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THE APPLICATION OF SATELLITE GENERATED DATA AND MULTISPECTRAL ANALYSIS TO REGIONAL PLANNING & URBAN DEVELOPMENT

SUBMITTED FOR PRESENTATION AT CONFER-IN 73

(E73-11045) THE APPLICATION OF SATELLITE GENERATED DATA AND MULTISPECTRAL ANALYSIS TO REGIONAL PLANNING AND URBAN DEVELOPMENT (OVAAC 8 international, Inc., Columbia, Md.) 14 p HC $3.00 CSCL 08F G3/13

N73-32221
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The subject of this paper is the application of satellite generated data and multispectral analysis to regional planning and urban development. The content is drawn from the author's experience as an investigator in an experiment funded by the National Aeronautic and Space Administration as part of the Earth Observation Program, and from OVAAC8's work in land planning using remotely sensed data.

The Satellite data used in the NASA study is generated by the Earth Resources Technology Satellite 1, (ERTS1) launched July 23, 1972 and still in orbit. The specific site under examination for the NASA portion of our work is the 4000 square miles within the County of Los Angeles, California. The County of Los Angeles Regional Planning Commission is the chief beneficiary of the results.

The paper is arranged in the following format:

Introduction
Electromagnetic Spectrum
ERTS System and Orbital Parameters
Sensor Systems and Data Products
Electronic Analysis System
Multispectral Analysis Methods

INTRODUCTION

NASA's earth observation program evolved in recognition of the need for more data and better quality information on the earth's resources, both natural and social. The program conceived was ambitious: world coverage on a repetitive basis. During the early planning stages many interest groups competed to have their information needs incorporated into the program. Information requirements impact upon every aspect of the system: the performance criteria for the spacecraft, its payload - the observation instruments, the data relays, the ground control facilities and the data processing facilities. Further, there were budgetary constraints, limits to the amount of hardware that could be placed in space, and parts of the technology to be used were newly developed. The significance of these remarks is that the resulting compromises were made in an endeavour to orbit a general purpose observation spacecraft. ERTS1 serves over 300 experiments in about 40 countries, covering vast areas of land and water, and including a wide range of disciplines: for example, cartographic, geologic, forestry, agriculture, hydrologic, and many more.

The program is clearly one of research and development; results must be evaluated within that context. The intent, as the scientific community would like to believe, is that with sustained concern for the careful management of the earth's resources a permanent operational observations program will develop. Hopefully that program would embrace a number of satellites and sensor packages better selected and designed to meet more specific and individual needs. Hopefully too, the data and information needs for all levels of government, local to national, will be better and more efficiently met.

To achieve the objectives of repetitive world coverage considerations of efficiency dictate utilizing the concept of remote sensing - or observations at a distance. All remote sensors require a platform; the following are possible: rocket, balloon, aircraft and satellite. Differences of opinion do exist regarding platform types - specifically between aircraft and satellite. Most arguments center around the information quality with respect to cost. It is important to stress here that the data collected by satellite sensors is not considered to replace data collected by other means but rather to supplement and complement other types, particularly aircraft. In our work we are using aircraft imagery in the following scales - 1:400,000, 1:125,000, 1:65,000 and 1:32,000, and much information compiled from ground data, in parallel with the ERTS data. Each data type yields unique and significantly different information. In some cases one source is used to corroborate or validate another source.

A prominent belief prior to the ERTS mission was that satellite sources would produce new information in addition to its repetivity and wide scale characteristics. Experiments have proven that assumption correct. Certainly the periodicy of the spacecraft, every 18 days, is extremely important for example, to agriculture in detecting crop diseases, and to forestry in detecting early fire hazards. Such coverage could hardly be matched by the most ambitious aircraft program as the only source of data collection.

A major thrust of our work is to be knowledgeable of all data sources so that we can draw upon the right combination, at the most appropriate levels of quantity and quality, relative to the information sought. Certainly all decisions should not require the same "grain" of information; I shall comment further on this theme at a later point in the paper.

