Robert N. Colwell
Walnut Creek, CA 94595
Charles E. Poulton
Santa Clara, CA 95051

SPOT Simulation Imagery for Urban Monitoring: A Comparison with Landsat TM and MSS Imagery and with High Altitude Color Infrared Photography*

Abstract: *On 24 June 1983 simulated SPOT imagery (10-metre resolution) and Zeiss, 6-inch focal length color infrared aerial photographs were simultaneously acquired of the Davis and Woodside test sites in northern California. These two sites, respectively, were well suited for evaluating the extent to which various kinds of remote sensing imagery could be used in monitoring and planning at (1) the urban-agricultural interface and (2) the urban-forest/range interface. For each site, simulated color infrared imagery was produced from the SPOT Simulation data and supplied to the investigators at a scale of 1:24,000. Approximately six weeks later, Landsat 4 acquired both MSS and TM data for these two sites, from which simulated color infrared imagery, scale 1:24,000, also was prepared. The interpretability of urban/suburban features on the simulated SPOT imagery was compared with their interpretability on the MSS and TM imagery, which had resolution of 80 metres and 30 metres, respectively, and also on the color infrared aerial photographs. From a comparative analysis of these image types, the investigators sought to determine, both qualitatively and quantitatively, the extent to which increased spatial resolution provides increased interpretability of urban/suburban features. At both sites the simulated SPOT imagery was found overall, to be decidedly more interpretable than the Landsat MSS and TM imagery, and in many instances nearly as interpretable as the color infrared aerial photography.*

Introduction

The purpose of this paper is to report on the usefulness of SPOT simulation imagery as compared with Landsat TM and MSS imagery and with high altitude color infrared photography for urban monitoring, based on evaluations made at two test sites in California.

SPOT simulation imagery from Flight Line 76 (designated as "Yolo County at Davis") and also from Flight Line 3 (designated as "San Mateo County at Woodside") was used in the comparisons. The SPOT simulation data were acquired on 24 June 1983, along with 9 by 9-inch color infrared aerial photography, taken with a Zeiss 6-inch focal length camera at an approximate scale of 1:42,000. The visually interpretable SPOT simulation imagery was produced at 10-metre resolution, as a color infrared simulation, at an approximate scale of 1:24,000. In addition, on the same day, low altitude (1500 feet) aerial oblique photographs and also terrestrial photographs of the same sites were taken in the form of natural color and color infrared stereograms through the use of a matched pair of 35-mm cameras.

Part of this study entailed comparing interpretability of the SPOT simulation imagery with that of the Landsat MSS and TM imagery acquired of the same sites on 12 August 1983. With respect to sea-

* Presented at the 1984 SPOT Symposium, Scottsdale, Arizona, 20-23 May 1984.

Photogrammetric Engineering and Remote Sensing,
Vol. 51, No. 8, August 1985, pp. 1093-1101.
0099-1112/85/5108-1093$02.25/0

sonal state of the vegetation, the SPOT simulation imagery was taken late in the drying season and the Landsat imagery during the middle of the dry season. A preliminary comparison of imagery acquired on the two dates showed that (1) there was some difference in the appearance of annual vegetation because of this difference in seasonal state but (2) this factor was not likely to affect, to any significant degree, the kinds of urban interpretability comparisons that were to be made.

Both of the test sites (Davis and Woodside) had previously been used in various NASA and other remote sensing applications programs. Thus, an abundance of background information was already available with respect to each of them. The setting of the Davis site was especially well suited for studying the urban-agriculture interface, and that of the Woodside site for studying the urban-forest/range interface.

Monitoring and Planning the Urban-Agriculture Interface

One of the most critical land-use problems in North America and in many other heavily populated regions of the world is urban-industrial sprawl into the best food-producing land. One reason why such sprawl is difficult to control results from the lack of sufficiently strong-impacting pictures of the adverse consequences of short-sighted planning for urban expansion. In many instances such pictures (e.g., aerospace photographs) would greatly facilitate the passage and implementation of effective land-use laws and ordinances.

Original human settlement tended always to be on the very best agricultural, timber, and range lands. In North America these settlements were initially established as an operating headquarters or as a service center of supporting business. Over the years, as the settlements have grown, the result almost always has been uncontrolled urban sprawl. This process has been governed almost entirely by land developer interests and priorities. One can hardly call it guided development.

