engineering, 1973.

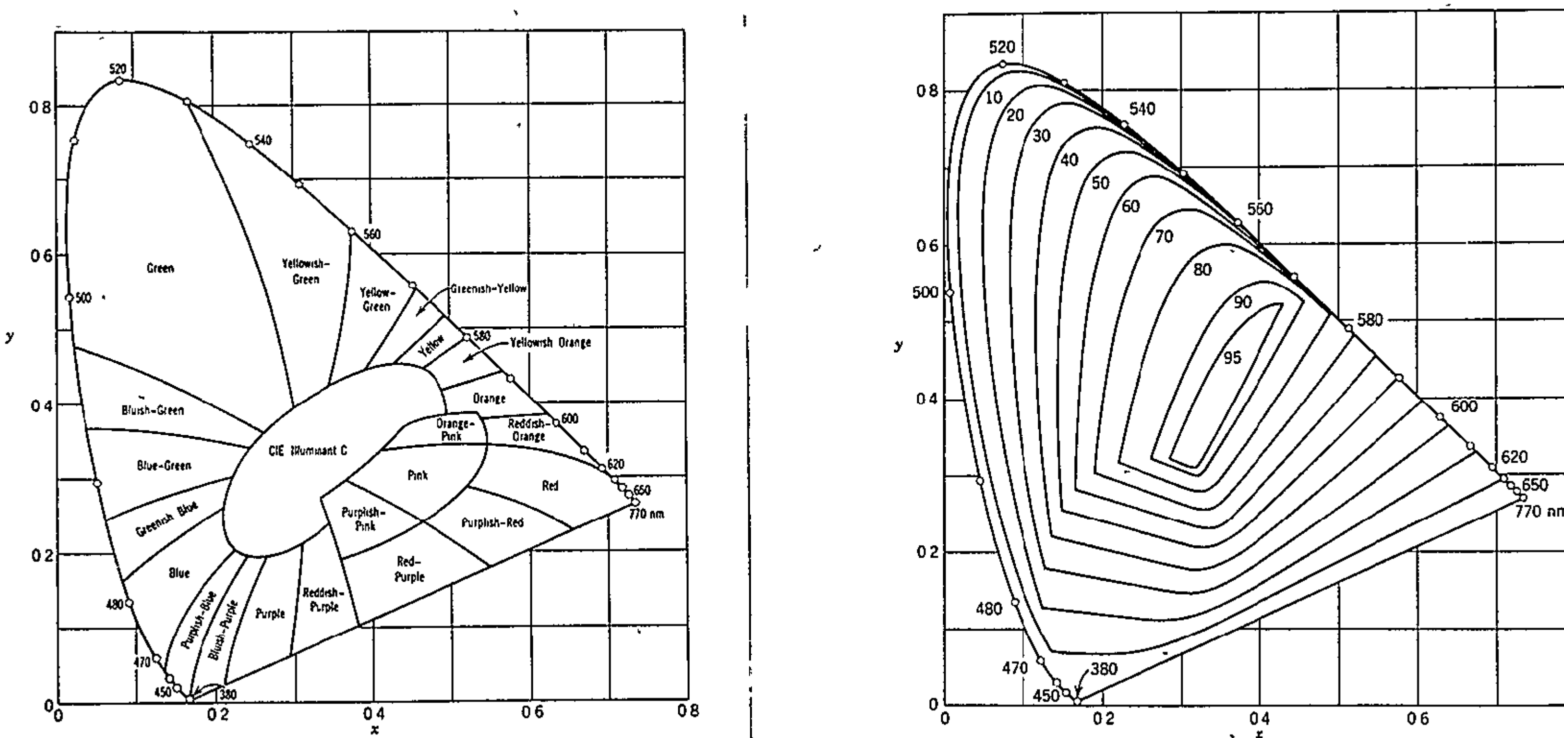


FIGURE 2.5.1 The left figure shows in plane view the positions of various colors on the CIE chromaticity diagram (after Judd, 1950). The right chart in polar view, shows the "MacAdam limits" of the chromaticity of real colors viewed in daylight (CIE Source C) for different values of their luminance, Y% (after Billmeyer and Saltzman, 1966).

According to methods discussed above in Section 2.4, the spectral transmittance properties of the diazo material were measured at 10 nanometer intervals for each of the three dyes: cyan, magenta, and yellow, for each of five different exposure values, and eight densities (.11, .41, .63, .75, .83, 1.00, 1.11, and 1.30). This information was placed on computer cards along with information on the energy distribution of the $D_{5,000}$ light source and number of allowable band combinations. All possible chromaticity coordinates represented by the various mixtures of color from the three diazo hues were then computed. The range of CIE values were then plotted for occurence in each .05 x .05 cell as shown in Figure 2.5.2. Intermediate values falling between any two measured levels of saturation (exposure values) or hue were interpolated from the values calculated at the measured intervals. This assured that we would obtain a good approximation of the total range of CIE coordinate values for various combinations of the three diazo dyes.

When a selected coordinate value is translated back by substitution in equations 1, 2, and 3, the relationship of the spectral band, diazo hue and exposure value (saturation) can then be determined to reproduce, as closely as possible, the selected color assigned to a particular set of density values.

The number of spectral band combinations allowed (see Table 2.5.1) was intentionally restricted to a maximum of 32 with three bands per composite. No single band could be represented more than twice. Allowing additional combinations, including more than three spectral bands per composite, would probably add to the enhancement process, but it also quickly adds to the overall cost of the analysis. The above criteria were thought to be adequate for most purposes in this study.

The objective of the CIE color prediction model is to maximize the color contrast among two or three selected points per composite. This is accomplished by defining the greatest vector distance in Euclidean space between two points, or the greatest area most closely approximating an equilateral triangle, as represented by maximizing the distance among three points (1,2), (1,3), and (2,3).

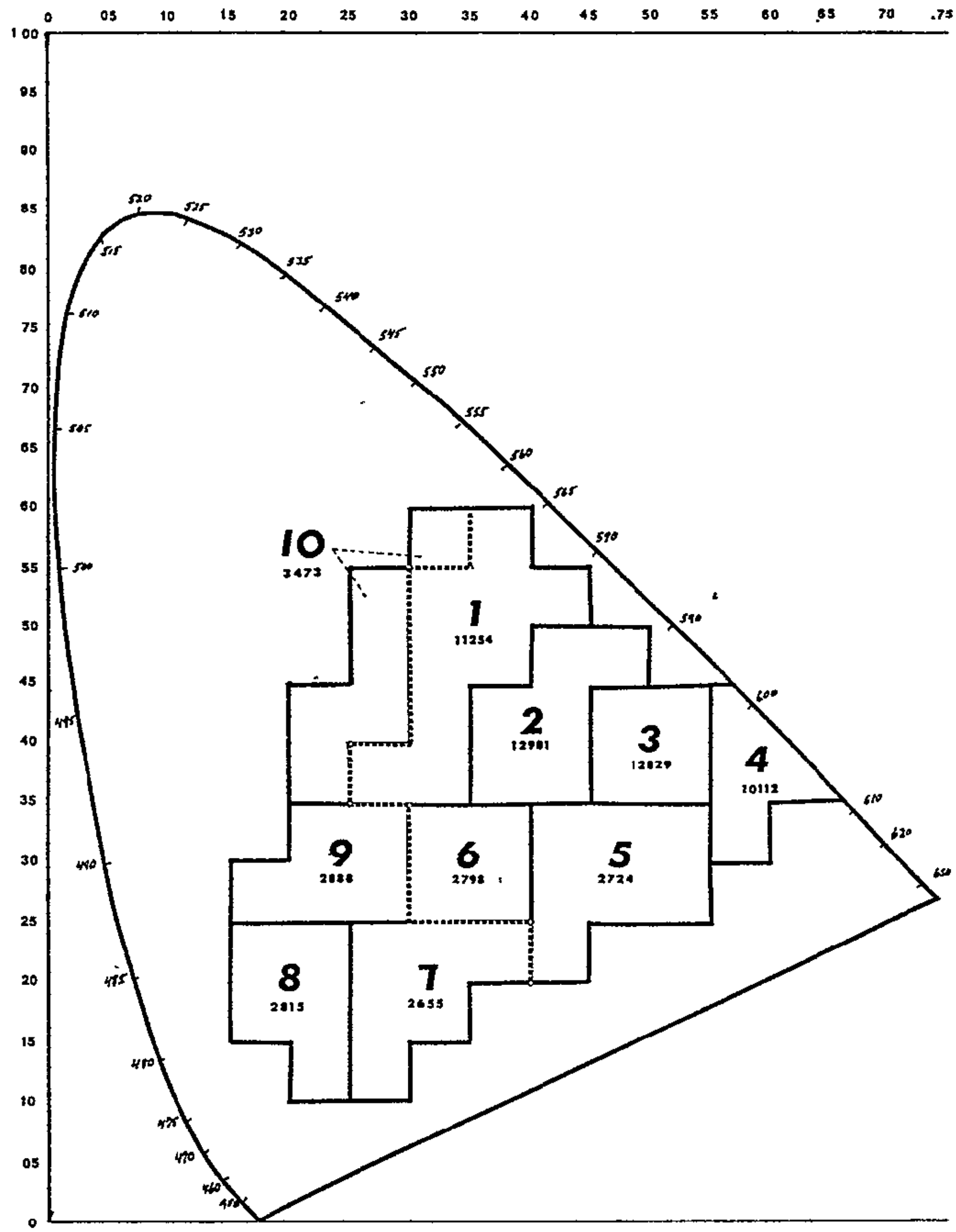


FIGURE 2.5.2 This graph illustrates the maximum range of CIE coordinate values for various combintaions of GAF cyan, yellow, and magenta films with respect to the theoretical total range indicated by the outer curved line. The large font numbers identify the ten visual sectors of the CIE prediction model. The small font numbers indicate the possible CIE coordinate values computed for each sector. The dotted line represents the light-dark boundary discussed in the text.

TABLE 2.5.1 Spectral Band Combinations for the CIE Model

4+4+5-	4-4+5-	7+5+5-	7+7+5-
4+4+7-	4-4+7-	7+5+7-	4-7+4-
5+4+4-	5-4+5-	4-5+4-	4-7+5-
5+4+5-	5-4+7-	4-5+5-	4-7+7-
5+4+7-	7-4+7-	4-5+7-	5-7+5+
7+4+4-	5+5+4-	5-5+7-	5-7+7-
7+4+5-	5+5+7-	7-5+7-	4+5+7+
7+4+7-	7+5+4-	7+7+4-	4-5-7-

Restrictions for selecting band combinations:

1. All selections have three (3) bands
2. All selections are unique regardless of order
3. No band number may be used more than twice
4. No band sign may be used more than twice.

Since it is important from a perceptional reference that these coordinates lie in distinctly different color zones and since these color zones, as perceived by a human observer, vary independently from a change in hue (λ), a perceptional reference was superimposed onto the CIE chromaticity chart. A total of 10 visual sectors were defined. These sectors were rectalinearized so as to conform to major divisions of 0.05 on the ordinate and coordinate axes as shown in Figure 2.5.2.

Using a single matrix design for the visual sector, it greatly simplified the programming routines over what would be required for a curvilinear arrangement while yielding very acceptable results. Since human color vision is highly variable among individuals, and since color contrast is the desired product, an approximation of the visual sectors seemed to be quite adequate to meet our objectives.

The visual sectors were defined by several factors: 1) the total color range of printing inks (Kodak, 1968), 2) MacAdam's ellipses illustrating the color sensitivity within the CIE chromaticity chart (Wright, 1958), 3) Judd's ellipses illustrating an equal energy distribution across the visual spectrum as it conforms to perceptibility scales (based on 100 just perceptible distances, jpd, within each ellipse (Judd, 1950), and 4) the distribution of the total number of possible selections of coordinates computed for each matrix cell (,05 x .05). Using a series of overlays, visual associations were made between the color distribution of the diazo materials and each of the above. Perceived hue shifts within the CIE chart were mapped from Kodak's color range of printing inks. From this, ten major color associations were defined. The boundaries of these associations were shifted to accumulate an approximately equal number of perceived differences within each visual sector and to obtain a reasonably equal distribution of computed coordinate selections for each sector. The number of possible selections was found to have about a 5-1 bias toward the red-green line. Therefore, the distribution was divided into groups, a light zone (red-green colors) and a dark zone (blue-green colors). The boundary shifts were then made accordingly, within each zone.

These matrix divisions, as illustrated in Figure 2.5.2, represent the perceptional component of the model as it is superimposed on the CIE chromaticity chart.

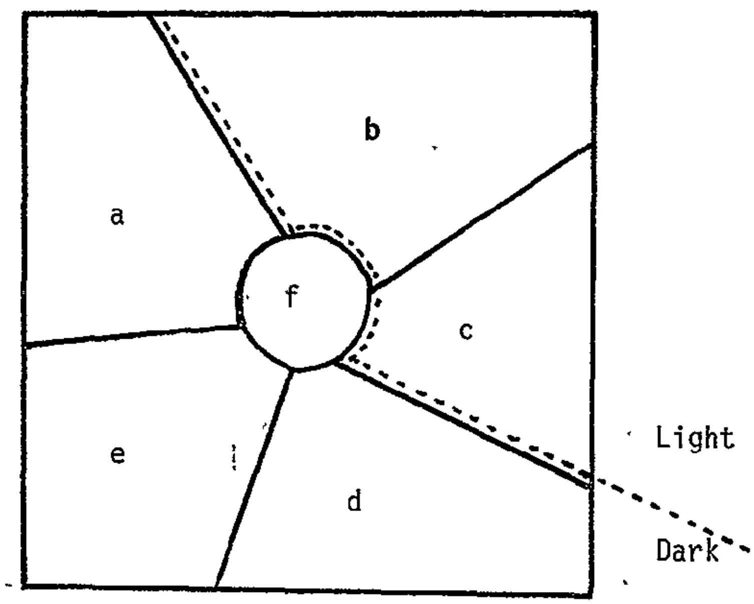
In operation, families of points representing the greatest perceptional differences are first selected. Then, from these families of points, as defined by each visual sector, coordinates which are spaced the greatest vector distance, or which define the greatest triangular area, are chosen. To select the visual sectors which have potentially the greatest visual contrast, a system of weights are used. The possible cell distances are 0, 1, 2, 3, and 4. Points selected within a cell receive no weight, but the weight increases as the straight line connecting two points crosses visual sector boundaries. (See Figure 2.5.3). Lines which connect points crossing the light-dark line were given the equivalent weight of crossing two visual sector boundaries. This assured two things: that no more than two points would be located on one side of the light-dark line, and that the side which was to have two points would have them spaced at the maximum distance as opposed to what might have occured on the opposite side. The change in luminance (Y%) was given a zero weight. Initially, experiments were conducted which assigned various weights to Y%; however, these failed because of the tendency to discriminate only on the basis of brightness.

The following is a summary of the components and operation of the CIE color prediction model:

INPUTS - 1. Density levels for which transmittance data was taken.
2. Transmittances (for each density level exposed, for each standard exposure level, for each hue).
3. $D_{5,000}$ source data.
4. Hue permutations.
5. Band names.
6. Permissable band combinations.
7. CIE Cell neighbor distances.
8. Densities in each band of the points to be differentiated.

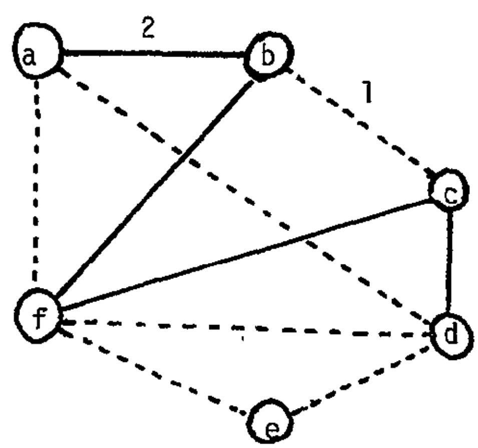
CELL DISTANCE MEASURE:

The distance from each cell to its nearest neighbors is defined as below:



The distance from "b" to "c" is 1.
The distance from "a" to "b" is 2.

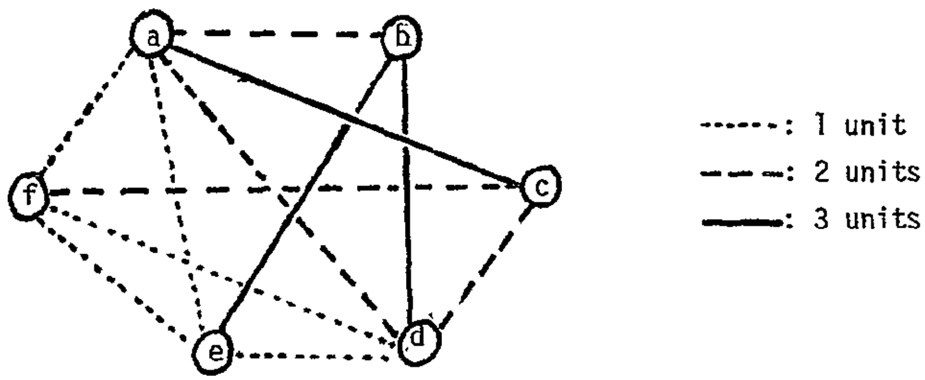
Represented graphically,



Now, no distance has been defined between "a" and "c". We define this to be the smallest distance path from "a" to "c", passing through one or more intermediate regions. Thus, from "a" to "b" is 2 units, and from "b" to "c" is 1, making a total of 3 units from "a" to "c". All paths are considered, and the shortest is selected.

FIGURE 2.5.3

This method applied to the previous graph yields:



As a result, cell distance is now defined between any two points.

FIGURE 2.5.3 (continued)

OUTPUTS - 1. Best pairwise discriminations.
2. Best triple discriminations found.

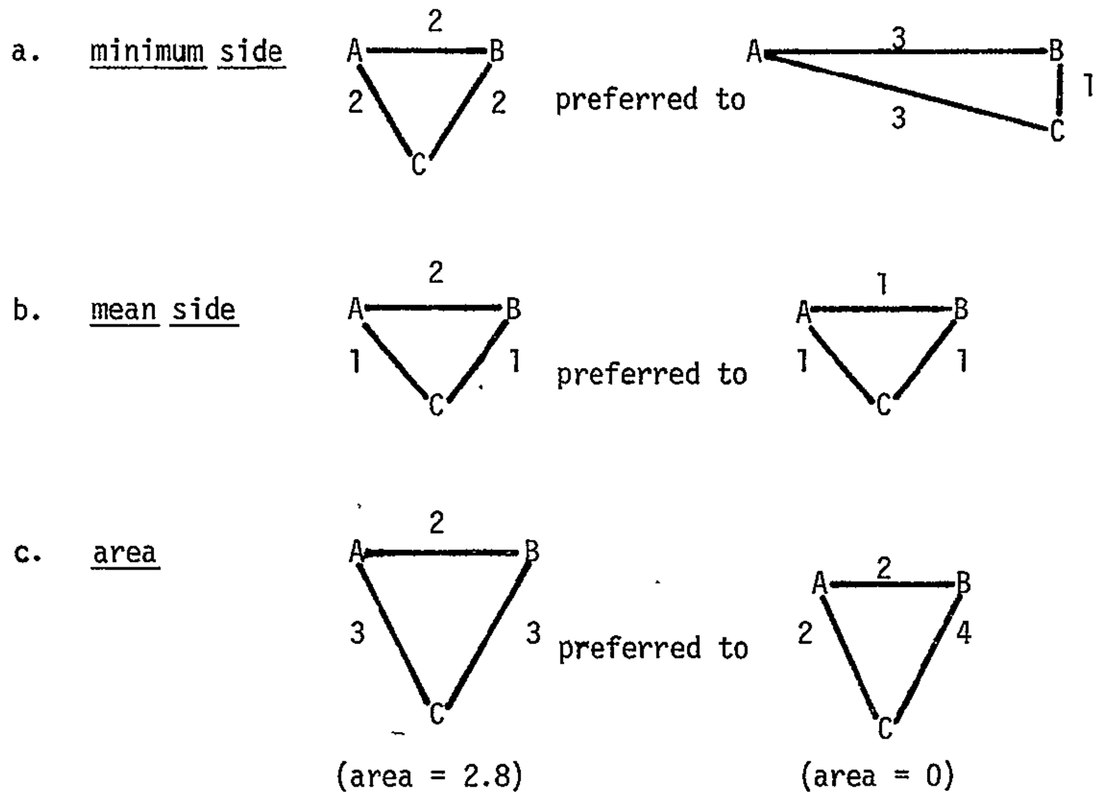
Criteria for assignment of bands to hues and exposure levels is represented graphically in Figure 2.5.4 and summarized below.

I. PAIRWISE
1. Must achieve better than minimum pairwise discrimination as determined by Euclidean distance between CIE points. (Reference to Figure 2.5.4.a).
2. Among assignments meeting criterion for I.1, choose those with maximum cell distance (Reference to Figure 2.5.4.b).
3. Among assignments with maximal cell distance, choose maximal Euclidean distance.

II. TRIPLES
1. All pairwise distances must satisfy I.1.
2. Find maximal minimum-side-distance. Select all assignments meeting II.1 with this as their minimum-side-distance.
3. Among assignments meeting criterion for II.2, select maximal mean side length.
4. Among assignments meeting II.3, choose the one with maximum area as determined by the CIE coordinates. (Reference to Figure 2.5.4.c).

The actual operational sequence is depicted in Figure 2.5.5.

Upon selection of the coordinate values, assignments of spectral band, hue, and exposure of the diazo are computed so that all three points are represented by the composite selected. These assignments are printed out according to hue; e.g., cyan DD+ (6), yellow BB- (2), magenta AA+ (8). For each hue assigned, there is a spectral band number, positive or negative film image, and an exposure value for the diazo film corresponding to the dial setting on the diazo machine.



Examples (all in the plane, ie. equal brightness) of choices made by the evaluation phase.

FIGURE 2.5.4 These examples show the scheme by which judgments were made to select coordinates which met the criteria for the best discriminations among pair or triple coordinate points. All examples are in a plane of equal luminance (Y%), the numbers refer to cell distance in a and b with the vector distance in c.

FIGURE 2.5.5 (Continued)

4. Test points in triples for sufficient discrimination and extract best triple discriminant
   i. check for failure of pairwise discriminant
   ii. compute minimum side cell distance
   iii. compute mean side cell distance
   iv. compute area of triangle defined by the 3 points

   (we maximize over (ii), then (iii), and finally (iv)).

Output the Results

Return

The program will take density range readings of up to 10 points within a scene; however, costs begin to mount appreciably if more than five or six points are run simultaneously. Five points, generating ten composites (three points compared per composite), may be run for about $15.00, while six points cost $21.00 to $24.00 per run on overnight batch processing on an IBM 370 system.

Since there is generally considerable variation in the densities/ category/band, the model works best using the median density value of a category as determined by sampling several known points in a scene represented by that category. In the case of the Skylab S190A data, the density ranges tended to overlap among the categories (see Figure 3.2.2). As a result, one of the three points in a composite often blended with the background. To remedy this, an average density of categories of interest within a scene, less those being specifically examined, was used as one of the data inputs so that each of the points of interest could be contrasted with a contrived value indicative of background. In many cases, this improved the separations of various categories.

Density differences as low as .05 on a single band can be separated; however, the color contrast is not very good and the variability of the diazo machine makes such separations less reliable. If the spectral bands on the sensor have been selected initially so as to assure discrete separations at optimal points along the spectral curve of a particular material(s) to be interpreted, then very good color contrast and separation of different categroies is possible. Figure 3.5.1 shows discrete separations of different categories as a result of using narrow band S192 data. From this, it should be clear that the filter selection on the sensor is equal to, if not more important than, the analysis tool.

2.6 Data Take Off

The S190A and S190B photographic products were enlarged for interpretation to a scale of 1:62,500 and in some cases, to a scale of 1:24,000 for a detailed comparison to LUNR. These two scales were selected to obtain the maximum enlargement of most photographic products, to obtain an acceptable minimum mapable unit, and to use base maps most consistent with existing land use planning data systems. The base maps at a scale of 1:62,500 are a New York State county series compiled by the New York State Office of Planning Services (OPS). The 1:24,000 scale base maps are USGS topographic 7½ minute quadrangles, which also form the base for the LUNR data. The UTM grid system was followed as being the most compatible with the two series of base maps, the LUNR format and as a standard for reference to other systems.

The interpretational process involves projecting the photographic products through a backlighted screen and onto a mylar map base on which the land use interpretation is drafted (sse Figure 2.6.1). The overhead projector and backlighted screen offer a system with good resolution and a wide range of interpretational scales. These are important features when evaluating various photographic products at different scales to one particular base map (and to different base maps).

The overhead projector used was a Transpaque Auto Level (Model 20400) with a 10" x 12" glass film holder to insure a flat image in a fixed position. The backlighted screen was constructed as a free standing wooden frame. The projected image was then focused on a mylar sheet taped flat to the back of the glass screen. This procedure permits good resolution and allows for direct interpretation of large areas on the mylar sheet. The mylar sheet was first prepared by drafting the UTM (10 km) grid lines and a few widely positioned linear features, such as major streams or large lakes, from the base maps (1:62,500 or 1:24,000). This provided a control by which the correct orientation and scale would be maintained on the projected image for accurate interpretation, drafting, and data take off.

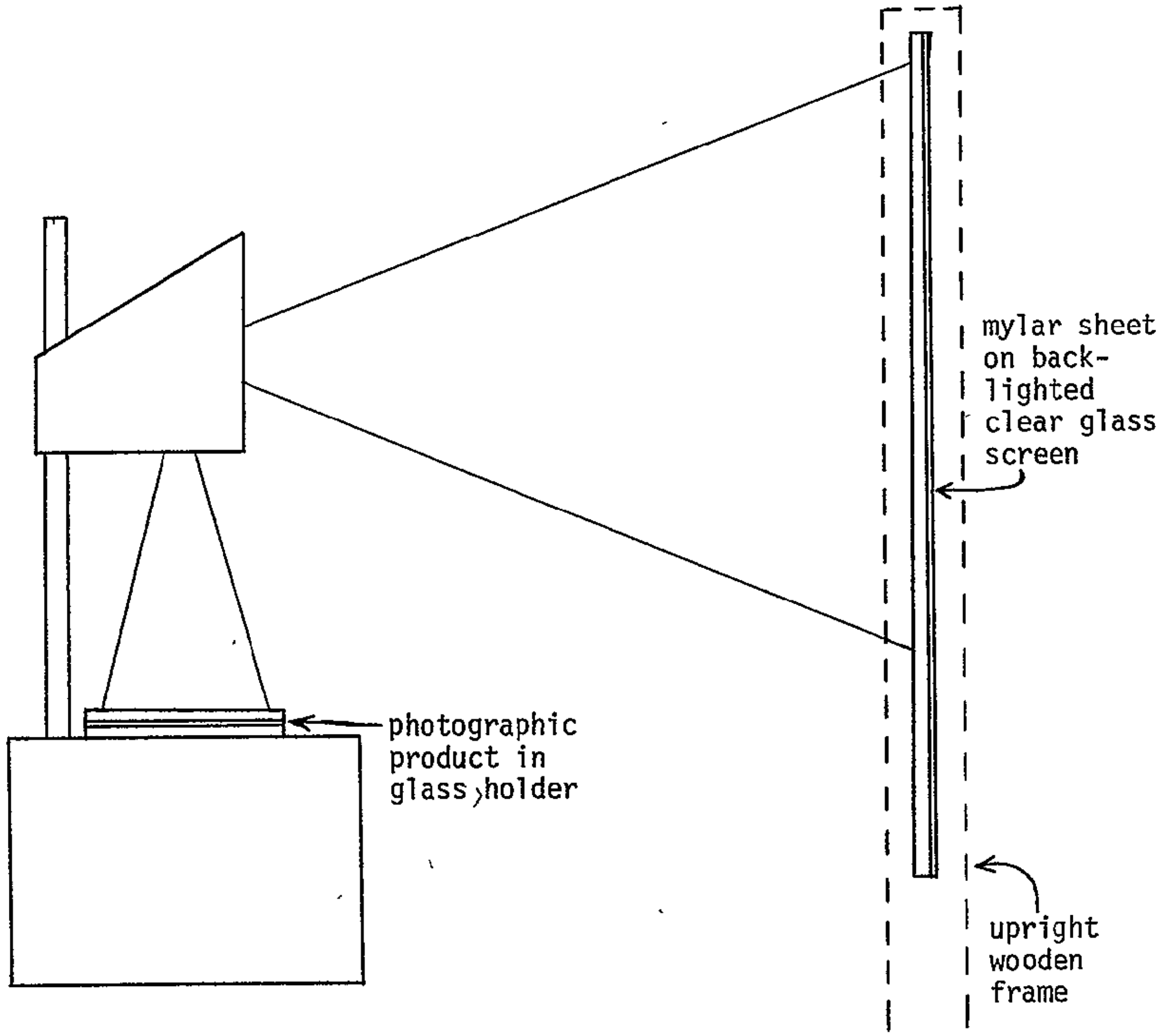


FIGURE 2.6.1 An Overhead projector is used to transfer the photographic image to the back-lighted screen for interpretation on the mylar sheet. The scale of the projected image is variable according to the distance between the projector and the screen.

Each test area was then delineated according to the category definitions in Section 3 for Interpretation of Land Use Features. The S190A color composites selected for each test site were used sequentially to construct a completed land use map. The following section 3.0 will discuss the color composites used for each test site, and the spectral information derived from each composite.

The minimum mapable unit was considered to be four hectares at the 1:62,500 scale and one hectare at the 1:24,000 scale. Although smaller features could be detected and often identified, it proved to be generally impractical to map and label them.

The data take off procedure for the 1:62,500 scale, pencil drafted mylar maps, consisted of overlaying a 1 kilometer UTM grid with a 25 dot array on each cell. Then the hectares in each category were totaled by the sampling technique of one dot within a particular category equal to four hectares. A total of 100 hectares per one kilometer cell were accounted for by this method and each test site was totally sampled to obtain the data presented for the summary data comparisons in Section 4 on Data Correlation. A similar procedure for the 1:24,000 scale maps involved using a one kilometer UTM grid with a ¼ hectare level grid array and totaling each category by hectare estimates.

3.0 INTERPRETATION OF LAND USE FEATURES

The interpretation process involves both the multispectral (S190A) and conventional film (S190B) products. The interpretation process is described below in detail for each of the three test sites (Tompkins County-Ithaca, Lower Hudson Valley-Newburgh and Kingston, and Suffolk County-Long Island). Prior to the initiation of the final interpretation phase, considerable effort had been put into the selection and definition of the various land use categories to be interpreted. Category definition is extremely important to insure repeatability and to assess accurately the major land use features that are used by planners and other user agencies. The selection and definition of categories used are discussed in Section 3.1 below.

3.1 Category Definitions

The first step in the interpretation process requires a system of definitions for categories of interest. Theoretically, categories should be defined so that they represent basic components of a classification system. As such, information might be derived from several sources, but it should still be compatible with information already classified in an inventory. This is not a simple task in that sensor characteristics define the parameter of the data (spectral and spatial properties); whereas, user agencies have specific semantics applied to various categories which are often difficult to resolve with the data. The problem is severe enough when an area is inventoried for the first time using a particular sensor system. It becomes even more difficult when an attempt is made to update an existing inventory such as LUNR which was designed in part using both spatial and inferential information from 1:24,000 scale black and white air photos. The resulting categories often incorporate economic or ownership features which are not discernible from high altitude or satellite data. Likewise, spectral features are not given any special consideration in the LUNR categories. These factors then add considerable complications to the update process such as was attempted in this study.

