Paper L 4

INTERACTIVE ANALYSIS AND EVALUATION OF ERTS DATA FOR REGIONAL PLANNING AND URBAN DEVELOPMENT: A LOS ANGELES BASIN CASE STUDY

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ABSTRACT 'N 74 30732

The progression endemic to the ERTS Data Use Experiment SR 124 in data quality, analysis sophistication and applications responsiveness is reviewed.

The roles of the variety of ERTS products, including the supporting underflight aircraft imagery at various scales, are discussed in the context of this investigation.

The versatility of interpretation techniques and outputs developed and implemented via the General Electric Multispectral Information Extraction Systems (in both the prototype laboratory – GEMS – version and the production field – IMAGE 100 – model) is described and exemplified by both system-expository and applications-explanatory products.

The wide-ranging and in-depth applications studied in the course of this experiment can be characterized as community-oriented and agency-directed. In the former, generic category, which is primarily data-contentual, problems analyzed dealt with agricultural systems, surface water bodies, snow cover, brush fire burns, forestry, grass growth, parks - golf courses - cemeteries, dust storms, grading sites, geological features and coastal water structure. The ERTS MSS band selectivity and measurements thresholds were of primary interest here.

The agency-directed application areas have been user-evaluational in nature. Beginning with overall urbanized regional analysis of land cover density-development intensity, residential areas were analyzed for ascertaining if housing types could be aggregated with any degree of reliability. It does appear that with the A-3 configurational U2 imagery for both input preparation and output evaluation, the ERTS CCT data analyzed interactively on the IMAGE 100 yields so-called Level III results of interest in certain on-going user-agency programs that would enable the users to monitor environmental factors using ERTS-IMAGE 100 outputs.

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PART 1
Presented by Gerald Willoughby

The results described in this presentation are drawn from ERTS-1 experiment SR 124; the Principal Investigator: Surendra Raje, the General Electric Company; the Co-Investigators: Dr. Richard Economy, GE; Jene McKnight, the County of Los Angeles Regional Planning Commission; and Gerald Willoughby, OVAAC8 International Inc. (Fig. 1).

The presentation will be given in two parts; the second half will be given by Mr. Raje. The first part is a synopsis of a substudy we began in October 1973 and which is not yet concluded. The information extraction techniques employed in the study are those provided by GE's IMAGE 100, the production model of the R&D GEMS System. Since IMAGE 100 only recently came on line, the entire SR 124 experiment has benefitted from just a few hours on the system. . .also the first opportunity for us to work with digital data instead of imagery. The data sources for the results that you will see are CCT's of March 1972.

The objective of the study was to test the compatibility of ERTS data in relation to an urban land use classification system of a user agency. . .that of our partner on the team. . .the Lost Angeles County Regional Planning Commission. The objective entails a number of substudies, one for each land class. In the short time available to us we have looked at and have results for only residential.

Before I begin to describe the method we use, I would like to comment upon the objective and in particular the concept of compatibility. We are land planners. . .we make a very significant distinction between <u>earth surface conditions</u>, the physical properties of objects, and <u>land use</u>, the institutionalization of a social abstraction. For purposes of regional and urban planning the distinction is extremely important. I would illustrate by drawing your attention to the similarities and differences among a public park, a private golf course and a cemetary; or a shopping center and light industry.

Los Angeles Housing

We chose housing to begin because of Los Angeles priorities. At the present time the County's planning process is wholly directed towards complying with State requirements which dictate the need for a General Plan. The Plan must include policy with respect to nine social, economic and natural environmental systems, called elements in the LA General Plan (Table 1). The Commission believes its present data base is adequate; one outstanding exception is housing. In order, then, that any results might be immediately applicable, operationally, housing was chosen.