In the technical portion of the paper which follows there is included a brief description of the satellite system and a detailed discussion of analysis methods for the following reasons: the characteristics of the ERTS hardware and orbital parameters dictate the characteristics of the data products; the multispectral analysis methods, some dramatically cost effective, are directly applicable to aircraft generated data and should be of special interest to land planners and resource managers regardless of the area of their jurisdiction or study.

ELECTROMAGNETIC SPECTRUM

A review of the concept of the electromagnetic spectrum (EMS) is a prerequisite to the understanding of multispectral observations and remote sensing which follows. The EMS classifies according to wave length or frequency all energy that moves with the constant velocity of light in a harmonic wave pattern. The spectrum is broadly subclassified according to wavelength into spectral "bands", where a band is described by a minimum and maximum value of wavelength. The full range includes, in increasing wavelengths, gamma rays, x-rays, ultraviolet, the visible spectrum, infrared and radiowaves. When energy generated by the sun strikes the earth's surface some portion of the energy is absorbed and some reflected. Part of the absorbed energy is converted into heat, and some portion is later emitted. The observation instruments, or "sensors", on board ERTS1 record and measure reflected energy in a range from .475 microns to 1.1 microns. This range includes the visible portion of the spectrum and part of the near infrared.

Energy, either emitted or reflected from an object varies in quantity at each wavelength over a particular range in the EMS. The amount of energy increases with the objects absolute temperature and reaches a peak at certain wavelengths. With increasing temperatures the peaks are reached at progressively shorter wavelengths. The earth, having an average temperature of 300 degrees Kevin, is described by a curve that peaks near 10 microns; it is this range which is of interest to us since the object under observation is the earth's surface. The sun peaks in radiant power at about 0.5 microns which allows for observations in the visible spectrum by conventional photography.

In the same way that the earth can be described by a curve, where the quantity of reflected energy is a function of wavelength, so can selected objects or object classes, i.e. grass, corn, concrete, asphalt and water etc. Of course, our interest is not simply water but perhaps water quality, not simply corn but the condition of crop health, not simply snow but the depth of snow. In this respect then, our interest lies in not only an object class but perhaps some quality condition of an object class. When the curves for a number of object classes are plotted, the following characteristics of the plots may be noted: there is substantial differentiation of reflectance for each object within certain bands of wavelengths, little differentiation at other bands, and overlap of the curves at some wavelengths. The major objective of our investigation is to discriminate among object classes, and to do so such that the results have a high level of accuracy and repeatability. To achieve that objective we measure the amount of reflected energy in that combination of bands which best discriminates one object class from another. The simultaneous utility of more than one band, whether in the context of observation or analysis is referred to as MULTISPECTRAL. ERTS1 observes, records and measures reflectance throughout a range of spectral bands - hence multispectral data; and the objective of our work is converting that data into useful information - using multispectral analysis.

ERTS1 SYSTEM

The ERTS system consists of the spacecraft, two packages of sensors, telemetry system, tracking and command system, and a ground data handling system for processing and distributing data to the investigators. The data is received at three groundstations in the U.S. and at one in Canada.

One important feature of ERTS which we are not using but of which one should be aware is the Data Collection System. Small platforms located on the ground carry sensors which record data taken from observations at or about the platform; this data is transmitted to the spacecraft when the satellite is within range of the platform. The satellite in turn transmits the data to a ground station in real time, if within range, or stores the data on tape, if out of range. In this way ERTS is used to relay data generated in remote or inaccessible areas to one of four ground stations for eventual transfer to the agency for which it was recorded. The storage of data by tape recorder serves not only the Data Collection System, but provides the means by which experimenters around the world may participate in ERTS research.

The orbital parameters, with the sensors, determine the type of data to be generated. The conditions under which the data is collected must be controlled to produce repetitive coverage under approximately constant observation conditions. The altitude of 917 kilometers is a compromise between the amount of communication time between spacecraft and groundstation, which increases as altitude increases, and the sensor resolution (the ability to detect) which decreases as altitude increases. To produce imagery at a constant scale, a fixed altitude therefore a near circular orbit is required. There is by design sidelap in the observations collected in two adjacent orbits. The amount of sidelap and the total time to complete the earth coverage are determined by the nodal time - the elapsed time of one orbit. The nodal period is 103.3 minutes; in 251 orbits, or 18 days there is complete world coverage.