In large part, the category selection is based on the U.S. Geological Survey Circular 671, "A Land Use Classification System for Use With Remote Sensor Data" (Anderson, Hardy, and Roach, 1974). Therefore, the numbers and category names pertaining to Level I and Level II categories are derived from the Circular 671. However, certain changes are made on some of the Level II categories. Residential is separated into light and medium to heavy. Commercial, Industrial, and Institutional are, depending on their spectral/spatial components, combined into a single category called Intensive. In Agricultural Land, Cropland/Pasture is defined as intensively managed, such as alfalfa and sod farms. Grazed land and brushy areas were combined into a single category. It is recognized, however, that this combination may be only useful in the northeast where inactive pasture quickly grows up into forest land. Wetland is redefined to include both non-forested (herbaceous) and brush or wooded wetlands. This is to include many wetlands in New York State which are wooded or have woody vegetation in association. These revised categories and the criteria for establishing each class is shown in Table 3.1.1.

The characteristics of each class are derived on the basis of what could be actually seen, i.e., a spacial pattern, or the variation of the spectral response which would permit a color separation on the basis of density differences among the three bands used in the S190A or tonal variation on each of the three film types interpreted from the S190B. Every attempt is made to minimize the incorporation of economic or ownership features in the category definitions, e.g., commercial and services. These features could be incorporated at a Level III classification, but it is not felt that such features are readily identifiable at Level II using satellite data. The classification system for space related data is discussed in greater detail in Section 7.

TABLE 3.1.1 A Two-Level Classification System for Interpreting Skylab Data

LEVEL I	LEVEL II	CHARACTERISTICS
1. Urban and Built Up Land	1. Light Residential	1 Small buildings less than vegetation (1 bldg. or less per ¼ hectare)
	2. Medium and Heavy Residential	2. Small buildings more than vegetation (2 bldgs. or more per ¼ hectare)
	4. Extractive	4. Raw extractive material sites with no vegetation
	5. Transportation	5. Linear 4-lane highways, railways, and airfield runways
	6. Intensive Development	6 Large buildings or building complexes with parking lots and some vegetation
	7. Strip Development	7 Intensive linear building developments along roadways
2. Agricultural Land	1. Cropland, Cropland Pasture and Sod Farms	1. Intensive monotypic vegatation less than 6 ft tall and/or soil in regular rectilinear formation
	2. Orchards, Vineyards and Horticultural Areas	2 Intensive monotypic vegetation less than 20 ft tall in block plantings with some soil possibly evident
	4. Pasture and Brushland	4. Vegetation less than 20 ft tall and less than 50% canopy cover
4. Forest Land	2. Coniferous	2. Trees over 15 ft, 50%+ canopy cover and 90%+ coniferous (plantations)
	3. Mixed Deciduous and Coniferous	3. Trees over 30 ft and 50%+ canopy cover
5. Water	1. Streams and Waterways	1. Open fresh water-linear
	2. Lakes and Ponds	2. Open fresh water-nonlinear
	3. Reservoirs	3. Open fresh water-dam or water control structure
	4. Bays and Estuaries	4. Open salt water - coastal configuration
6. Wetland	1. Marsh, Bog and Herbaceous Wetlands	1. Water with herbaceous vegetation
	2. Brush and Wooded Wetlands	2. Water with woody vegetation and trees
7. Barren Land	2. Sand	2. Sand with no vegetation
	4. Bare, Exposed Natural Rock	4. Natural rock with little vegetation

3.2 Interpretation of S190A

Color composites for each of the three test sites were selected by the CIE color prediction model according to the spectral responses (density range) of the land use and vegetation endemic to that area. The color composites indicated by the model were checked against low altidude air photos, LUNR and S190B photographic products, to determine which composites provided the most reliable and consistent information throughout the test site. The color composites which fulfilled this task on inspection were then used to interpret the entire area. From this point on, no further reference was made to air photos or other ground truth information. Usually four to five composites were considered necessary for a complete interpretation for all categories. The sequence in which these color composites were used depended on the interpreters' evaluation of the most reliable and efficient sequence.

To an experienced interpreter, the composite selected by the model was sometimes only used as a guide for discriminating certain categories which have broad spectral ranges. Alterations can then be made in the composites to further improve discrimination of that category. The reason for this is that the model operates on single density inputs/spectral bands/categories. Where there are broad ranges of density values, only the medium value is used. Often it is more efficient and cost effective, in these cases, to make some adjustments in the selected composites than to run several iterations of the color prediction model. These composites are then tested as a possible aid before the final interpretation process is begun. An example of a S190A color composite interpretation can be seen in Figure 3.2.1 which includes one UTM cell (100 square kilometers) at a scale of 1:62,500 from the Lower Hudson Valley test site.

Several categories proved very difficult to interpret, such as wetlands, light residential, orchards, and the distinction between cropland and pasture/brushland. Due to the fact that all photographic products came from the SL3 mission at approximately the same date in mid-September,

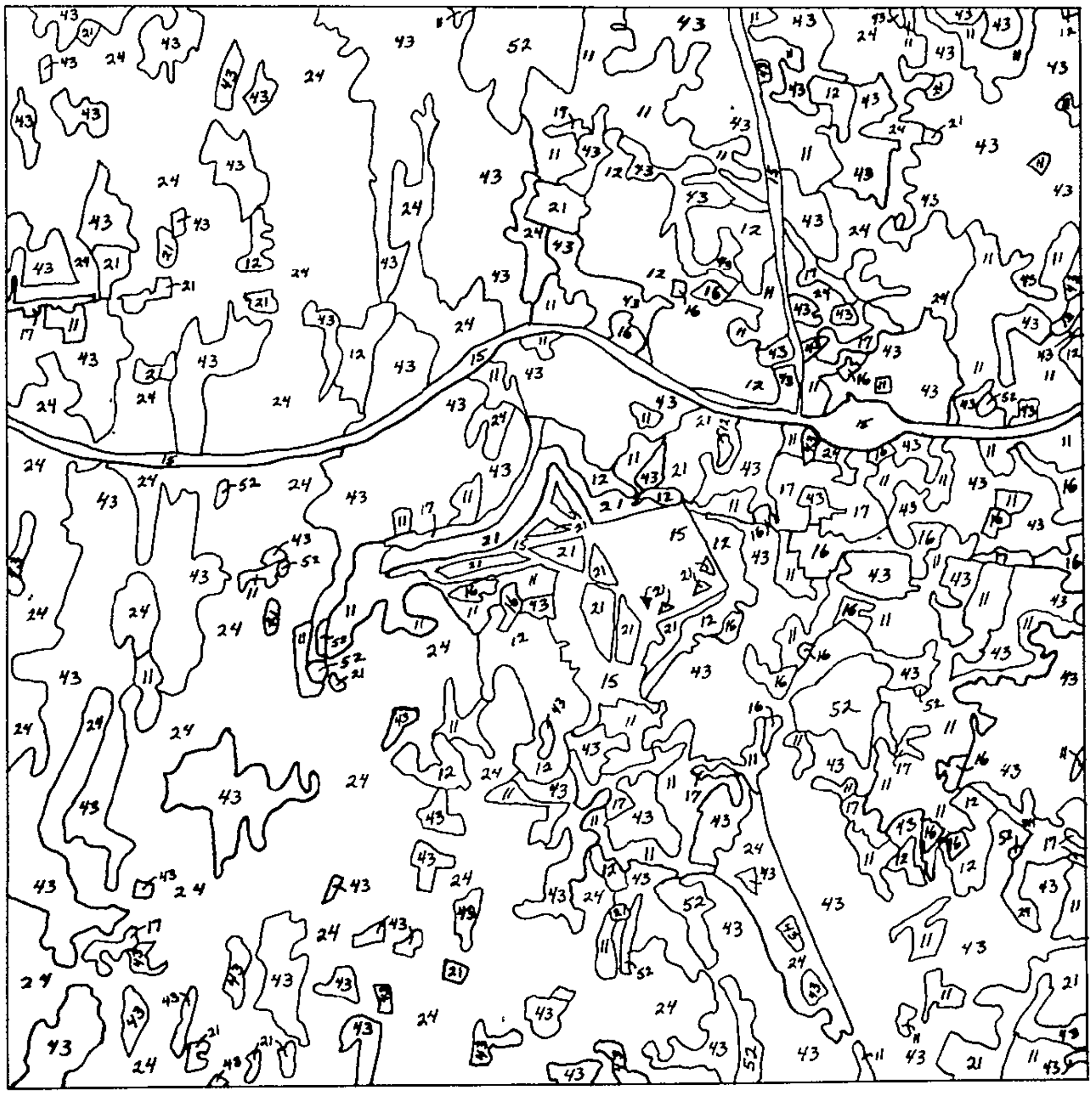


FIGURE 3.2.1 One UTM (100 square kilometers) cell interpretation from the S190A color composites at a scale of 1:62,500 on the Lower Hudson Valley test site. The UTM coordinate reference is 4590000m N. and 570000m E. for this cell.

it was not possible to test the seasonal variations as was done with ERTS-I (LANDSAT-I). That report indicated that spring and early summer multispectral imagery were necessary aids to interpretation of the above mentioned categories. This was primarily due to spectral signature shifts: in natural vegetation throughout the growing season, management practices in active agricultural areas, and canopy closure which obscured ground information. Therefore, the lack of other usable Skylab data over New York State precluded any seasonal investigation.

In general, the separation between extractive (14), intensive development (16), and some gravelly, bare agricultural soils (21) could only be made on the basis of location and spatial configuration. The spectral responses of these materials is very similar and could not be the only basis for discrimination. The distinction between coniferous and deciduous also proved to be difficult. Coniferous are often found in small plantations or scattered on sides of hills and steep gorges. As such, they did not appear to be discrete enough to call a separate category. Therefore, to circumvent this problem, all forest is classified as mixed.

In an attempt to further determine why these categories were difficult to interpret, a series of density measurements were made on the 1:250,000 S190A multispectral filter bands AA, BB, and DD. A sample of each land use category was located on the three bands by cross reference to other information and several density measurements were made to determine the range. After selecting two to three different areas for each category on the Lower Hudson Valley area, it became evident that in several categories there existed a large amount of density overlap (see Figure 3.2.2).

These histograms are only a beginning step in showing the relative difference in information content of wide band filters (S190A) vs. narrow band filters (S192) but they do show why certain spectral responses in different categories appear similar. Certain categories have very large density overlap in all three bands, which makes any color composite enhancement and separation improbable. However, if a category

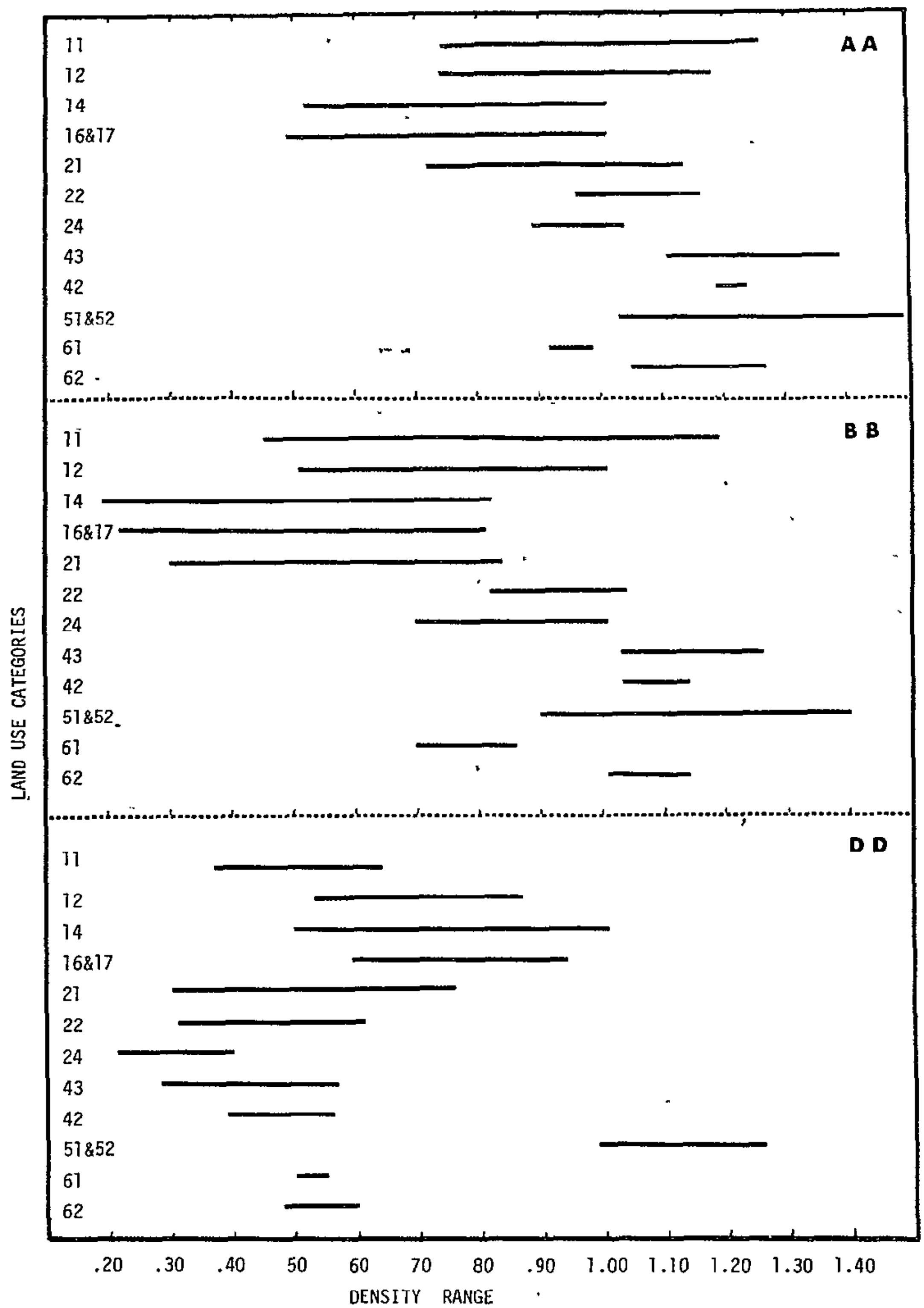


FIGURE 3.2.2 A density range histogram to show the relationship between land use categories.

density range is distinct in any one band, then the color composite process can further enhance the difference. Therefore, the entire process is dependent on the selection of the original filters to be able to discretely record the spectral responses.

Further research on this approach would require extensive density measurements to be able to construct histograms which would show the density range for each land use and the frequency of occurence for each density point. Section 3.5 and 5.1 discuss in greater depth the merits of a narrow band system for discrete spectral records.

Due to time and cost limitations, only a limited number of experiments were performed on the CIE computer model. This is the reason why each color composite suggested by the model had to be carefully evaluated. This also explains why an interpreter could, on certain occasions, extrapolate to some intermediate composite which would be a more visually accurate rendition with less category color overlap but could not further enhance difficult separations.

Each spectral band was individually inspected to determine its overall character and resolution. Filter band DD (infra-red) proved to be extremely grainy in structure and limited the resolution of the IR record. This also effectively degraded the composite when used in conjunction with the other two bands. The poor IR resolution also contributed to the difficulties in interpreting wetlands, built up land and some vegetation types which are usually better contrasted by using the IR record.

The filter bands AA and BB had good resolution but the spectral differences between these bands for several categories were small. The black and white films showed features such as roadways and runways (asphalt and concrete) about 100 feet wide, and streams or canals approximately 500 feet wide. Water bodies could be discerned only if they exceeded approximately 500 feet in diameter. However, minimum identifiable units were often smaller than was practical to delineate and label on a map. Therefore, the minimum mapable unit was approximately four hectares in area on the 1:62,500 scale map.

The 4X enlarged S190A color and color IR films provided by NASA were projected to a scale of 1:62,500 and visually compared with the S190A color composites. The resolution of the S190A color film is less than the filtered black and white bands AA and BB and does not contain as much spectral information as the color composites. However, on at least two occasions, it made some light rural residential areas more evident than the color composites, but in most cases all agricultural, water, and vegetation related categories were more difficult to discern. The S190A color IR film had definitely less resolution and information content than the filter bands AA and BB, the color composites, or the color film on the S190A.

3.2.1 Tompkins County-Ithaca

Four composites were used for mapping the interpretational categories in this test area. A listing of these composites and the specific band combinations are in Table 3.2.1. The photographic products were produced from SL3 data, Frame 36, Rolls 38, 41, and 42. The ranking of 1-4 was chosen by the interpreter on the basis of which composites provided the primary information and which composites were used as secondary interpretational checks. The black and white positive films of Filter DD and Filter BB were also found to be somewhat useful as secondary interpretational checks. Composite #1 was reproduced to illustrate this test site (Figure 3.2.3).

The light residential (11) category proved to be difficult to interpret in the more sparsely populated rural areas, particularly in forested regions. This was due to the resolution limits of the film and the interpreters decision on when light residential was too scattered to be mapped as that category.

Another area of difficulty was the delineation between cropland/cropland pasture (21) and pasture/brushland (24) because of a similar spectral response in the late growing season and relative low intensity

FIGURE 3.2.3 The primary S190A color composites for the interpretation of Suffolk County, Long Island (left) and Tompkins County (right) at a scale of 1:250,000.

farming methods in this area. The area has from moderate to low agricultural viability which makes identification sometimes difficult and tends to include farm areas that are no longer in active production.

Both wetlands categories (61 and 62) proved to be impractical to intrepret because of their generally small area, the low resolution on the IR film and generally poor spectral information on this IR filter record. Spring or fall coverage would have been helpful if taken when vegetation was not in full foliage.

The topographic features of this area include steep wall valleys and gorges which produced shadow areas on the photographic products. These small areas were referenced to topographic maps, so that later all interpretational anomalies were resolved.

TABLE 3.2.1 The Four Color Composites (S190A) Used For the Interpretation of the Tompkins County Test Area. The composites specify the band, negative or positive, diazo film color, and diazo exposure setting on the GAF Model #240.

1.	Filter BB-	cyan	(6)	3.	Filter BB-	cyan	(6)
	Filter DD+	yellow	(4)		Filter BB+	yellow	(4)
	Filter AA-	magenta	(5)		Filter DD+	magenta	(8)
2.	Filter DD-	cyan	(10)	4.	Filter BB-	cyan	(6)
	Filter BB-	yellow	(2)		Filter AA+	yellow	(4)
	Filter BB+	magenta	(6)		Filter AA-	magenta	(4)

3.2.2 Lower Hudson Valley-Newburgh

The five color composites, in order of interpretational sequence, for this test area are listed in Table 3.2.2. A photographic reproduction of composite #3 is included in Figure 2.3.1 at a scale of 1:250,000. The original photographic products are from SL3 mission, Frame 236, Rolls 44, 47, and 48.

TABLE 3.2.2 The Five Color Composites (S190A) Used For the Interpretation of the Lower Hudson Valley Test Site. The composites specify the band, negative or positive, diazo film color and diazo exposure setting on the GAF Model #240.

1.	Filter BB+	cyan	(6)	4.	Filter DD+	cyan	(8)
	Filter DD+	yellow	(6)		Filter BB-	yellow	(4)
	Filter BB-	magenta	(8)		Filter BB+	magenta	(4)
2.	Filter BB+	cyan	(4)	5.	Filter BB-	cyan	(6)
	Filter DD-	yellow	(2)		Filter DD+	yellow	(4)
	Filter AA-	magenta	(10)		Filter AA+	magenta	(2)
3.	Filter BB+	cyan	(4)				
	Filter DD-	yellow	(4)				
	Filter BB-	magenta	(10)				

The forested, hilly topography and small parcels in each land use made the interpretation process difficult in both identification and delineation. This further compounded the problem of interpreting wetlands (61 and 62), light residential (11) and in some cases, medium/heavy residential (12) at this time of year. Certain steep valleys contained shadows which had to be identified so as not to mislabel them during the interpretation process.

The medium to low agricultural viability and inactive farms in the area made it difficult to distinguish between cropland/pasture (21) and pasture/brushland (24). For basically the same reasons, it was often difficult to separate the pasture/brushland from the mixed forest (43) category.

3.2.3 Suffolk County - Long Island

The four composites used for interpretation are listed in Table 3.2.3 and ranked according to which composites provided the primary information and which composites were used for secondary interpretational information. Composite #1 is photographically reproduced in

TABLE 3.2.3 The Four Color Composites (S190A) Used For The Interpretation of the Suffolk County, Long Island Test Area. The composites specify the band, negative or positive, diazo film color, and diazo exposure setting on the GAF Model #240.

1.	Filter BB-	cyan	(8)	3.	Filter BB-	cyan	(6)
	Filter DD+	yellow	(8)		Filter DD+	yellow	(8)
	Filter AA-	magenta	(2)		Filter BB+	magenta	(10)
2.	Filter DD-	cyan	(4)	4.	Filter BB+	cyan	(6)
	Filter BB+	yellow	(2)		Filter AA+	yellow	(4)
	Filter AA-	magenta	(6)		Filter BB-	magenta	(8)

Figure 3.2.3 to illustrate the types of information evident in one possible composite for this area. The original photographic products are from SL3 mission, Frame 238 on Rolls 44, 47, and 48.

The relatively flat topography and generally short forest height made most category interpretation fairly consistent, except for the light residential category (11) which still could be a problem when it was scattered in rural areas. This was only partially due to forest canopy cover and mostly related to the resolution limitations. The cropland/cropland pasture (sod farms) category (21) was distinct in most cases due to intensive management practices on an otherwise dry, sandy natural soil condition.

Although wetlands were generally larger than four hectares, it was still very difficult to accurately identify these two categories (61,62). The vegetative cover and poor IR record are the most important reasons.

Spring or fall coverage would be helpful in wetlands interpretation in this area also.

3.3 Interpretation of S190B

The S190B film products exhibit good resolution and contrast even when projected up to a scale of 1:24,000. Conventional air photo interpretation techniques (texture, tone, configuration, etc.) were used to identify the land use categories. The resolution of the photographic products was determined for high contrast situations to be as follows: Black and White High Resolution 30-40 feet, Aerial Color High Resolution 45-50 feet, and Color IR Film 60-70 feet.

3.3.1 Tompkins County-Ithaca

The S190B photographic product available over the Tompkins County test site was the black and white High Resolution Film: Roll 85, Frame 345. The 1:950,000 scale film was enlarged by conventional darkroom techniques to a scale of 1:250,000, This enlarged film was then put on the overhead projector and further enlarged for the interpretation process (1:62,500 scale) on the backlighted screen.

The film resolution was excellent, aiding in both identification and delineation of most categories. However, the tonal separation of the levels of gray proved to be a problem in two cases. The water boundaries (51, 52, and 53) and wetlands (61 and 62) were difficult to differentiate from the forest (43) and pasture/brushland (24) categories, as there is very little tonal difference during this time of year on the black and white film. A second problem in differentiation was between urban intensive (16) and cropland/cropland pasture (21), and the pasture/brushland (24). This was mostly due to overlapping density values among these categories. This was also mentioned in Section 3.2.1 and stems from the low level of intensity (viability) in farming methods. It can even be a problem to differentiate the two categories when field checking on the ground.

A second interpretation test was carried out on a small section of this area to determine if larger scales would improve accuracy. A 8" x 10" black and white film enlargement at a scale of 1:24,000 was interpreted directly off a light table at the same scale. The increased scale made certain features easier to interpret and delineate. This was particularly true on all of the Urban and Built Up Land categories which are differentiated by building size, density, and layout. One category which had not been identified on other interpretations was Orchards (22). They became interpretable because the pattern of individual trees which made up the orchard configuration could be identified.

3.3.2 Lower Hudson Valley-Newburgh

A NASA supplied 2X enlargement of the Aerial Color Film, Roll 88, Frame 274, was projected for interpretation onto the backlighted screen at a scale of 1:62,500. The overall blue-green color of the photographic product, due to atmospheric conditions, made conventional air photo interpretation techniques difficult when the differentiation depended on color. This difficulty exists between the natural vegetation categories of forest (43) and pasture/brushland (24). Sometimes, the distinction between pasture/brushland (24) and cropland (21) was also difficult in areas of low agricultural viability. The delineation of water boundaries was not totally reliable when adjacent to natural areas of vegetation because of similar color hues for both areas. Likewise, neither wetland category (61 or 62) was interpreted in this area due to small size and lack of spectral separation.

The color film resolution and color contrast proved generally reliable for interpreting all Urban and Built Up Land categories, except the light residential (11) category, which was under full forest canopy cover. A second interpretation was made on this film using the Kingston area from the same frame. The film was enlarged to approximately a scale of 1:30,000 on a microfiche reader (Teledyne Post Micro-Reader, Model #64018). The interpretation was done directly off the screen of the microfiche reader onto clear acetate. This was later transferred onto mylar at a 1:24,000 scale using USGS topographic maps as a means of establishing the geographic reference. This interpretation was to compare both 1972 low altitude (1:24,000) photography and the 1968 LUNR inventory (1:24,000) with S190B color interpretation.

The test area was 5 kilometers x 20 kilometers and included low to high relief topography. The land use varied from large areas of forest (43) and mixed agriculture (21,24), to small rural residential areas (11, 12). The very small, scattered areas of each land use made delineation a problem but the area had been chosen because the New York State Catskill Commission had indicated this to be an area of very high land use change.

In general, the microfiche reader functioned very well, as it had greater field of view, less distortion, and more magnification than a Bausch and Lomb Zoom Transfer Scope which was tested initially. The large area visible on the screen of the microfiche reader was a distinct advantage for orientation and interpretation. The larger scale (1:24,000) interpretation and mapping made for a more detailed final product than the interpretation on the same film at a scale of 1:62,500.

Another interpretation was made of the Newburgh area using the NASA supplied 2X enlargement of the Color IR Film, Roll 87, Frame 299. The procedure was the same as described above for the Color Film interpretation of the Newburgh area using the projector and backlighted screen technique at a scale of 1:62,500.

Although Urban and Built Up Land can be easily distinguished at Level I, it is difficult to discriminate the appropriate Level II categories. This seems to be due both to the resolution and spectral composition. For the same reasons, it is hard to separate the forest (43), pasture/brushland (24), cropland (21), and wetland (61, 62) categories, although all open water categories are distinct due to information in the IR band.

3.3.3 Suffolk County-Long Island

The NASA supplied 2X enlargements from the Color Film (Roll 88, Frame 277) was used for interpretation by the projector and backlighted screen technique at a 1:62,500 scale.

The intensive agricultural practices made identification of cropland (21) very reliable, except when only bare, sandy soil is exposed. These areas appeared similar to bare sand (72), extractive (14) and intensive development (16). In these cases with which they may be associated, the interpretation of these categories tended to rely on configuration and proximity to other features.

The generally blue-green color of the photographic product made separation of pasture/brushland (24) from forest (43) a hard distinction, as was noted previously in Section 3.3.2. However, the short forest height and flat topography made the residential (11, 12) categories more evident than in the Lower Hudson Valley test site. In general, both water boundaries and wetlands could be distinguished more readily than the Lower Hudson Valley test site. This is probably due to the contrast between dry, sandy soil vegetation types and the wetland vegetation (or water).

3.4 Comparison of ERTS and Skylab S190A

The ERTS imagery and S190A photographic products were processed according to the information in Section 2.2 and sample color composites from each system are seen in Figure 2.2.1. The Lower Hudson Valley (Newburgh) test site interpretation was carried out from the ERTS imagery using the three composites listed in Table 3.4.1. The ranking of 1 to 3 is on the basis of usefulness for category interpretations.

A complete evaluation of the ERTS imagery can be found in the Final Report-"ERTS Evaluation for Land Use Inventory, (Resource Information Laboratory, 1974). In general, the ERTS color composites could be used to interpret all Level I categories, except wetlands at this time of year. However, the Level II categories could not easily be interpreted; this is primarily due to the lack of resolution which made the Urban and Built Up Land categories very hard to differentiate. The interpretation map from the ERTS color composites contained a minimum mapable unit of ten hectares. When compared to the S190A interpretational map, the ERTS map appeared very generalized in detail and limited in the categories interpreted. Part of this variation in interpretability pertains to the category definitions as discussed above in Section 3.1.

When the individual bands are compared between systems, the S190A bands are superior in contrast and resolution; however, the ERTS band 7 does seem to show more spectral information. This is probably due to an IR spectral record that extends further into the near IR region than does the S190A Filter DD.

TABLE 3.4.1 The Three Color Composites Used For The ERTS Interpretation of the Lower Hudson Valley Test Site. The composites specify the band, negative or positive, diazo film color, and diazo exposure setting on the GAF Model #240.

1. Band 5- cyan (7)
   Band 7+ yellow (4)
   Band 4- magenta (8)

2. Band 7+ cyan (5)
   Band 7- yellow (6)
   Band 5+ magenta (6)

3. Band 7+ cyan (8)
   Band 5- yellow (4)
   Band 5+ magenta (4)

3.5 Comparison of S190A and S192 Multispectral Systems.

The S190A filter bands are relatively broad and overlap to some extent as shown in Figure 2.0.1. As a result, the density ranges for various spectral categories are not discrete and tend to overlap among different spectral bands. This is illustrated in Figure 3.2.2 where a density range histogram shows the relationship between different land use categories. Where there is a significant overlap in all three bands, it is difficult or impossible to achieve any color separation, as discussed in Section 3.2.

Therefore, a request was made to NASA to obtain a sample of the narrow band S192 multispectral scanner data. A sample was supplied for the Lansing, Michigan area in all thirteen bands. Only six bands were selected (3, 5, 7, 10, 11, and 12) and enlarged to a scale of approximately 1:125,000. Using only a 1:250,000 scale USGS topographic map for reference, the sample density values were chosen and the CIE model color composites were generated. Four of these color composites are shown in Figure 3.5.1 and listed in Table 3.5.1. These sample areas were later defined with high altitude Color IR photographs obtained for the same area during September, 1972.

A visual examination of the high altitude Color IR photo compares favorably with the color composites. No actual interpretation was done from the S192 color composites because the experiment was carried out very late in the project. The main purpose of the experiment was to test the CIE Color Prediction Model for color composites using narrow band spectral data.

In essence, greater color contrast could be obtained among the interpretation categories in the S192 data than in the S190A data. It seems evident that the objective of improving category separation using narrow spectral bands was accomplished, although additional tests are necessary to explore the actual potential of the S192 narrow band multispectral scanner data from the full 13 band array.

TABLE 3.5.1 The Four Color Composites From the S192 Examples in Fig.3.5.1. The composites specify the band, negative or positive, diazo film color, and diazo exposure setting on the GAF Model #240.