METHODOLOGY OVERVIEW

In the distinction between Class Analysis (supervised learning) and Cluster Analysis (unsupervised learning) the results (in Part 1) have been generated wholly from the former. Class Analysis utilizes the technique of training on a test site which is known to contain the class of interest. Using IMAGE 100 we trained on residential test sites selected from aerial photography* (Fig. 2). The test sites were homogeneous with respect to their distinguishing housing types and community structure. Following the training procedure and electronic analysis, color enhanced "themes" supposedly representative of the residential class are provided across the entire field of view on a TV monitor. We took slides of these themes and compared them to land uses given on Los Angeles base maps.

METHODOLOGY IN DETAIL

The primary residential classifier we used is Dwelling Units Per Acre; this will have to be expanded, we know, to include Floor Area Ratios, Building Coverage and Net Green Space values (green space contrasted with open space). Secondary classifiers consist of two subsets. The first describes community structure: for example, the street system. . . single or double loading and the existence of rear yard servicing. The second set describes predominant features of the individual lot: for example, roof tones (a consistent and recognizable pattern in most Los Angeles developments), the frequency of swimming pools, and laneway characteristics. . .single/double, asphalt/concrete, to front yard garage or to rear yard garage.

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*See page 7

We selected test sites using U2 1:32,000 aerial photography and recorded them by ink drawings on tracing paper. We had anticipated photoreducing these to register with the digital data display on the TV monitor but found this step unnecessary* due to the very high quality of the digital data; all test sites were easily located (Figs. 3 and 4).

IMAGE 100 has the capacity to enlarge any given field of view. The scale factor chosen, 3 in our work, is largely a tradeoff between the quality of detail required to train by, and the overall size of the field of view required for results (Fig. 5).

Themes are areas which appear on the TV monitor color enhanced (Fig. 6). Hopefully they represent classes having similar spectral properties. . .but such a conclusion is the result of the evaluation stage. After a site is selected for analysis, it is so identified by means of an electronic cursor, a theme is produced following the completion of two routines:

1. One dimensional histograms are constructed for each channel; these give the upper and lower limits in the reflectance scale and the distribution of pixels within the range bounded at the limits. The limits are first set by choosing a threshold for pixel counts but may be adjusted later if a more selective or less selective reflectance range is desired (Fig. 7).

2. The second routine provides four dimensional histograms. Color space is cellularly divided according to criteria prescribed by the analyst for the number of divisions in each of the four reflectance scales derived during routine one. The cells which contribute to the final spectral signature upon which a color enhanced theme is generated are chosen according to the number of pixels they contain, per cell, in relation to a lower limit, or threshold (Fig. 8).

When the two routines are complete a spectral signature is in theory established. All pixels, having similar spectral properties, over the entire field of view are color enhanced providing the theme.

Three parameters influence the generation of themes:

1. The upper and lower limits in the 1-D histograms

2. The number of divisions per channel in the 4-D histograms

3. The threshold for pixel counts in the 4-D histograms

Experimentation during analysis, an advantage of IMAGE 100, is required in the choices to be made for each parameter. Through an iterative process of changing choices and checking monitor results at selected locations for which ground truth information does exist (the selected test sites for example) many themes can be generated: with varying results. A 16-level, 4-D histogram may tend to be too inclusive: yet a 64-level, 4-D histogram too selective. The objective, of course, is to produce as discrete a spectral signature as possible, representative of the class.

For illustrative purposes the slides † show four themes corresponding to different criteria used in their generation. The test site is in Beverly Hills and is residential, single family detached with a density of 1.3 units/acre.

Theme 1: 1-D limits were established, a 4-D threshold of 2 prescribed and a 64-level, 4-D histogram run

Theme 2: 1-D limits were narrowed, the 4-D threshold kept at 2, and a 32-level, 4-D histogram run

Theme 3: 1-D limits were held, the 4-D threshold changed to 38 and the 32-level, 4-D histogram repeated

Theme 4: 1-D limits were broadened, the 4-D threshold changed to 2, and the 32-level, 4-D histogram repeated

EVALUATION

The themes displayed on the monitor were recorded on slides and later projected onto Los Angeles land use maps and the two registered. A Dot planimeter was used to record observations.