The node time, the local solar time when the spacecraft crosses the equator, governs the illumination conditions. For conventional photo interpretation low sun elevation angles are desirable to produce shadows. For radiometric purposes (the measurement of reflected energy) a high sun angle is desirable to produce sufficient reflected energy from low reflective materials. The respective time periods maximizing those conditions are 9:30 - 10:00 A.M. and 2:00 - 2:30 P.M. Since cloud cover conditions in the northern hemisphere are better in the morning, the time at the descending node (equatorial crossing) is 9:42 A.M. The orbit inclination, 99.114 degrees is chosen to produce a sun-synchronous orbit, consequently constant illumination conditons throughout the year.

A ground swath 185 kilometers wide is viewed by the sensors as the spacecraft moves over the surface of the earth. The ground coverage pattern is traced by ERTS moving north to south. Assume the first orbit is number N, day M; the next trace N+1, Day M is shifted to the west 2900 kilometers. Fourteen orbits are completed in one day. On the 15th orbit, orbit N, day M+1, the swath is adjacent to the first orbit, N, M, of the previous day by 159 kilometers. In 18 days, 251 revolutions world coverage is completed; during the next 18 days the same orbits are traced again and this pattern is repeated for the life of the spacecraft. The coverage provides a 14% crosstrack overlap.

SENSOR SYSTEMS AND DATA PRODUCTS

ERTS1 carries two sensor packages: the Return Beam Vidicon (RBV) and the Multispectral Scanner (MSS). The RBV is not being used this mission because of a malfunction. I include a brief description here because this system is important and will be on future flights. The RBV contains three cameras, similar except for spectral filters in the lens which restrict observations to a specific band in each camera. The bands are designated bands 1, 2 and 3 covering the wavelength range from .475 to .850 microns. The cameras are aligned in the spacecraft to view the same 185 kilometer (100 nautical miles) square ground scene, and are reshuttered to provide successive views including overlap. The images are stored on photosensitive surfaces and scanned to produce video outputs which are either stored or transmitted to the ground station.

The MSS provides the data now being used by all investigators. This system gathers data by imaging the earth's surface in four spectral bands simultaneously through the same optical system.

Band 4	0.5 to 0.6 microns
Band 5	0.6 to 0.7 microns
Band 6	0.7 to 0.8 microns
Band 7	0.8 to 1.1 microns

An oscillating mirror observes the earth's surface and directs the light through an optical chain, much like a telescope, to glass fibers, six per band. The fibers conduct the light to an individual detector through an optical filter unique to the band. An image of a line across the swath is swept across the fibers each time the mirror scans causing a video signal to be produced at the scanner's electronic output. The signal is stored or transmitted.

The final products available to the investigator fall into two categories: 1) Four band digital data provided on computer tapes; 2) imagery in various formats. Since our digital experimentation has been concluded just recently I shall describe only the imagery formatted data and imagery analysis. NASA recomposes the video data into products which resemble photographs by writing on film with an electron beam. The processing procedure is complex in the sense that geometric and radiometric corrections, which I shall not describe, are made at this stage.

Black and white imagery, for each 100 x 100 nautical miles ERTS scene, for each band, is available in positive or negative, paper print or transparency format. Data for any combination of three, of the four, bands can be combined into one scene by NASA's preprocessing in false color using blue, green and red. These colors, by standard procedure, are allocated to any three bands, but in sequence from band 4 to 7. The color composites produce six hues including yellow, magenta and cyan, all with varying intensities. The significant factor is that each combination of bands yields uniquely different spectral information, and as a result varying degrees of spatial information. The intensity of the color depends upon the amount of reflectance in each spectral band.