UPPER LEFT			UPPER RIGHT		
Band 7+	cyan	(4)	Band 5-	cyan	(6)
Band 11+	yellow	(2)	Band 5+	yellow	(4)
Band 5+	magenta	(4)	Band 10+	magenta	(2)
LOWER LEFT			**LOWER RIGHT**		
Band 5+	cyan	(6)	Band 12+	cyan	(4)
Band 3+	yellow	(2)	Band 5+	yellow	(2)
Band 3-	magenta	(6)	Band 10-	magenta	(6)

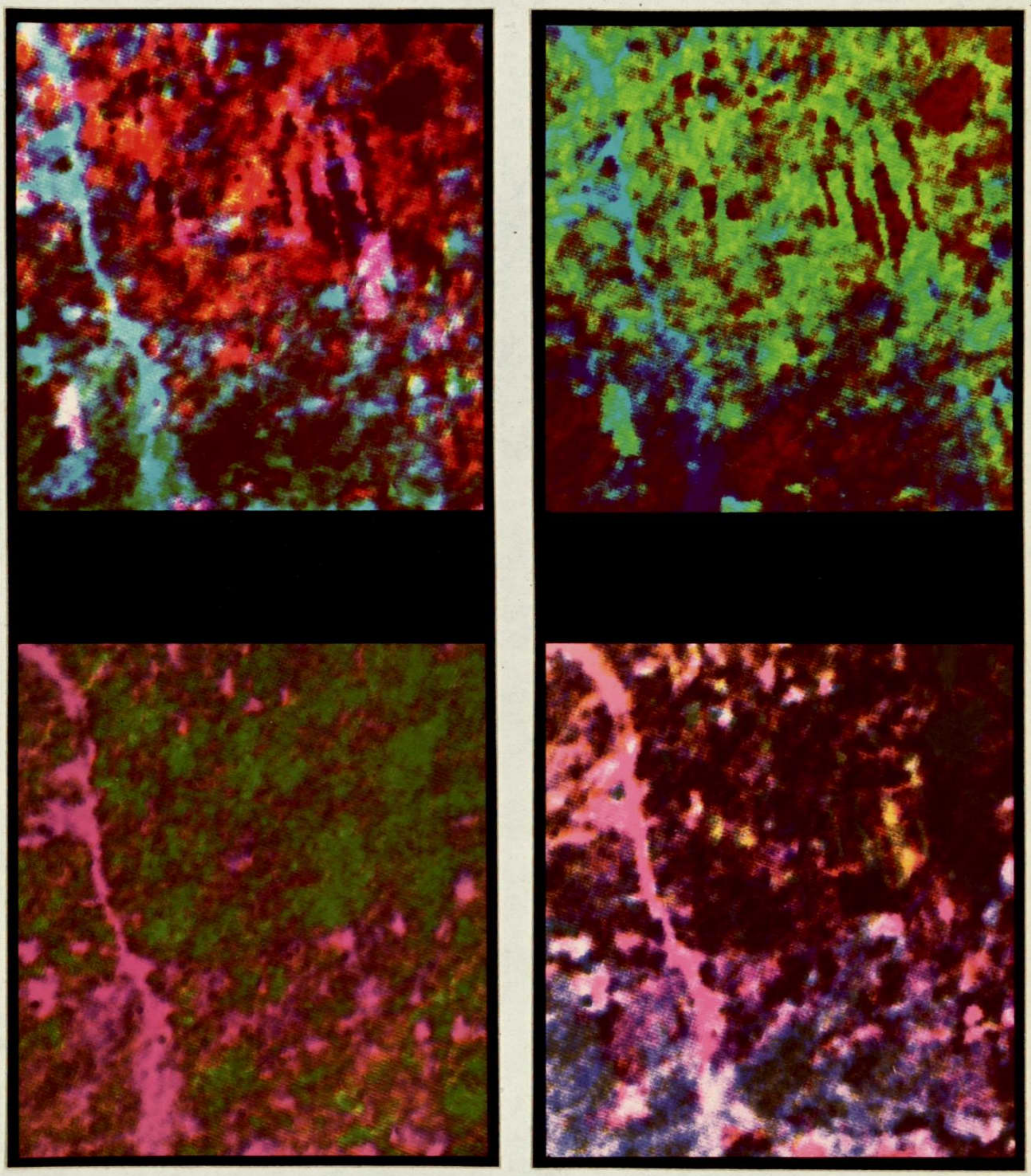


FIGURE 3.5.1 Four color composites from the S192 multispectral scanner system taken over Lansing, Michigan, and shown here at a scale of 1:125,000. (Reference Table 3.5.1)

4.0 COMPARISON OF LAND USE DATA OBTAINED FROM SKYLAB S190A AND S190B IMAGERY

In this section, land use data obtained from Skylab S190A and S190B imagery is compared either to 1968 LUNR data or data interpreted from 1972 low altitude aerial photography. The New York State Land Use and Natural Resources (LUNR) Inventory provides a comprehensive land use inventory of New York State. Black and white aerial photographs taken in 1968 are the major source of information. Other information sources include existing maps, reports and directories, public agency records, and direct contact with various public officials in most counties.

The LUNR inventory provided point and linear/area information on eleven major categories of land use: agriculture, forest land, water resources, non-productive land, residential land use, commercial areas, industrial areas, public and semi-public land use, and transportation. Most of these categories were disaggregated into more detailed categories. In all, 55 of these secondary categories were identified (see Appendix B).

A new categorization system was developed for interpretation of Skylab imagery. Six level I and 19 Level II categories were identified primarily on the basis of spatial and spectral response (see Section 3.1). In order to make a comparison between the two data bases, most of the 55 secondary LUNR categories were uniquely assigned to a Skylab interpretation category (see LUNR classification system, Appendix B). Several LUNR categories were, however, based primarily on ownership or activity characteristics (e.g., public and semi-public, and outdoor recreation) and had no consistent visual or spectral characteristics. Outdoor recreation, for example, included such diverse uses as public parks, campgrounds, and drive-in movies. When such categories were encountered, they were re-interpreted directly from the original aerial photographs and placed into appropriate Skylab categories.

In addition to the comparison with LUNR data in three test areas, a comparison was made in a fourth area (Kingston, Ulster County) to land use data interpreted directly into Skylab categories from 1972 aerial photographs. The significance of the comparisons presented in this section is compromised by several factors which should be considered when evaluating the results. First, the LUNR maps are comprised of curvilinear figures which closely approximate polygons. These polygon-like figures represent the interpreters' view of what appeared to them to be the relative boundary lines delineating various land use features in the black and white photographs. Likewise, the Skylab interpretations result in maps having polygon-like figures (see Figure 3.2.1) defined according to spectral and spatial features. The difficulty encountered in trying to update a detailed inventory such as LUNR is similar to matching polygons from two different data sources. Each of these inventories has its own set of parameters which define their prospective polygons. Differences in these parameters include different sensor systems, scales, category definitions, and the time of year that the data was collected.

A second problem is that most of the comparisons are made to the LUNR inventory which is based on 1968 aerial photography. In the last five years, that intervened between the LUNR inventory and the Skylab missions, many changes in land use have occurred.

A third problem is that any land use data acquisition system is not completely accurate. This is true for both the LUNR inventory and for the direct interpretation of the 1972 photography. These inherent errors are minimized, however, by basing the comparison on the less specific Skylab categories. For the purpose of calculating the accuracy of the Skylab data, as shown in the various tables, the LUNR inventory and the interpretation of 1972 aerial photographs are considered to be 100% accurate. Ground truth checks of the 1968 data exist for the Hudson Valley and Suffolk County test sites. For interpretations in these areas, adjustments have been made and are discussed in the text.

Finally, it must be noted that each Skylab interpretation represents only a sample of size, one from an infinity of possible interpretaions. Different interpreters working with the same S190A multispectral composites or S190B photographs would undoubtedly produce somewhat different maps. It is impossible to know how large the variance for each category is without an analysis of interpretations performed on the same area by several interpreters. Spot field checks, however, were made on each site to verify possible land use changes or classification problems.

4.1 Comparison of Skylab S190A Data to 1968 LUNR Data (Levels I and II)

The tables in this section compare land use data interpreted from Skylab S190A multispectral composites to the 1968 New York State Land Use and Natural Resources (LUNR) Inventory for each of the three test areas. Separate tables are developed for Level I and Level II land use categories. The following definitions apply to the statistical tables.

Error: $a_i - k_i$

Aggregate Error: $\frac{1}{2}\sum\left|a_i - k_i\right|$

Relative Error: $(a_i - k_i)/k_i$

Relative Aggregate Error: $\dfrac{\frac{1}{2}\sum\left|a_i - k_i\right|}{\sum k_i}$

Where: a_i is the area in land use category i as determined from the S190A interpretations; and

k_i is the area in category i as derived from the LUNR inventory.

Both the category specific error and relative error are straight forward calculations. A negative value indicates an under-estimation of the acutal area; a positive value indicates an over-estimation. Since the categories are mutually exclusive and exhaustive, total under-estimation must equal total over-estimation. Therefore, when calculating the aggregate error, the sum of the absolute values of the error is divided in half in order to avoid double counting. In order to achieve an overall measure of error, the absolute value of the relative error for each category is multiplied by the proportion of the test area in that category.

These weighted errors are then summed and divided in half to avoid double counting. That is, relative aggregate error is equal to:

$$\tfrac{1}{2} \Sigma \frac{(a_i - k_i)}{k_i} \frac{k_i}{\Sigma k_i} = \tfrac{1}{2} \frac{\Sigma |a_i - k_i|}{\Sigma k_i}$$

Although this value is intended to give an overall measure of relative error, it should not be considered in isolation from the category specific relative errors. It is, after all, the amount of land in each category that practitioners are interested in. Furthermore, the overall measure can be misleading if large areas of easily discernable categories (ie, water) are included in the test areas. Contrarily, relative errors must be considered in relation to the amount of land in the category. Large relative errors are common when only a small amount of land is contained in a given category. This is frequently the case in Level II categories.

Tables 4.1.1, 4.1.2, and 4.1.3 indicate the relative error of the S190A interpretation for each caetgory in both Level I and Level II. The aggregate error is also summarized for both Level I and Level II categories. Overall Level I aggregate error for the Tompkins County and Newburgh test sites is 12 percent while somewhat lower for Suffolk County at 7 percent.

Ground truth checks on the 1968 LUNR data indicate an overall accuracy of 95% for the Newburgh and Suffolk County sites. Using these adjusted accuracies, the aggregate Level I error for the Newburgh sites is 7 percent and only 2 percent for the Suffolk County site. In the case of Tompkins County, the only figure available indicates a 16 percent increase in developed land over the five year period from 1968-1973.

In general, cultural features tend to be under-estimated while vegetative features are over-estimated. As discussed in Section 3, this may be due in part to advanced seasonal growth which would mask some of the cultural features. The effective error is pronounced when it is considered that the 1968 LUNR and 1972 Kingston photography was taken in

TABLE 4.1.1.a COMPARISON OF SKYLAB S190A (MULTISPECTRAL) DATA TO 1968 LUNR DATA (LEVEL I):

TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190A (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	3,481	2,272	-1,209	- .35
2	41,512	36,380	-5,132	- .12
4	9,095	16,140	7,045	.77
5	5,185	5,208	23	.00
6	724	0	- 724	- 1.00
7	3	0	- 3	- 1.00
AGGREGATE	60,000	60,000	7,068	.12

TABLE 4.1.1.b COMPARISON OF SKYLAB S190A (MULTISPECTRAL) DATA TO 1968 LUNR DATA (LEVEL II):

TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190A (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	1,859	236	- 1,623	- .87
1.2	417	928	511	1.23
1.4	185	64	- 121	- .65
1.5	227	80	- 147	- .65
1.6	650	964	314	.48
1.7	143	0	- 143	- 1.00
2.1	17,819	3,744	-14,075	- .79
2.2	118	0	- 118	- 1.00
2.4	23,575	32,636	9,061	.38
4.2	594	0	- 594	- 1.00
4.3	8,501	16,140	7,633	.90
5.1	63	0	- 63	- 1.00
5.2	5,046	5,208	162	.03
5.3	75	0	- 75	- 1.00
5.4	0	0	0	0
6.1	435	0	- 435	- 1.00
6.2	290	0	- 290	- 1.00
7.2	3	0	- 3	- 1.00
7.4	0	0	0	0
AGGREGATE	60,000	60,000	17,684	.29

TABLE 4.1.2.a COMPARISON OF SKYLAB S190A (MULTISPECTRAL) DATA TO 1968 LUNR DATA (LEVEL I):

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190A (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	7,558	6,724	- 834	- .11
2	7,929	12,808	4,879	.62
4	18,210	17,128	- 1,082	- .06
5	3,781	3,340	- 441	- .12
6	2,509	0	- 2,509	- 1.00
7	10	0	- 10	- 1.00
AGGREGATE	39,997	40,000	4,878	.12

TABLE 4.1.2.b COMPARISON OF SKYLAB S190A (MULTISPECTRAL) DATA TO 1968 LUNR DATA (LEVEL II):

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190A (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	4,720	3,620	- 1,100	- .23
1.2	290	1,260	970	3.34
1.4	513	396	- 117	- .23
1.5	480	632	152	.32
1.6	1,215	532	- 683	- .56
1.7	340	284	- 56	- .16
2.1	1,502	860	- 642	- .42
2.2	2,125	60	- 2,065	- .97
2.4	4,302	11,888	7,586	1.76
4.2	56	0	- 56	- 1.00
4.3	18,154	17,128	- 1,026	- .06
5.1	3,176	2,948	- 228	- .07
5.2	142	392	250	1.76
5.3	463	0	- 463	- 1.00
5.4	0	0	0	.0
6.1	891	0	- 891	- 1.00
6.2	1,618	0	- 1,618	- 1.00
7.2	0	0	0	0
7.4	10	0	- 10	- 1.00
AGGREGATE	39,997	40,000	8,957	.22

TABLE 4.1.3.a COMPARISON OF SKYLAB S190A (MULTISPECTRAL) DATA TO 1968 LUNR DATA (LEVEL I):

RIVERHEAD-SOUTHAMPTON, SUFFOLK COUNTY (SKYLAB SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190A (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	9,239	9,084	- 155	- .02
2	12,818	9,984	- 2,384	- .22
4	17,737	21,452	3,715	.21
5	18,575	18,520	- 55	.00
6	1,142	88	- 1,054	- .92
7	484	852	368	.76
AGGREGATE	59,995	59,980	4,091	.07

TABLE 4.3.1.b COMPARISON OF SKYLAB S190A (MULTISPECTRAL) DATA TO 1968 LUNR DATA (LEVEL II):

RIVERHEAD-SOUTHAMPTON, SUFFOLK COUNTY (SKYLAB SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190A (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	5,065	372	- 4,693	- .93
1.2	261	7,512	7,251	27.78
1.4	381	0	- 381	- 1.00
1.5	1,036	688	- 348	- .34
1.6	2,111	512	- 1,599	- .76
1.7	384	0	- 384	- 1.00
2.1	7,494	9,120	1,626	.22
2.2	375	8	- 367	- .98
2.4	4,949	856	- 4,093	- .83
4.2	16	0	- 16	- 1.00
4.3	17,721	21,452	3,731	.21
5.1	111	0	- 111	- 1.00
5.2	167	260	- 147	- .88
5.3	155	0	- 155	- 1.00
5.4	18,142	18,260	188	.01
6.1	921	84	- 837	- .91
6.2	220	4	- 216	- .98
7.2	484	852	368	.76
7.4	0	0	0	0
AGGREGATE	59,995	59,980	13,221	.22

early spring (late March and early April) before there was any leaf development. Water is fairly accurately interpreted, but upland wetlands could not be interpreted. Again, as discussed in Section 3, the spectral response of wetlands is highly variable depending on the season. Forest is over-estimated for several reasons: 1) the time of year, as indicated above; 2) the category definition of brushland for LUNR included vegetation up to 30 feet in height, whereas the Skylab classification included vegetation less than 20 feet in height with less than 50% canopy cover, (this would mean that there would likely be some shift to forest from a change of category definition alone); and 3) there has been a general trend over the last five years for an increase in forest land in New York State.

The source of error on each of the Level II categories is more difficult to assess. In large part, it is probably due to the effects of resolution and scale (80-100 feet and 1:62,500 for S190A; 1-2 feet and 1:24,000 scale for LUNR). However, there is a substantial amount of discrepancy introduced from changes in category definition. For instance, LUNR classified three residential categories on the basis of lot frontage. Since lot frontage would be meaningless on satellite data, housing units per area are used. This immediately changes the interpretation particularly with repsect to "light and medium residential." In all three areas, light residential is substantially under-estimated and medium to heavy residential is greatly over-estimated. Combining residential as single category results in 48 percent under-estimation for Tompkins County, a 3 percent under estimation for Newburgh, and a 48 percent over-estimation for Suffolk County. Tompkins County is substantially more rural than either Newburgh or Suffolk County with much of the rural residential occurring as strip development along secondary roads. In addition, most of the residential areas are located on the sides of the the fairly steep hills. Therefore, it is likely that the topography and scattered patterns combined with masking vegetation greatly affected the interpretability of this category. This is also likely the case in the Newburgh site, although not nearly to the same extent. Suffolk County,

C, 2

however, has relatively flat terrain and a figure of 48 percent, while likely an over-estimation, it does indicate a trend of growth over a five year period similar to that found with the S190B interpretation. (See Section 4.2).

Summing up the relative error for the remainder of Level II urban categories, under-estimates occur of 8 percent (Tompkins County), 28 percent (Newburgh), and 69 percent (Suffolk County). Again, part of the under-estimation is likely due to lack of resolution and the fact that intensively developed categories are generally small in area and also tend to be scattered. Therefore, there would be difficulty in mapping many of these features at scales of 1:62,500. On Suffolk County, the soil conditions are quite sandy, resulting in a high reflectivity as compared to Tompkins County and Newburgh. This may have resulted in some confusion with bare soil in active cropland areas.

In the case of agricultural land, most of the active cropland was placed in the pasture/brushland category. Since, essentially, all the crops would have been harvested or would have evidenced distinct spectral changes as result of senescence, most of this error was likely due to seasonal variation. Most of the active cropland was identified by the spectral contrast produced by fall plowing.

The Level II aggregate error for Tompkins County is 29 percent and 22 percent for the Newburgh and Suffolk County sites. Using the adjusted accuracy figures of the 1968 LUNR inventory for Newburgh and Suffolk County, the Level II aggregate error is reduced to 18 percent for each site.

4.2 Comparison of Skylab S190B Data to 1968 LUNR Data (Levels I and II)

The tables in this section compare land use data interpreted from Skylab S190B high resolution photography (black and white, color, and color infra-red) to the New York State LUNR Inventory. Separate tables are developed for Level I and Level II categories.

Comparisons were made for each of three test areas, and a sub-area in Tompkins County. In Tompkins County, S190B black and white photography was interpreted at a scale of 1:62,500, and in addition, a 17 square kilometer sub-area was interpreted at a scale of 1:24,000. For the sub-area, interpretations at both scales were compared to the LUNR data base. In the Newburgh (Orange County) test area, both S190B color and color infra-red photography were interpreted at a scale of 1:62,500 and each was compared with the LUNR Inventory. Finally, in the Riverhead-Southampton (Suffolk County) test area, S190B color photography was interpreted at a scale of 1:62,500 and compared to the LUNR Inventory.

The following definitions apply to the statistical tables:

Error:	$b_i - k_i$
Aggregate Error:	$\frac{1}{2} \Sigma \lvert b_i - k_i \rvert$
Relative Error:	$(b_i - k_i)/k_i$
Relative Aggregate Error:	$\dfrac{\frac{1}{2} \Sigma \lvert b_i - k_i \rvert}{\Sigma k_i}$

Where: b_i is the area in land use category i as determined from S190B interpretation; and

k_i is the area in category i as derived from the LUNR Inventory.

A total of six separate interpretations were done on S190B photography. Two interpretations were done at scales of 1:24,000, one black and white and one color. The color (1:24,000) interpretation was over the Kingston site, which represents a special case and is discussed in Section 4.5. The other 1:24,000 scale interpretation was on the city of Ithaca, using black and white film enlarged to the same scale. The remaining interpretations were all done at map scales of 1:62,500. Black and white film was interpreted for Tompkins County; color film was interpreted for the Suffolk County and Newburgh areas; and color IR was also interpreted for the Newburgh site.

Since there are three different film types with different resolutions covering three different areas, the interpretation results are such that it is difficult to make overall generalizations. Therefore, the discussion will proceed on the basis of each site. The S190B black and white film has the best overall resolution for high contrast objects. Tables 4.2.1, 4.2.2, and 4.2.3 summarize the data for Tompkins County and the City of Ithaca. Level I aggregate error is 13 percent for the whole site and 17 percent for the sub-area of Ithaca at map scales of 1:62,500. The 1:24,000 scale interpretation has a Level I aggregate error of 20 percent. Level II aggregate error is 33 percent and 38 percent, respectively at 1:62,500, and 23 percent at 1:24,000.

Except for water, the relative error for each of the separate categories on both Level I and Level II is quite high. The best explanation appears to be that the interpreter was unable to discriminate successfully among the subtle shades of gray for the very small areas representing some of the categories. Although the resolution is the best of any of the films looked at, it is insufficient to pick up the subtle nuances which are generally used to interpret many of the categories on large scale aerial black and white photography. Hence, the interpreter is left mostly with subtleties in tone and certain broad spatial patterns.

Aggregating the urban category data, as in Section 4.1, the relative error for residential is over-estimated 17 percent (Tompkins County - 1:62,500), 64 percent (Ithaca - 1:62,500), and 17 percent (Ithaca - 1:24,000). Intensive development is under-estimated 47 percent, 46 percent, and 42 percent, respectively. As indicated in Section 4.1, developed lands representing mostly urban categories increased during the five year period by 16 percent. Based on the 1968 ratio of residential to commercial or intensive, about 35 percent of that increase would have been commercial and 65 percent residential. It is likely that much of what was classified commercial on LUNR was interpreted on the black and white Skylab film as medium-heavy residential.

On vegetative categories, the results are worse considering that total areas are much larger. Active agriculture and forest are greatly

TABLE 4.2.1.a COMPARISON OF SKYLAB S190B (B&W) DATA TO 1968 LUNR DATA

TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	3,481	5,580	2,099	.60
2	41,512	34,436	- 7,076	- .17
4	9,095	14,848	5,753	.63
5	5,185	5,136	- 49	- .01
6	724	0	- 724	- 1.00
7	3	0	- 3	- 1.00
AGGREGATE	60,000	60,000	7,852	.13

TABLE 4.2.1.b COMPARISON OF SKYLAB S190B (B&W) DATA TO 1968 LUNR DATA

TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	1,859	2,840	981	.53
1.2	417	2,104	1,687	4.05
1.4	185	0	- 185	- 1.00
1.5	227	68	- 159	- .70
1.6	650	568	- 82	- .13
1.7	143	0	- 143	- 1.00
2.1	17,819	28,532	10,713	.60
2.2	118	0	- 118	- 1.00
2.4	23,575	5,904	-17,671	- .75
4.2	594	0	- 594	- 1.00
4.3	8,501	14,848	6,347	.75
5.1	63	72	9	.14
5.2	5,046	5,064	18	.00
5.3	75	0	- 75	- 1.00
6.1	435	0	- 435	- 1.00
6.2	290	0	- 290	- 1.00
7.2	3	0	- 3	- 1.00
7.4	0	0	0	0
AGGREGATE	60,000	60,000	19,752	.33

TABLE 4.2.2.a COMPARISON OF SKYLAB S190B (B&W) DATA TO 1968 LUNR DATA

ITHACA, TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	986	1,108	122	.12
2	574	264	- 310	- .54
4	83	216	133	1.60
5	50	52	2	.04
6	4	0	- 4	- 1.00
7	3	0	- 3	- 1.00
AGGREGATE	1,700	1,700	287	.17

TABLE 4.2.2.b COMPARISON OF SKYLAB S190B (B&W) DATA TO 1968 LUNR DATA

ITHACA, TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	232	148	- 84	- .36
1.2	291	712	421	1.45
1.4	0	0	0	0
1.5	26	0	- 26	- 1.00
1.6	393	248	- 145	- .37
1.7	44	0	- 44	- 1.00
2.1	175	104	- 71	- .41
2.2	7	0	- 7	- 1.00
2.4	392	160	- 231	- .59
4.2	0	0	0	0
4.3	83	276	193	2.33
5.1	30	8	- 22	- .73
5.2	20	44	24	1.20
5.3	0	0	0	0
5.4	0	0	0	0
6.1	4	0	- 4	- 1.00
6.2	0	0	0	0
7.2	3	0	- 3	- 1.00
7.4	0	0	0	0
AGGREGATE	1,700	1,700	638	.38

TABLE 4.2.3.a COMPARISON OF SKYLAB S190B (B&W) DATA TO 1968 LUNR DATA

ITHACA, TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:24,000)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	986	880	- 106	- .11
2	574	521	- 53	- .09
4	83	240	157	1.89
5	50	59	9	.18
6	4	0	- 4	- 1.00
7	3	0	- 3	- 1.00
AGGREGATE	1,700	1,700	332	.20

TABLE 4.2.3.b COMPARISON OF SKYLAB S190B (B&W) DATA TO 1968 LUNR DATA

ITHACA, TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:24,000)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	232	427	195	.84
1.2	291	185	- 106	- .36
1.4	0	0	0	0
1.5	26	4	- 22	- .85
1.6	393	257	- 136	- .35
1.7	44	7	- 37	- .84
2.1	175	157	- 18	- .10
2.2	7	38	31	4.43
2.4	392	326	- 65	- .17
4.2	0	0	0	0
4.3	83	240	157	1.89
5.1	30	41	- 11	.37
5.2	20	18	2	.10
5.3	0	0	0	0
5.4	0	0	0	0
6.1	4	0	- 4	- 1.00
6.2	0	0	0	0
7.2	3	0	- 3	- 1.00
7.4	0	0	0	0
AGGREGATE	1,700	1,700	394	.23

over-estimated, whereas, pasture/brushland is greatly under-estimated. To some degree, the error reflects the fact that the LUNR category brushland is lumped with pasture and compared to the Skylab pasture/brushland category. As discussed in Section 4.1, because of differences in seasonality and category definitions, together with the five year growth potential, it is probable that LUNR brushland should have been included in forest.

Water is interpreted with considerable accuracy; however, most of this is due to defining the boundaries of Lake Cayuga. Wetlands could not be distinguished.

The aggregate error on the Level II categories for the 1:24,000 scale interpretation improved considerably, almost matching that of Level I. (See Tables 4.2.2 and 4.2.3). This is likely due to the scale enlargement where some subtle features normally used by an interpreter became apparent. For example, large buildings on the Cornell University campus and the Cornell orchards could be identified at the larger scale.

Two interpretations, one color and the other color IR, were done on the Newburgh site at a scale of 1:62,500. (See Table 4.2.4 and 4.2.5). Level I aggregate error was 13 percent for the color and 11 percent for the color IR. Level II aggregate error was 25 percent for the color and 20 percent for the color IR.

Adjusted for the 95 percent accuracy of the LUNR interpretation, the Level I error is reduced to 8 percent on the color and 6 percent on the color IR. Correspondingly, Level II error is reduced to 21 percent on the color and 16 percent on the color IR.

Cultural features were under-estimated and vegetative features were over-estimated on both interpretations. Water was accurately interpreted especially on the color IR, but wetlands were not detected on the color and only to a small extent on the color IR. Again, summarizing the relative error for Level II urban categories, residential was under-estimated 21 percent on the color and 28 percent on the color IR. Intensive development was under-estimated 52 percent on the color and 24 percent on the color IR.

TABLE 4.2.4.a COMPARISON OF SKYLAB S190B (COLOR) DATA TO 1968 LUNR DATA

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	7,558	5,216	- 2,342	- .31
2	7,929	10,624	2,695	.34
4	18,210	20,720	2,510	.14
5	3,781	3,440	- 341	- .09
6	2,509	0	- 2,509	- 1.00
7	10	0	- 10	- 1.00
AGGREGATE	39,997	40,000	5,204	.13

TABLE 4.2.4.b COMPARISON OF SKYLAB S190B (COLOR) DATA TO 1968 LUNR DATA

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	4,720	2,112	- 2,608	- .55
1.2	290	1,856	1,566	5.40
1.4	513	208	- 305	- .59
1.5	480	552	72	.15
1.6	1,215	448	- 767	- .63
1.7	340	0	340	- 1.00
2.1	1,502	616	- 886	- .59
2.2	2,125	0	- 2,125	- 1.00
2.4	4,302	10,008	5,706	1.33
4.2	56	0	- 56	- 1.00
4.3	18,154	20,720	2,566	.14
5.1	3,176	3,020	- 156	- .05
5.2	142	420	278	1.96
5.3	463	0	- 463	- 1.00
5.4	0	0	0	0
6.1	891	0	- 891	- 1.00
6.2	1,618	0	- 1,618	- 1.00
7.2	0	0	0	0
7.4	10	0	- 10	- 1.00
AGGREGATE	39,997	40,000	10,206	.25

TABLE 4.2.5.a COMPARISON OF SKYLAB S190B (COLOR INFRA-RED) DATA TO 1968 LUNR DATA (LEVEL I)

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	7,558	5,560	- 1,998	- .26
2	7,929	9,764	1,835	.23
4	18,210	20,800	2,590	.14
5	3,781	3,696	- 85	- .02
6	2,509	136	- 2,373	- .95
7	10	44	34	3.40
AGGREGATE	39,997	40,000	4,458	.11

TABLE 4.2.5.b COMPARISON OF SKYLAB S190B (COLOR INFRA-RED) DATA TO 1968 LUNR DATA (LEVEL II)

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	4,720	1,780	- 2,940	- .62
1.2	290	1,852	1,562	5.38
1.4	513	304	- 209	- .41
1.5	480	704	224	.47
1.6	1,215	804	- 411	- .34
1.7	340	116	- 224	- .65
2.1	1,502	1,200	- 302	- .20
2.2	2,125	0	- 2,125	- 1.00
2.4	4,302	8,564	4,262	.99
4.2	0	0	0	0
4.3	18,154	20,800	2,646	.15
5.1	3,176	3,088	- 88	- .03
5.2	142	608	466	3.28
5.3	463	0	- 463	- 1.00
5.4	0	0	0	0
6.1	891	76	- 815	- .91
6.2	1,618	60	- 1,558	- .96
7.2	0	0	0	0
7.4	10	44	34	3.40
AGGREGATE	39,997	40,000	7,871	.20

Pasture/brushland was greatly over-estimated. This was partly due to factors discussed above: seasons, category definitions, and the five year growth potential. However, on the Newburgh site, the LUNR brushland category was moved into forest. This improved the forest category, but it still left the pasture/brushland category very high. It appears that perhaps as much as 50 percent of the error is due to the large number of orchards in the area being aggregated into pasture/brushland. Many of these orchards may have been detected on the basis of spatial patterns at a greater magnification and mapping scale, as was the case for the 1:24,000 scale interpretation of the Ithaca area.

The Suffolk County site was interpreted from color and had the lowest aggregate error: 5 percent on Level I and 19 percent on Level II. (See Table 4.2.6) The aggregate error, however, is distorted because a large part of the site included ocean and estuaries. Subtracting these areas,the aggregate error becomes 7 percent on Level I and 27 percent on Level II. Again, adjusting these figures for the 95 percent accuracy of LUNR yields a 2 percent aggregate error at Level I and a 23 percent aggregate error at Level II. This is somewhat closer to the color interpretation on the Newburgh site. The improvement on Level I categories over that of the Newburgh site is probably due to effects of the level topography and the more concentrated land use on Long Island.

Aggregating the Level II urban categories relative error for residential was over-estimated by 35 percent compared to 1968 LUNR and intensive was under-estimated by 32 percent. In comparing the Level II relative error between light residential and medium to heavy residential, based on the definitions applied to these categories, the LUNR interpreters placed most of the residential into the light category; whereas, on Skylab it was mostly medium to heavy. In this case, most of the developments on Long Island were cluster developments where the road frontage was apparently relatively large as compared to the lot depth. Therefore, category definition probably affects the outcome in this case.