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† Not all slides presented at the meeting are included in this paper.

For illustrative purposes typical analysis results are shown for a test site in San Fernando Valley. Each column of the chart, headed by a color, represents a theme; for this test site we generated six themes Table 3 gives the raw data.

In Table 4, summarizing the analysis, the first column gives the land uses. In each theme column the figures given under "a" give the area of the land use class which is color enhanced as a percentage of the total color enhanced area or theme. In each theme column the figures under "b" give the area of the land use class which is color enhanced as a percentage of the total land area for the class. Essentially this method looks at classification accuracy two ways, although as planners we are more interested in those figures under "b".

The results show for this test site, which is not a typical, that we can identify, using the best value attained, 82.1% of the residential land use class upon which we trained, and this class in turn represented 76.6% of the total land area. Percentage wise, we are picking up high values for other land uses, although these do represent very little acreage.

Again, I would repeat, we have had very little machine time and our sample size is therefore small. For evaluation purposes we feel we could achieve more reliable results using U-2 photography although the choice would tend to weaken our purpose of working with a user agency and their land classification system, Table 5. We have now decided to use both sources, maps and aerial photos, and compare results which should be interesting.

The Los Angeles land classification was consciously used as the vehicle to test. . .the objective of the study: you can see some of the difficulties we encounter where classes are loosely defined. . .the last five, for example:

RECREATION
PUBLIC
SERVICES
OPEN SPACE
VACANT

From our viewpoint, as planners, a concept of much more interest than land use, proposed by us at a previous NASA symposium and as well at an Los Angeles ERTS symposium, is the concept of "development intensity." Land is classified according to its ground cover, either natural or man made, and ranked according to the proportions of each. Used by imaginative planners this information can enormously impact upon policy and standards for the use of land. Using the identical analysis methods I have described, information much more tractable and appropriate can be extracted from ERTS data and, based on previous work we have done using imagery, we are very confident in getting good results. . . particularly now that we have a digital analysis capability. We expect to continue both the land use experimentation and experimentation in the development intensity concept.

Question by Dr. L.W. Morley, Director, Canada Center for Remote Sensing: Could you elaborate upon your use of the U2 imagery ?

Answer by Mr. Willoughby: In this substudy, the U2 imagery was used to prepare the training-sites definition for IMAGE 100 runs which themselves used ERTS CCT inputs. As I mentioned, we are also using the U2 imagery to evaluate the IMAGE 100 outputs.

Comment by Mr. Raje: The use of U2 imagery mentioned by Mr. Willoughby was "light-box" use, visual photo-interpretive and in quasi-ground-truth sense. We are also machine-analysing, i.e., signature-acquiring, the multispectral underflight aircraft data for evaluating the corresponding ERTS-products analyzed results. This work will be reported later.

PART 2

Presented by Surendra Raje

Mr. Willoughby reported on the application of the more common approach, the Training-Testing Method, of machine analysis of multispectral data. I am reporting briefly on the application we have made extensively of the Slicing-Clustering Approach. The terminology here refers to spectral or color space: slicing the available spectral region into predetermined sequence or interactively defined volumes; clustering the actual distribution of cells in color space that yield the dominant themes in the entire field of view.

This method is more appropriately applied to large areas, such as the Urban Regions. We have thus analysed some eight regions in the metropolitan Los Angeles Basin. I shall briefly discuss the Central Los Angeles -- Regional Core -- area. Most of this work was done on the GEMS facility at GE's Valley Forge Center and analysed by the County of Los Angeles co-investigators. Some of it has been reported previously. I am describing the IMAGE 100 'Re-Runs' of this sub-study, with CCT input since GEMS only accepted film input .

It will be instructive, in passing, to compare the same area as seen first on the GEMS, then on IMAGE 100 in film input and on it in CCT input.