One effective means of reducing uncontrolled urban sprawl in the future is to counter with sound, visually impacting information designed to show feasible alternatives that might be employed, within the framework of rational enabling legislation and land-use ordinances. Because of its increased spatial resolution compared to that of Landsat MSS and TM imagery, SPOT imagery can provide this visually impacting information and thus play a significant role in the important world problem of guiding urban-industrial expansion. One example of the potential of using high resolution space photography for such purposes is to be found in the SPOT simulation imagery that covers the Davis test site. As will presently be seen, an interpretation of this imagery provides excellent confirmation of historical facts in the urban growth of Davis, a university/farming community. Consequently, this exercise illustrates how such interpretations could be used in many other geographic areas, as well as to document and reinforce urban-agricultural planning needs.

Merely from an examination of the simulated SPOT imagery for the Davis area, as shown in Plate 1, much can be inferred as to the nature and appearance of this area in times past and some of the factors that have influenced the patterns of expansion. To be specific, one could readily infer, merely from a study of Plate 1, that most of the early development of Davis occurred when railroads were the primary mode of long distance transportation, at which time Davis was primarily a "railroad" town. In fact, the railroad "Y" at point (1) is still an important attribute of Davis and explains why the original business district of Davis, at point (2), was located nearby. The original residential district at (3), evident by the prominence of large trees, was obviously developed north and west of the railroad tracks in juxtaposition to the business district. The original Davis High School building at (4), and the associated playing fields at (5), were quite logically built in close proximity to the original residential area. Even in those earlier days, part of the area at (6) was reserved as a park for recreational use and that area remains preserved somewhat in its original tree-covered, park-like state today.

In the year 1909, the University of California's Davis campus was established and, as an important part of that establishment, the site immediately south and west of the original Davis urban area was designated as a 2600-acre agricultural experiment station (Area 7) in keeping with the Federal Land Grant educational system. The fact that such an experimental area is still in existence today can be readily inferred by the smaller-than-normal agricultural fields (Area 8) and the intensity of its secondary road system as compared to surrounding areas. Note that this road system is clearly evident on the SPOT simulation imagery of Plate 1.

Partly because of the importance of agricultural aviation, we are not surprised to find that the university established its own airport at (9) near the west edge of the "University Farm."

By 1940 approximately 1100 students were enrolled at U.C., Davis, and the University's complex of buildings devoted to classroom instruction and to university administration was developing around the "Quad" at (10)—also handy to the business district a few blocks to the east. Again, it is significant that these institutional buildings are clearly evident on the SPOT simulation imagery, as are the large buildings in the business district, thereby allowing accurate determination of the presence of these features.

In the late 1940's, with the tremendous influx of students whose education had been interrupted by World War II, a very sizeable expansion of the Davis