The errors in agricultural land categories are, again, probably due to seasonal variations in the spectral character of the land. The

TABLE 4.2.6.a COMPARISON OF SKYLAB S190B (COLOR) DATA TO 1968 LUNR DATA

RIVERHEAD-SOUTHAMPTON, SUFFOLK COUNTY TEST AREA(SKYLAB SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	9,239	9,836	597	.06
2	12,818	10,449	- 2,369	- .18
4	17,737	19,264	1,527	.08
5	18,575	18,236	- 339	- .02
6	1,142	997	- 145	- .13
7	484	1,227	743	1.54
AGGREGATE	59,995	60,009	2,860	.05

TABLE 4.2.6.b COMPARISON OF SKYLAB S190B (COLOR) DATA TO 1968 LUNR DATA

RIVERHEAD-SOUTHAMPTON, SUFFOLK COUNTY TEST AREA (SKYLAB SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	SKYLAB S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	5,065	780	- 4,285	- .85
1.2	261	6,384	6,123	23.46
1.4	381	424	43	.11
1.5	1,036	956	- 80	- .08
1.6	2,111	1,252	- 859	- .41
1.7	384	40	- 344	- .90
2.1	7,494	10,388	2,894	.39
2.2	375	0	- 375	- 1.00
2.4	4,949	61	- 4,888	- .99
4.2	16	0	- 16	- 1.00
4.3	17,721	19,264	1,543	.09
5.1	111	24	- 87	- .78
5.2	167	260	93	.56
5.3	155	0	- 155	- 1.00
5.4	18,142	17,952	- 190	- .01
6.1	921	897	- 24	- .03
6.2	220	100	- 120	- .55
7.2	484	1,147	633	1.37
7.4	0	80	80	1.00
AGGREGATE	59,995	60,009	11,416	.19

total amount of agricultural land interpreted is off 18 percent. It would probably not be too far wrong to assume that this represents the approximate growth of developed land for this part of Long Island.

4.3 Comparison of Skylab S190A and S190B Land Use Data (Levels I and II)

Tables in this section compare the errors and relative errors as calculated in sections 4.1 and 4.2 for each of the three test sites. Separate tables are presented for both Level I and Level II categories for each of the three test sites and each film type. In general, the aggregate error for the S190A compares favorably with that for the S190B on both Level I and Level II categories. This is somewhat surprising in that the resolution of the S190B is two to three times that of the S190A. However, it does seem to indicate that multispectral imagery can be used to good advantage over that of conventional film types used in photo interpretation. No trends are apparent in comparing the relative error among the Level I and Level II categories. The error rate appears to vary independently between the S190A and S190B among the various levels. Part of this variation results from variations in the sites and in interpreter judgment. Figure 4.3.1 summarizes and contrasts the aggregate error for both systems on all three test sites.

Three staff members interpreted the S190A and S190B data. Since, in each case, each interpreter was either working on a different site or a different film type, variations would naturally be introduced. Variations in general were greater for categories comprising small areas. No attempt was made to establish the variation on either the relative or aggregate error. To do so would require special tests to determine the average learning curve of each interpreter for each film type, and at least five to six different interpreters interpreting each film. The test would have to be set up as a typical "blind fold test" where interpreters would train on one area and then interpret an unknown area using information acquired in the training set. This kind of testing ought to be done with some of the Skylab data; however, it was considerably outside the scope of this project's objective and funding.

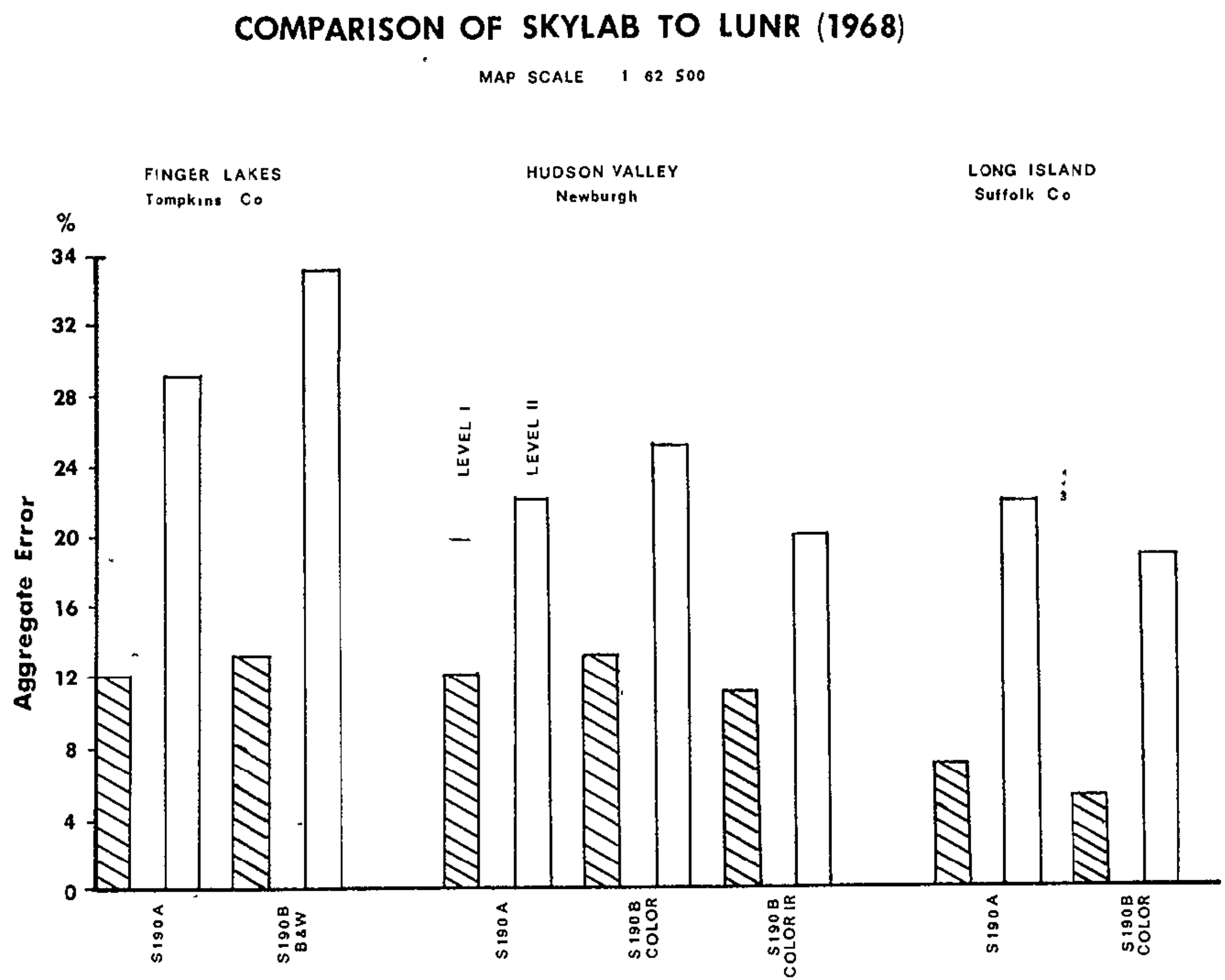


FIGURE 4.3.1 Comparison of Skylab S190A and S190B Data to the 1968 LUNR Inventory. (Level I categories are indicated by hatched lines).

TABLE 4.3.1.a COMPARISON OF SKYLAB S190A AND S190B (BLACK AND WHITE) TO 1968 LUNR DATA (LEVEL I)

TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	S190A ERROR	S190B ERROR	S190A REL ERROR	S190B REL ERROR
1	3,481	-1,209	2,099	- .35	.60
2	41,512	-5,132	-7,076	- .12	- .17
4	9,095	7,045	5,753	.77	.63
5	5,185	23	- 49	.00	- .01
6	724	- 724	- 724	-1.00	-1.00
7	3	- 3	- 3	-1.00	-1.00
AGGREGATE	60,000	7,068	7,852	.12	.13

TABLE 4.3.1.b COMPARISON OF SKYLAB S190A AND S190B (BLACK AND WHITE) TO 1968 LUNR DATA (LEVEL II)

TOMPKINS COUNTY TEST AREA (SKYLAB INTERPRETATI N SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	S190A ERROR	S190B ERROR	S190A REL ERROR	S190B REL ERROR
1.1	1,859	- 1,624	981	- .87	.53
1.2	417	511	1,687	1.23	4.05
1.4	185	- 121	- 185	- .65	- 1.00
1.5	227	- 147	- 159	- .65	- .70
1.6	650	314	- 82	.27	- .13
1.7	143	- 143	- 143	- 1.00	- 1.00
2.1	17,819	-14,075	10,713	- .79	.60
2.2	118	- 118	- 118	- 1.00	- 1.00
.4	23,525	9,061	-17,671	.39	- .75
4.2	594	- 594	- 594	- 1.00	- 1.00
4.3	8,501	7,633	6,347	.91	.75
5.1	63	- 63	9	- 1.00	.14
5.2	5,046	162	18	.03	.00
5.3	75	- 75	- 75	- 1.00	- 1.00
5.4	0	0	0	0	0
6.1	435	- 435	- 435	- 1.00	- 1.00
6.2	290	- 290	- 290	- 1.00	- 1.00
7.2	3	- 3	- 3	- 1.00	- 1.00
7.4	0	0	0	- 0	0
AGGREGATE	60,000	17,684	19,752	.29	.33

TABLE 4.3.2.a COMPARISON OF SKYLAB S190A AND S190B (COLOR) TO 1968 LUNR DATA (LEVEL I)

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	S190A ERROR	S190B ERROR	S190A REL ERROR	S190B REL ERROR
1	7,558	- 834	-2,342	- .11	- .31
2	7,929	4,879	-2,695	.62	- .34
4	18,210	-1,082	2,510	- .06	.14
5	3,781	- 441	- 341	- .12	- .09
6	2,509	- 2,509	-2,509	- 1.00	- 1.00
7	10	- 10	- 10	- 1.00	- 1.00
AGGREGATE	39,997	4,878	5,204	.12	.13

TABLE 4.3.2.b COMPARISON OF SKYLAB S190A AND S190B (COLOR) TO 1968 LUNR DATA (LEVEL II)

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	S190A ERROR	S190B ERROR	S190A REL ERROR	S190B REL ERROR
1.1	- 4,720	-1,100	-2,608	- .23	- .55
1.2	290	970	1,566	3.34	5.40
1.4	513	- 117	- 305	- .23	- .59
1.5	480	152	- .72	.32	- .15
1.6	1,215	- 683	- 767	- .56	- .63
1.7	340	- 56	340	- .16	1.00
2.1	1,502	- 642	- 886	- .42	- .59
2.2	2,125	-2,065	-2,225	- .97	-1.00
2.4	4,302	7,586	5,706	1.76	1.33
4.2	56	- 56	- 56	- 1.00	-1.00
4.3	18,514	-1,026	2,566	- .06	.14
5.1	3,176	- 228	- 156	- .07	- .05
5.2	142	250	278	1.76	1.95
5.3	463	- 463	- 463	- 1.00	-1.00
5.4	0	0	0	0	0
6.1	891	- 891	- 891	- 1.00	-1.00
6.2	1,618	-1,618	-1,618	- 1.00	-1.00
7.2	0	0	0	0	0
7.4	10	- 10	- 10	- 1.00	-1.00
AGGREGATE	39,997	8,957	10,206	.22	.25

TABLE 4.3.3.a COMPARISON OF SKYLAB S190A AND S190B (COLOR IR) TO 1968 LUNR DATA (LEVEL I)

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	S190A ERROR	S190B ERROR	S190A REL ERROR	S190B REL ERROR
1	7,558	- 834	-1,998	- .11	- .26
2	7,929	4,879	1,835	.62	.23
4	18,210	-1,082	2,590	- .06	.14
5	3,781	- 441	- 85	- .12	- .02
6	2,509	-2,509	-2,373	- 1.00	- .95
7	10	- 10	34	- 1.00	3.40
AGGREGATE	39,997	4,878	4,458	.12	.11

TABLE 4.3.3.b COMPARISON OF SKYLAB S190A AND S190B (COLOR IR) TO 1968 LUNR DATA (LEVEL II)

NEWBURGH, ORANGE COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	S190A ERROR	S190B ERROR	S190A REL ERROR	S190B REL ERROR
1.1	4,720	-1,100	-2,940	- .23	- .62
1.2	290	970	1,562	3.34	5.38
1.4	513	- 117	- 290	- .23	- .41
1.5	480	152	224	.32	.47
1.6	1,215	- 683	- 411	- .56	- .34
1.7	340	- 56	- 224	- .16	- .65
2.1	1,502	- 642	- 302	- .42	- .20
2.2	2,125	-2,065	-2,125	- .97	- 1.00
2.4	4,302	7,586	4,262	1.76	.99
4.2	56	- 56	- 56	- 1.00	- 1.00
4.3	18,154	-1,026	2,646	- .06	.15
5.1	3,176	- 228	- 88	- .07	- .03
5.2	142	250	466	1.76	3.28
5.3	463	- 463	- 463	- 1.00	- 1.00
5.4	0	0	0	0	0
6.1	891	- 891	- 815	- 1.00	- .91
6.2	1,618	-1,618	-1,558	- 1.00	- .96
7.2	0	0	0	0	0
7.4	10	- 10	34	- 1.00	3.40
AGGREGATE	39,997	8,957	7,871	.22	.20

TABLE 4.3.4.a COMPARISON OF SKYLAB S190A (MULTISPECTRAL) AND S190B (COLOR) ERRORS TO 1968 LUNR DATA (LEVEL I)

RIVERHEAD-SOUTHAMPTON, SUFFOLK COUNTY TEST AREA(SKYLAB SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (hectares)	S190A ERROR	S190B ERROR	S190A REL ERROR	S190B REL ERROR
1	9,239	- 155	597	- .02	.06
2	12,818	-2,834	-2,369	- .22	- .18
4	17,737	3,715	1,527	.21	.08
5	18,575	55	- 339	.00	- .02
6	1,142	-1,054	- 145	- .92	- .13
7	484	368	743	.76	1.54
AGGREGATE	59,995	4,091	2,860	.07	.05

TABLE 4.3.4.b COMPARISON OF SKYLAB S190A (MULTISPECTRAL) AND S190B (COLOR) ERRORS TO 1968 LUNR DATA (LEVEL II)

RIVERHEAD-SOUTHAMPTON, SUFFOLK COUNTY TEST AREA (SKYLAB SCALE: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	S190A ERROR	S190B ERROR	S190A REL ERROR	S190B REL ERROR
1.1	5,065	-4,693	-4,285	- .93	- .85
1.2	261	7,251	6,123	27.78	23.46
1.4	381	- 381	43	- 1.00	.11
1.5	1,036	- 348	- 80	- .34	- .08
1.6	2,111	-1,599	- 859	- .76	- .41
1.7	384	- 384	- 344	- 1.00	- .90
2.1	7,494	1,626	2,894	.22	.39
2.2	375	- 367	- 375	- .98	- 1.00
2.4	4,949	-4,093	-4,888	- .83	- .99
4.2	16	- 16	- 16	- 1.00	- 1.00
4.3	17,721	3,731	1,543	.21	.09
5.1	111	- 111	- 87	- 1.00	- .78
5.2	167	- 147	93	- .88	.56
5.3	155	- 155	- 155	- 1.00	- 1.00
5.4	18,142	118	- 190	.01	- .01
6.1	921	- 837	- 24	- .91	- .03
6.2	220	- 216	- 120	- .98	- .55
7.2	484	368	633	.76	1.37
7.4	0	0	80	0	1.00
AGGREGATE	59,995	13,221	11,416	.22	.19

4.4 Comparison of ERTS-1 and Skylab S190A to LUNR Inventory

The ERTS-1 interpretation from data collected over the Newburgh site in August, 1973, is compared to LUNR in Table 4.4.1 and to the S190A interpretation in Table 4.4.2. ERTS-1 has a resolution of approximately 100 meters; whereas, the S190A photography has a resolution of about 30 meters. The difference in aggregate error largely reflects the difference in resolution as discussed above in Section 3.4. Water details were more accurately interpreted on the LANDSAT data than on Skylab. However, other features appeared to be more discernable on the Skylab data.

The accuracy obtained on the ERTS interpretation was quite poor. For sake of comparison, an ERTS scene of August 30, 1973, was interpreted. By using this particular scene, it was felt that the spectral components of the scene would not have changed much from that appearing on the Skylab photography 20 days later. No ERTS data was available for the time of the Skylab coverage.

The aggregate error compared to LUNR is 28 percent on Level I and 42 percent on Level II. Adjusted to reflect the accuracy of LUNR, the error is reduced to 24 percent on Level I and 39 percent on Level II.

Atmospheric degradation was quite severe on this ERTS scene. In addition, from data obtained on previous studies (Hardy, et al, 1974), middle to late summer proved to be the worst season to inventory most kinds of land use. These two factors combined likely contributed to a large amount of error, particularly on the Level I categories where better results would have been expected.

4.5 Comparison of Skylab S190B (Color) to 1972 Aerial Photography

Data and comparisons in this section differ in two respects from those in the previous sections. First, the baseline data is derived from 1972 aerial photography, mitigating the error resulting from land use change which occurred between the acquisition of the two data bases.

TABLE 4.4.1.a COMPARISONS OF ERTS-1 DATA TO 1968 LUNR DATA

NEWBURGH, ORANGE COUNTY TEST AREA (ERTS-1 INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	1973 ERTS-1 (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1	7,558	3,484	- 4,074	- .54
2	7,929	19,056	11,127	1.40
3	--	--	--	--
4	18,210	13,688	- 4,522	- .25
5	3,781	3,772	- 9	.00
6	2,509	0	- 2,509	- 1.00
7	10	0	- 10	- 1.00
AGGREGATE	39,997	40,000	11,126	.28

TABLE 4.4.1.b COMPARISONS TO ERTS-1 DATA TO 1968 LUNR DATA

NEWBURGH, ORANGE COUNTY TEST AREA (ERTS-1 INTERPRETATION SCALE: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	1973 ERTS-1 (Hectares)	ERROR (Hectares)	RELATIVE ERROR
1.1	4,720	200	- 4,520	- .96
1.2	290	1,644	1,354	4.67
1.4	513	176	- 337	- .66
1.5	480	584	104	.22
1.6	1,215	876	- 339	- .28
1.7	340	4	- 336	- .99
2.1	1,502	40	- 1,462	- .97
2.2	2,125	0	- 2,125	- 1.00
2.4	4,302	19,016	14,714	3.42
4.2	56	0	- 56	- 1.00
4.3	18,154	13,688	- 4,466	- .25
5.1	3,176	3,128	- 48	- .01
5.2	142	644	502	3.53
5.3	463	0	- 463	- 1.00
5.4	0	0	0	0
6.1	891	0	- 891	- 1.00
6.2	1,618	0	- 1,618	- 1.00
7.2	0	0	0	0
7.4	10	0	- 10	- 1.00
AGGREGATE	39,997	40,000	16,662	.42

TABLE 4.4.2.a COMPARISON OF ERTS-1 AND S190A DATA TO 1968 LUNR DATA

NEWBURGH, ORANGE COUNTY TEST AREA (ERTS AND SKYLAB SCALES: 1:62,500)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	1973 ERTS ERROR	1973 S190A ERROR	ERTS REL ERROR	S190A REL ERROR
1	7,558	- 4,074	- 834	- .54	.11
2	7,929	11,124	4,879	1.40	.62
4	18,210	- 4,522	- 1,082	- .25	- .06
5	3,781	- 9	- 441	.00	- .12
6	2,509	- 2,509	- 2,509	- 1.00	- 1.00
7	10	- 10	- 10	- 1.00	- 1.00
AGGREGATE	39,997	11,126	4,878	.28	.12

TABLE 4.4.2.b COMPARISON OF ERTS-1 AND S190A DATA TO 1968 LUNR DATA

NEWBURGH, ORANGE COUNTY TEST AREA (ERTS AND SKYLAB SCALES: 1:62,500)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	1973 ERTS ERROR	1973 S190A ERROR	ERTS REL ERROR	S190A REL ERROR
1.1	4,720	- 4,520	- 1,100	- .96	- .23
1.2	290	1,354	970	4.67	3.34
1.4	513	- 337	- 117	- .66	- .23
1.5	480	104	152	.22	.32
1.6	1,215	- 339	- 683	- .28	- .56
1.7	340	- 336	- 56	- .99	- .16
2.1	1,502	- 1,462	- 642	- .97	- .42
2.2	2,125	- 2,125	- 2,065	- 1.00	- .97
2.4	4,302	14,714	7,586	3.42	1.76
4.2	56	- 56	- 56	- 1.00	- 1.00
4.3	18,154	- 4,466	- 1,026	- .25	- .06
5.1	3,176	- 48	- 228	- .01	- .07
5.2	142	502	250	3.53	1.76
5.3	463	- 463	- 463	- 1.00	- 1.00
5.4	0	0	0	0	0
6.1	891	- 891	- 891	- 1.00	- 1.00
6.2	1,618	- 1,618	- 1,618	- 1.00	- 1.00
7.2	0	0	0	0	0
7.4	10	- 10	- 10	- 1.00	- 1.00
AGGREGATE	39,997	16,662	8,957	.42	.22

Second, data is referenced to the UTM grid at the hectare level (ie, grid lines are at intervals of .01 kilometers). For both data bases, each cell in the test area is coded according to its predominant use.

Three comparisons are made. Table 4.5.1 is an area-wide comparison of S190B to LUNR similar to those in Sections 4.1 and 4.2, except that in this case the comparison is made on a cell to cell basis at the hectare level. Table 4.5.2 makes the same comparison to 1972 photography interpreted by using the same category definitions used for Skylab (see Table 3.1.1). Table 4.5.3 makes a direct comparison between the 1968 LUNR interpretation and the 1972 photo interpretation.

Data was recorded first on Opscan mark sense forms* along with the UTM coordinates for each hectare cell for each of the three interpretations of an area 5 x 20 kilometers. This resulted in a total of 30,000 cells of information which had to be merged and compared. In addition to the cell comparisons summarized in the tables, a listing was made of the total number of cells compared to each category. This indicated into which category misclassified or mismatched cells were placed.

A second variable in making comparisons that has not been discussed so far is translational error. This is the error incorporated into any map related to how accurately the interpreter records information on a point to point basis. This is a particular consideration for computer storage systems since information stored cannot be easily adjusted to account for a slight shift in boundary lines. When making visual comparisons, the user generally compensates by observing the shapes and relative positions of the areas being compared.

The aggregate error shown on Table 4.5.1 comparing the S190B color at 1:24,000 scale to the LUNR interpretation at the same scale, is 17 percent on Level I and 27 percent on Level II. The LUNR accuracy for this site is only 84 percent. Therefore, the total adjusted aggregate error would only be 1 percent at Level I and 13 percent at Level II.

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*Manufactured by Optical Scanning Corporation

TABLE 4.5.1.a COMPARISON OF SKYLAB S190B (COLOR) TO 1968 LUNR DATA

KINGSTON, ULSTER COUNTY TEST AREA (SKYLAB SCALE: 1:24,000)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	1973 S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
0*	138	138	0	0
1	1,497	538	- 959	- .64
2	2,442	1,883	- 559	- .23
4	5,407	7,093	1,686	.31
5	299	250	- 49	- .16
6	216	98	- 118	- .55
7	1	0	- 1	- 1.00
AFGREGATE	10,000	10,000	1,686	.17

TABLE 4.5.1.b COMPARISON OF SKYLAB S190B (COLOR) to 1968 LUNR DATA

KINGSTON, ULSTER COUNTY TEST AREA (SKYLAB SCALE: 1:24,000)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	1973 S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
0*	138	138	0	0
1.1	1,021	397	- 624	- .61
1.2	261	35	226	.87
1.4	70	7	- 63	- .90
1.5	68	54	- 14	- .21
1.6	20	40	20	1.00
1.7	57	5	- 52	- .91
2.1	361	1,200	839	2.32
2.2	1	0	- 1	- 1.00
2.4	2,080	683	- 1,397	- .67
4.2	139	0	- 139	- 1.00
4.3	5,268	7,093	1,825	.35
5.1	245	250	5	.02
5.2	54	0	- 54	- 1.00
5.3	0	0	0	0
5.4	0	0	0	0
6.1	71	21	- 50	- .70
6.2	145	77	- 68	- .46
7.2	0	0	0	0
7.4	1	0	- 1	- 1.00
AGGREGATE	10,000	10,000	2,689	.27

*Cells not recorded in the computer tabulation.

TABLE 4.5.2.a COMPARISON OF SKYLAB S190B (COLOR) TO 1972 PHOTOGRAPHY

KINGSTON, ULSTER COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:24,000)

LEVEL I CATEGORIES	1972 PHOTOS (Hectares)	1973 S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
0*	528	138	0	0
1	834	538	- 296	- .35
2	2,167	1,883	- 284	- .13
4	5,951	7,093	1,142	.19
5	308	250	- 58	- .19
6	212	98	- 114	- .54
7	0	0	0	0
AGGREGATE	10,000	10,000	1,142	.11

TABLE 4.5.2.b COMPARISON OF SKYLAB S190B (COLOR) TO 1972 PHOTOGRAPHY

KINGSTON, ULSTER COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:24,000)

LEVEL II CATEGORIES	1972 PHOTOS (Hectares)	1973 S190B (Hectares)	ERROR (Hectares)	RELATIVE ERROR
0*	528	138	- 0	0
1.1	663	397	- 266	- .40
1.2	46	35	- 11	- .24
1.4	25	7	- 18	- .72
1.5	65	54	- 11	- .17
1.6	35	40	5	.14
1.7	0	5	5	1.00
2.1	1,163	1,200	37	.03
2.2	1	0	- 1	- 1.00
2.4	1,003	683	- 320	- .32
4.2	1,001	0	-1,001	- 1.00
4.3	4,950	7,093	2,143	.43
5.1	269	250	- 19	- .07
5.2	39	0	- 39	- 1.00
5.3	0	0	0	0
5.4	0	0	0	0
6.1	0	21	21	1.00
6.2	212	77	- 135	- .64
7.2	0	0	0	0
7.4	0	0	0	0
AGGREGATE	10,000	10,000	2,211	.22

*Cells not recorded in the computer tabulation.

TABLE 4.5.3.a COMPARISON OF 1968 LUNR TO 1972 AERIAL PHOTOGRAPHY

KINGSTON, ULSTER COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1:24,000)

LEVEL I CATEGORIES	1968 LUNR (Hectares)	1972 PHOTOS (Hectares)	ERROR (Hectares)	RELATIVE ERROR
0*	138	528	0	0
1	1,497	834	- 663	- .44
2	2,442	2,167	- 275	- .11
4	5,407	5,951	544	.10
5	299	308	9	.03
6	216	212	- 4	- .02
7	1	0	- 1	- 1 00
AGGREGATE	10,000	10,000	943	.09

TABLE 4.5.3.b COMPARISON OF 1968 LUNR TO 1972 AERIAL PHOTOGRAPHY

KINGSTON, ULSTER COUNTY TEST AREA (SKYLAB INTERPRETATION SCALE: 1;24,000)

LEVEL II CATEGORIES	1968 LUNR (Hectares)	1972 PHOTOS (Hectares)	ERROR (Hectares)	RELATIVE ERROR
0*	138	528	0	0
1.1	1,021	663	- 358	- .35
1.2	261	46	- 215	- .82
1.4	70	25	- 45	- .64
1.5	68	65	- 3	- .04
1.6	20	35	15	.75
1.7	57	0	- 57	- 1.00
2.1	361	1,163	802	2.22
2.2	0	0	0	0
2.4	2,081	1,004	-1,077	- .52
4.2	139	1,001	862	6.20
4.3	5,268	4,950	- 318	- .06
5.1	245	269	24	.10
5.2	54	39	- 15	- .28
5.3	0	0	0	0
5.4	0	0	0	0
6.1	71	0	- 71	- 1.00
6.2	145	212	67	.46
7.2	0	0	0	0
7.4	1	0	- 1	- 1.00
AGGREGATE	10,000	10,000	2,160	.22

*Cells not recorded in the computer tabulation.

Very likely, these adjusted figures are somewhat specious. However, this again demonstrates the necessity to apply more rigorous statistical methods to determine the accuracy of the interpretation for various categories in an inventory. Making the same comparison to the 1972 photography, the Level I aggregate error is 11 percent and 22 percent. The relative error among the categories is also much lower in Table 4.5.2 than in Table 4.5.1. However, looking at Table 4.5.3, which compares LUNR to the 1972 photography, there is a aggregate error of 9 percent on Level I and 22 percent on Level II. Part of this error reflects land use change over four years, but probably a bigger source of error comes from three sources: 1) differences in category definition, 2) interpretation variability, and 3) translational error. In the case of the residential sub-categories, it is likely that the discrepancies are due in part to the LUNR category definition and in part to the actual interpretation. According to local officials, the region was supposed to have undergone an increase in the number of rural residential units. If this is the case, then one can only conclude that the 1968 interpretation was in error, or that the interpreter was liberal in circumscribing areas around these units.

It should be stressed here that numbers representing various categories on any photo interpretation are only relative to the rest of the interpretation. In no way should they be considered absolute numbers. This poses certain problems in comparing data from two different sources in that the total error and variation about the mean error is seldom, if ever, calculated. But without such information, it is not possible to give precise accuracy figures or make statistical comparisons among different interpretations of the same area or different areas.

In further examination of Table 4.5.2, only five of the nineteen categories had any substantial number of hectares. Of these, light residential was generally scattered. Even so, in absolute numbers the error is not as great as the percentages would seem to indicate. Examination of the totals for the cell by cell comparison reveal that most of the light residential, not categorized as such, was placed in the forest category. As large areas are heavily forested, this would indicate that the canopy was obscuring a good portion of the residential units. Photography obtained in a different season would probably reflect a more accurate level for this category.

The same tabulation shows that active agriculture, pasture/brushland and forest were often confused. Some of the error is undoubtedly translational error; however, as discussed previously, additional variation is introduced with the time of year involved plus the small size of the areas concerned.

Coniferous forest was not detected. The cell by cell comparison shows that most of it was lumped into the mixed forest category. Combining these two categories brings the error down to 19 percent overestimation. An inventory update for this area, using 1972 photography showed that the Catskill region, which included this test site, had an increase in forest land although the average increase was not that high.*

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*Land Use and Natural Resources (LUNR) Inventory - Ulster County, prepared for the Temporary State Commission to Study the Catskills, by the R.I.L., Department of Natural Resources, Cornell University, September 1974.

5.0 ASSESSMENT OF SKYLAB PHOTOGRAPHIC SENSORS FOR LAND USE INVENTORIES

During the course of this study, a sample of each film type exposed in the SL3 Mission has been examined from both the S190A and S190B photo systems with respect to its interpretability for various land use categories. The results of various intrepretations have been described in detail in Sections 3 and 4. This section will attempt to assess each sensor/film type combination as to its relative utility for land use inventory analysis and its potential for updating an existing inventory.

For the readers' clarification, it should be kept in mind that statements on assessments of the various film/sensor systems are limited to this one time period. In various sections of the report, statements appear in the text concerning seasonality effects. These are generally based on previous experience with LANDSAT (ERTS-1) data or aerial photography. Additional comments on seasonality effects will appear in Section 5.3.

Overall, in terms of interpreter preference, a ranking of sensor/film types would be as follows: 1) S190B color, 2) S190A multispectral color composites, 3) S190B black and white (in certain categories, specific spatial patterns were characteristic; this would be preferred to the color composites because of the increased resolution), 4) S190B color infra-red, 5) S190A color, 6) S190A color IR. Because of the good tonal contrast and excellent resolution, the S190B color proved to be the overall best choice for conventional photo interpretation assuming that special equipment is used to enlarge the scene to its resolution limits. In situations where a facility does not have expensive viewing equipment, enlargements of black and white color separations can be made to any desired scale and then reconstituted to approximate color by the diazo process as shown in Figure 2.3.1. Although some detail may be lost in the color separation process, the overall effect is to increase the amount of information that an interpreter can extract at this larger scale, compared to interpretations done at smaller scales.