It will be further informative to compare this standard, linear input Fig. 9 with the Hadamard TransforMed View of the Same Scene Fig. 10. It should be pointed out that while this Rotation of Axes in Color Space yields dramatic patterns of interest to an Urban Planner, as Mr. Willoughby and Mr. McKnight have often reported before, so far this is only what Dr. Economy describes as Preprocessing.

Proceeding with actual signature acquisition, which yields to Theme Generation, per se, let us begin at one end of spectral space in this field of view: we obtain the Theme of Water. (The number given to a theme, here No. 3, is only pertinent to the selection of the color, here it is blue!).

Next in spectral sequence is the Theme: Heavy Industrial followed by Heavy Commercial Fig. 11. The so-called windowing feature on the IMAGE 100 enables a closer visual inspection of any area of special interest. Here, e.g., the LA CBD was enlarged X3 times the scale in the main field of view which incidently is loaded at 1 ERTS pixel to 1 TV pixel. Next in the theme, Low Density Residential, we pick up the higher quality housing, e.g., in west and south Los Angeles. Finally, the greener ground areas emerge in this theme of Parks, Golf Courses, Cemeteries.

What is the significance of this sequence of themes? First of all, each theme in itself reveals what Mr. Willoughby previously characterized as Land Cover Density - Development Intensity as obtained in the ground scene covered. What is of particular interest to urban planners in this application of the Slicing-Clustering Method is the interrelationship of these various themes within a given area: thus they find this 8-Theme Composite picture (Fig. 13) of tremendous interest. This should be compared with LA Land Use Map. What it brings out, our planner-co-investigators excitedly say, is an entire new insight into Urban Structure never before offered to them. Let me emphasize here that we are looking at internal delineation. . . intraurban as contrasted with interurban relationships here.

Mr. Jene McKnight and his associates in Los Angeles have found this and similar sets of urban regional analyses of the Los Angeles Basin giving new insights into the problems of the LA Regional Core. They plan to pursue using this output in Urban Design Studies they had proposed before CoLAGE - ERTS activity began.

This brings us to address briefly to the Cost-Benefit Analyses questions generally and specifically those raised in the EarthSat-Booze-Allen-Hamilton Study for the Department of the Interior. As the County of Los Angeles co-investigators pointed out to the Interviewers in Los Angeles and we did in the Sioux Falls Interview and Questionnaire, the Dollar Value of this effort exceeds the total investment committed to the project by NASA, GE and the County. The Underflights Aircraft Imagery CoLA-RPC has received alone exceeds in benefits the total cost as the County and the Community at large in Los Angeles assess it.

As for the ERTS Data proper, as analysed photo-interpretationally as well as electronically, let us briefly look at the Applications Overview (Table 6) of the type of problems tackled in this project. We barely had time to review only the Agency-Directed Items. While we are attempting to estimate the Dollar Value of the results both to CoLA-RPC and the Community at Large there and elsewhere, all of us on the Colage Team feel very strongly that the fact that ERTS provides entirely new type of data and IMAGE 100 analyses it in very novel and flexible fashion, we should be and are addressing to the problems of newer and more appropriate uses of these new products rather than to jam these results into older practices-procedures. At a recent National Land Use Institute held in Washington, I found very keen interest expressed by Urban and Regional Planners from around the Country to these newer products and tools and approach.

Referring back to the Los Angeles County Comprehensive General Plan elements, Mr. McKnight intends to use results shown above in the Seismic Safety Element work getting underway at the County early in 1974. Mr. Charness, his associate in charge of the Environmental Assessment Group, has already been using results from this project in the Conservation Element work. He also has entered the item in the Comprehensive General Plan issued by the County last August. As pointed out in a previous report, the County created a Position of Remote Sensing Planner in the early phase of this joint project.

The use of the products from this project by the Secondary Users in the Los Angeles Region has been rather extensive, especially since early May when we had organized a Regional Meeting to Review Results of this and other ERTS Projects in the Southern California.