ELECTRONIC ANALYSIS SYSTEM

The analysis mode is electronic which uses a complex configuration of electronic equipment which I shall describe only to the extent that the anlaysis is understood. Two major systems form the configuration. The first is the special purpose equipment used to measure reflectance, store spatial and spectral information for instantaneous replay and modification, and display results. The second is a general purpose computer which directs the analytical and processing operations, stores analysis results and provides printouts in various formats. Both systems are controlled by an analyst at a console which contains the computer terminal, and a colour television screen. The TV screen displays the imagery being observed and by colour enhancement shows the spatial distribution of object classes having specified spectral properties. The TV screen also displays statistical data which I shall describe.

The colour imagery is mounted in glass holders and placed in an optical tower - essentially an elaborate light box. A TV camera scans the imagery and converts the resulting video into a digital format. The TV camera has a power zoom lens which, when adjusted, changes the size of land area to be analysed. The analyst, from the console, can change the zoom ratios and move the imagery north/south, east/west and by rotation. All manoevers are calibrated to allow for repetitive and comparative analysis; all movements show on the TV screen. The camera when scanning redivides the spectrum into red, blue and green channels using filters. The digitized video in each channel is routed to the "signature analyser" which measures the reflectance in each channel.

The identity of an object class is established by these measurements. When the three quantities of reflectance are <u>unique</u> for one object, relative to the three quantities of reflectance for other objects, a "SPECTRAL SIGNATURE" is in theory established, and on that basis the object, or class of objects, should be distinguishable from others.

MULTISPECTRAL ANALYSIS METHODS

When digital data is used, the analysis is conducted in four channels. Since the imagery is limited to three we may conveniently describe a spectral signature as colour "space". Colour space is defined by a box whose edges are determined by the maximum and minimum levels of reflectance on each of three axis representing the red, green and blue channels. Such a parallelepiped concept of colour space, although convenient, reflects the limitation of processing technology. Spectral signatures are not so simply defined, and colour space is in fact an irregularly defined space. For that reason we use three successive stages in the development of a signature, each a refinement of the former, and each a better approximation of an object's spectral properties. These stages are defined as follows, and described in three dimensions as shown on the slide:

1. PARALLELEPIPED (Figure 1)
2. POLYHEDRON (Figure 2)
3. MULTICELL (Figure 3)

I shall describe two major analysis routines, each employing the three stages of signature development. Both have variations and subroutines which I shall not describe. The two routines are

A. CLASS ANALYSIS
B. CLUSTER ANALYSIS

A. Class Analysis

This routine is distinguished by the fact that we begin with an object that is known. Assume for illustrative purposes that the class is a specific tree species, known to fall in the field of view which appears on the TV screen. The analyst moves a cursor, electronically generated in the TV image, to enclose the area which has the trees. The cursor is rectangular, can be changed in size in either direction, and is moved by a joystick. The analyst, having set the cursor, types instructions which cause the reflectance measurements to be taken, and "one-dimensional histograms", which I shall describe, to be run.

A binary system is used to divide the reflectance measured into 32 levels of intensity, or "grey levels", which correspond to an intensity range of 0 to 100 per cent: no reflectance to total reflectance. The TV image contains a matrix of 500 x 500 picture elements or "pixels". When a histogram is run, every pixel within the cursored area is scanned and for each pixel, reflectance is measured. The pixel is allocated to one of the 32 grey levels according to the measure of intensity. This routine is done for each channel, and takes a total of about two seconds. The histogram is the record which contains the distribution of pixels according to their intensities in <u>each</u> respective channel - hence the prefix "one-dimensional". The histograms, by request, are displayed on the TV screen or stored on tape. The area within the cursor appears pink in colour indicating that this stage of analysis has been completed. The colour enhancement is in fact instantaneous since the analysis was completed in less than two seconds.