The black and white S190B has the best resolution properties. However, from an interpreter's view, the tonal distinctions for various land use categories are often not discrete enough to give a high level of confidence on accuracy, particularly on vegetative features. Nevertheless, certain features which have specific spatial patterns are defined sufficiently only on the black and white (S190B), such as orchards and residential categories (particularly light residential). In these cases, extreme enlargements of the high resolution black and white film can provide reasonably accurate information on the location and areal extent of these categories.

The S190B color infra-red film is best used for interpreting water related information, including wetlands. The experience gained on this project is limited to coverage near the end of the growing season in the middle of September. Most agricultural crops have been already harvested by this time leaving stubble and undergrowth in the fields. Therefore, it is not expected that there is as much spectral distinction among vegetative categories at this time as might be the case in different parts of the growing season.

The color and color infra-red films examined on the S190A were the 4X enlargements provided by NASA. Although the quality in terms of color balance and resolution appeared to be improved over the original 70mm dupes, neither film type compared favorably with information which could be derived from the S190A color composites. In the case of the infra-red film, the resolution was much worse than what could be obtained by synthetically constructing a color infrared composite from the black and white filtered S190A bands (AA+, BB+, DD+). Likewise, neither the resolution nor the tonal contrast of the S190A color film could match that obtained with various color composites constructed to enhance and contrast specific categories.

5.1 Information Content with Respect to Spectral Bands

In applying the CIE Color Prediction Model for analysis of the density variations among the S190A filtered black and white bands, one can maximize the number of category separations. Since the model works on the basis of black and white density inputs, repeatability is hampered mostly by variations in the diazo dyes. Except where density differences between two categories are very slight, resulting in poor color contrast, most people with normal color vision should not have much difficulty interpreting the results.

In view of the data analysis in Section 4, it is apparent that the interpretation results from the S190A compared very favorably with that obtained from the S190B. Since the resolution of the S190B was two or three times greater than the S190A, one can only conclude that compositing and color coding densities from the multispectral bands results in better category discrimination and increased accuracy, assuming equivalent resolution of the film/sensor configuration, than in the case with conventional black and white, color, or color infra-red.

Certain problems exist with the spectral band configuration chosen for the S190A. In general, the spectral bands are much too broad for good category separation based on discrete density ranges. This is complicated by the fact that in each case the filter bands overlap considerably (reference Figure 2.0.1). Since the percent transmittance in the overlap areas range up to nearly 40%, a considerable amount of continuous tonal overlap can be expected, ie, densities from filter band AA would tend to grade into densities in filter band BB. The results of this filtering have been discussed in Section 3.2, and summarized in Figure 3.2.2. As indicated in Section 3.5, narrow band data obtained from an S192 converted film product collected over Lansing, Michigan, upon inspection, appeared to give much more discrete separations than the broader band S190A coverage used in New York. This view seemed to be confirmed when high altitude color infra-red photography was obtained for the same areas. It should be noted, however, that no comparison of bands from equivalant regions was made since there was not immediate availability of S190A coverage of the Lansing, Michigan area. Therefore, only a qualitative assessment can be made.

Only six of the spectral bands on the 13-channel S192 scanner were selected after careful inspection. Selection was based on observable density shifts from band to band and on whether the bands collected data along important segments of the characteristic chlorophyll curve. Since only a single test was run, it is not possible to speculate on what the full potential of the narrow band S192 data might be. However, it appears that enough distinctions are evident between the S190A and S192 to make possible applications for proposed narrow band multispectral scanner systems very intriguing.

It should be noted that many of the major density discriminations on the selected S192 channels occurred in the infra-red bands from 1.0 to 2.43 nanometers. This region cannot be photographed. Since this is the case, it is likely that electronic scanner systems which also have the capacity of collecting thermal data will likely be the major collection devices of the future, especially where great resolution is not required.

In cases where resolution is a major factor, it seems quite reasonable, based on the data shown, to suggest that four earth terrain-mapping cameras be constructed in a S190A camera mode. Each camera should have a narrow band filter which yields discrete data segments from the characteristic chlorophyll curve. These data segments should include the maxima and minima reflectance regions of chlorophyll in the visible region as well as a single band well into the near infra-red which does not include the leading edge of the infra-red portion of the curve. That portion of the curve apparently shifts considerably with changes in the growing season as well as with spectral variations among different vegetation types. Since density values recorded on film are an average of the transmittance received by that band, care should be taken so that the average transmittance of the chlorophyll curve in one band path does not approximate that in another band path. If this occurs, a continuous gradation of tone in some categories might occur between two adjacent bands making separation difficult or impossible.

5.2 Effects of Resolution on Category Definitions

As it has been stated in previous discussions, the increased resolution of the S190B film/sensor system contributed greatly to the ease in interpretability of those categories which have less distinct spatial patterns such as light residential, orchard, and intensively developed areas. This is not to contradict the data shown in Section 4, but merely to emphasize that interpretability is influenced by a number of factors, one of which is being able to easily associate certain patterns with a familiar category such as a residential complex. The resolution limits of the S190B sensor are such that it does permit the identification of very large man-made structures as can be seen in the black and white enlargement of Ithaca (Figure 2.3.2), but most physical structures are not that large. As indicated above, the color S190B system is preferred for two important reasons: 1) good resolution which begins to put spatial patterns into more meaningful relationships, and 2) it presents a more pleasing scene which the interpreter can again easily translate. The ground resolution element of the S190B color covers about 2,500 square feet. Few residential units are that large and are therefore not directly identified on the basis of a single point, but only as a pattern of points. In this sense, one would expect a greater interpretation bias for picking up organized residential units such as within a city or clustered subdivisions. There is considerable evidence to suggest that a great deal of urbanized expansion takes place intially as individual scattered units interspersed among several different land use types. Therefore, unless these units are large structures, such as a shopping center, they will probably go undetected most of the time simply because they do not exhibit a readily identifiable pattern and the resolution is insufficient to specifically identify the object.

Another factor which may account for some increased detectability of new residential units vs. older ones is the type of roofing material used. Many new houses tend to use light colored, highly reflective roofing. Many older ones have darker non-reflective materials. To what extent this is a factor is unknown, but anything that would raise the albedo level would increase the detectability.

In the case of the S190A color composites, some of the areas were correctly classified as being spectrally different from surrounding land use on the basis of increased contrast. This contrast varies among the different spectral bands. As such, it is possible to generate a different hue reflecting a different land use even though the spatial pattern may be indistinct. In the case of conventional black and white or color film, the tonal contrast may not be sufficient by itself to identify discrete features among integrating land uses. Therefore, except where patterns are evident, a great deal of urbanized expansion is likely to go undetected especially where complex land use patterns and topography exist. This appears to be the case in the Tompkins County and Newburgh sites in contrast to the more organized and uniform site on Long Island. These difficulties are reflected in the tables in Section 4.

It should be kept in mind that one of the main advantages of satellite systems is the synoptic view obtained from the space platform. From its vantage point, the satellite can view macro-processes that can only be glimpsed piecemeal, if at all, from airborne systems. Perhaps, not enough attention is being focused on analyzing these macro-processes, particularly those related to land use and natural resources. (The weather satellites already provide important information on macro-processes affecting our climate). It is undoubtedly a major feat to classify individual acres of land or even smaller features from space, but the question should be raised whether the information gained is sufficiently accurate and useful to compete with data already available or easily acquired by local agencies. This question as it applies to New York State is addressed in part in Section 6.

Category definitions can be shaped by the resolution of the sensor used or they can dictate the necessity of acquiring data with a minimum resolution. To a large extent, both the type of sensor system and a minimum required resolution are important to obtain useful information. The difficulty is in defining the categories in some hierarchical order from general to specific that accounts for the spatial and spectral properties at each level of classification. In order to arrive at an optimal system more information is required on user needs and how data, once acquired, is finally applied. Thereafter, better sensor systems can be defined which will more fully meet the requirements of the user community (see the discussion in Section 7).

Restricting this assessment to sensors used in the Skylab Project, the most optimal system with respect to resolution is the S190B earth terrain camera. As indicated above, the maximum resolution of this sensor using black and white film appears to be about 30 to 40 feet. Referencing the discussion in Section 4, the maximum benefits of this resolution are only evident with extreme magnifications. But, again, lack of tonal separation and spectral distinctions limits the usability of conventional black and white film. The benefits of both tonal separation and spectral distinction are evident when comparing the interpretation results between the S190A and the S190B. By increasing the contrast of land use categories within a scene as can be done with spectral data combined with the ability to discriminate patterns with increased resolution in the S190B camera, much more information should be derived without the requirement for new technical developments. Therefore, as discussed in the previous sections, using the earth terrain camera in a spectral mode would appear to be the most efficient use of existing equipment.

5.3 Effects of Seasonality on Land Use Interpretations

As indicated in various comments in Sections 3 and 4, seasonal changes very likely have considerable influence on the interpretability of certain categories of land use. Most obvious are the categories made up of vegetation or associated with vegetation. Phenological shifts throughout the year dramatically affect the object to background contrast ratio. Such shifts will affect the interpretation of all the vegetation categories. The most difficult part of the problem is defining the transition zone of integrating categories, for instance, forest to brushland to pasture to active agriculture, or pasture to light residential, or forest/brushland to residential. The most difficult time to get good object to background contrast is middle to late summer. The best contrast ratio appears to be in late spring when leafing is commencing, or early fall when senescence and coloration of the foliage has started.

Since New York State coverage on Skylab missions was restricted to September 10-19, 1973, no seasonal changes were observed. However, some seasonal analysis was accomplished on ERTS (LANDSAT) data (Hardy, et al, 1974). Results of that study indicate that changes in the spectral response of vegetation will cause shifts in the size of parcels of vegetation categories and correspondingly in urban or residential areas. Since vegetated areas may be small in spring and fall and correspondingly expand in summer, areas for other categories adjoining would show inverse relationships. On the basis of interpretation results obtained in the ERTS study on New York State, mid-May or mid-October would likely provide the best results on land use interpretation for most categories. The period of June through September appeared to yield the worst results when compared to the 1968 LUNR data. There was also some indication that combining data from different seasons in a single color composite often improved the results of the interpretation.

6.0 INFORMATION/DATA REQUIREMENTS SURVEY

6.1 Introduction

It has already been noted that a significant gap exists between research and application in the field of remote sensing (Henderson, 1974, p. 985-987). Floyd M. Henderson states that the researcher in remote sensing is frequently unaware of what data and information the potential user requires, and users are often unaware of the capabilities and limitations of remote sensing systems. The result is a dearth in operational applications of remote sensing technology.

This communications gap is also considered in a recent paper by Ronald L. Shelton and Ernest E. Hardy (Shelton and Hardy, 1974). They note that "General public understanding of the technologies (remote sensing and computer-based information systems) is weak, and engineers and technicians often fail to communicate the full potential (and limitations) of their devices to the potential and actual user." They further note that repeatedly, technology application projects dealing with land use and natural resources are failing because the administrator was unaware of the technical constraints, or because the technologist failed to communicate or to understand these himself, or because the technologist ignored or did not fully understand the needs or context of the project.

Henderson offers three suggestions for applied research to help remedy these problems:

- Potential users should be familiarized with basic remote sensing techniques, applications, capabilities and limitations. Emphasis should be directed toward methods applicable to the users' particular needs and budgetary constraints;
- The needs of potential users at all jurisdictional levels should be ascertained. Once this information is obtained, then research can be directed toward solving these applied problems; and
- Display format and classifications schemes must be oriented to the intended user.

6.2 Objectives of Study

Based on the above mentioned considerations, two primary objectives were conceived for the Data/Information Requirements Survey:

- To acquaint users of land related information with satellite imagery (ERTS, as well as Skylab) and with the general concept of multispectral analysis; and
- To attempt to determine their land related information needs in terms of scale, geographic accuracy, categorical detail, and frequency, and insofar as possible, to relate these needs to satellite acquired information.

6.3 Design of Investigation

6.3.1 Study Areas. Three study areas were chosen in New York State for the overall Skylab project: the Finger Lakes area, the Hudson Valley, and Suffolk County on Long Island. These areas were chosen primarily because good coverage was available from both the Skylab S190A and S190B camera systems.

In each of these three areas, several counties were selected for inclusion in the Data/Information Requirements Survey. In the Finger Lakes area, Cayuga, Monroe, Ontario, Seneca and Tompkins counties were selected. Monroe County lacks Skylab coverage, but was included because it contains a major urban area (Rochester) and has experienced rapid suburban growth.

The remaining counties are largely rural in character, but each, with the exception of Seneca County, contains a moderate size urban area. Dutchess, Orange and Ulster counties were selected in the Hudson Valley. Each of these counties has experienced considerable population growth, and each contains at least one moderate size, albeit declining, urban area. Suffolk County on Long Island experienced by far the greatest rate of growth of any county in the state between 1960 and 1970, and is the most populous county included in the survey. In terms of land use, it is also one of the most diverse.

6.3.2 Survey Procedure. In each of the counties in the three study areas, several governmental agencies, functional departments, and non-governmental organizations that make use of land related information were selected for inclusion in the survey.

As a preliminary step in the survey process, discussions were held with Cooperative Extension agents from Dutchess, Orange, Ulster and Suffolk counties. Extension education, along with teaching and research, is one of the principal responsibilities of the statutory colleges at Cornell University. The county agents provide the link between the University and the citizens of the state. Consequently, the county agents have first-hand knowledge of those local and regional agencies and organizations with interests in land use and natural resources, as well as considerable insight into local problems and needs. The agents provided a preliminary list of contacts in their respective counties. This list was augmented with several regional agencies whose jurisdiction overlapped the study areas. In the Finger Lakes area, direct contact was made with the appropriate agencies. A list of the selected agencies, departments, and organizations contacted is provided in Appendix A.

Due to the apparent communications gap that exists between researcher and information user, a two-phase survey procedure was initiated. The introductory phase was intended to acquaint the potential user with Skylab and ERTS imagery, with the concept of multispectral analysis and with the use of false color composites to delineate certain land uses and natural characteristics. The advantages and limitations of this type of analysis in particular, and satellite imagery in general, were discussed. Factors considered included scope, scale, resolution, categorical detail and definition, and frequency of coverage. Examples of S190A and S190B imagery, both hard copy and false color diazo composite transparencies, were demonstrated to survey participants. It was intended that this introductory phase would provide participants with a common knowledge base, and allow them to respond to questions in the second phase with a broadened understanding of remote sensing technology. The second phase of the survey procedure consisted of an in-depth interview structured around a detailed questionnaire.

In order to facilitate the study of a diverse group of information users, a conceptual framework was devised. In a sense, each agency or organization (potential user) can be viewed as an information processing unit. Here information is interpreted in a general way so as to include such things as numerical data, maps, written reports, recommendations, actions, etc. Information comes into the agency or organization, and there, may be combined with additional information, or otherwise transformed. The agency/organization output is new information, or in some cases the same information. The three components of information flow may be characterized as reception, conduction (processing or transformation) and output transmission (Churchman, Ackoff and Arnoff, 1957, p. 76). The various agencies and organizations, linked by information flows, together form a communication network.

The conceptual framework described above provides the basis of the interview questionnaire. The network model may suggest points in the system where different types of information might best be acquired, where different acquisition systems might be used, and how this information might be developed into an integrated information system.

The questionnaire was organized into five sections:

1. Agency/Organization Characteristics. Possible distinguishing characteristics include: function, subject area, geographic jurisdiction, organizational relationhips, personnel, and kinds and scope of activities.

2. Data/Information Needs. Factors include: categorical detail and definition, resolution and desired frequency.

3. Data/Information Acquisition and Storage. Factors include: methods of acquisition and storage, and transmission of data and information between various agencies and organizations.

4. Data/Information Processing and/or Analysis; Factors include: extent and methods of analysis, and use of computing equipment. These factors may bare on the kinds, quality, format and amounts of data/information required.

5. Agency/Organization Products and/or Services. Factors include: products and services (output transmission) and immediate users and beneficiaries of this output (including the nature of the links between them and the transmitting agency).

For this particular survey, it was felt that an in-depth interview structured around a questionnaire had several advantages over other techniques:

1. It mitigates ambiguities which might otherwise exist because of the diversity of respondents;

2. It allows the respondent to make conditional responses, and to expand on his answers where appropriate;

3. It allows for additional, unanticipated avenues of inquiry;

4. The questionnaire structure ensures a systematic and complete interview; and

5. In those cases where the follow-up interview was not possible, the availability of the questionnaire allowed the participant to respond by mail.

6.4 Investigation Phase

A rather diverse group of users of land related information was studied. For purposes of analysis, they have been categorized as follows:

- Planning Agencies
  - Town Planning
  - County Planning
  - Regional Planning
- Other Agencies and Organizations
  - County Environmental Organizations
  - Operating Agencies
  - Research Organizations

6.4.1 Planning Agencies. In the conduct of this survey, contacts were limited to those planning organizations with full-time professional personnel. Discussions were held with professionals in agencies at the town, county and regional levels. In addition to these jurisdictions, many minor civil divisions (cities and villages) have active planning boards, some of which are professionally staffed; however, because of their limited geographic jurisdiction and the intensity of development, it was decided to omit these agencies from the survey.

Town Planning. In New York, towns are the major political subdivisions of the counties. There are some 930 towns in the state. Many, but not all, of these have citizen planning or zoning boards. Very few, however, employ full-time professionals. Most of those that do are locàted on Long Island and in the lower Hudson Valley - areas subject to considerable development pressure. Town planning boards not having their own staff usually rely on the county planning departments for technical assistance, or employ consultants on a part-time or contingency basis.

Five town planning departments were included in the survey - two in the lower Hudson Valley and three in Suffolk County. Also included was a privately funded, professionally staffed planning group with an area of interest that includes most of two towns on eastern Long Island. This group will be discussed separately.

These agencies were small, employing from one to three planners or professionals in related areas. The geographic area of the towns ranged from 29 to 100 square miles. Population densities ranged from about 200 to over 4,000 persons per square mile.

Most of the work of these agencies consisted of analysis and evaluation of specific projects and development proposals - site plan analysis, subdivision review, recommendations for re-zoning, etc., and other short-term studies. For the most part, town planning agencies were engaged primarily in what might be termed management functions - coping with recurring, short-range problems. Except for the planning activities in one town, policy formulation was clearly of secondary importance to those management functions.

Because most of their activities involved specific sites and relatively small areas, town planners desired land related information with a high degree of geographic accuracy - well under ten meters. For specific projects, land related information referenced to the parcel was considered desireable.

Land use classification schemes varied from town to town. They were either based on the Standard Land Use Coding (SLUC) system, The New York State Land Use and Natural Resources (LUNR) Inventory, or developed internally without particular regard to existing systems. The required level of categorical detail varied among and within agencies, depending on the use to which the information was to be put. Using the four level SLUC system as a reference scale, no agency required much more than second level detail for general planning purposes. For specific projects, however, considerably more detail was required. It should be recalled that most activities at the town level are related to specific projects.

There was no consensus in the responses to the question of how frequently land related information should be updated. Responses ranged from two to five years for urban and rural areas, and from one to five years for suburban areas and areas of environmental concern.

Town planning agencies usually noted land use change in two ways: through periodic field surveys and through development of proposals submitted for review. In one intensively developed town, air photo coverage is obtained every five years and used with ground surveys to update their inventory.

In general though, because of the management orientation of these agencies, the comprehensive updating of land use assumes a less important role than in more policy-oriented agencies. At the town level, up-to-date information, with the required degree of detail, can be obtained as needed for specific projects either through ground surveys or aerial photography, or a combination of the two.

At the town level, field surveys were a useful and viable inventory method. They were not only capable of yielding as much categorical detail as was required, but they also afforded the planning staff the opportunity to become intimately familiar with the area in which they worked. This is of no mean importance in the field of planning where credibility and citizen acceptance are essential to success.

Field observation is particularly well suited for noting new development, where changes are abrupt and usually obvious. Changes in natural characteristics, however, may be more subtle and may not always be apparent from the ground. Natural characteristics, including wetlands, water areas, vegetation type, are becoming increasingly important factors in land use planning. This information, however, was largely absent from otherwise complete inventories at the town level.

None of the town planners had any previous professional contact with either Skylab or ERTS imagery. The initial reaction to satellite imagery was positive, particularly to the high resolution Skylab photography. Upon reflection, however, the inevitable question was "what can it do for me?" The reaction is understandable when one considers the geographic area with which they are concerned. The towns range in area from about 23 to 100 square miles. The Skylab S190A image covers a ground area approximately 100 miles on a side or roughly 10,000 square miles; the ERTS image covers a rhombus-shaped area of more than 13,000 square miles. Thus, with Skylab imagery the town planner is concerned with about only ¼ to 1 percent of the total field of view; the ERTS imagery, even less.

The broad and synoptic view afforded by satellite imagery is, however, not without benefit to town planners. The imagery showed the towns in their regional context. In particular, the false color enhanced imagery dramatically showed large scale associations between general land uses and natural features.

The privately funded, non-profit planning group included in the survey was less concerned with management functions, and more with influencing decisions which affect long-range land use policies. In general, many of the same comments concerning information requirements apply to this group as apply to official town planning agencies. Largely because of the need to establish support for a policy plan developed outside of the usual government framework, the information on file is generally more comprehensive and categorical detail greater than that of their official counterparts. They too felt that satellite information could not compete with the information they obtained through conventional methods, but that the photographic overview was a useful supplement to this information.

County Planning. The county is the primary political subdivision of the state outside of New York City. Excluding the five counties that comprise New York City, there are 57 counties in the state. Only two of these counties lack citizen planning boards, and all but four of those with planning boards employ professional personnel.

Ten county planning departments were included in the survey: Suffolk County on Long Island; Orange, Ulster and Dutchess counties in the lower Hudson Valley; and Monroe, Ontario, Seneca, Cayuga, Tompkins, and Broome counties in the generously defined Finger Lakes study area.

NEW YORK STATE COUNTIES IN SURVEY

County	1970 Pop. (Thous.)	Land Area (sq.mi.)	1970 Pop. (per sq.mi.)	% Of NY Pop.	% Of NY Area
Broome	221.8	714	310.7	1.22	1.49
Cayuga	77.4	698	110.9	.42	1.46
Dutchess	222.3	813	273.4	1.22	1.70
Monroe	711.9	675	1054.7	3.90	1.41
Ontario	78.8	651	121.1	.43	1.36
Orange	221.7	833	266.1	1.22	1.74
Seneca	35.1	330	106.3	.19	.69
Suffolk	1127.0	929	1213.2	6.18	1.94
Tompkins	77.1	482	159.9	.42	1.01
Ulster	141.2	1141	123.8	.77	2.39
Total	2914.3	7266	401.1	15.98	15.19
State	18,241.3	47,831	381.4	--	--

County planning departments varied considerably in organization, staff size and range of staff specialties and type of activities with which they were involved. Staff size was largely dependent on county population and rate of growth, but was also influenced by organizational ties with regional planning agencies. In some cases, regional planning boards provided technical support, and in other cases, staff personnel were shared with the regional agencies. The departments were staffed largely by people whose primary academic training was in planning, but other specialties included: landscape architecture, geography, civil engineering, geology, sociology and demography. The more quantitatively oriented subject areas, e.g., operations research, systems analysis, statistics and economics, are conspicuously absent. Only the largest agencies had personnel with any significant specialized training in air photo interpretation.

The work of county planning departments was largely a mixture of policy planning (anticipatory decision-making) and management functions (day-to-day decisions involving recurring sorts of problems). The relative amount of staff resources devoted to each category of activities varied considerably from county to county. Some county departments were involved almost exclusively in policy formulation, and the towns either had professional staff or engaged consultants to carry out management functions. In other cases, these activities were provided for the towns by the county planning staff.

To some degree, all county planning agencies engaged in research but this was usually applied research directed to specific local problem areas. The research findings were intended to provide an information base for management-type decisions and policy planning.

Almost all of the departments regarded their activities, vis-a-vis land related information, as embracing four basic functions: collection, processing and storage, analysis and interpretation, and to some extent, use of interpreted information for decision making (or at least for making recommendations to decision makers).

Not all agencies had a standard land use classification system or up-to-date land related information file. In several cases, this was due to the need to resolve a specific problem as it arose - an activity which requires more detailed and up-to-date information than could be maintained in a comprehensive file. In these cases, information was obtained as needed.

Those departments that did have a land use classification system, based it on either the New York State Land Use and Natural Resources (LUNR) Inventory, the Standard Land Use Code (SLUC), or the New York State Board of Equalization and Assessment Property Title Classification Code (NYSEBA), or some combination of them. The LUNR system was most widely used, but usually with some modifications. Modification amounted usually to the combining of several related land use categories. Much of the popularity of LUNR was attributed to the fact that this inventory was available to their county at minimal cost.

The statewide LUNR inventory was produced primarily through the manual interpretation of aerial photographs, backed up with secondary sources of information. Quality control was accomplished through systematic field checks. Because of the methodology used and the fact that the inventory was statewide, it tends to have a strong bias toward visually discernable characteristics, as opposed to land uses defined by social or economic activities. As a result, the inventory was generally considered more than adequate in rural areas, but deficient in intensively developed areas. Planners in these latter areas preferred the SLUC or NYSBEA systems, both of which are based more on actual activities than is the LUNR system. Specifically, several counties were developing classification systems based on the NYSBEA Property Title Classification Code. Depending on the degree of cooperation that exists between county planning and assessment departments, such land use information files have the potential for virtually continuous updating. Such systems could provide a new dimension in the analysis of regional dynamics.

For general planning purposes, the county planning departments required categorical detail in the 1-2 to 3 digit range in the four level SLUC system, (and between the first and second levels in LUNR). For specific projects of limited geographic dimension, most required still greater detail.

Significantly, except for several externally produced transportation studies, little or no use was made of statistical models or simulation techniques. Most of the "models" used in the planning departments were subjective and intuitive, based in a large part on experience and quantitative urban theory. This is not to say they are invalid, but unlike more rigorous models, the planner never has to definitively state his information requirements. Because of the subjective nature of their models, most planners appeared more comfortable with more detailed and specific information.

Requirements for locational accuracy varied in much the same way as did needs for categorical detail. Accuracy requirements ranged from lot line referencing for specific studies in more intensively developed areas to general patterns in rural areas.

There was little consensus as to how often land use information should be updated except that revised information should be available at intervals of no more than five years. In general, frequent updating of urban and agricultural areas was considered less necessary than for suburban and rural non-farm areas, and areas of environmental concern.

Even though the counties studied ranged in size from 330 to 1,141 square miles, field surveys were still an integral part of the land use inventory updating process. In some areas, the field survey was supplemented by aerial photography and/or reports from individual towns, where town planning departments operated. Such reporting, however, was not done systematically. Field surveys were found acceptable where development was minimal or where most change occurred in relatively limited areas.

Direction, extent, and rate of development were of primary concern to county planners. Development can occur in three ways: "infilling," widely scattered, and/or along the fringes of presently developed areas. The inventory updating system must be capable of detecting such changes. Further, the acceptable error limits are largely a function of the actual rate of change. The inherent error in the detection system must be sufficiently small so that error does not either obliterate or overstate actual change. This, together with requirements for categorical detail, is in the end the most important factor in determining the utility of satellite acquired land use information for planning purposes.

Although, at present, satellite data appears to be of limited value to county planners in terms of providing acceptable mapped or quantifiable information, the images themselves are useful for overall visual analysis. Depending on the particular geographic configuration, most counties can be completely covered within a single satellite image, versus several hundred low altitude aerial photos in mosaic. The satellite image thus provides a valuable device for communicating large scale county planning problems to the general public.

Regional Planning Agencies. For planning purposes, New York is divided into eleven major regions. Three of these, the Genesee-Finger Lakes, Central and Southern Tier East Regions, intersect, at least in part, the Finger Lakes study area. The three counties in the Hudson Valley and Suffolk County on Long Island are contained in the New York Metro Region. This region is divided into three subregions. Mid-Hudson, New York City and Nassau-Suffolk. The three upstate regions and the two downstate subregions with counties in the survey, contain 28 of New York's 62 counties and approximately 39% of its total land area of 47,831 square miles. In 1970, 36.1% of New York's population of 18.75 million people resided in these three regions and two subregions.

Six government supported regional planning agencies were included in the survey: 1) Central New York Regional Planning and Development Boards; 2) Genesee-Finger Lakes Regional Planning Board; 3 Southern Tier East Regional Planning and Development Board; 4) Southern Tier East Regional Planning Board; 5) Tri-State Regional Planning Commission; and 6) Nassau-Suffolk Regional Planning Board.

The jurisdiction of the Nassau-Suffolk Regional Planning Board is the two Long Island counties east of New York City. These two counties comprise one of the three subregions in the New York Metropolitan Region (except for Sullivan and Ulster counties), as well as southeastern Connecticut and northern New Jersey. The Regional Plan Association (RPA) was also included in the survey. RPA is a privately funded, non-profit planning and research organization concerned with a 12,800 square mile, three state area centered about New York City.

For the most part, the functional activities of these agencies were research (primarily applied), planning and policy formulation (largely recommendation). Although these regional agencies were at times involved with management type functions, such activities occupied a far smaller fraction of staff time and resources than they did at or below the county level. In addition to region-wide planning activities, these agencies sometimes provided specialized services to county agencies within their jurisdiction.

Most of the regional agencies were concerned to some degree with a range of substantive areas. These included: land use, natural resources, housing, transportation, economic and human resources development, social policy planning, and environmental quality. Emphasis, however, varied considerably from region to region, and often changed within regions over time. For example, at the time of the survey, one region was involved largely with physical planning, while another was concerned primarily with economic and human resource development.

Agencies ranged considerably in size - from a staff of four in one case to a staff in excess of 150 at the Tri-State Regional Planning Commission. The remainder ranged between about 10 and 40 persons. In some cases, however, personnel were shared by both the regional and county planning boards, which increased the range of talent available to each. In most cases, staff were sufficiently large to allow for greater specialization than was found in the subregional agencies. The larger regional agencies employed specialists in aerial photo interpretation and cartography, which enhanced their ability to utilize newer techniques for obtaining land related information. In addition, because of the extensive area for which information had to be collected, regional agencies appeared to be more amenable to innovative methods of collection than were the subregional agencies.

All of the regional agencies had comprehensive land use information files. With the exception of the Tri-State Regional Planning Commission and The Regional Plan Association, all agencies used the LUNR system, or some modification of it, or used LUNR in combination with the Standard Land Use Classification System. Tri-State and RPA used a highly aggregated derivative of the SLUC system. In these classification systems, commercial public and semi-public, and industrial land use, and utilities are categorized as "non-residential." Agriculture, forests and extractive industry are categorized as "vacant." The other regional agencies used a breakdown that was more specific than the eleven major LUNR categories, but in general was not so specific as the second level LUNR categories.

For some localized projects, however, greater categorical detail was required.

Tri-State and the Nassau-Suffolk Regional Planning Boards referenced land use information to a grid system having cells one mile on a side. Both of these systems had been developed prior to the inception of LUNR, which employs a one kilometer grid based on the Universal Transverse Mercator (UTM) system. The axes of the coordinate system used by Tri-State run parallel to the Manhattan Street system and reflect the Commission's earlier, more limited role as a transportation planning agency. Tri-State is presently converting to the metric based UTM system.

Central New York and the Genesee-Finger Lakes Regional Planning Boards used the one kilometer LUNR grid. The former agency found this grid generally too course, and prefered ¼ km^2 cells. The latter agency also prefered ¼ km^2 cells in intensively developed areas.

The grid system is used primarily to reference mapped information for computer storage, and subsequent summarization and analysis. Mapped information generally reflects a higher degree of geographic detail. Most final regional maps were produced at a scale of 1"= 2 miles. At this scale, a ground accuracy of 100 meters would appear to be tolerable since 100 meters on the ground is .0031 inches on the map.