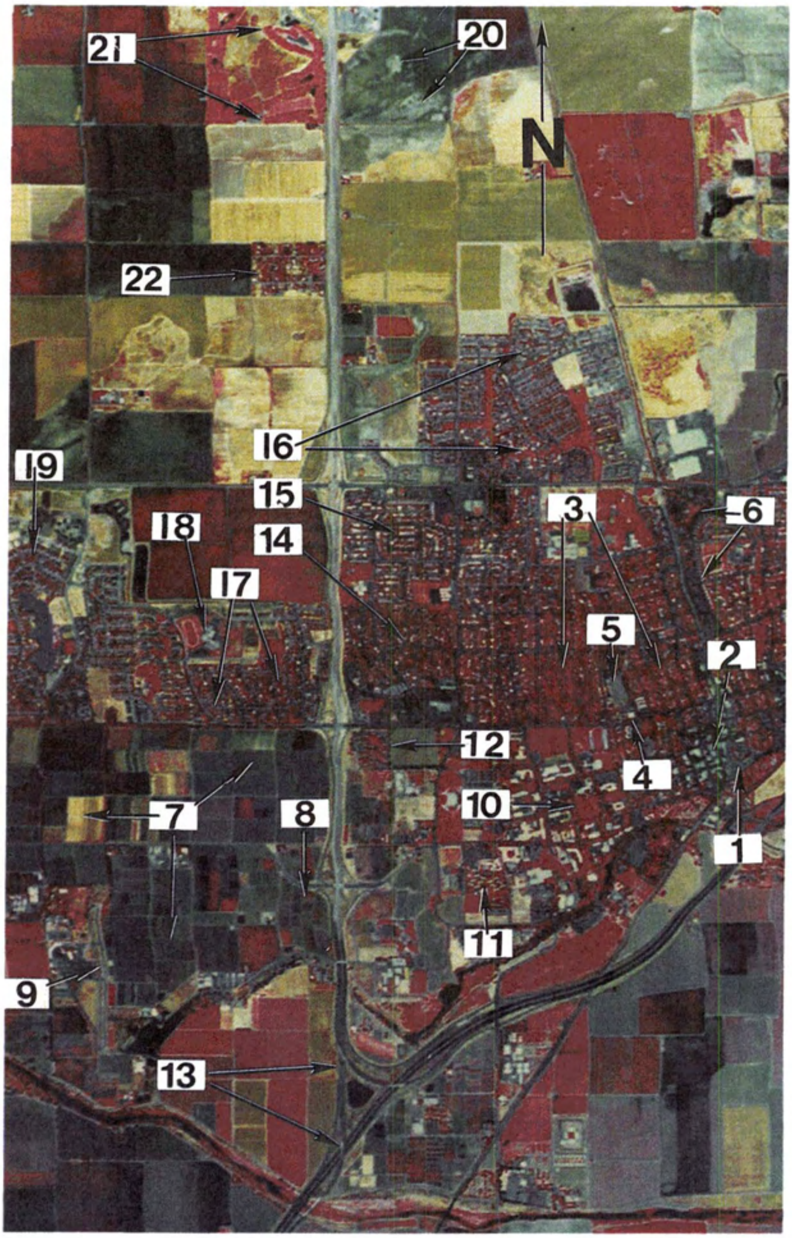

PLATE 1. SPOT image color infrared simulation of the NASA Davis, California Test Site acquired on 24 June 1983.

campus took place and a large number of modern student dormitories began to appear at areas labelled (11) and (12). By this time a decline in the importance of railroading, combined with the burgeoning of student enrollment, caused university-related activities to replace railroad-related activity as the primary industry associated with the town of Davis. Consistent with the replacement of railroad transport by highway transport, the original Davis "Y" at point (1), marking the junction of two major railroad routes, became secondary to the new Davis "Y" at point (13), marking the junction of two major highway routes (the east-west trending Interstate 80 and the north-south trending State Highway 113, an important bypass connection with Interstate 5 north of Davis). This caused a new focal point for expanding urbanization near that segment of Highway 113 that was close enough to Davis to offer a realistic commute possibility. Normally expected commercial development at the highway "Y" was restricted by the presence of the "University Farm," the freeway system, and the watercourse of Putah Creek. Because the combination of these factors prevented urban expansion to the south and southwest, such expansion was destined to take place north of "old town" and the University Farm.

Davis and its environs are notoriously flat. Flat lands are ideal for bicycling, and bicycles are an extremely useful means of overcoming congestion in such populous areas. Heavy dependence on the bicycle by both students and staff probably explains why most of the post-war housing developments surrounding Davis—including those in Areas (14) and (15)—tend to be clustered fairly close to the University. That these housing developments are of recent vintage is readily inferred from their relative absence of large trees, compared to "Old Town" Davis at (3). Naturally, the first of these developments was adjacent to "Old Town" and in close proximity to the already existing High School, a strong drawing card. Note Areas (14) and (15).

It was also most logical for one of the next development areas to be Area (16), some distance immediately north of the High School—more recent than Areas (14) and (15) as evidenced by the smaller trees. Note that the attractiveness of Area (16) was enhanced by (a) a large greenway, parking lot, club house, and golf course winding through the development; (b) a potential commercial area in the southeast corner of the development, along the railroad; and (c) another business area on the southwest.