The tendency in the distribution of pixels throughout the range of grey levels is to cluster about one particular level. Such a distribution allows us to set upper and lower limits eliminating grey levels having low pixel counts. In effect this step brackets the portion of the grey level range having the greatest spectral activity. Since the limits are set in each channel we have in theory defined colour space corresponding to Stage 1, the PARALLELEPIPED concept of the spectral signature. With this specific signature, a search procedure begins over the entire field of view, 250,000 pixels, to find locations having similar spectral properties as that determined for the cursored area containing the object class being observed. Locations meeting the required spectral criteria are recorded and similarly colour enhanced on the TV screen. This routine takes about 2 seconds to examine 3000 square nautical miles, if a minimum camera zoom is being used. All locations are recorded on computer tape for future use.

Spectral properties of objects depend upon a complex number of factors such as texture, illumination and haze conditions; in addition there is considerable overlap, spectrally, among object classes; to further complicate matters there exists considerable "noise" throughout the data collection and processing system, and the analysis system. As a result when specific object classes are colour enhanced "false alarms" may be apparent to a knowledgeable observer - in other words some areas may be enhanced that definitely do not contain the tree species being examined. Similarly areas known to contain the same species may not be enhanced. The analyst can by moving the cursor to these areas add or subtract such locations; adjustments to the histograms can be made simultaneously to reflect the spatial modifications. This iterative process, the repetition of electronic analysis and subsequent validation and modification of the signature, is identified as the "training" portion of the analysis. Significantly, the training procedure should be accomplished using a very few but well chosen (truly representative and homogeneous) training sites. Following this procedure large areas, perhaps relatively unknown, may be searched, and the required object classes mapped in short periods of time.

Next is Stage 2 in the development of the spectral signature. The area chosen for training is sufficiently large such that the cursor may be moved within its boundaries. By cursoring as many different locations as possible, and running histograms at each location a further refinement to spectral space is made. While training areas are chosen based upon our belief that they are homogeneous, the condition of homogeneity is more theoretical than real - in nature and in man's built environment such an object class, homogeneously discrete, would be exceptional. By sampling a number of subareas we are actually setting a series of upper and lower limits. Graphically this representation, in three dimensions, takes the form of a POLYHEDRON- a closer approximation of the spectral signature than the parallelepiped established in Stage 1.

Stage 3 in signature development is obtained by the use of "three-dimensional histograms". The colour space is now divided into smaller three dimensional spectral regions called "cells". The number of divisions chosen by the analyst along the edges of the three dimensional colour space, or correspondingly within the grey level range between the limits in each channel, determine the total number of cells. The number of cells chosen varies directly with the degree of accuracy required in determining the spectral signature. The intent is to examine the colour space, as it is constructed to this point but now subdivided into cells, and to discard those cells which have low pixel counts. Until this stage of signature development the configuration of colour space had been modified only by adjusting the edges through the use of maximum and minimum limits. This concluding stage of signature development provides an internal examination of the spectral configuration. After the low count cells are eliminated the resulting colour space should very closely approximate the spectral signature of the object or object class. Assuming that the configuration is unique, discrimination among objects or classes can be accomplished.

The number of divisions in each channel, chosen by the analyst to produce the three dimensional colour matrix, is programmed at the control console. The divisions need not be equal in each channel. If the analyst anticipates greater spectral activity in one channel more divisions in that respective channel may be chosen. The choice in the number of cells, channel to channel, is based upon the requirements of analysis efficiency and signature accuracy. The larger the number of cells used, the more computer time and cell by cell examination required to find low pixel counts. An examination of large portions of a colour space having low or no counts is inefficient; on the other hand those areas of colour space having great spectral activity, high pixel counts, should be finely subdivided in order to achieve greater accuracy.

Each cell is given a three digit computer file number; each digit represents the cell location with respect to the red, green and blue axes of the colour space. Computer printouts in various formats give the pixel count for each cell. One format is a list, file by file, giving the counts; another format gives the same information but in successive two dimensional matrices, say red/blue, for each location along the green axis. The latter format has greater utility since it provides some indication of spectral "clustering" - grouping of cells having high pixel counts (see figures 4 and 5).