In conclusion, I should like to indicate that the major objectives set forth for this investigation have been met already. In view of the Program Procession, we hope to report some of the more exciting items underway, such as Temporal Compositing Analyses in the final report due in the first quarter of 1974. Finally, both the Los Angeles Planning Community, through the County and vicinity, and ourselves are looking forward to operationalize all the items researched and developed during this project. . .prior to ERTS-B launch, I might add".
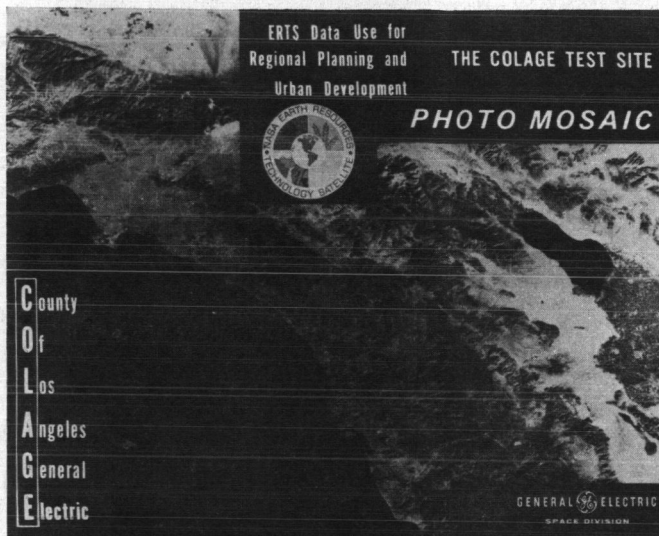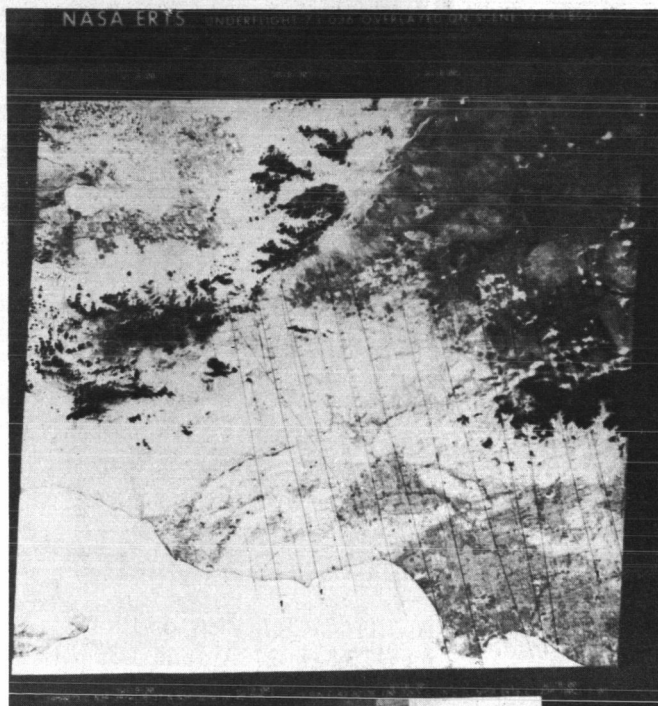
Figure 1. CoLAGE Test Site Overview

Figure 2. Flightlines of U2 with A-3 Configuration Flown
3/14/73 during which ERTS Overflew

Figure 3. Portion of Frame 178. Flt 73-036 Showing
Residential Areas Around Los Alamitos Naval Air Station

Figure 4.   IMAGE 100 CRT View of ERTS
Scene 1234-18021 Around Los
Alamitos Naval Air Station, CCT
Input @ 3 by 4 Enlargement in
X to Y. Note Area 4