It was generally agreed that land use information for suburban areas (areas of rapid development) and areas of environmental concern should ideally be updated annually; and that updating at five year intervals would be sufficient for agricultural and rural non-farm areas. For urban areas, the suggested interval for land use updates ranged from one to five years.

Most of the data and information used by these agencies was obtained from secondary sources. These sources included county planning departments, and local,state and federal governmental agencies. Outside of the Metropolitan New York Region, the New York State Land Use and Natural Resouces Inventory was the major source of land related information. The Tri-State region, however, is flown periodically in order to update their land use inventory. The Nassau-Suffolk Regional Planning Board and the Regional Plan Association, as well as county agencies in the region, also used this photography. The other regional agencies made some use of low altitude black and white aerial photography for partial updating of land use inventories and for special studies of projects in limited areas. Nassau-Suffolk and Tri-State also made use of high altitude black and white photography.

Analytic techniques employed by the regional agencies were generally more sophisticated then at the subregional level. They ranged from visual analysis of mapped information (subjective models) to quantitative and statistical analysis, to mathematical modeling and simulation. The latter activities were usually contracted out, except at Tri-State where their large and specialized staff allowed them to do such work "in-house." A consequence of the greater emphasis and quantitative analysis and modeling, was a more explicit determination of information requirements.

6.4.2 Other Agencies and Organizations. Because of the considerable variation in the function of these agencies and organizations, and the limited number surveyed, it is impossible to make even tentative generalizations. Rather, a description of the activities and land-related information requiremtnts of each is presented. These agencies and organizations can be roughly grouped into three categories: County Environmental Organizations, Operating Agencies, and Research Organizations.

County Environmental Organizations. Three county-wide environmental groups were included in the survey. Two were Environmental Management Councils, funded 50% by the New York State Department of Environmental Conservation and 50% by the county. The third organization was a creation of, and entirely funded by, the county. All three groups, however, served in a similar advisory capacity to their county legislatures on environmental and related matters. Most of the manpower was voluntary, although one EMC did utilize the services of a staff member of the planning department on a full-time basis. All of these organizations relied heavily on their respective county planning departments as the primary source of data and information. Some initiated limited field surveys for supplemental information.

Most projects of these organizations were done on an ad hoc basis, with both categorical detail and geographic specificity largely dependent on the specific project. Most of these projects were intended to provide information for developing or influencing environmental policies. For those organizations without professional staff support, analysis was largely qualitative, relying heavily on mapped information and to a lesser extent on aerial photography.

One of the primary functions of these environmental groups is to stimulate citizen interest. Consequently, information must be presented so that it is interesting and understandable to the general public. Because of the considerable information content and credibility of satellite imagery, it was considered ideal for educational and public relations applications.

Operating Agencies. Three operating agencies in Suffolk County were included in the survey: Suffolk County Department of Parks, Recreation and Conservation, Suffolk County Department of Environmental Control, and Town of Babylon Department of Environmental Control.

The Department of Parks, Recreation and Conservation was primarily concerned with the development and management of the county's park system. Land use and natural resource data, and much of the analysis used to determine the amount, type and location of parks and recreation areas was provided by the County Planning Department. In addition, the computerized assessment file was used to locate large tracts of land which might be suitable for park development. The land use and natural resource information required for the design and development of sites and facilities had to be both categorically detailed and geographically specific. Low altitude black and white photography was freqeuntly used in site planning.

The Department of Environmental Control was charged with countywide resource management and environmental planning. Their concerns included land, water and air quality, and waste disposal. Staff specialties included: civil and environmental engineering, planning, ecology, geology, hydrology, and marine science.

Because of its impact on the quality of the environment, intensively developed land and the concomitant effluent were a primary concern of this agency. Accordingly, they required detailed information about man's activities on the land. This type of information, they found, was best provided by the county assessment office and/or site plans provided by developers. The land use classification system employed was based on that developed by the New York State Board of Equalization and Assessment.

In addition, because much of the work done by this agency was of an engineering nature, considerable map accuracy was required.

The town of Babylon Department of Environmental Control performed monitoring functions for the Town of Babylon similar in many respects to those done by the County Department of Environmental Control. In addition, they were responsible for the management of solid waste disposal operations in the town. They worked closely with both the Town and County Planning Departments and found these to be adequate sources of land related information.

Research Organizations. Three research-oriented organizations were included in the survey: The Marine Resources Council, the Cary Arboretum of the New York Botanical Gardens, and the Brookhaven National Laboratory.

The Marine Resources Council (Long Island) is a professionally staffed agency concerned with research and monitoring of marine water quality, marine resources, tidal wetlands, and other coastal zone resources. It is closely allied with the Nassau-Suffolk Regional Planning Board and obtained all required land use information from them. The most useful application of satellite information that they could foresee was the continual monitoring of erosion and shoreline changes and marine water quality.

The primary function of the Cary Arboretum is plant research (both pure and applied), and the propagation and collection of plant species.

They were to some degree, involved with land use and environmental planning and management, particularly as it applied to natural resources They had prepared environmental and resource impact statements, environmental management plans, and have made recommendations to various levels of government and private activities.

At the time of the survey, projects had not been of sufficient scope to warrant satellite acquired imagery. However, since most of their work concerned analysis of vegetative cover, multispectral imagery acquired through low altitude flights was thought to be potentially useful. Satellite imagery might also be useful in some of the educational functions of the Arboretum.

The Brookhaven National Laboratory was involved in a large array of research projects related to energy demand, production and its environmental impacts. One project involved, in part, the development of a mathematical air quality model for the northeastern United States. One independent variable considered for inclusion was generalized land use, since some activities on the land are a source of pollutants. The large geographic area eliminated the need for both categorical detail and geographic specificity. In fact, in such a large scale model too much detail could be a liability.

The multistate scope, and the many political jurisdictions made the accumulation of data from separate files difficult. Since the model was under development, specific land use categories could be designed so as to accomodate available data. Such large scale (multistate) projects requiring only very generalized land use information would appear to be potential clients for satellite information.

6.4.3 Previous Surveys. Two earlier mail surveys of information needs were conducted, and the responses summarized. (Wulff, 1973, and Stevens, 1974). These reports are included as Appendices C and D, respectively.

The November, 1975, Progress Report tabulated the responses from the 51 questionnaires which were returned out of the 160 which were mailed to regional and county planning boards, county Cooperative Extension agents, and private planning consultants in New York State.

The most significant finding was that "land assessment and planning should be conducted with information as specific as one to ten acres." This is in general agreement with the findings of the more recent survey. It was also noted that "only a few respondents voiced skepticism about the planning potential of Skylab data." The planners who were contacted in person in the recent survey were generally not so optimistic, probably because they were afforded the opportunity to evaluate the product first hand.

The January, 1974, Progress Report tabulated the responses from the questionnaires which were mailed to wildlife biologists and environmentalists at the regional level in state and federal agencies. Of the 81 questionnaires which were mailed, a total of 24 were completed and returned.

As in the other mailed survey, there was a general concensus for geographic specificity. Seventy-four percent of the respondents required data as specific as one to ten acres. Twenty-one of the respondents indicated that knowledge of present land use was necessary for their work.

6.5 Land Use and Natural Resources Information Workshop

As part of the Information/Data Requirements Survey, a Land Use and Natural Resources Information Workshop was held at Cornell University on April 7. The participants included those agencies and organizations contacted in the two phases of the survey, as well as planners from nearby counties and Cooperative Extension personnel. The purpose of this Workshop was two-fold: first, to introduce the conferees to a range of remote sensing and aerial photo research, and to the resources at the Resource Information Laboratory; and second, to bring professionals and interested citizens from different parts of the state together to discuss common problems and different approaches to their solutions.

Topics covered were:

- Land Use Inventories and Information Systems
- Large Scale Land Use and Natural Resource Inventories, such as,
  - New York State Land Use and Natural Resource Inventory
  - Land Use Update for the Temporary Catskill Study Commission
  - New York State Wetlands Inventory
  - Analysis of Land Use Change/USDA
- Aerial Photo Interpretation
- Multispectral Analysis and Satellite Imagery
- Automated Data Storage and Retrieval
- Integrated Planning Information Systems
- Information Needs Survey: Results and Conclusions

The presentation on Integrated Planning Information Systems was made by Lawrence Stid, Deputy Director, Genesee-Finger Lakes Regional Planning Board. All other presentations were made by either Resource Information Laboratory personnel or consultants.

Both objectives of the Workshop appeared to have been accomplished. Information was presented in each area that was new to many of the participants. The topics covered were generally considered to be complimentary, and to comprise a balanced, integrated program. Particular interest was generated by the presentations on the hierarchical land use information storage and retrieval system under development at the Resource Information Laboratory, and on the analytic capabilities of the integrated information system in use at the Genesee-Finger Lakes Regional Planning Board.

Many of the questions asked during the Workshop were specific and directed to particular aspects of the presentations. One general theme which did emerge, however, was the need for a more coordinated approach to the acquisition of land use information.

6.6 Synthesis

Because of the diversity of agencies and organizations included in the survey, it is impossible to make any statistically valid generalizations. Even among public planning agencies, differing objectives, jurisdictions, budgets, staff sizes and specialties made each agency virtually unique. Based on a subjective evaluation of the interview responses, some general patterns do, however, emerge.

6.6.1 Planning Activities. In order to assess the utility of satellite imagery as a source of land related information, it is useful to look at what planners do. Their activities might be divided into two general categories:

- Policy Planning
- Management Functions

Policy Planning is generally conceived of as long-range, anticipatory decision-making. Planners try to devise strategies for dealing with uncertain contingencies. They are concerned with a variety of physical, social and economic variables and parameters.

Management Functions usually involve shorter range, recurring types of problems, usually of limited scope. Examples of management functions include: subdivision and site plan review, project impact statements, and design of specific facilities or sites.

To some degree, all planning agencies were involved in both policy planning and management functions, but the relative proportion of resources devoted to each activity varied considerably. For example, some county planning departments were involved largely in policy formulation, whereas, another somewhat harried, county planner described the bulk of his work as "putting out brushfires." A subjective assessment of the range of relative proportions of the two activities is shown graphically in Figure 6.6.1 below. Operating agencies, as well as planning agencies, are included in this illustration.

The significance of this, vis-a-vis land related information requirements, is that management functions generally require both greater geographic accuracy and greater categorical detail than does policy planning. Policy planning involves the prediction of the consequences of alternative actions and evaluation of these consequences and requires generally comprehensive, albeit less detailed knowledge of the area.

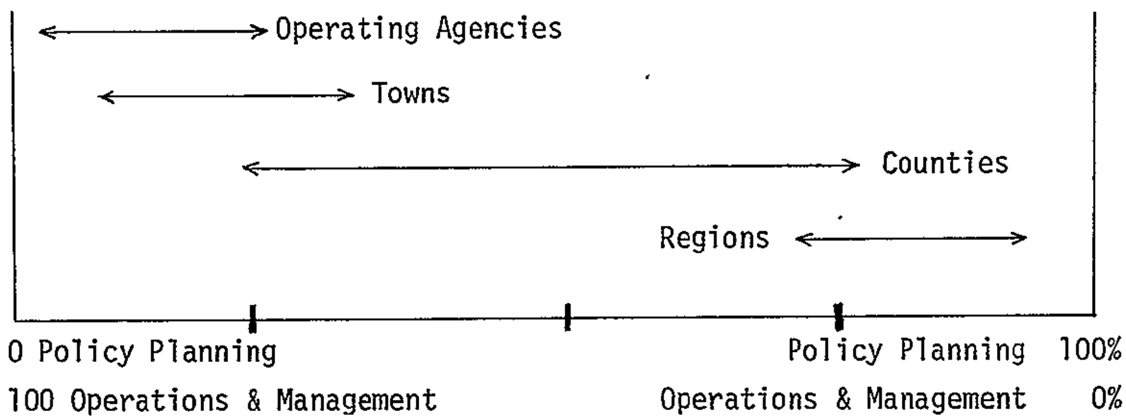

FIGURE 6.6.1

Range of Mix of Planning Activities at Different Jurisdictional Levels

6.6.2 Land Use Classification. The specific land use classification system required or employed is another important factor in evaluating alternative methods of data acquisition. Any land use may be characterized by several components, including:

- man's activities on the land;
- the characteristics of the land, and;
- ownership.

Different systems of classification emphasize different components, and their suitability to different situations varies accordingly.

Several widely acknowledged land use classification systems exist, each based on somewhat different criteria and objectives. The agencies that participated in the survey generally based their particular systems on a modification of either the LUNR, SLUC, or NYSBEA systems, or a combination of two or more of these. The first two classification levels for each of these systems, as well as those suggested in the U.S. Geological Survey Circular 671, are presented in Appendix B.

The LUNR classification system was widely used at all levels of planning activity (to a large degree because the inventory had already been done), however; it was not found to be universally adequate. This classification scheme was found to be particularly deficient for the more intensively developed areas.

LUNR was a statewide land use inventory - the first such inventory in the country. Most of the land use information was obtained from aerial photography, and accordingly, the LUNR categories exhibit a strong emphasis on natural resources and visual characteristics. This categorization scheme was found to be generally adequate in rural areas, however, as the intensiveness of development increases, so does the importance of information based on activities. Activities are, in part, a determinant of future growth, they generate traffic and require services. In general, activities can only be inferred from aerial photography and, often, serious discrepancies were found to exist between visual characteristics and actual activities.

Two other systems were used as a basis for classifying land: The Standard Land Use Coding System (SLUC) and the New York State Board of Equalization and Assessment Property Type Classification System (NYSBEA).

The SLUC system is based on man's activities and classification systems based on it were generally used in intensively developed areas. An inventory based on this system invariably requires a ground survey.

The NYSBEA code is intended to provide a uniform property classification system for local assessment and taxation purposes. Accordingly, the system is based on economic activities and the income producing capability of property. This system has the potential for almost continuous updating of land use if a suitable degree of cooperation exists between the assessment and planning departments. Several county planning departments were in the process of developing land use information systems based on the NYSBEA code.

6.6.3 Categorical Detail. Based on the discussions with participating planning agencies, the range of desired categorical detail at each level has been subjectively referenced to the four-level SLUC system.

This is illustrated in Figure 6.6.2. In general, the higher in the planning hierarchy and the greater the jurisdictional area, the less detailed need be the categories.

It is significant to note that only the largest regional and county agencies used mathematical modeling, simulation or computer analysis in their activities. These analytic techniques, whatever their merits or faults, require that underlying assumptions and information requirements be made explicit. Most planning, however, remains to a large degree based on subjective judgment and experience. Information requirements, therefore, need not be made explicit. It was found, in general, that planners felt more comfortable with greater categorical detail in that specific categories can always be aggregated into more general categories.

Graphic Comparison of Categorical Detail Required at Different Jurisdictional Levels

	SLUC Level		
Jurisdictional Level	1	2	3
Tri-State	--		
Region	--------		
County	----------	--------	
Town		----------	
Project			----------

FIGURE 6.6.2

6.6.4 Map and Air Photo Scales. Comparison of the scales of the maps which are used for storing and/or analyzing land related information is helpful in assessing the utility of satellite data at various jurisdictional levels. In addition, since most agencies use aerial photography to some extent, a comparison of commonly used air photo scales provides further insight. This information is provided in Table 6.6.1 below. In Table 6.6.2, the smallest regional, county and town map scales encountered are compared to the scales of the basic S190A and S190B imagery.

TABLE 6.6.1 Frequently Used Map and Air Photo Scales by Jurisdictional Areas

	MAP SCALES	AIR PHOTO SCALES
Regions:	1:250,000 (1" = 4 miles)	1" = 2000'
	1:125,000 (1" = 2 miles)	1" = 400'
Counties:	1" = 1 mile	1" = 2000'
	1" = 4000'	1" = 800'
	1" = 3000'	1" = 400'
	1" = 2000'	1" = 200'
	1" = 1000'	-----
Towns:	1" = 3000'	1" = 1000'
	1" = 2000'	1" = 400'
	1" = 600'	1" = 200'
Projects:	1" = 400'	1" = 400'
	1" = 200'	1" = 200'
	-----	1" = 100'

TABLE 6.6.2 Ratio of Smallest Regional, County and Town Map Scales Encountered to Scales of Basic S190A and S190B Imagery

MAP SCALES	S190A (1:250,000)	S190B (1:950,000)
Regions (1:250,000)	11.4 : 1	3.8 : 1
Counties (1:62,500)	45.6 : 1	15.2 : 1
Towns (1:36,000)	79.2 : 1	26.4 : 1

6.6.5 General Comments. Although generally skeptical about the value of Skylab (and ERTS) imagery as a potential source of mappable or quantifiable information of sufficient detail for decision-making, many planners felt that it might be nonetheless a significant visual adjunct to information acquired in other ways. The most frequently cited advantages of Skylab imagery were that:

- it provides a single synoptic view of the area in question;
- it shows large scale associations and inter-relationships;
- it places the given area in its regional context; and
- it has dramatic impact and credibility that mapped information often lacks.

The latter point is not unimportant. Planning recommendations must be implemented if they are to have any effect and citizen approval is a prerequisite to implementation. Any device which helps support the recommendation is of importance to the planner.

6.6.6 Comparison of Acquisition Systems. As was noted previously, a piece of land possesses several sets of attributes which may be used to classify it. This suggests a multidimensional classification system (Guttenberg, 1959), or at least a systematic way of incorporating information acquired from several sources, and at several levels, into a unified whole.

One might visualize a multidimensional system as a series of overlays, each showing a separate dimension or set of attributes. Notationally, a land use might be denoted as a vector rather than a single symbol. Each element of the vector would represent a different dimension, e.g., the first element might be used to classify a piece of land according to its visual characteristics, the second element might represent activity, and the third might represent ownership. Such a multidimensional scheme suggests areas of application for different information acquisition systems. Based on the interviews with planning agencies and organizations in New York State, a tentative scheme for incorporating data from alternative acquisition systems is presented in Figure 6.6.3 below.

Multi-Dimensional Framework for Relating Several
Land Related Information Acquisition Systems

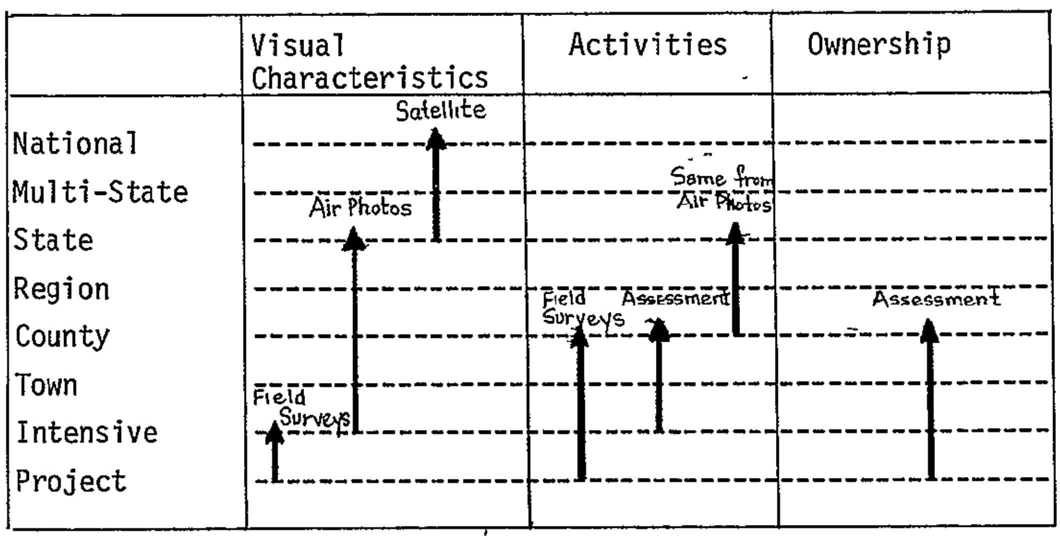

FIGURE 6.6.3

When evaluating the utility of any acquisition system for land use inventories, and its range of application, the character of the area (intensive vs. extensive) and the availability of other data sources must be considered. In particular, several factors limit the applicability of satellite acquired data for land inventories in New York State:

- the availability of LUNR as a baseline land use inventory;
- the amount of intensively developed land; and
- the introduction of the NYSBEA coding system, and the potential for almost continuous updating.

Conversely, in other, less intensively developed states, where no comprehensive inventories exist, satellite obtained land information may have a greater range of applicability.

Figure 6.6.3 also suggests that some land related information might best be obtained at lower levels in the planning hierarchy and channelled upwards and aggregated as necessary. Such a system would require the adaptation by individual agencies of classification systems that are, if not identical, at least compatible at each level. It further suggests a need for greater coordination (both horizontal and vertical) between agencies, and development of more systematic channels of communication.

6.6.7 Summary. As planning activities become more localized, greater locational accuracy and greater categorical detail are required for land related information. This is primarily a function of:

- the smaller jurisdictional area;
- the increased emphasis on management functions;
- the increased level of citizen participation, and the concomitant need for greater credibility; and
- the relative ease of obtaining more detailed information for smaller geographic areas.

As the intensiveness of development increases, the emphasis on activities as a factor in the classification of land use increases. The dichotomy between land use requirements in intensively and extensively developed areas suggests a multidimensional classification system. By identifying several dimensions, a systematic connection between the information needs of planners and the methods of acquiring land related information has been established.

7.0 SPACE REMOTE SENSING AND APPLICATIONS TO LAND USE AND NATURAL RESOURCE SURVEYS

The major difficulty of those who attempt to deal with the problems of increasing demands, resource management, planning land use, and promoting ways of protecting the environment, is trying to find information from the systems already in existence that is adequate for their needs. It is hard to locate, and it is in forms that are not useful for a particular purpose. Moreover, systems may not allow the user to assemble or aggregate the data in the way most useful for his needs.

Land use planning, at any level, requires a great assortment of information sources. Land use planning, to be productive, must consider the human needs for the product of the resource in terms of social, cultural, and economic values of the society to be served. It should consider the inherent biological capabilities of the resource to meet society's needs. The statistical data required to make the predictions necessary to promote good land use planning are extremely hard to assemble. Consequently, at most levels of government, and for individual managers as well, there exists a massive problem to create from any source a data base that is both adequate and functionally efficient in meeting the needs of the planner, the resource manager, and society as a whole.

Requirements for information change, sometimes rapidly. As a standard procedure in our democratic society, production is most efficient when the best resources are used. Our technology has rarely succeeded in making the use of lower quality resources an economic success. Consequently, it is a natural sequence of events that leads us to situations that require ever increasing amounts of information about our dwindling supply of natural resources. Data requirements of land (and resource) planners must be determined by whatever issue is being addressed. And the issues vary widely over time. We are currently working with planning guides and legislative control measures that were designed to manage resources in the face of ever increasing pressure from an expanding population, and the demands that increased population would create. In spite of predictions and the closeness of the date when the population pressure may cease to be as important a factor, we have had little or no preparation for such a major change. But in spite of changes in absolute figures, due to our economic processes that reward best those who utilize the best resources, we will still see great demands for accurate, frequent and comprehensive data concerning our land and the natural resources it provides.

In an early report concerning potential benefits of remote sensing in land resource management, it was concluded that the major beneficial application of satellite remote sensing would be for land use and natural resource planning and management. (Belcher, Hardy, Shelton, and Schepis, 1967). That conclusion is still valid. For if government units are to have any impact on the decisions concerning the way land resources will be used, there must be provision for the frequent acquisition, processing, storage, and retrieval of data as an integral part of the process. Satellite acquired data appears to be a source of information that meets the stated requirements.

7.1 Limitations and Advantages of Satellite Data

Space acquired imagery offers a new tool to land use managers and planners. As with all "new" tools, the potential audience of users is skeptical about using it until examples of substantial rewards from its use are provided. And, in addition, it faces the predictable problem of proving itself to be more efficient and a better source of information than existing sources already familiar to the users. In practice, these conditions place satellite acquired information in a direct competitive position with conventional low altitude aerial photography. The professional planners are using low altitude aerial photography. They are used to working with it, they understand its capabilities, and they know how to budget for its use. It is natural for them to evaluate any and all new sources of information directly against those sources currently in use.

In the test sites selected for this project, we had a representative sample of some of the most difficult areas of the country in which to apply remote sensing techniques to land resource planning applications. Land ownerships are small. Local government areas are small and complex. Climatic conditions are highly variable, and land management patterns are extremely complex and show high degrees of variability over time. These conditions offer a severe test of the utility of any source of data.

There tends to be a major difficulty in the intermixing of different land uses in the imagery. When land use patterns are independent in units of pixel size or even smaller, the amount of intermixing is high. In addition, we found substantial unique land use areas with identical spectral responses to completely different uses. For example, the urban core of a city may show the same spectral response as a stone quarry and freshly ploughed gravel soil where there is a high content of stone (a common event in the northeastern United States).

The solution to the limitations composed of factors of complexity lies in different approaches to the classification theory and how it is applied. In the description process of the classification system, and through the use of interpretation techniques that use either manual or human interactive capabilities, it is feasible to account for the condition generated by the complex land use patterns. The classification needs to be based on a process of aggregation of basic information rather than the relatively simpler process of direct read-out of a land use identified only by a particular spectral response.

This will lead to inferential concepts of analysis, which put greater demands on the interpreters' talents. The process can be assisted by automated procedures, but will not be completely successful if only automatic processes are used. Inferential analysis depends on the users' ability to recognize patterns that are generated by an association of events that are subsequently recognizable in the "cover" pattern that can be recognized on the remotely sensed data. When this approach to classification and interpretation is developed, then we can approach a higher degree of maximization of utility of the satellite acquired resource information. But the ability to maximize the use of information retrievable from satellite acquired data can not be realized until inferential concepts are applied in the classification and interpretation phases of data processing.

In as much as we have a prior-established hardware package on the satellite, the spectral characteristics are predetermined as far as most any user is concerned. Therefore, his classification system must be based on the spectral characteristics the system can provide. This requirement leads to the recognition that the definitions of the classification system must incorporate the variations that occur in the imagery. This requires great knowledge of local conditions including atmospheric conditions, phenological characteristics, and land management practices, as well as the social, cultural, and economic conditions of the area.

With the above concerns considered, it was feasible to perform mapping activities for the test areas that qualify for high accuracy in the use of the USGS 671 classification scheme. That system calls for a level I classification based solely on satellite imagery. That was accomplished, with the exception of some wetland types that were not identifiable. The level II units, designed for use with high altitude imagery, also were identifiable with limited modification and with a process that enlarged the imagery to a much larger scale. Many land uses that would logically fall in a level III system of classification (here considered similar to the New York State Land Use and Natural Resource Inventory (LUNR) classification) were also readily retrievable.

There is a major advantage possible in relation to the use of satellite imagery with a USGS 671 type of classification. With a uniform source of data, then each user may make his own modifications for his special purpose . But they should be made in a way that allows reaggregation within the chosen standard system. In this way, total area data can be made available that will be comparable on a region to region, or even nation-wide, basis.

Another major problem of concepts of analysis that remains to be solved is the propensity of researchers to report the accuracy levels of their findings on the basis of comparisons with an existing, unverified inventory product. This leads to major deviations of accuracy. There is a general lack of statistical verification of accuracy of classification systems, especially in large area studies, where time lapse situations produce high variability on a "per category" basis. Accuracy levels need to be presented, based on the relation to true accuracy on the ground as determined by post-analysis surveys. This step is most frequently omitted in studies where "training sets" or areas are used in the preliminary phase, but post-survey field analysis is omitted.

Scale of imagery is a frequently discussed topic. One goal of this project has been to develop techniques that allow us to work with whatever scale of imagery we receive. In photographic data acquisition processes, we select the scale the user feels will best meet his needs. In the case of satellite acquired imagery, the user is "given" a scale which he must work with. Through the use of the photographic and projection processes described in this report, it is feasible to remove the basic restraints of scale in relation to satellite imagery. Enlargement to scales of 1:250,000, 1:125,000, and 1:62,500 are entirely feasible. And they will maintain interpretable fidelity to those levels. Projection to scales of 1:24,000, 1:12,000, and even larger is possible, and has been done with high degrees of accuracy and consistency.

Simply increasing the size of an image does not increase the amount of retrievable information. But recognizing that our audience of users expects to work with information at a large scale (1:24,000 or larger), it is essential that we have the capacity to present the data to them in a format and scale they are willing to use in their work.

Most decisions on resource management are made at a low unit level of government. In the northeast that is the town or village. Most towns are about 36 square miles in area and fit within the area of one 1:24,000 topographic map. Satellite imagery, at a scale of 1:3,000,000 represents the typical town in an area of less than one quarter of a square inch on the image. Unless this scale can be enlarged in a manner that provides a high degree of recognizable data, most potential users are convinced they have no use for the imagery.

A list of limitations of satellite acquired imagery that are readily recognized, (for many of which solutions are possible) would include:

1. Climatic conditions - can not be selected to the advantage of the user as readily by satellite acquired sources as with low altitude platforms.
2. Scale of imagery - still considered by most users as a major problem, but techniques for resolving this are being developed.
3. Time frame of acquisition - user has less control over time of acquisition, but the greatest problem is the delay between date of acquisition and availability of processed imagery.
4. New skills required - satellite imagery is a new tool requiring new skills. Acceptance is very dependent on our ability to create favorable situations relative to technology transfer. Education for the user community is essential.
5. User contacts - there is a need for more general conferences for users of data. The community of technicians needs to be broadened to incorporate the user community.
6. Technical problems of standardization - many such problems still exist, and relate directly to responses of various images to variations in atmospheric conditions, recognition of seasonal variations and accuracy over periods of time.

There are many advantages to satellite acquired imagery for the user. Those currently applicable are within the area of technology related to data acquisition. The major identified advantages include:

1. Low cost - as long as the user can acquire imagery in a manner similar to present arrangements, low cost is a readily recognized benefit.

2. Frequency of cover - satellite imagery can be obtained at frequent, regular intervals, providing a much needed time lapse information source.

3. Large area coverage - this is a major advantage, providing working material for major resource inventory projects. It is rare to find uniform coverage for an area the size of a state. Satellite imagery provides whole country or even continental coverage.

4. Standardization within scanner system - the equipment in the system provides highly standardized products. Therefore, the variables that do occur have an identifiable source which often can be calibrated. Photographic processes frequently have high degrees of variability in the final product.

5. Storage and cataloging - storage and organization of the materials can be managed in very efficient systems, whether organized for large or small areas. Storage space required for the imagery is minimal.

6. Geographic referencing - in manual and visual processing procedures, geographic referencing is readily achieved. Adaptation to standardized map systems is feasible and adds greatly to the utility of the imagery.

7. Synoptic views - planners and resource managers need the opportunity to view their area of concern in relation to its surroundings. Satellite imagery provides this opportunity.

8. Presentation source - satellite imagery provides an excellent means of presenting planning programs and projects to the general public. It has great utility as a tool to win public support for planning and management decisions, which is an extremely important step in the total resource planning/management process.

7.2 Cost Effectiveness

It is not possible to provide a complete, tested comparison of a large area of the cost effectiveness of satellite imagery. To do so requires development of a major, large-area survey that could be carried out using both conventional photographic sources, and compared with information retrievable from satellite imagery. The results would have to be carefully weighed to consider the levels of accuracy achieved, and the true utility of the information. Although an adequate comparison test has not been undertaken (for a large area such as a whole state) in a way that the utility of the information could also be tested, it is possible to discuss costs of different systems based on experience obtained in managing resource inventory projects and the research undertaken in this project. It is a complex problem to attempt such an analysis, as we can not deal with inputs and results that are directly comparable. The following are among the major difficulties in making a cost comparison of the two sources of data.