Apparently somewhat contemporary with development of Area (16) was that of Area (17) adjacent to both the University Farm and Highway 113. This placed the development in a reasonably close proximity to the central activity of the Davis community and also near to a major street leading into the main business district of Davis and to the University. The increased population resulting from development of Areas (14) and (17) resulted in a new school at (18) on the northwest corner of the initial development in Area (17). This, in turn, provided a strong attractor for more expansion of Area (17) to the west.

Judging from the simulated SPOT imagery, this expansion has become one of the most elegant of the suburban housing areas in Davis, Area (19). It is complete with artificial lakefront property, a park and activity center, and an additional shopping area. From what one can see in this image, however, one might wonder whether residents of this particular area will be distressed by increasing airplane traffic in and out of the Davis Airport at (9) occasioned by the fact that Area (19) is in direct line with the airport's only runway and only a scant mile away. Whether this potential problem could have been avoided by more forward-looking planning is academic at this point.

What might the future hold? Factors already mentioned will probably continue to restrict southward expansion of Davis across Interstate 80. This likelihood is reinfored by the following positive attractors to the north:

- The next most logical expansion area is north of Area (17). An important consideration, however, should be the unusually high productivity and uniformity of the soil in this area for crop production—a factor which should hold the area in commercial agriculture.
- The SPOT image pattern that is seen in an area centered about two miles north of town along Highway 113 (Area 20) suggests greater soil variability and thus the possibility of a lower priority in that area for continued agricultural use. Consequently, this may be the most judicious area for future urban expansion.
- A golf course, readily identifiable on the SPOT simulation imagery, has already been developed two miles north of town along Highway 113 at point (21). This may prove to be a drawing force tending to move residential expansion northward along 113 in the event that land (hopefully in the poorer agricultural soil areas) is made available for urban development.
- One small development that comprises about 30 acres is already in place one mile north of town, Area (22). This will function as a drawing force and a focal point for expansion of urban, residential, and even small commercial developments designed to service the area as it grows. It is logical that future growth would eventually require an additional school and churches in this area—assuming of course that the economy of Davis can grow, or that some further diversification of industrial development can support another substantial increase in the population.
- The existence of the north-south railroad may limit expansion of Area (16) to the east, although additional urbanization could spread north from existing developments east of the railroad track. An additional limitation may result from the fact that this area lacks a major highway to facilitate north-south traffic as 113 does on the west.
- To some degree, further expansion of Area (16) northward along the railroad is restricted by the presence of a drain ditch, associated ponds and a pumping station, and by the convergence of the railroad and Highway 113 as one moves northward.

LANDSAT TM COMPARISON, DAVIS SITE

Nine different color enhancements were made of the TM data to compare interpretability. Examination of this imagery in comparison with the simulated SPOT imagery revealed the following:

- Simulated color infrared renditions can be made with TM that are spectrally comparable to those made with SPOT, and these renditions are adequate for differentiating features where the spectral signature is the primary criterion.
- Where spatial discrimination and ground resolution are important, however, TM is leagues behind the SPOT simulation. Specifically, on the TM imagery:

- the secondary road system in the University Farm is not discernible;
- streets within the urban areas are mostly evident because of the pattern in tree distribution, and none of the smaller houses can be seen as they can on the SPOT simulation;
- large buildings are indistinct, although evident; and
- highway interchange detail is fuzzy on TM and clear on SPOT and the median strip in the freeway is not discernible on TM but it is on the SPOT simulation image.

The experienced urban interpreter will appreciate that the above disadvantages severely limit the usefulness of TM data because these kinds of image interpretation depend very largely on resolution detail that preserves the integrity of building shape, discriminates the various features of ground cover, allows detection of major and minor streets and secondary roads, and allows one to draw effectively on spatially related, convergent, and associated evidence for the correct identification decision.

In view of the foregoing, it is the judgment of these writers that, unlike TM data, SPOT data of the quality of this simulation experiment can come close to taking the place of 1:40,000 to 1:50,000 scale aerial color infrared photography, especially when one considers the advantages of being able to digitally analyze the data for special problems and applications including (1) quantifying certain components of an urban/industrial area, (2) determining the area occupied by each such component, and (3) developing numerical discriminations to support and strengthen the visual interpretations.