Figure 5. Functional Flow Around IMAGE 100
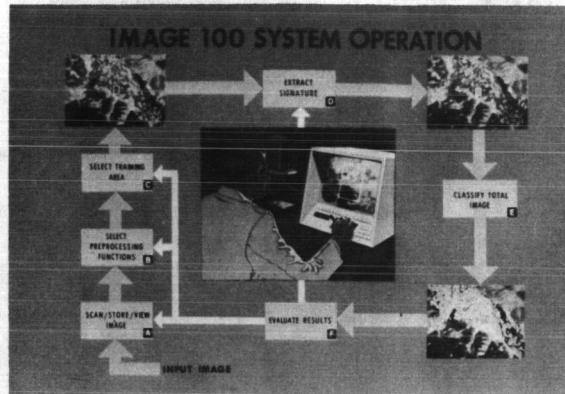

Figure 6. Theme Alarm Corresponding to Training
Site 4 of Fig. 4
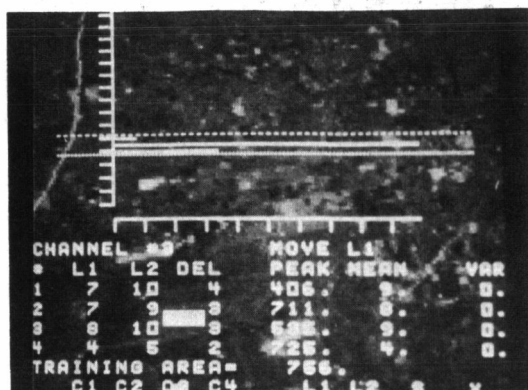
Figure 7. 1D Histogram Display, Channel 3
for Signature of Site 4 of Fig. 4

Figure 8. 2D Cluster Display, Ch 2 vs Ch 4,
Projected for 4D Histogram
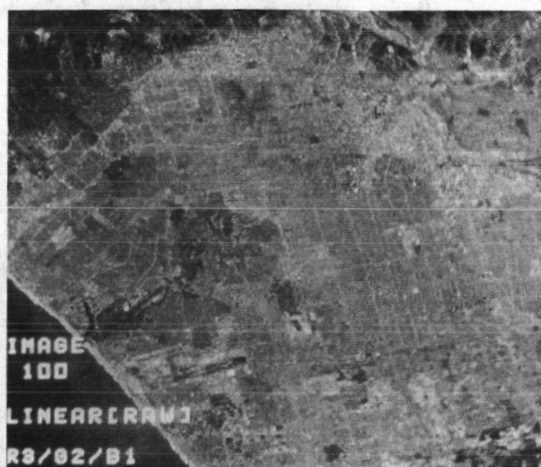
Figure 9. West Central Los Angeles - CCT -
Loaded in Standard, Linear Mode for Display

Figure 10. Hadamard Transformed
Representation of Scene from Fig. 9

Figure 11. Predominately Heavy Commercial
Areas Enhanced by Slicing in Color Space
LA CBD Enlarged 3X

Figure 12. Green Spaces in the Field of
View Enhanced. Enlargement of
Wilshire CC 3X

Figure 13. An 8-Theme Composite Superposing
the Above Themes Generated Sequentially

TABLE 1
ELEMENT PRIORITIES
(OCTOBER 15, 1973)

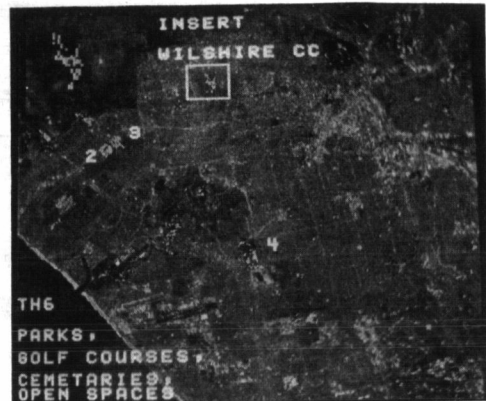|			
	1ST PRIORITY	1.	SEISMIC SAFETY
		2.	PUBLIC SAFETY
		3.	SCENIC HIGHWAYS
		4.	TRANSPORTATION NOISE
MANDATED		5.	CIRCULATION
BY STATE		6.	WATER AND WASTE MANAGEMENT
LAW: MUST			
BE COMPLETED	2ND PRIORITY	7.	HOUSING
BY SEPTEMBER		8.	LAND USE
1974		9.	OPEN SPACE
		10.	CONSERVATION
		11.	PUBLIC SERVICES AND FACILITIES
COMPLETED BY	3RD PRIORITY	12.	RECREATION
SEPTEMBER 1975		13.	HUMAN RESOURCES
RPC CRITERIA		14.	ENVIRONMENTAL QUALITY