1. We do not know how much information can actually be retrieved from any of the sources of data under study.

2. The costs of data acquisition are only fragmented parts of any resource inventory and changes proportionately according to the design, scope, area, and purpose of the inventory.

3. It is not possible to do exactly the same kind of an inventory from the various sources of data, except in the case of gross classification units.

4. There is a great number of methodologies to be considered, ranging from completely manual processes to completely automated systems. Assignment of amortization costs for capital equipment has not been determined in a realistic or satisfactory way. (For example, if one project must hire computer services, while another has access to a computer on a no charge basis; or in some instances, the computer is considered a capital item of the institution involved; therefore, depreciation costs are not charged to individual projects).

5. Differences in availability of sources of talent are difficult to quantify. The labor requirements for various government agencies and institutions vary widely, and have a major influence on costs.

6. There may be no need for the information available from a particular source of data, thereby negating the value of any comparison of cost effectiveness. Some countries or local areas may have no resource information and satellite imagery would provide excellent first level data. But other countries may have such complete coverage of good sources of data that satellite sources would contribute no new information.

7. Photography provides a source of both area and point data. Usually other forms of imagery currently available provides mainly area data.

7.2.1 Acquisition Costs. Recent research projects carried out by the authors which required acquisition of various types of aerial photography were reported on in June, 1975. (Hardy and Hunt, 1975). The following costs for air photo acquisitions were reported.

Type of Photography	Cost Per Square Mile
Low Altitude B&W	\$ 4.00+
High Altitude B&W	\$ 3.11
High Altitude Color	\$ 6.00+
High Altitude Color	\$ 6.22

In addition to the above costs, some companies queried stated the cost for a well verified index mosaic would be about the same as the cost of photography. Therefore, if useful base maps are not available, the cost could double.

Acquisition of photography, especially the high altitude coverage, may have restrictions due to time frame requirements and local climatic conditions. There is always the problem of acquisition during suitable weather, for low or high altitude photography. But it was pointed out by contractors that metropolitan areas create their own climatic and haze problems, and therefore, the aerial survey companies were reluctant to guarantee satisfactory results in acquiring high altitude coverage with color film, or any other film with similar exposure characteristics. The chances of acquiring comparable low altitude, high altitude, and space imagery of any particular large area within a specified time frame are not very good. If large urban areas were to be covered, no guarantees of success were offered.

In considering acquisition of imagery for a 10,000 square mile area, we can present some comparisons. Costs for manual preparation of satellite data, using photographic enhancement techniques, are $.04 per square kilometer for S190A imagery. This includes the cost of ten color composites for comparing at least five Level I type categories.

Cost figures for machine processed data presented by NASA representatives at a conference in Albany, New York, on June 19, 1975, identified costs for three systems of processing. Their products were different and additional interpretation by the user was expected. Costs quoted for machine processing of one 10,000 square mile image were: Process A = $2,217., Process B = $4,667., Process C = $39,375. No recognition was made of equipment costs or depreciation.

With this information, the following table can be presented concerning data acquisition.

TABLE 7.2.1 COST OF IMAGERY ACQUISITION FORM VARIOUS SOURCES FOR AN AREA OF 10,000 SQUARE MILES

Type of Imagery	Cost for 10,000 Square Miles	Condition Statement
Low Altitude B&W (1:24,000)	$40,000	Manual inter. required
High Altitude B&W (1:78,000)	$31,000	" " "
High Altitude Color IR (1:78,000)	$62,000	" " "
High Altitude Color (1:67,)00)	$62,000	Difficult to acquire in urban areas
Satellite Imagery		
Manual Photographic Processing* (Scale: 1:250,000)	$ 1,040	Wide variety of map units
Process "A"* (scale unreported)	$ 2,217	Unique equipment required
Process "B" (scale unreported)	$ 4,667	" " "
Process "C" (scale unreported)	$39,375	Unique process system required

*It was suggested that equipment for digital image display would cost about $32,000, and a line printer for read-out could be acquired for $12,000. Manual photographic processing equipment costs are below $8,000 and the process can be performed with off the shelf photographic equipment.

Cost effectiveness can be discussed only in part in terms of the cost of data acquisition. Some major questions to consider are:

What kind of an inventory can be produced?

What are the scale restraints?

How available is the data source?

With low altitude imagery, the number of units possible to use in an inventory is extremely high. Over 300 items can be identified without exhausting the capabilities of the imagery. There are few scale restraints, as information can be transferred to most any desired base map for display. The data can also be incorporated in computerized data banks. Perhaps a major advantage, frequently overlooked, is the fact that it can be co-referenced easily with information from other sources. A major problem is the low frequency of available cover dates. However, in most instances, the frame of reference for sequential coverage is in at least years, and frequently decades. Much of the country and the world have no coverage available to the general public.

High altitude photography can produce inventories similar to those developed with low altitude imagery. Far fewer items of point data can be provided, however. And only a few major improvements are found with the use of high altitude color photography over black and white photography. The more efficient way to work with high altitude photographs for large area land use inventories, using manual interpretation, appears to be in mono rather than stereo mode. This process requires identification of land use based primarily on recognizable cover types. (Hardy and Hunt, 1975). High altitude photography, whether color or black and white, offers trade-off situations that need to be considered carefully in comparing it, and the results it can produce, with other sources of data. There is very little high altitude photography available, and it is only available to a selected audience of users. Scale restraints with regard to enlargement of high altitude photography are not severe, as most applications require transfer to base reference maps of desired scale for publication use.

Satellite imagery has a number of distinct advantages to enter into cost considerations. It is available, there are major areas of coverage, and it is acquired at known frequencies within a desired time frame. The major concerns are directly associated with cost of retrieving data and the method of processing desired.

There is little chance of directly matching an intensive inventory of of land use prepared for acquisition through photo interpretation with results from satellite acquired imagery. A major restraint is the loss of much of the point type information in the satellite imagery. Therefore, we are concerned mainly with area measurements and selected linear features. Well documented research comparing the different sources and their utility in providing definitive statistical comparison is available in limited situations.

Some comparisons are possible, however, drawing on an assortment of experience and published records. Recent projects involving detailed inventories, and using aerial photography have been carried out satisfactorily in non-profit institutions with costs of approximately $14. per square mile for an inventory of 120 items. This prepared the material for input into a computer system, but the intended product was drafted maps at a scale of 1:24,000. If an inventory of 30 to 40 items was required, this same process could be accomplished for approximately $8. to $9. per square mile.

Considering the interpretation of imagery suitable to extract data to inventory land resources at Levels I and II of the USGS Circular 671 classification model, we would be acquiring about 30 types of cover information that could be aggregated from Level II to Level I categories. Using this as a standard and considering the results found in this report, this kind of inventory can be produced from satellite imagery mapped at a scale of 1:62,500 for approximately $.50 per square mile. (No cost is identified for acquisition of the satellite imagery).

On a state-wide basis, for a state the size and complexity of New York State (approximately 50,000 square miles), this identifies the cost of a level II classification with hard copy maps as the end product at about $25,000 if satellite acquired imagery (S190A) is used. The cost for conventional photographic approaches would be: Photo acquisition = $200,000; Interpretation and map preparation at a scale of 1:62,500 (estimated) = $125,000, for a total of $325,000.

It appears there is little question that satellite acquired imagery, processed in the manner discussed would show a distinct cost effectiveness ratio for the applications considered. The other approaches previously mentioned as "A", "B", and "C" would have successively less cost effectiveness with the higher figure exceeding that of conventional air photo interpretation on a state-wide basis.

There is a residual value in aerial photography that is difficult to evaluate. The photography would be available and of use in a great many other applications, so its cost would legitimately be shared over time with many applications.

7.2.2. Accuracy Considerations. There is concern expressed by many users over the cartographic accuracy of much of the satellite acquired information, as well as that acquired from photographic interpretation techniques. This concern seems to center on the accuracy of the product relative to meeting national map accuracy standards. A question of greater importance would appear to be whether the accuracy of the classification decision process is maintained at its highest possible level. After that activity maintains high accuracy levels, then the concern for meeting map accuracy standards gains validity.

This situation needs more exploration and research. The accuracy of decision making is relatively unspecified in most projects. Therefore, we have little true knowledge of the accuracy of the inventory data in most cases. A general statement that has been used in discussion of this topic with professional planners and which was not seriously refuted, was to the effect that most information used in the decision making process falls within an 80 to 90 percent level of accuracy. This identifies a range of accuracy we should use as an initial goal, with higher levels of accuracy reserved for the near future.

7.2.3 Unsual Benefits. A previous publication on applications of remote sensing discusses the possibility of acquiring unique information from satellite sources that would prove unusually beneficial and might not be available from any other source. (Belcher, Hardy, Shelton, and Schepis, 1967). There is reason to believe these opportunities continue to exist. Some of the examples cited included generation of world wide maps of forest resources, soils, etc., the potential discovery of disease-free strains of major edible grain crops, and control of major epidemic or disaster situations.

These opportunities still exist, and although we cannot claim cost effectiveness benefits, nor can we identify their value, it should be recognized that major intangible benefits are possible. If one such benefit materializes, it could conceivably dwarf any cost-benefit relationship discussed in this paper, whether considered on the basis of application at the state or national (and perhaps world-wide) level.

7.3 Considerations for a National Land Use Classification System Based on Remote Sensing

Concern for the management of the nation's (and the world's) land resources recently has created a recognition of the need for some form of action to foster inventory procedures at the national level. Land based resources are a fundamental finite resource. In two hundred years this country, with its profit motivated economy, has succeeded in bringing the scarcity of land based resources to the forefront as a major issue of concern to the nation. National legislation has been proposed and legislative action may be close at this time. The need for a national land use survey has been recognized and the proposed classification of land use, based on remotely sensed information and reported in USGS Circular 671, was an outgrowth of that recognized need.

The basic concerns are influenced by a wide variety of situations, including changes in the population (increase or decrease), our stance as a nation concerning the food/population relationships for the world as a whole, and our ability to develop technological improvements rapidly enough to counter increasing demands.

Recent announcements about the declining rate of population increase at first indicate we can relax our concern for anticipated demand for land resources. But continued concentration of the population into areas of favored, but limited land-based resources must be anticipated. Therefore, a decrease in the population growth rate, even down to zero population growth, will not necessarily reduce our need for knowledge about our land resources.

The basic concepts and ideas of inventorying the nation's land resources is not new. The past efforts have been centered around statistical estimation processes, mainly because of financial restraints related to data acquisition. Remote sensing systems now offer a means of acquiring the raw data efficiently and it now remains a problem for solution by the scientific community to find efficient ways of using the data to develop a national land use inventory.

Major problems exist in trying to generate a national inventory. First, an acceptable classification system must be designed that meets the needs of the potential user audiences. It must take into account the existing data base, and if possible, allow for the continuation of data acquisition that maintains the same standards and the same basic types of information. Meeting this criteria was one of the major goals of the authors of USGS Circular 671. That classification system was developed with the assistance of Federal Agency Personnel with major concern and/or responsibility for acquiring and recording land use data. If it is followed to a reasonable extent it will allow for the aggregation of data that is currently in use or considered of value to Federal agencies.

There are many levels of government to consider below the Federal level. These include the regional units (made up of groups of states), state governments, intra-state regional groups, and local government units within states, which in the Northeast include county,town, city, and village government units. Due to the concept of residual powers deferring to the next lower level of government, the major demand for land resource information occurs at correspondingly lower levels of government. As local governments are concerned with smaller units of land, they tend to acquire information in large scale map units (1:24,000 or larger). This situation counter-balances their interest in large area surveys to the extent local resource managers frequently are reluctant to consider the use of satellite acquired data. This points to the need to consider the concerns and abilities of the professional planinng staffs at the level of local governments when we survey the possible audience of users of satellite sensed data. This also identifies the situation that substantiates the idea that highly sophisticated processing techniques for remotely sensed resource data may not be acceptable to the largest probable audience of users. The typical user at the local government level is familiar with, and feels confident with data derived from, air photos. He has developed his data base for his work on this kind of information It will be extremely difficult for him to justify switching to a new source of unknown quality and one that may not provide working data that corresponds to his present data base. Premature sophistication of the satellite data processing procedures may exclude this group from the audience of users for an extended period of time.

To a great extent a similar analogy could apply to foreign applications of satellite data. In many cases, the schism between individual talent, need, and financial resources may be even wider than that recognized within the United States. If so, we can predict a similar reduction in the audience of potential users on an international basis.

The generation of the USGS Circular 671 classification system was undertaken with the hope of meeting a number of goals. It was understood that most states and local governments would want more detailed land use inventories. The hope has been expressed that the 671 classification would provide a framework for aggregating data from lower levels of government, and from smaller area studies, up to units that are useful for statistical records of land use at the national level. This still appears to be feasible.

Another major goal in the design of that inventory was to understand what information could be acquired if a national land use survey was undertaken using 1) satellite imagery and 2) high altitude imagery. The reports received concerning the "state of the art" of remote sensing at the time the inventory was designed indicated level I units of classification were feasible from satellite acquired imagery, and level II units could be acquired from high altitude imagery. These considerations still hold.

As a result of our research, it appears the "level" concept is justified and still valid. The fact that more information can be acquired from satellite imagery than is required to satisfy level I demands is a very favorable situation. If that were not the case, a major revision of the concepts on which the system is based would be required.

A natural resource inventory should be designed in such a way that it can draw on any source of information that can provide input data. It is expected that more detailed inventories will be prepared at state and local government levels. They will have to use imagery of appropriate scale and detail to meet their special needs. If possible, it would be desirable to aggregate that kind of resource information into a national inventory system. If that is not a feasible approach, or is feasible for only parts of the country, the 671 classification can serve as the basis for a whole-country inventory, or as the means of filling in missing areas in a uniform, standardized classification system.

The total land area of the mainland of the contiguous 48 states is 3,000,000+ square miles. This amounts to approximately 300 frames of imagery if each frame covers 10,000 square miles. According to the costs previously identified, a nation-wide level I classification of land use could be produced with the following range of costs. Provision for base maps, and various processing steps not taken into consideration. Based on 300 frames of imagery.

Photographically enhanced (scale of 1:62,500) $1,500,000 @ 50¢/sq. mi.

Process "A"	@	$2,217/frame	-	$ 665,100
Process "B"	@	$4,667/frame	-	1,400,100
Process "C"	@	$39,375/frame	-	11,812,500

There is a great variation in the products that could be produced, and that is not discussed here. Based on previous experience in managing large scale inventories, it would be possible to inventory the land use of the same 48 states using conventional large scale aerial photographs and classifying the land use into as many as 100 classification units for an estimated $50 million. There would be many obvious problems in managing such a large scale project, and it would require a number of years to accomplish a complete inventory. But this at least provides a background against which we can measure the significance and feasibility of a nation-wide level I inventory.

There were difficulties experienced in this research project in using the test imagery for certain applications. One major area of difficulty occurred in relation to classifying wetlands.

Basically, wetland is a mixture of land with water. The percentage of the component parts vary, producing an array of mixtures of spectral responses. They vary over short and long periods of time, and they are not spatially or spectrally discrete. Certain common wetland types are not identifiable from spectrally based sensors due to the amount of above ground vegetative cover. These circumstances frequently exist in the case of upland wetlands in humid areas. Spruce forests and shrubby cover frequently mask wetland areas beyond recognition from any form of readily available remote sensors. Highly refined, discrete wavelength bands in the near infra-red and thermal infra-red ranges may be capable of providing this information.

Another major problem exists in the evident lack of adequate documentation of classification units and systems. Most classification systems are not comparable or transferable from one part of the country to another because they lack adequate description, or have been designed on the basis of very narrow use concepts. This is an even greater problem when considered on a world wide basis.

We can design inventory processes in two basic ways. One would allow each user to set up his own classification requirements and then have sensors designed to acquire that data. The other approach would be to acquire data in a fixed reference frame and let the user select desired information from that source. The second approach is most desirable of the two because of data analysis cost factors, it allows standardization of image components, and it permits users to draw material from a standard source based on known or identifiable values. This also will allow aggregative procedures for use by resource managers at successively higher levels of generalization.

Decision makers do not necessarily know what data source will serve their purpose best. Due to typical financial restraints, they are generally forced to use what is available rather than explore or experiment with new approaches. Consequently, satellite data, almost without exception, will be compared directly to air photos of the same area (low or high altitude) with a resultant quick decision that it is not as good or as useful as the information already available. In interview situations it required lengthy discussions in most cases to get professional planners to recognize potential applications for satellite imagery.

Favorable conclusions concerning this section can be drawn. Skylab type data can accomplish and provide a remote sensor program geared to land resource management. Many more problems exist in the areas of technology transfer, user education, classification theory, and categorical definition and description than remain in the area of acquisition of Skylab type remote sensor data. With some modification of Skylab sensors, there is no doubt all of the level I and level II units of the USGS 671 classification could be acquired. In addition, major portions of a level III classification system, similar to the New York State LUNR Inventory could be acquired from the same sources. The major remaining problem to be solved involves the design of classification systems suitably related to the sensor configuration to maximize acquisition of useful data.

7.4 Land Resource Management from Space Acquired Information

Management decisions concerning our land resources are made on the basis of information provided to or by local planners and managers. The accuracy level of this information frequently is unknown. In conversations with this group of decision makers, there is a general concurrence that resource management decisions are frequently made on the basis of information with an accuracy level of 80 to 90 percent. In spite of the existence of new techniques, new sources of data, and new kinds of information available, there is an urgent need in the eyes of professional planners to defend the previous, or older systems of data acquisition.

Two reasons are given for this need. The first is a danger of removing credibility of their previous decision making processes if they simply shift to a new, unproven data source. The second is that it is extremely difficult to guarantee the accuracy levels of the new sources of data. These reasons are fundamental to the problem of promoting the use of satellite acquired information in natural resource management.

In the work of Belcher, Hardy, Shelton, and Schepis (1967) it was concluded the major benefit from space acquired data would be in the field of management of natural resources. It also was recognized that benefits could be derived in two ways. One, the lower cost of acquiring data can be compared directly in terms of dollar costs and if comparable data can be acquired, benefits can be calculated easily. The second benefit source was identified as improved production from our resources due to better management based on the satellite sources of information. This is by far the greatest source of dollar benefit, but it is a much more difficult source to monitor and evaluate.

The results of current research show that the satellite acquired data is a suitable means of providing useful information for resource management. Resolution capabilities in certain processes allow reproduction in scales normally used by resource managers and the minimum unit of information (pixel) is satisfactory for a majority of basic resource management concerns. These circumstances lead logically to a search for other basic problems that might limit the use of remotely sensed data for management applications.

The pattern of progressive events is not organized in the most fruitful order. Generally, satellite imagery is most useful, and has its highest proportion of direct applications for relatively large areas of the earth's surface. On the other side of the problem, land resource management is most often applied to small areas of a few acres or a few square miles at most.

This pattern of events is particularly true in areas of high population density. Where population pressure is great, we tend to have strong local governments. They are involved with a high proportion of decisions, and they acquire good data, at large scale, to assist in the process. Unfortunately, this places satellite acquired information in a low relative position for these kinds of applications. The result is that satellite data sources have a decreasing relative value (in the view of the potential users) as the number of potential decision-making groups increases.

Land use managers and the institutional arrangements within which they must operate result in a highly fragmented pattern of concern and authority. It is rare that areas larger than a county can be looked at in terms of management decisions that will actually be applied. The solution to this problem will require major changes in the structuring of political considerations and in the resource management of those units. These are restraints that greatly influence the use of satellite imagery, yet their solution is not within reach of the community of researchers involved with remote sensing. There are some areas of progress, however, where groups of towns or counties are joining together for the solution of certain problems. And river basin commissions, as well as regional agencies, are organized across local political boundaries in many areas.

In some cases, specially organized units are performing without direct concern for the local resource management units. Special topic studies are being conducted at higher levels. Special areas of concern, such as the coastal zone areas, are being surveyed and inventoried by specially organized units. They are frequent users of information derivable from remotely sensed sources.

In view of the range of audiences to be served and the disparity in capability to work with sophisticated sources of data, it is evident a wide range of products should be made available from satellite acquired data sources. There is a need for manually prepared visual materials as well as the automatically processed products. It is frequently observed by people experienced in this field that the more sophisticated the system employed for data acquisition and processing, the smaller is the number of potential users. (After six years of running the User Serivce for the New York State Land Use and Natural Resources Inventory, we found 90% of the requests are for map products, while less than 10% call for computer graphic displays. The Canada Land Inventory now provides hard copy maps as a readily available product. This experience can be documented in a number of instances in addition to those cited).

In view of our experience, when applications involving decision making groups organized at levels below the federal and state governments, and which are concerned with correspondingly smaller land areas of natural resources, the most likely product request will be for hard copy maps or images for direct use in mapping presentation material. If these kinds of users can not be served, it will greatly reduce the number of users and uses of satellite acquired data. This situation calls for continued consideration of automated, manual, and inter-active processing and retrieval systems.

Research has shown a high degree of genuine utility for satellite acquired data for land resource management. But there appears to be a number of "missing links" that require connection before its use can be maximized. There is a need to increase the speed with which the transfer of this new technology can be made from the scientific/research community to the audience of users. There is a need to show the new knowledge and how it can be used by resource managers at all levels, but especially at the lower levels of government. There appears to be a major lack of research in relation to basic classification theory. This is prohibiting the use of satellite acquired data for inferential analysis, which is likely to be the most rewarding form of application. (Currently, most all work is simply producing information by direct identification which is at the lower level of potential rewards). And there is a need to generate the realization among potential users that satellite imagery can provide the synoptic, over-all view of their study area and neighboring areas.

In summary, research has shown that the satellite acquired information is useful in land resource management. But to maximize that use, preparation to increase its value to users at the lower levels of the decision making processes is necessary. To maximize its use will require continued production of data and information in a variety of formats, ranging from completely manual to completely automated systems. And there will be a need to emphasize research activities to resolve the four problems, mentioned above, identified with the realm of technology transfer. It appears the technical phases of the total process are well developed. The use this system of data acquisition will receive is now limited by the lack of adequate solutions to the above problems.

8.0 RECOMMENDATIONS, SUMMARY AND CONCLUSIONS

8.1 Recommendations

(1) In designing future data collection systems (electronic or photographic), greater attention should be placed on the most important kinds of information to be collected. For instance, most of the earth's population is associated with land masses covered with vegetation. Aside from water, chlorophyll is probably the dominant spectral response during the growing season. From an assessment of where life can be supported, chlorophyll and water are certainly the most important spectral responses. Therefore, it is strongly recommended that in the selection of filter bands for future systems the maxima and minima reflectances of the characteristic chlorophyll curve be observed. In addition, for electronic systems a thermal band to indicate human or natural activity should be included. Based on data analysis on both the S190A and S192 multispectral system, the following channels expressed in nanometers are suggested for future designs: Band 1 - 0.52-0.58, Band 2 - 0.60-0.67, Band 3 - 0.75-1.0, Band 4 - 1.1-1.35, Band 5 - 1.48-1.85, Band 6 - 2.0-2.43, Band 7 - 10-12.

(2) Resolution is also an important feature especially for urban areas. The resolution (10-12 meters) obtained on the black and white film of the Earth Terrain Mapping camera would be very desirable. In manned data collection missions, a multispectral camera array made up of four Earth Terrain cameras in an S190A mode would be most acceptable. Three cameras should carry black and white film configured with narrow band filters with approximate band pass of 0.52-0.58, 0.60-0.67, and 0.75- 0.90. The fourth camera should have high resolution color film This system could probably permit classification down to some Level III type categories. For electronic scanning systems, 30-40 meters would be a very usable scale. This should allow accurate classification of data down to Level II type categories.

(3) Greater attention must be paid to land use category definitions, with more emphasis being placed on the basic spectral and spatial components of each category being defined. In trying to provide updated information for inventories and at the same time satisfy various users, a unified land use classification system is necessary. Categories should not be defined so much with names, but more so with the spectral and spatial components; eg., residential could be defined as patterns of roof tops and pavement interspersed with vegetation such as trees or grass. Knowing the spectral characteristics of each material and approximate percentage of each component, a good general definition of residential can be made. Similarly, spectral and spatial components could be considered for other categories. A further consideration is that all categories have a range of variability and definitions must accommodate these variables to the extent that is practicable.

(4) Considerably more emphasis is needed on technology transfer. The public, including government officials, has to be convinced that in some cases data can be obtained more efficiently by satellite or high altitude aerial coverage than by more conventional techniques. At the same time, they need to be made more aware that new kinds of information are potentially available from satellite. Since town and county level planning boards generally represent small areas, which do not often have serious data acquisition problems, more emphasis should be placed on supplying information to officials at the state and multistate or federal levels. At the local level in New York State most satellite data is not sufficiently detailed to meet the users' needs. It is, however, ideal for large scale planning at the state level. Here for the first time, state planners can view inter-associations throughout their state. Such information should be very useful in planning transportation corridors, water resource management, managing prime agricultural land, forest management and planning for controlled urban growth centers. Further research in technology transfer to determine users' needs will undoubtedly produce many more applications.

(5) Finally, much more emphasis should be placed on the continued development of low cost analysis systems. The system presented in this report, while not complete in every respect, does represent a significant step in that direction. In terms of world-wide applications, most data analysis centers cannot afford large capital investments in specialized hardware and software packages. Therefore, there should be continued support for supplying photographic type products either from camera systems or electronic scanners, so that researchers working individually or with small budgets are not unnecessarily penalized in obtaining satellite data. Eventually, costs for analysis of any satellite data, either by computer or manual methods, should not exceed several hundred dollars per frame. As costs are brought down to this level, public acceptance of an operational satellite resource management system will become more of a reality.

8.2 Summary and Conclusions

Simplified photo processing steps using a conventional dark room set up have been developed to balance the contrast and density range of multispectral bands for either the Skylab S190A system or the LANDSAT (ERTS) system. These steps are low cost, require only conventional photo technician knowledge and they produce consistent and reproducible results. Enhanced black and white enlargements of the S190A filter bands (AA, BB, and DD) are used to produce color composites of various land use categories.

Density readings obtained from each S190A spectral band for known areas representing different land uses are fed into a computerized CIE Color Prediction Model. This model relates the density values in each spectral band for each category of land use to the spectral properties of the various diazo films. It then produces a combination of spectral band, diazo hue and exposure value for each diazo film which will maximize the color contrast among the land use categories being examined. Three categories per composite can be compared. Up to 20 composites can be generated for under $25 plus the cost of diazo materials.

Two special experiments were conducted to investigate the potential for other photo enhancement techniques. The first used color separation techniques to make black and white negative separations of both the S190B color and color IR films. These black and white separations were then enlarged to scales of 1:48,000 and reconstituted into color and color infra-red by using suitable combinations of diazo material. The final product was quite acceptable for interpretation; however, the procedure involves dark room techniques requiring very controlled procedures. Therefore, it is not a recommended procedure unless adequate enlargements of the S190B data cannot be made by other means.

The second experiment used Agfa coutour film to see if further enhancement would result. The concensus was that this film type was too difficult to use, expensive, time consuming, and produced unreliable and non-reproducible results.

The filters on the S190A camera array are too broad. They also overlap considerably in transmittance. These two factors severely limit the potential of the multispectral camera system as used in the present configuration. Even though these limitations exist, the S190A data, when sufficiently enhanced photographically and with the CIE Color Prediction Model, can produce information nearly equal in detail and accuracy to the S190B system. This is surprising in that the S190B has two to three times the resolution of the S190A. Information extracted from S190A imagery is theoretically at its maximum level of interpretability using manual techniques; whereas, unmodified S190B film types are not necessarily interpreted at maximum efficiency without the use of special PI equipment which was not available for this study. (The 1:24,000 scale interpretation of the Ithaca and Kingston sites does show improvement in the error rate which seems to indicate that the interpretation techniques employed were insufficient to take advantage of all the resolution capability of the S190B films). These results combined with that obtained on the S192 multispectral scanner tend to support the thesis that narrow band multispectral sensor system can provide better data than that obtainable from conventional formats of the same resolution. Furthermore, as discussed in Section 5.2, increasing contrast along with resolution should increase detection and interpretation accuracy.

Based on resolution alone, the Skylab S190A sensor proved to be significantly superior to the LANDSAT (ERTS) system in acquiring land use information. Spectrally, the S190A was not an improvement over ERTS. In fact, the infra-red bands were significantly degraded due to emulsion grain. They also contained less spectral information than did the equivalent LANDSAT bands.

Land use information can be interpreted for Level I and most Level II categories at accuracies acceptable for policy planning. However, it has not been shown that satellite data can successfully update existing detailed inventories such as LUNR to acceptable accuracy levels. Neither is such data acceptable for operational planning or site planning. Improvements towards satisfying some of these needs might be made by using a combination of S190B cameras in a S190A mode configured with narrow band filters.

Satellite coverage provides users with a unique synoptic view that shows large scale relationships not readily available from other sources. This snyoptic view is especially important in studying land use dynamics operating on a macro-scale. Moreover, satellite scenes are an important tool in themselves to quickly demonstrate land use features of a region to public officials. In terms of policy planning decisions, there is much to the axiom "seeing is believing." Likewise, satellite scenes are a credible educational tool to instruct the public on a variety of geographical or environmental topics.

In assessing the utility of any information acquisition system, other available data sources should be considered, eg. existing inventory information, soils maps, etc. Other factors that should be considered include the size of the area in question; the extent of the planning activities and the number of jurisdictional levels which are to be served; and the varying requirements for categorical detail and geographic specificity.

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APPENDIX A

AGENCIES/ORGANIZATIONS PARTICIPATING IN SURVEY:

Babylon Town Department of Environmental Control
Babylon Town Planning Department
Brookhaven National Laboratory
Broome County Planning Advisory Board
The Cary Arboretum of the New York Botanical Gardens
Cayuga County Environmental Management Council
Cayuga County Planning Board
Central New York Regional Planning and Development Board
Dutchess County Cooperative Extension
Dutchess County Department of Planning
Genesee-Finger Lakes Regional Planning Board
Group for America's South Fork
Huntington Town Planning Department
Monroe County Department of Planning
Nassau-Suffolk Regional Planning Board
Onatrio County Planning Board
Orange County Cooperative Extension
Orange County Environmental Control Commission
Poughkeepsie Town Planning Board
Regional Marine Resources Council (L.I.)
Regional Plan Association
Seneca County Planning Board
Smithtown Town Planning Board
Southern Tier East Regional Planning and Development Board
Southern Tier East Regional Planning Board
Suffolk County Cooperative Extension
Suffolk County Department of Environmental Control
Suffolk County Department of Parks, Recreation and Conservation
Suffolk County Planning Commission
Tompkins County Planning Department
Tri-State Regional Planning Commission
Ulster County Cooperative Extension
Ulster County Environmental Management Council
Ulster County Planning Board
Warwick Town Planning Board

APPENDIX B

STANDARD LAND USE CLASSIFICATION SYSTEM (SLUC)

ONE DIGIT CODE	ONE DIGIT CATEGORY	TWO DIGIT CODE	TWO DIGIT CATEGORY
1	Residential	11	Household Units
		12	Group Quarters
		13	Residential Motels
		14	Mobile Home Parks or Courts
		15	Transient Lodgings
		19	Other Residential, NEC*
2	Manufacturing	21	Food and Kindred Products
		22	Textile Mill Products
		23	Apparel and Other Finished Products Made From Fabrics, Leather, and Similar Materials
		24	Lumber and Wood
		25	Furniture and Fixtures
		26	Paper and Allied Products
		27	Printing, Publishing and Allied Industries
		28	Chemicals and Allied Products
		29	Petroleum Refining and Related Industries
3	Manufacturing (continued)	31	Rubber and Miscellaneous Plastic Products
		32	Stone, Clay and Glass Products
		33	Primary Metal Industries
		34	Fabricated Metal Products
		35	Professional, Scientific, and Controlling
		36	Instruments, Photographic and Optical Goods Watches and Clocks
		39	Miscellaneous Manufacturing, NEC
4.	Transportation, Communication and Utilities	41	Railroad, Rapid Rail Transit and Street Railway Transportation
		42	Motor Vehicle Transportation
		43	Aircraft Transportation
		44	Marine Craft Transportation
		45	Highway and Street Right-of-Way
		46	Automobile Parking
		47	Communication
		48	Utilities
		49	Other, NEC

*Not Elsewhere Coded

ONE DIGIT CODE	CATEGORY	TWO DIGIT CODE	CATEGORY
5	Trade	51	Wholesale Trade
		52	Retail Trade, Building Materials, Hardware, and Farm Equipment
		53	Retail Trade
		54	Retail Trade: Food
		55	Retail Trade: Automotive, Marine Craft, Aircraft, and Accessories
		56	Retail Trade: Apparel and Accessories
		57	Retail Trade: Furniture, Home Furnishings and Equipment
		58	Retail Trade: Eating and Drinking
		59	Other Retail Trade, NEC
6	Services	61	Finance, Insurance, and Real Estate Services
		62	Personal Services
		63	Business Services
		64	Repair Services
		65	Professional Services
		66	Contract Construction Services
		67	Governmental Services
		68	Educational Services
		69	Miscellaneous Services
7.	Cultural, Entertainment, and Recreational	71	Cultural Activities and Nature Exhibitions
		72	Public Assembly
		73	Amusements
		74	Recreational Activities
		75	Resorts and Group Camps
		76	Parks
		79	Other, NEC
8	Resource Production and Extraction	81	Agriculture
		82	Agricultural Related Activities
		83	Forestry Activities and
		84	Fishing Activities
		85	Mining Activities
		89	Other, NEC
9	Undeveloped Land and Water Areas	91	Undeveloped and Unused Land Area
		92	Noncommercial Forest Development
		93	Water Areas
		94	Vacant Floor Areas
		95	Under Construction
		99	Other, NEC

Source:
Marion Clawson, with Charles L. Stewart, Land Use Information (Washington, D.C.: Resources for the Future, Inc., 1955).