MONITORING AND PLANNING IN THE URBAN-FOREST/ RANGE INTERFACE

As previously indicated, the monitoring of Urban-Forest/Range interface relationships was studied on data from Flight Line 3, "San Mateo County at Woodside." This test site is in the foothills of the Santa Cruz Mountains which form the backbone of the San Francisco peninsula. The site is transected by the San Andreas fault. The area overlooks the South and East Bay portions of San Francisco Bay. Natural cover is redwood-Douglas fir forest and oak woodland, together with various shrublands and grasslands, depending on soil type, slope, aspect, and elevation. Because the area offers fantastic vistas and open space, it is in high demand for secluded and exclusive suburban homes and for larger-acreage, suburban living in the grasslands and oak woodlands of the rolling foothills. Because of the high intensity residential, business, and industrial use of this part of the San Francisco peninsula, there is pressure to expand residential areas over the oak woodland foothills, in the trough of the San Andreas fault, and up the slopes into the redwood-Douglas fir forests and the high grassland parks of the Santa Cruz Mountains.

This diversity of environments, together with the development that has already taken place, provides an ideal area in which to determine the usefulness of the SPOT simulation imagery for monitoring these urbanization processes. An excellent opportunity also exists in this geographic area for the assessment of environments that are comprised primarily of forests, woodlands, brushfields, and grasslands, out of which the urban expansion must be carved.

Our evaluation was approached by first making a complete delineation of all vegetation and urban types on the simulated SPOT imagery of the Woodside test site, as provided to us in the form of a 1:24,000 scale color infrared print. These delineations were then compared to the types discernible on the previously described simultaneous CIR aerial photography and on the TM and MSS color infrared imagery. Obviously, there were advantages in the stereo evaluation of the aerial photography. There were features, such as individual small and medium size houses, large buildings, and parking lots where the stereo capability often provided the only reliable means of discriminating, even on the aerial photography. Consequently, we should emphasize here that (1) the SPOT sensor system, in one mode of operation, will provide a stereo capability, and (2) a form of "synthetic stereo" can be incorporated in Landsat MSS and TM imagery for areas in which terrain data are available. But, in relation to the present study, the key point is this: for those urban/suburban features that are necessary and feasible to map at a scale of 1:24,000, the SPOT Image simulation seemed fully adequate for feature delineation and for the identification.

There were, of course, many small features which could be mapped only as point locations. Most of these required stereo examination, and some required ground examination for reliable identification. We found, for example, that the resolution provided by SPOT simulation imagery permitted sufficiently good detection of individual trees and small clumps of trees or shrubs to enable us to develop an index of proportional conifer versus hardwood cover in the forested and wooded areas, as shown in Table 1. In the urban planning context, such information is indicative of the developmental status of the natural vegetation, its relative economic value, some of its scenic qualities, and the site potential for forestry—all of which are important to the land use planner.

The last line of this table suggests that at least three and possibly four classes of mixed conifer-hardwood timber could be differentiated in the SPOT imagery. With larger samples and an improved sampling design, even more differentiation might be possible. This led us to compare possibilities for the discrimination of individual and small clumps of hardwood (oak) trees in drying grassland areas among the SPOT, TM, and MSS image types (Table 2).

These data are of obvious importance in relation

TABLE 1. PERCENT HARDWOOD IN MIXED CONIFER-HARDWOOD STANDS*

	Dots on Hardwood in Random Set of Ten Dots				
Item	Stand 1	Stand 2	Stand 3	Stand 4	Stand 5
No. Obs.	6	7	14	16	16
Sum	24	37	20	40	69
Mean	4.00	5.29	1.43	2.50	4.31
S.E. mean	1.53	1.48	1.18	1.32	2.64
% Hardwood	40	53	14	25	43

* Based on the interpretation of simulated SPOT imagery and found to be in close agreement with the interpretation of simultaneously acquired CIR aerial photography, scale 1:42,000.

to our ability to assess, from SPOT simulation imagery, the ecological and scenic qualities of the open foothills. We found, similarly, that thin hedgerows (much less than 10-metres wide and some as narrow as 5 metres) were detectable when they occurred on spectrally contrasting backgrounds. Practically all of the secondary two-lane roads and a few single-track roads also were detectable where not overhung by trees.