The first important feature of the analysis mode is the capability of showing on the TV screen, by enhanced colour, the <u>spatial distribution</u> of pixels which correspond to any combination of spectral cells so chosen by the analyst. The request is programmed at the control console and the results are almost instantaneous. Should the spatial distribution correspond to an object or class, in the judgement of a knowledgeable observer, we would conclude that the spectral signature for the class had been established. Providing the signature was within the required limits of accuracy relative to the use of the information, we could proceed to search large areas of land and map locations which had the object class. The second important feature is the <u>speed</u> of analysis. The electronic mode has the capability of examing 480 cells, a three channel colour matrix approximately 8 x 8 x 8, and providing pixel counts for each cell over a land area of about 3000 square miles in two seconds. What does take time is the "training" procedure - the validation of results based on selected test sites. The time spent for this step is directly dependent upon the adequacy of information about the site, or the extent of the knowledge of the observer - one or the other. The third important feature of the electronic mode is the provision of land area calculations for any class of objects which has been adequately determined from the spectral analysis. The TV image is composed of 250,000 pixels; each pixel represents a discrete area of land of which the quantity is a function of the specific zoom ratio of the camera lens being used at the time of analysis. Area calculations for object classes are made by request on the TV screen along with the colour enhancement of the class. All statistical data can be stored on tape, of course, for further analysis or documentation.

In summary there are three significant products resulting from the analysis:

1. Colour photographs taken of the TV screen which documents the spatial distribution of selected features on the earth's surface which correspond to the spectral properties determined by the analysis.

2. Computer printed thematic maps which give the same information as 1. above.

3. Statistical data: A) Spectral information provided by computer printed histograms; B) Area calculations for the object classes being observed.

This concludes the routine we have described as Class Analysis.

B. Cluster Analysis

The basis of the previous analysis was the beginning with a known object class, and the use of three stages of spectral signature development. The major distinction in Cluster Analysis is that the analyst does not begin with the knowledge of an object class and that only Stage Three of spectral signature development, the three dimensional histogram routine is used.

The analyst arbitrarily, although systematically, chooses to divide the grey level scale in each channel into segments, or sub-ranges, and instructs the computer accordingly. Using any combination of sub-ranges among the three channels, three dimensional histograms are run. Recall however, from the previous analysis that histograms were prepared for specific, known objects. In this analysis objects are not known, consequently the entire land area under investigation is assumed to be an "object class" - an unusual application of the concept. Three dimensional histograms are prepared for the whole site using the combination of sub-ranges chosen.

From the results of the histograms, cells with high activity counts tend to cluster in spectral space. The assumption is made that these clusters represent an object class. The analyst displays on the TV screen all locations which are represented by the spectral clusters, chosen in any combination from the histograms. These locations take a particular configuration over the site; we call this configuration a "theme", reluctant yet to call it an object class until sufficient validation is made. An arbitrary colour is allocated to the theme to distinguish it from following themes which are generated using the same method but which represents other chosen combinations of sub-ranges in the grey level scales of the three channels. Eventually the entire site is covered by themes, assuming that the number of sub-range combinations exhaust the total colour space. By overlaying the themes on maps, which can be done on the TV screen, the "fit" between a real object class and a theme can be determined. The boundaries of a theme we identify as "spectral contours", and as such they may be thought of much as the contours on a topographic map. The objective, through an iterative process, is to adjust the contours until the fit meets whatever criteria is necessary to establish the quality of information required. Cluster analysis provides the same results: spectral signatures of object classes within the land area under investigation. As is the case with the Class Analysis, land features over large areas may be distinguished and mapped based upon the knowledge of a few well chosen training sites.

For purposes of describing the methods of analysis much reference was made to object and object classes. The concept of an object class may be more theoretical than real. Certainly the dynamic qualities of natural systems complicates the distinction. Changes in the seasons, varying stages of growth and development, differences in health and vitality, variations in environment - all these characteristics suggest that a discrete object class, consistent over periods of time and consistent regardless of location, may not be distinguishable. Certainly the sensors on board the spacecraft in no way take into account these characteristics; they very simply measure the spectral properties of the earth's surface at a point in time. Our work, in contrast with that of other researchers who are seeking "absolute" spectral signatures, is more pragmatic. We choose to substitute the training procedure, which I have described, for the belief in a concept of the absolute spectral signature. Recall that the training procedure uses the interactive qualities of a knowledgeable observer, a TV display and a control console. The spectral signature is incidental providing we can locate object classes at any point in time. Retraining is an accepted routine when searching for the same object class at another point in time or at another location. This orientation does not preclude comparative analysis in time and location, which is one objective in the study.