THESE ARE DONE BUT WILL BE RE-EVALUATED FOLLOWING COMPLETION OF 1-6 ABOVE

GENERAL PLAN TO BE COMPLETED BY SEPTEMBER 1975 THEN PERIODIC REVIEW

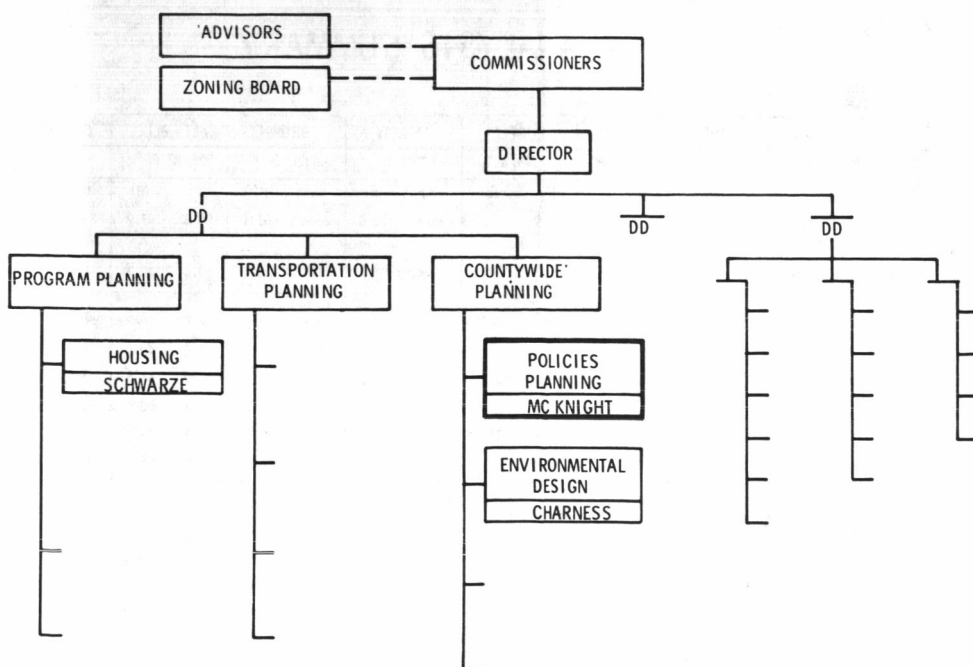# TABLE 2
COLA REGIONAL PLANNING
COMMISSION ORGANIZATION

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TABLE 3
COLAGE IMAGE 100 HOUSING STUDY
TEST SITE NO. 1
SAN FERNANDO VALLEY
RAW DATA OBSERVATIONS

Land Use

Classification		Purple	Yellow	Brown	Lt.Blue	Dk.Blue	Black
Single-family residential	(L)	918	827	683	528	417	189
Multiple-family residential	(M)	3	2	1	1	2	0
Commercial	(C)	33	11	8	4	4	1
Recreational	(R)	11	4	6	8	7	1
Public	(P)	24	27	21	11	15	5
Services	(S)	89	29	21	30	27	23
Open Space	(O-1)	109	66	56	35	29	10
Vacant	(Z-1)	4	3	2	1	1	1
Area Alarmed		1,081	969	798	618	502	230
Total Area		1,360	1,435	1,394	1,470	1,394	1,344