In terms of mapping vegetation types and inferring landform and soils for purposes of land-use planning and possible urban expansion, we found that all of the conditions, except soil features that cannot be inferred from vegetation, were detectable by and mappable on the SPOT simulation imagery.

One of the important land-use changes in this area is development of very expensive homes on large lots within the redwood-Douglas fir type. This kind of development is important to monitor and control because of the especially high demands that it places on various public services—including those associated with fire control, police protection, and the installation and maintenance of utilities. We selected three developing areas and counted habitations on the ground or from existing maps, on aerial photography, and on SPOT, TM, and MSS imagery. The results of this comparison are shown in Table 3.

The data of Table 3 clearly show that, for the stated purpose, SPOT is almost as good as small-scale aerial photography and that SPOT simulation imagery is superior to Landsat TM and MSS imagery. From this we conclude that the SPOT imagery is, in fact, useable for monitoring housing development in wooded regions.

In these kinds of areas watershed runoff can be a serious problem, primarily because of the increase in impervious surface that results from residential development. Table 4 shows the results of a test in which a random dot grid of 100 dots per square inch was used to record hits on housing units in the largest of the three test areas. This could not have been done with TM or MSS data with acceptable reliability because of the lower spatial resolution of such data.

A comparison was not done on the aerial photography because the scale of 1:42,000 was too small and the results would have been somewhat scale dependent. Given several such data sets, one could develop an index of increased runoff that would be expected from housing developments such as these. Field sampling and measurement could determine

TABLE 2. OAK TREES DISCERNIBLE IF ON A DRY GRASS BACKGROUND

Number of Oak Trees Counted by Interpreter					
Air Photography		Spot Imagery		TM	MSS
Positive	Likely	Positive	Likely	Likely	Likely
20	1	19	3***	0	0
8	0	8	1***	0	0
23	0	14	6	0	0
7	2	12*	0	0	0
10	0	7**	0	0	0
8	2	15***	4***	0	0
17	0	17	2***	0	0
93	5	92	16***	0	0

* Includes shrub patches that look like trees
** Border trees blend with hedgerow
*** Difference probably due to shrub patches that look like trees on the Spot Image.

TABLE 3. INCREASE IN HOUSING IN TIMBERED AREAS, 1976-1983

# of Houses		# of Houses in 1983*			
Area	in 1976	Air Photog	SPOT	TM	MSS
A	11	16	11	0	0
B	39	56	56	3	1
C	13	18	14	7	5
TOTAL	63	90	81	10	6

* Count includes "Positive" plus "Likely" interpretations, but excludes the lowest confidence class.

the average percentage of the total area that was occupied by roof area, impervious driveways, and sidewalks for different classes of development. SPOT data analyzed for percentages of these openings in the timber would provide a useful index for planning runoff-water control for housing developments within critical watersheds.

The extreme northern part of Flight Line 3 did include extensive industrial and commercial areas. We were not provided with simulated SPOT imagery in false color for that part of the area; however, the false color simulated SPOT imagery that was produced for us provided only the options of looking at (1) limited residential classes and (2) institutional buildings, such as schools and churches. On the black-and-white strip printout of SPOT simulation imagery, however, we did make comparative counts of institutional and business buildings and compared them with the results that we obtained by interpreting the aerial photography. This information is summarized in Table 5. (A TM image was not available to us for this northerly area and MSS images were not useful for this purpose.)

These results confirm the useability of SPOT simulation imagery for acquiring building-by-building data in institutional, commercial, and industrial areas. Generally speaking, the differentiation of certain broad classes of residential, commercial, and industrial areas can be done from the TM and MSS data, but accuracy would surely drop for the commercial-industrial discrimination, especially with MSS data where the type of area can be inferred only from convergent and associated evidence.

Finally, a few general observational notes are summarized in Table 6 that illustrate the capabilities of using SPOT simulation imagery for visual interpretation of urban/industrial features in a region where the urban-forest/range interface is important.