In the man-made environment, an urban area for example, the distinction among object classes is equally difficult. While the dynamic qualities are not as predominant as natural systems, the heterogeneous characteristics - the mixture of man-made materials with natural systems indicates very complex object classes. The concept of "land use" as a class, a preoccupation among some researchers, is in my opinion, incorrect. Land use is a social abstraction; there exist no explicit relationships between the spectral properties recorded by the sensors and the use of land. Furthermore, there is no agreement among planners regarding land use classifications, nor their utility, however defined, in the planning process. Caution too is appropriate in the misuse of data. The satellite as a data generator is one source among many. The first criteria in acquiring information is confidence that the data source is the most appropriate one. In that respect the extraction of land use in urban areas from satellite imagery is suspect. Of course, correlations may be made which relate observations to use; but the distinction between extraction and correlation is significant.

For the use of satellite data more rigorous concepts of object classes are required; more imaginative ones are possible. Since we constantly seek new urban planning and urban design "tools" the imaginative approach is not without merit. We have examined a concept which I inappropriately designated "intensity". Unfortunately the nomenclature persists. Intensity identifies an object class based upon the relationship, in area, of land covered by something man-made, and land covered by some feature of the natural environment. We subclassify in a range of coverage from none to 100%. The County of Los Angeles Regional Planning Commission expects such information, when accurately mapped, will have wide policy application and the Commission sees this particular kind of information as very specific to its needs. The concept is also appropriate with respect to the properties the sensors are recording.

The intensity concept is basically a device which looks at man's relationship with the natural environment. Clearly, the application of space generated data is dependent upon the importance an agency places upon the natural environment. The LA County Planning Commission is now cognizant of this importance demonstrated by their publication, not without problems, of an Environmental Development Guide - their first. Like most urban areas the further expansion of physical development is in conflict with the desire to preserve the natural environment in LA, for example the Santa Monica Mountains. LA's problems are compounded by continual crises caused by natural systems: forest fires, mudslides, and earthquakes.

Where environmental factors do impact upon policy, satellite generated data is appropriate. Consequently the NASA study has examined many object classes in the natural environment, to varying degrees of rigor: snow cover and depth, grass types, crop types and cultivation and irrigation characteristics, forest fire burns, graded construction sites and water bodies, for example. Beyond object classes such as these, to more complex social concepts we are exploring the intensity concept which I have described, and for which, I repeat, the natural environment is an integral component.

The information use, beyond its application to resource management and land planning, has regulatory possibilities (monitoring construction sites) and a potential for hazard warnings (fire and flood). The intensity concept if utilized will impact upon policy which effects land use changes, land coverage, housing densities, and conservation policies. In absolute terms this concept could relate population levels with open space/green space standards and recreation standards, influence transportation policy and consequently economic activity.

I shall conclude by commenting on information and multispectral analysis as they relate to policy planning. Policy decisions vary in complexity; they are implemented over a wide range of land areas and over varying periods of time. The information requirements, and consequently the data sources, which impact upon these decisions should be selected for their appropriateness in quantity and quality. The more data sources available, providing each yields significantly different information, the greater the potential for the most efficient match between information and policy. Satellite generated data is unique - large scale coverage on a repetitive basis. Considered complementary and supplementary to other data sources, space data will be appropriately used.

Multispectral analysis using electronic modes provides obvious benefits: speed and economy, in both analysis and mapping. These benefits allow us to spend our budgets examining alternate policy packages. In the particular mode we have used, the analyst, using the TV screen to observe, and the control console to instruct, participates in an interactive process which allows the examination of various combinations of object classes, where those combinations may reflect land use patterns or natural resource management policies.