TABLE 4
HOUSING TEST SITE NO. 1
SAN FERNANDO
ANALYSIS SUMMARY

THEME			PURPLE		YELLOW		BROWN		LT. BLUE		DK. BLUE		BLACK	
AREA ALARMED %			79.5		67.5		57.2		42.0		36.0		17.1	
	(ACRES)	(%)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
SINGLE-FAMILY RESIDENTIAL	1,020.2	76.6	84.9	82.1	85.3	74.0	85.6	61.1	85.4	47.2	83.1	37.3	82.2	16.9
MULTIPLE-FAMILY RESIDENTIAL	5.5	0.4	0.3	50.0	0.2	33.3	0.1	16.7	0.2	16.7	0.4	33.3	0.0	0.0
COMMERCIAL	42.9	3.2	1.1	70.2	1.1	23.4	1.0	17.0	0.6	8.5	0.8	8.5	0.4	2.1
RECREATION	25.6	1.9	1.0	39.3	0.4	14.3	0.8	21.4	1.4	28.6	1.4	25.0	0.4	3.6
PUBLIC	31.9	2.4	2.2	68.6	2.8	77.1	2.6	60.0	3.0	31.4	3.0	42.9	2.2	14.3
SERVICES	88.5	6.6	2.0	91.8	3.0	29.9	2.6	21.6	5.4	30.9	5.4	27.8	10.0	23.7
OPEN SPACE	125.0	9.4	8.1	81.3	6.8	49.3	7.0	41.8	5.8	26.1	5.8	21.6	4.3	7.5
VACANT	4.6	0.3	0.4	80.0	0.3	60.0	0.3	40.0	0.2	20.0	0.2	20.0	0.4	20.0
	1,332.3	100.0	100.0		100.0		100.0		100.0		100.0		100.0	

(A) AREA ALARMED AS A % OF THE THEME,
e.g., AREA IDENTIFIED IN PURPLE (79.5% OF SCENE)

(B) AREA ALARMED AS A % OF THE CLASS,
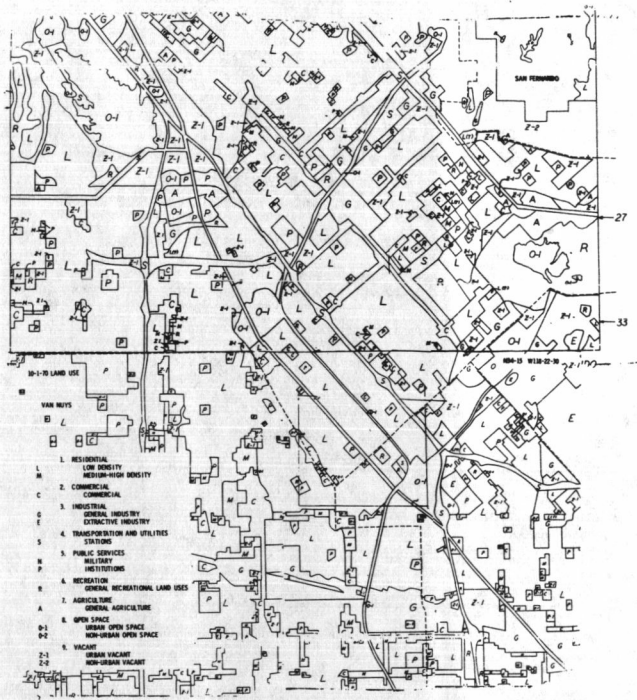e.g., LAND USE

TABLE 5

TABLE 6
APPLICATIONS OVERVIEW

COMMUNITY-ORIENTED	AGENCY-DIRECTED
● DATA-CONTENTUAL	● USER-EVALUATIONAL
- AGRICULTURAL SYSTEMS	- URBANIZED REGIONS
- SURFACE WATER BODIES	● RESIDENTIAL AREAS
- SNOW COVER	- HOUSING TYPES
- BRUSH FIRE BURNS	
- FORESTRY	
- GRASS GROWTH	
- PARKS, GOLF COURSES	
- DUST STORMS	
- GRADING SITES	
- GEOLOGICAL FEATURES	
- COASTAL WATER STRUCTURE	