TABLE 4. PERCENTAGE OF AREA IN HOME CLEARINGS, AREA A (FROM 5 REPETITIONS OF 100 RANDOM DOT COUNTS)

Repetition Number	Percent in Home Clearings
1	15
2	13
3	15
4	16
5	11
Average	14

SUMMARY AND RECOMMENDATIONS

In summary, these authors believe that the potential of the SPOT simulation imagery for urban-industrial monitoring and planning is very great. For such purposes, one can do just about as much with these data as with small-scale CIR aerial photography. Spatial resolution is especially important in the image analysis of urban-suburban features because of the inordinant amount of dependence on geometric and spatial relationships and on detailed shapes of features as well as on convergent and associated evidence for the identification of features in the urban/industrial setting. In addition, there is the ever present requirement for a high level of ground knowledge and an understanding of what is likely to be encountered in each type of area that is to be interpreted.

In spite of the greater interpretability of SPOT imagery (as compared with Landsat MSS and TM imagery) that is made possible because of its higher spatial resolution, we must recognize that there are still needs—especially in the developing nations of the world—for small-scale, highly generalized resource analyses and maps that are appropriate to scales of 1:1,000,000 in some instances and to 1:250,000 and 1:200,000 in others. In these cases, spatial resolution of the quality of Landsat MSS is still preferred because it generalizes to a desirable degree by washing out the "noise" that is present in simulated SPOT imagery as a result of its higher spatial resolution. One can, in fact, greatly overkill the information needs in a developing nation with information visually interpretable from Landsat MSS imagery, and all the more so with that interpretable from imagery of the quality of the TM and of the SPOT simulation used in the present study.

In our opinion, therefore, SPOT IMAGE Corporation should plan to put out not only high resolution data and imagery but also generalized editions of their imagery in which pixel clusters have been averaged to create a data set with coarser resolution (e.g., on the order of 50 to 80 metres). In our judgment, an averaging approach to the production of

TABLE 5. INSTITUTIONAL BUILDING COUNT

Type Bldg	Air photography		SPOT Imagery		Comment
	Positive	Likely	Positive	Likely	
Schools	6	0	6	2	1
Churches	1	0	4	0	2
Business 1	0	0	7	0	3
Business 2	9	0	5	0	4
Golf Club	1	0	2	0	5

Comments:
1. Confused parking lot for building on SPOT
2. Confused parking lot for building on SPOT
3. Orchard and roadways looked like business area on SPOT
4. Confused parking lot for building on SPOT
5. Building appeared same dark blue as parking lot on SPOT

such generalized editions would be preferred to a data-sampling approach that skipped rows and columns to degrade the imagery.

One of the obvious advantages of SPOT is going to lie (1) in its stereo imaging capability for selected areas and (2) in the fact that, with one data set, the user has the flexibility of setting his resolution requirements from 10 metres maximum to match the level of generalization at which he is working in the interpretation and analysis phases of resource assessment and monitoring projects.

We perceive another area where the highest resolution capability of SPOT, and even of the TM for that matter, will function as a distinct disadvantage. That is in certain developing countries within which the military establishments adopt a pseudosecurity policy. This problem already exists with Landsat MSS applications. In some countries, highly generalized 1:200,000 scale resource maps and reports have been confiscated by military departments, shrouded in secrecy, and made totally unavailable to the responsible renewable resources agencies that stand to gain the most from use of the information. Unless an educational program with national military departments is mounted early in the promotion stages of SPOT applications, this problem is likely to be even more serious. It is a real shocker for international agencies of the AID type, while working with their contractors, to embark on critically needed resource analysis/monitoring projects only to find that the local military establishment is throwing unanticipated and occasionally crippling road blocks in the way of project implementation. It is even worse to complete an information-gathering project and have the results buried under a vague cloak of presumed security.

TABLE 6. NOTES ON MISCELLANEOUS FEATURES INTERPRETATION FROM SPOT

Item	Note
1	Median in freeway clearly discernible.
2	Two- and four-lane sections of freeway distinguishable.
3	Differentiate black-top from concrete road surfaces (also on TM and MSS if the road/street is detected).
4	Differentiate concrete overpasses on black-top sections of freeway.
5	Most urban streets visible when not tree lined.
6	Two-lane roads visible through woods and grasslands if not obscured by overhanging trees.
7	SPOT is almost as good as 1:42,000 aerial photography for the interpretation of urban/suburban features that are feasible to map at a scale of 1:24,000.