NEW YORK STATE BOARD OF EQUALIZATION AND ASSESSMENT PROPERTY TYPE CLASSIFICATION (NYSBEA)

CATEGORY CODE	CATEGORY	DIVISIONS CODE	DIVISION
100	Agriculture	110	Livestock and Products
		120	Field Crops
		130	Truck Crops (Mucklands)
		140	Truck Crops
		150	Orchard Crops
		160	Other Fruits
		170	Nursery and Greenhouse
		180	Fur Products
		190	Fish, Game and Wildlife Preserves
200	Residential	210	One-Family Year-Round Residences
		220	Two-Family Year-Round Residences
		230	Three-Family Year-Round Residences
		240	Rural Residence with Acreage
		250	Estate
		260	Seasonal Residences
		270	Mobile Homes
300	Vacant Land	310	Residential
		320	Rural
		330	Commercial
		340	Industrial
		350	Urban Renewal or Slum Clearance
400	Commercial	410	Living Accomodations
		420	Dining Establishments
		430	Motor Vehicle Services
		440	Storage, Warehouse and Distribution Facilities
		450	Retail Services
		460	Banks and Office Buildings
		470	Miscellaneous Services
		480	Multiple Uses or Multi-Purpose
500	Recreation and Entertainment	510	Entertainment Assembly
		520	Sports Assembly
		530	Amusement Facilities
		540	Indoor Sports Facilities
		550	Outdoor Sports Activities
		560	Improved Beaches
		570	Marinas
		580	Camps, Camping Facilities and Resorts
		590	Parks

C-3

CATEGORIES CODE	CATEGORY	DIVISIONS CODE	DIVISION
600	Community Services	610	Education
		620	Religious
		630	Welfare
		640	Health
		650	Governmental Centers
		660	Protection
		670	Correctional
		680	Cultural and Recreational
		690	Miscellaneous
700	Industrial	710	Manufacturing and Processing
		720	Mining and Quarrying
		730	Wells
800	Public Services	810	Electric and Gas
		820	Water (Supply and Flood Control)
		830	Communication
		840	Transportation
		850	Waste Disposal
		860	Special Franchise Property
900	Wildlife and Forested Lands	910	Private Wild and Forested Lands
		920	Private Hunting and Fishing Clubs
		930	State-Owned Forest Lands
		940	County-Owned Reforested Lands

NEW YORK STATE LAND USE AND NATURAL RESOURCES INVENTORY (LUNR)

PRIMARY CODE	PRIMARY CATEGORY	SECONDARY CODE	SECONDARY CATEGORY	
R	Residential Land Use	Rh	High Density (50' Frontage)	1.2
		Rm	Medium Density (50'-100' Frontage)	1.1-1.2
		Rl	Low Density (100'+ Frontage)	1.1
		Re	Residential Estates (5+ Acres)	1.1
		Rs	Strip Development	1.1
		Rr	Rural Hamlet	1.1
		Rc	Farm Labor Camp	1.1
		Rk	Shoreline Cottage Development	1.1
C	Commercial Areas	Cu	Central Business District	1.6
		Cc	Shopping Center	1.6
		Cs	Strip Development	
		Cr	Resorts	
P	Public and Semi-Public Areas		No Secondary Area Categories	
OR	Outdoor Recreation Facilities		No Secondary Area Categories	
I	Industrial Areas	Il	Light Manufacturing	1.6
		Ih	Heavy Manufacturing	1.6
T	Transportation	Th	Highway Interchanges, Limited Access, Rights-of-Way, etc.	1.5
		Tr	Railway Facilities	1.5
		Ta	Airport Facilities	1.5
		Tb	Barge Canal Facilities	
		Tp	Marine Port and Dock Facilities	
		Ts	Shipyards	1.6
		Tl	Marine Locks	
		Tt	Communication and Utility Facilities	1.6
E	Extractive Industry	Es	Stone Quarries	1.4
		Eg	Sand and Gravel Pits	1.4
		Em	Metallic Mineral Extraction	1.4
	Eu	Eu	Underground Mining	
A	Agriculture	Ao	Orchards	2.2
		Av	Vineyards	2.2
		Ah	Horticulture, Floriculture	
		Ay	Special Farms	
		At	High Intensity Cropland	2.1
		Ac	Cropland and Cropland Pasture	2.1
		Ap	Permanent Pasture	2.4
		Ai	Inactive Agricultural Lands	2.4
		Ui	Other Inactive Lands	2.4
		Uc	Lands Under Construction	1.6

PRIMARY CODE	PRIMARY CATEGORY	SECONDARY CODE	SECONDARY CATEGORY	
F	Forest Land	Fc	Forest Brushland	2.4,4.3
		Fn	Forest Land	4.3
		Fp	Plantations	4.2
W	Water Resources	Wn	Natural Ponds and Lakes (1+ Acres)	(5.2)
		Wc	Artificial Ponds and Reservoirs (1+ Acres)	(5.3)
		Ws	Streams and Rivers (100'+ Width)	5.1
		Wh	Hudson River	5.1
		Wm	Marine Lakes, Rivers, and Seas	5.4
		Wb	Shrub Wetlands, Bogs, and Marshes	6.1
		Ww	Wooded Wetlands	6.2
N	Non-Productive Land	Ns	Sand (Unstabilized)	7.2
		Nr	Rock (Exposed)	7.4

Two-digit numbers in parentheses indicate category as ignment of LUNR information to the Skylab interpretation categories.

LAND USE CLASSIFICATION SYSTEM FOR REMOTE SENSING DATA (671)

LEVEL I CODE	LEVEL I CATEGORY	LEVEL II CODE	LEVEL II CATEGORY
1	Urban and Built Up Land	11	Residential
		12	Commercial Services
		13	Industrial
		14	Extractive
		15	Transportation, Communication and Utilities
		16	Institutional
		17	Strip and Clustered Settlement
		18	Mixed
		19	Open
2	Agricultural Land	21	Cropland and Pasture
		22	Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas
		23	Feeding Operations
		24	Other
3	Rangeland	31	Grass
		32	Savanna
		33	Chaparral
		34	Desert Shrub
4	Forest Land	41	Deciduous
		42	Evergreen (Coniferous and Other)
		43	Mixed
5	Water	51	Streams and Waterways
		52	Lakes
		53	Reservoirs
		54	Bays and Estuaries
		55	Other
6	Unforested Wetland	61	Vegetated
		62	Bare
7	Barren Land	71	Salt Flats
		72	Beaches
		73	Sand Other Than Beaches
		74	Bare Exposed Rock
		75	Other
8	Tundra		No Secondary Classifications
9	Permanent Snow and Ice Fields		No Secondary Classifications

APPENDIX C

INITIAL SURVEY TO EVALUATE THE USE OF SATELLITE IMAGERY AS AN INFORMATION SERVICE FOR LAND USE AND NATURAL RESOURCES*

The Resource Information Laboratory, in late October and early November, 1973, forwarded some 160 questionnaires to Regional Planning Boards, County Planning Boards, County Cooperative Extension Agents, and private planning consultants throughout the State of New York. The overall return was approximately 31.9% (51 responses).

The Regional Planning Boards, County Planning Boards, and private planning consultants gave an approximate 61% return (29 out of 48). However, only 28 were calculated as one return was left blank and stated that they were not qualified to answer the questionnaire. Generally, the response from the group was quite high for most questions.

The response from the County Agents was rather poor. There were a total of 112 questionnaires circulated to County Cooperative Extension Agents throughout the state and only 22 were answered (19.6%). Part of the poor returns can be attributed to the type of questions asked, e.g., regional planning matters. Several responses stated that they were not qualified to answer the type of questions asked, and one specifically said that this type of information was not relevent to county agricultural agents' role in planning. (This reply was not calculated in the tables). Nevertheless, the present stiuation indicates that there is a tremendous need to illustrate and educate county agents on the potential of satellite data, if it is to serve a useful purpose at the county level.

This appendix is a brief review of the returns. The format is as follows: 1) Question, 2) Main Responses to the Question, 3) The Significance of the Replies.

Question I:

Do you conduct regional studies? If so, what is a typical area covered (to the nearest square mile)?

* R.T. Wulff, Progress Report, November, 1973.

Response:

Table I. Average Size = 4,210 square miles
Number of Responses = 31
Did Not Respond = 18

There was a large variation in the areas of concern, from the smallest area of 10-15 square miles, to the largest area of 14,067 square miles.

Question 2:

What is the size of the smallest data unit that you would use (i.e.- for vegetation, it may be 10 acres; or, for waterbodies, 1 acre, etc.)?

Response:

This question was asked in order to obtain an approximate idea of the data unit size presently required by land use planners.

Table II.	Size in Acres	Percentage #1	Percentage #2	Number of Users
(41 Responded; 8 Did Not)	0 2.0	48.9	58.5	24
	2.1 - 5.0	12.3	14.7	6
	5.1 - 10.0	12.3	14.7	6
	10.1 - 25.0	--	--	--
	25.1 - 65.0	8.1	9.7	4
	65.1	2.0	2.4	1
		*	100.0%	41

NOTE: #1 - Percentage of total received.
#2 - Percentage of those actually answering the question.
* - These questions allowed the user to respond to more than one category.
** - Not all the answers are given in this report.

The present ERTS information at 1:62,500 has an approximate resolution of 45 acres. However, the Skylab imagery is believed to have a greater resolution and the user needs are more likely to be met. There were only a few responses that indicated an interest in using less definitive imagery (e.g., 25 acres + data size) as a guide to indicate seasonal and general land use trends. Moreover, the thinking of almost all planners and county agents was that land assessemnt and planning should be conducted with information as specific as 1 - 10 acres.

Question 3:

In what form do you want the initial data (e.g., computer tapes, acetate overlays, USGS topographic map bases, etc.)?

Response:

This question was asked for several reasons including: which format is most acceptable to present planning techniques; would output from the satellite be compatible with these techniques; and, are there any categories not presently used that could be supplied by satellite data. The strongest aggreement was the use of acetate overlays with USGS-type maps.

Table III.

Form of Data	Percentage #1	Percentage #2	Number of Users
Acetate overlays with USGS topo map base	55.1	57.4	27
Acetate overlays without USGS topo map base	22.4	23.4	11
Computer tapes	18.4	19.1	9
USGS topo maps	14.3	14.9	7
	**	**	*

(47 Responded, 2 Did Not)

Question 4:

What is your area of concentration (e.g., regional recreation planning, water quality analysis, etc.)?

Response:

The question was asked to see what cross section of experts were answering the form. It also was asked to clarify whether the given areas of concentration could be obtained from remote sensing techniques. Factors such as social, economic, and political concerns are obviously important in planning. However, these are difficult, if not impossible, to obtain from satellite imagery. There was a strong agreement for a general category that was called County and Regional land use planning (44 out of 48). This category included environmental inventory, planning, and land uses in general.

Table IV

Area of Concentration	Percentage #1	Percentage #2	Number of Users
County & Regional Land Use Planning	89.8	91.7	44
Water Quality and Utility Planning	16.3	16.7	8
Education	6.1	6.3	3
Transportation	6.1	6.3	3
(48 Responded)	**	**	**

Question 5:

Do you use consultants and/or regional maps of other disciplines in your analysis? If so, what disciplines?

Response:

The intent of this question was to ascertain what types of consultants and maps are used by the people interviewed. Some 38 out of 48 respondents said that they used consultants in their operations. There was a considerable variety of data maps (23 different types). The main categories mentioned included soils (16 out of 48-33.3%), geology (10 out of 48-20.8%), and transportation maps (9 out of 48-18.8%).

Table V

Consultants &/or Type of Maps	Percentage #1	Percentage #2	Number of Users
Do you use regional consultants (yes)	77.5	79.2	38
Do you use regional consultants (no)	20.4	20.8	10
Soils maps	32.7	33.3	16
Geology maps	20.4	20.8	10
Transportation maps	18.4	18.8	9
	**	**	**

Question 6:

Do you use any of the following natural resource data? If not, please state the data that you use.

Topography slope	Wildlife habitat
Topography orientation	Unique resources
Vegetation type	Geology (surface)
Vegetation edges (ecotone)	Geology (sub-surface)
Water (if so, state type)	Soils
Wildlife quality	Other

Response:

The main purpose of this question was to obtain an idea of what natural resource data is presently being used in the planning fields. With this information, it would be possible to guide future data retrieval. Generally, the answers for this question had a strong agreement. Table VI indicates that the following categories were used extensively: soils-46 out of 47-97.8%, topographic slopes-45 out of 47-95.7%, water, ponds, lakes, and streams-39 out of 47-83.0%, vegetation type-35 out of 47-74.5%, geology (surface)-34 out of 47-72.3%, unique resources-33 out of 47-70.2%, and topographic orientation-32 out of 47-68.0%.

Table VI

Natural Resource Data	Percentage #1	Percentage #2	Number of Users
Soils	94.0	97.8	46
Topographic slopes	91.8	95.7	45
Water,Ponds,Lakes, & Streams	79.6	83.0	39
Vegetation type	71.4	74.5	35
Unique resources	67.3	70.2	33
Topographic orientation	65.3	68.0	32
Geology (sub-surface)	59.2	61.7	29
Geology (surface)	69.4	72.3	34
Wildlife habitat	51.0	52.2	25
(47 Responded, 2 Did Not)	**	**	**

Question 7:

What existing cultural conditions are most important to your needs?

Present ownership	Project demand
Distance from present development	Cost of land
Present use	Present property taxation
Possible future use	Other
Existing legislation & financing	

Response:

This question was designed to determine what cultural data is either presently being used or is required by land planners. Several categories in the list would be impossible to obtain from either conventional remote sensing methods (aerial photographs, etc.) or satellite imagery, and they include present land ownership, project demand, and existing legislation and financing. However, other categories may be obtainable from satellite imagery, and they include present use and distance from present development. There were no questions in the questionnaire that asked for weighting. The answers to this question, however, had some weighted replies. Eight of the nine gave first preference to present use (the last choices did not agree).

Table VII

Existing Cultural Conditions	Percentage #1	Percentage #2	Number of Users
Present Use	91.8	93.8	45
Possible Future Use	79.6	81.3	39
Present Ownership	63.3	64.6	31
Cost of Land	57.1	58.3	28
Distance from Present Development	53.1	54.2	26
Existing Legislation & Financing	51.0	52.1	25
Project Demand	49.0	50.0	24
Present Property Tax	46.9	47.9	23
Sewage and Water	10.2	10.4	5
(48 Responded, 1 Did Not)	**	**	**

Question 8:

Generally, there are several elements considered important as guides for the spatial allocation of activities. The factors include type of activity, surrounding uses, distance from other activities and settlements, availability and diversity. Are there other factors that you consider important?

Response:

This question was designed to see what guides planners used for location activities on the land. There was no attempt to delineate every factor affecting location. For example, people's values and choices were not mentioned but they would play a major role in any planning. Due to the general nature of this question, there was a tremendous variation in the answers. It was impossible to draw trends from the responses. There were three categories that received more than four responses.

Table VIII

Categories	Percentage #1	#2	Number of Users
Demand, Need, Feasibility	35.7	47.6	10
Transportation/Accessibility	18.4	32.1	9
Natural Factors/Environmental Constraints	18.4	32.1	9
Population Density/Migration	8.2	14.3	

(28 Responded, 21 Did Not)

Question 9:

What natural resource data not presently obtainable would you like to see more available?

Response:

The intent of this question was to obtain ideas for possible new data types. There were twenty-six responses that varied from the need to know forest stands to historic settlements.

Table IX

Category	Percentage #1	#2	Number of Users
Floodplains (5,10,20 & 50 yr levels)	10.2	19.2	5
Seasonal coverage	10.2	19.2	5
Forest (nature stands, heights, types boundaries, etc.)	8.2	15.4	4
Ground water data (movement quantity, quality, etc.)	8.2	15.4	4
Historic settlement	6.1	11.5	3
Wildlife Habitat	6.1	11.5	3
Publication on What Information is Presently Available	6.1	11.5	3
(26 Responded, 23 Did Not)	**	**	**

Question 10:

Any other comments?

Response:

The last question responses varied from enthusiastic: "practical application of this new wealth of information is unlimited," to skepticism: "I am a bit skeptical of your product, frankly. Nonetheless, I hope you are successful in influencing the pattern of development for the better." There were only two comments that showed obvious skepticism and sixteen that gave positive responses.

Table X

Response	Percentage #1	#2	N Number of Users
Keep us informed	16.3	42.1	8
Education on the matter needed	6.1	15.8	3
Data must be more detailed	6.1	15.8	3
Need to coordinate information with other agencies	4.0	10.5	2
When is it available	4.0	10.5	2
Skeptical	4.0	10.5	2
(19 Responded, 30 Did Not)	**	**	**

SIGNIFICANCE OF THE SURVEY:

The survey, although limited in sample size (restricted to New York State), gave some guides for future research with satellite data and indicated the need for better communications with the users. Many respondents asked to be kept informed and only a few voiced skepticism about the planning potential of Skylab data. However, thirty-six (36 out of 41 or 77.9%) answers stated that they used data units of 10 acres or less. Moreover, at this time the mapping resolution of present ERTS information at 1:62,500 is approximately 25 acres. It is thought that this problem is one that can be resolved through education on the Skylab's potential. For example, the phenological qualities did not appear to be fully understood (5 responses). It is the feeling of the Resource Information Laboratory that generalized data taken at regular intervals[1] can be used to augment the current more detailed information.

The survey indicated that the present information being used by land planners can, to some extent, be supplied by satellite imagery. The natural factors that were most widely used included soils, topographic slope, water-ponds, lakes, and streams, vegetation type, geology (surface), unique resources, and topographic orientation (approximately in that order of importance).

The most outstanding natural data required by planners but not presently available included floodplains (5, 10, 20 & 50 year levels), forest (nature stands, heights, type boundaries, etc.), and ground water information.

[1]ERTS Evaluation for Land Use Inventory, Type II Report, December 13, 1972, to June 13, 1973, Contract NAS 5-21886, Department of Natural Resources, Cornell University, Appendix B, page 8 figures show 52.1% required data of one year or less; this is more frequent than what is presently available.

APPENDIX D

NATURAL RESOURCE INQUIRY*

A questionnaire was sent out to wildlife biologists and environmentalists on the regional level in state and federal agencies. It's aim was to assess the value of satellite data to people involved in environmental studies. Eighty-one questionnaires were distributed and thirty-one were returned. This was a 38 percent return. However, 7 of those returned did not reach the addresses, presumably because they had moved. The return of actual responses was 24 or a 32 percent response.

A few of the respondents indicated that they did not actually feel qualified to answer the questionnaire because either they only reviewed, or remote sensing data was not applicable to their work. This may explain the poor response received.

The review of the questionnaire data includes a listing of the questions and the responses along with an analysis of the responses.

Question 1: Do you conduct regional studies? If so, what is the nature of the study (ie, analysis of wildlife habitat, hunting activitity, etc.)

Response: 95.8% conducted regional studies:

Category	
Environmental analysis	12.5%
Wildlife and fisheries habitat	58.3%
Wetlands	20.8%
Timber	8.3%

Of the respondents studying wildlife and fisheries habitat, 38 percent were working on the applied field level while the other 62 percent were in regional supervisory capacity. Some of the respondents were studying one

*D. S. Stevens, Progress Report, January 1974.

or more species, such as: pheasant, wild turkey, beaver, or bear. Others studied specific regions.

Question 2: What is the typical area covered in your regional study? (In approximate square miles)

There was a great range in responses to this question. Some respondents listed several regions of different sizes.

Square Miles	Percentage of Respondents
Less than 100	37.5
1,000 - 5,000	25.0
5,000 - 10,000	8.3
Greater than 10,000	29.2

Question 3: What is the minimum size of the data unit required for your study (ie, for vegetation it may be 10 acres, for water-bodies it may be 1 acre, etc.)

This question was included to see how the data unit requirement for wildlife habitat analysis corresponded to the interpretable unit size of satellite imagery. The minimum interpretable unit for the ERTS imagery was about 25 acres at a scale of 1:62,500.

Response:

Data Type	(Acres) Minimum Unit Size	Percentage of Respondents
Forest	5 - 20	8.6
Open Land	1 - 10	45.7
	40 - 100	8.6
Wetlands	1 - 10	17.1
Water	1 - 10	11.4
Not Applicable		8.6

This indicates thet 74.2 percent of the respondents required data in a unit size of 1 to 10 acres. This resolution capability is not possible with the present ERTS imagery using manual interpretation. However, a preliminary view of the Skylab imagery indicates that it has considerably greater resolution so it may be useful for these studies.

Question 4: Do you currently use any of the following data sources?

Response:

Data Sources	Percentage of Yes	Scale
Air photos	100	varied
USGS topographic maps	100	90%-1:24,000
County Maps	70.8	varied
Tax Maps	16.8	varied
Other		

If you do not use any of the above or similar sources, what is your data source?

This question was included to find whether the personnel in wildlife used any map data. It is clear that they do use at least some data of this kind. Other specialty maps used were soil maps, road maps, and flood plain maps, in approximate order of importance.

Question 5: Do you use consultants or information from other disciplines in your analysis? If so, what disciplines?

Response:

None	7	Extension Agents	2
Soil	9	Census	2
Forestry	6	Outdoor Recreation	2
Engineers	5	National Marine Fisheries	1
State Fish & Game	5	Archeology	1
EPA Water Quality	3	Planners	1
Landscape Architects	3	Weather	1
Hydrolic Tables	3	Transportation	1
Geologists	2	Power Transmission	1

Response to this question indicates a variety of disciplines are used in wildlife habitat evaluation. Only 29 percent did not use any consultants.

Question 6: In what form would you like your initial data (ie, computer tapes, acetate overlays, topography maps similar to USGS)?

Response:

Data Type	Percentage of Respondents
Topographic Maps	95.8
Acetate Overlays	79.2
Computer Printout	4.2
Vegetative Diversity	4.2
Undecided	4.2

This question was asked to find what format was desired by researchers, and whether satellite imagery could be presented in a compatible format. 79.2 percent wanted acetate overlays that could be used with topographic maps. This would be a suitable format for mapping vegetational or cultural information from satellite imagery. Only one person desired computer information, several said they definitely did not want any computer analysis.

Question 7: Do you use any of the following resource data? Please check whether the data is required, or of no use for your analysis.

Response:

	Percentage of Responses		
	Required	Desirable	No Use
Topography			
Slope	43.5	52.2	4.3
Aspect	23.8	61.9	14.3
Geology			
Surface	26.0	60.9	13.0
Sub-Surface	13.6	54.5	31.8
Soil Type	45.5	54.5	0.0
Climate			
Rainfall			
Monthly Averages	21.7	60.9	17.3
Seasonal Averages	23.8	52.3	23.8

	Required	Desirable	No Use
Other:	Largest Storm, Evapotranspiration		
Temperature			
Monthly Averages	22.7	50.0	27.3
Seasonal Averages	17.0	50.0	33.0
Other:	First and Last Frost, Solar Radiation		
Vegetation Type			
Forest General	66.6	19.0	4.3
Deciduous	77.3	13.6	9.1
Coniferous	77.3	13.6	9.1
Species Composition	56.5	34.8	88.7
Brushland General	72.7	18.2	9.1
Species Composition	43.5	39.1	17.4
Agricultural General	66.6	19.0	14.3
Abandoned Fields	54.2	33.3	8.3
Pastures	56.5	34.8	8.7
Active Cropland General	33.3	42.9	18.5
Crop Type	33.3	42.9	18.5
Index of Diversity of Vegetative Types	50.0	31.8	18.2
Water			
Ponds and Lakes	90.5	9.5	0.0
Streams and Rivers	85.7	14.3	0.0
Wetlands	82.6	17.4	0.0
Seasonal Fluctuation	61.9	33.3	4.8

Other: Developed Areas, Tidal Range, Marsh Vegetation, Topography of Lake Bottoms, Beaver Flowage, Native Hay

This list of resource information was included to find what types of data were used. Some of this information cannot be obtained from satellite imagery (ie, weather information); however, it can be monitored in other ways by satellite. The vegetation was broken down into several levels of precision in hopes of determining how specific the needs of the respondents were. Unfortunately, most repsondents indicated they wanted all levels rather than distinguishing between levels. 56 percent of the respondents required species of vegetation. Information this specific is difficult, if not impossible, to obtain from satellite imagery. However, 20.8 percent could use a break down of forest into deciduous and coniferous types, which can be determined from satellite data. Specific agricultural information was required by only 33.3 percent of the respondents.

Question 8: What factors do you feel are necessary to define wildlife habitat? Please indicate what specific species, if any, you are considering.

Response:

	Percentage of Respondents
Cover	
Generalized Vegetation Types	66.6
Specific Species	66.6
Specific Vegetation Conformations	58.3
Topographic Features	58.3
Food	
Generalized Vegetation Types	50.0
Generalized Animal Types	50.0
Specific Species	45.8
Abundance	54.1
Water	
Type	62.5
Minimum Amount	54.1
Seasonal Fluctuation	45.8
Space	
Minimum Area Characterized by:	
Vegetation Type	58.3
Human Density	41.6
Diversity	33.3
No Response	16.6

This was asked to determine what factors were required for habitat analysis; to determine if habitat could be analyzed by satellite. Vegetative cover was judged the most important factor. However, species was required. Many of the other factors could be determined by satellite imagery.

Question 9: Do you feel wildlife habitat can be accurately mapped over extensive areas using any of the above criteria?

Response: 83.3 percent of the respondents did feel that habitat could be mapped with the above information. 16.7 percent did not respond to this question.

Question 10: What cultural information is necessary for your needs?

Response:	Percentage of Respondents
Population Density	62.5
Present Land Ownership	54.2
Present Land Use	87.5
Size of Land Parcel	54.2
Possible Future Use	66.6
Cost of Land	33.3
Present Property Taxation	12.5
Hunting/Fishing Pressure	62.5
Hunting/Fishing Success	62.5
Other: Shoreline Development, Recreational Habitats	
No Repsonse	8.3

This question was designed to see what cultural information was used or would be used by wildlife biologists. Some factors such as cost of land, land ownership, and hunting/fishing pressure or success, cannot be determined by satellite data or other remote sensing methods. However, others such as present land use and parcel size, could possibly be determined by satellite. Present land use was the factor of most use to the respondents, (87.5%).

Question 11: Are there natural resource data not presently obtainable that you would like to see more available?

Response: Response to this question was 54%. The responses varied widely, some requests did not deal with data applicable to remote sensing. The responses can be roughly grouped into categories as follows:

Categories	Percentage of Respondents
Digest of Information Available	23.0
Shoreline Vegetation Inventories	15.4
Analysis of Critical Habitat (ie, endangered species, breeding or wintering habitat)	23
Analysis of Urban Fringes	15.4
Data on Specific Game Species Habitat	15.4
Time Pursuing Game	7.8

Apparently, the other 46 percent of the respondents did not have any need for new information.

In general, it would seem that personnel responding to this questionnaire would like to obtain information in the same general format that it has been available to them in the past. This would be in the form of acetate overlays showing cultural or natural configurations.

The vegetational information required by wildlife personnel, such as species composition of forests, is not feasible from satellites. However, generalized vegetational types, agricultural areas, water and topography can be obtained using satellite data. The greatest difficulty in application of satellite data to this field is the requirement of data units less than 10 acres for most features.

This questionnaire did indicate the need for greater communication with wildlife personnel since 23 requested greater availability of satellite data. These people were apparently not aware of the distribution sources currently available.

Although this questionnaire is of limited extent (24 replies), it does give some idea of the needs of wildlife personnel and feasibility of using satellite data to meet these needs.

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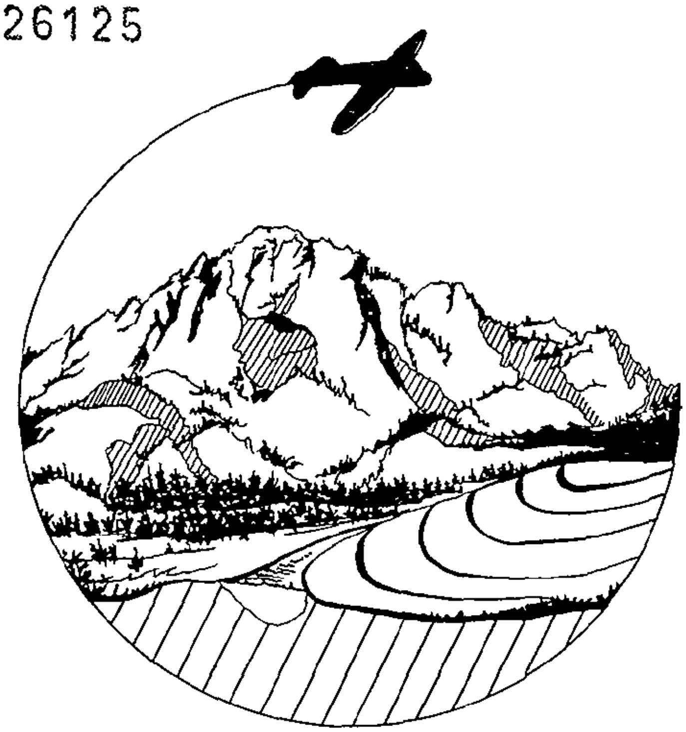

RESOURCE INFORMATION LABORATORY

ENHANCEMENT AND EVALUATION OF SKYLAB PHOTOGRAPHY FOR POTENTIAL LAND USE INVENTORIES

PART II

DEPARTMENT OF NATURAL RESOURCES
NEW YORK STATE COLLEGE OF
AGRICULTURE AND LIFE SCIENCES
AT CORNELL UNIVERSITY

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