Notwithstanding these difficulties, we are enthusiastic about the potential for civilian application of 10- and 20-metre resolution imagery from space. But, the quality of this imagery will place new demands on interpreters and analysis in at least two areas if full benefit of the system is to be realized. First, it will no longer be adequate in most instances to deal with broad land-cover classes such as grassland, hardwood, conifer, bare ground, rock, etc. In such instances there should be included on each analyst team a person who is particularly knowledgeable in plant sociology and in vegetation-landform-soil relationships, i.e., a person who can "read a landscape and understand it." Without this capability, much of the spectral variability will go unaccounted for and important vegetation and land-cover discriminations will go undetected. This will be particularly true for instances in which digital data analysis is relied upon as the primary mechanism of image interpretation. The second area is legend refinement. It will be increasingly important to use hierarchical land-cover legend systems that are developed without a land-use bias and which accurately represent the biological and environmental parameters which typify the landscape conditions. If the full power of SPOT imagery is to be realized, it will be necessary almost always to apply a hierarchical legend to the fourth or fifth and, occasionally, even to the sixth levels of classification detail. Such legend systems already exist but are not generally appreciated or used by the remote sensing community.

The increased spatial resolution of the SPOT Simulation imagery makes it apparent to us that many *space* photos soon will look very much like *aerial* photos. Consequently, we conclude that, in the near future, direct visual analysis rather than computer-aided analysis very often will be used as the primary means of information extraction from space photography. Therefore, we consider it to be high time for the scientific community to resume vigorously one kind of research that it has almost completely abandoned for the past two decades, viz., research designed to improve the ability of humans to extract information from photos by direct visual analysis.

Forthcoming Articles

The September 1985 issue will be dedicated to the NASA Landsat Image Data Quality Analysis (LIDQA) Final Symposium and will include 22 articles to be presented at that Symposium. Listed below are articles scheduled for future issues beginning in October 1985.

M. L. Benson, B. J. Myers, I. E. Craig, and *W. C. L. Gabriel*, A Practical Field Stereo Viewer for 230-mm Color Transparencies.
Steven L. Birge, Highway Dimensions from Photolog.
D. E. Bowker, Priorities for Worldwide Remote Sensing of Agricultural Crops.
S. Curry, J. M. Anderson, S. Baumrind, and *B. Wand*, Stereo Camera and Stereo X-Ray Devices: Comparison of Biostereometric Measurements.
J. L. Davidson, Stereo Photogrammetry in Geotechnical Engineering Research.
S. F. El-Hakim, Photogrammetric Measurement of Microwave Antennae.
W. Frobin and *E. Hierholzer*, Simplified Rasterstereography Using a Metric Camera.
Gary E. Ford and *Claudio I. Zanelli*, Analysis and Quantification of Errors in the Geometric Correction of Satellite Images.
Lawrence Fox III, John A. Brockhaus, and *Nancy D. Tosta*, Classification of Timberland Productivity in Northwestern California Using Landsat, Topographic, and Ecological Data.
Clive S. Fraser, Photogrammetric Measurement of Thermal Deformation of a Large Process Compressor.
John N. Hatzopoulos, An Analytical System for Close-Range Photogrammetry.
Fred C. Martin, Using a Geographic Information System for Forest Land Mapping and Management.
Haim B. Papo, Deformation Analysis by Close-Range Photogrammetry.
Alain Royer, Pierre Vincent, and *Ferdinand Bonn*, Evaluation and Correction of Viewing Angle Effects on Satellite Measurements of Bidirectional Reflectance.
Robert A. Ryerson, Richard N. Dobbins, and *Christian Thibault*, Timely Crop Area Estimates from Landsat.
Gerry Salsig, Calibrating Stereo Plotter Encoders.
Patricia A. Schultejann, Structural Trends in Borrego Valley, California: Interpretations from SIR-A and SEASAT SAR.
S. S. Shen, G. D. Badhwar, and *J. G. Carnes*, Separability of Boreal Forest Species in the Lake Jennette Area, Minnesota.
C. Dean Tritch, Is Your Contact Printer *Really* a "Contact" Printer?
T. H. Lee Williams, Implementing LESA on a Geographic Information System—A Case Study.