Document Title: Demonstration of Orthophotographic Representation and Analysis, Final Research Report, Revised November 2001

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Document No.: 191862

Date Received: January 11, 2002

Award Number: 97-LB-VX-K004

191862

FINAL RESEARCH REPORT

(Revised)

DEMONSTRATION OF ORTHOPHOTOGRAPHIC REPRESENTATION AND ANALYSIS

97-LB-VX-K004

Revised November, 2001

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EXECUTIVE SUMMARY

In a collaborative project labeled "OPRA" (Orthophotographic Representation and Analysis) between the University of Maryland Baltimore County and the Baltimore County [Maryland] Police Department, alternative methods of displaying crime data in the context of geographic information systems were explored. The primary purpose of the project was to introduce and evaluate the use of digital aerial orthophotography as a complement to the linear and relatively featureless streets basemaps in common use in law enforcement and elsewhere. Secondary objectives were

- The compilation, integration, and distribution of spatially-enabled data for use at the precinct level.
- Examination of the utility of global positioning systems technology in the police department as an alternative to conventional address matching, or geocoding.
- Evaluation of the effectiveness of orthophotos as tools, based on interviews with 24 police officers in the Essex precinct.

The generalized project study area, encompassing the communities of Essex, ~~Dundalk~~, and Middle River, was originally selected based on the prevalence of crime across several communities in the historically industrial part of eastern Baltimore County. Subsequently, study areas were narrowed to more manageable proportions as a result of consultation with commanders in two precincts, limiting the analysis to the Essex precinct. Digital aerial orthophotography was acquired from the county's Office of Information Technology to cover the precinct area. A comprehensive spatially-enabled database was assembled to include some 200 census variables and numerous other indicators with potential application in law enforcement and crime analysis. The integration of these attributes with both the conventional streets database and the raster orthophotography was demonstrated. Police officers were surveyed in order to assess their reactions to maps with and without orthophotography at both neighborhood and community scales.

Given that orthophotography provided opportunities for the enhanced visualization of locational information relating to crime, an effort was made to examine an alternative model for recording and mapping that locational information in order to enhance positional accuracy. A comparison was made between conventional geocoding and two types of global positioning systems instrumentation, one delivering sub-meter accuracy, the other a hand-held so-called "recreational" type. During the course of the project, the federal government removed selective availability from the universal GPS signal, thus immediately improving the accuracy of both sub-meter and hand-held location readings. Results indicated the presence of issues specific to the crime types examined, with the probability of greater GPS-geocoding difference for some crime types or circumstances than others. Of particular interest was the finding that, following the removal of selective availability, hand-held GPS units could deliver sufficient accuracy to make wearable GPS a viable option for officers in the field.

In addition to these efforts in Baltimore County, the PI delivered numerous presentations in three countries in order to disseminate project findings and raise awareness of the potential offered by the law enforcement applications of orthophotography and GIS. Dialog in the listserv for the Crime Mapping Research Center relating to the use of orthophotography was compiled and included as an appendix in this report.

The project resulted in several positive outcomes:

- The practical application of digital aerial photography and its associated coverages, notably building footprints, was demonstrated in the context of a large police agency.
- This capability was supplemented with GPS technology capable of enhancing the positional accuracy of crime incident information by removing dependence on street addresses for the coding and mapping of incident data.
- It was shown that incident data could be enriched through improvements in the visualization of incident location and context. Digital photographs or scanned images could be linked to crime records quite easily, as could other types of imagery such as 360 degree panoramas or digital video.
- Data integration, involving the acquisition of numerous data sets that could serve as resources for field officers, commanders and analysts alike, was developed and integrated into a regional crime analysis system in order to show that maps or photographs alone provide insufficient contextual information. In combination, however, the benefits of synergy became apparent.
- In a survey of a small sample of police officers in one precinct, reactions to a comparison between aerial photographs and conventional digital maps generally favored the former.
- Overall, it was shown that it is feasible to assemble a compendium of digital, spatially-enabled crime and other collateral data that can be made accessible to anyone in a police agency either through a network or at stand-alone work stations.

While the technical feasibility of these technological improvements was demonstrated in the course of this project, the issue of economic feasibility from a costs versus benefits standpoint was not addressed and should be the subject of additional research. One apparent benefit lies in the savings resulting from the fact that much of the information used to enhance or improve digital maps is collected and used by agencies other than police departments. The costs associated with developing layers are fixed, one-time expenses; benefits are multiplied by allowing several agencies access to the files, which in turn fosters partnering among agencies.

Clearly, the universal deployment of the methods discussed here is not economically feasible, nor is it necessary. What is important in the short term is to make the possibilities known to the 16,000 police departments in the U.S., so that they are in a position to pick and choose the applications that they find most cost-beneficial.

I. NEED FOR BETTER VISUALIZATION OF CRIME DATA

Increasingly, police departments employ geographic information systems (GIS) technology in various applications, including criminal intelligence and crime analysis, crime prevention, public information, and community policing. Within this trend toward the adoption of computer mapping and analysis, a complementary technology, global positioning systems (GPS) is also gaining momentum.

Typical applications of crime mapping involve taking a georeferenced crime data base, filtering the data as needed, and mapping it over a streets data base in order to put the crime data in its spatial context. Other spatial contexts may be used, such as census tracts, zip codes, or city/county council districts, but the most frequent underlying context is streets.

Digital street maps typically provide extremely limited contextual information. Streets are represented as single lines, sometimes color coded to indicate whether the street is a freeway, arterial, or collector, etc. Streets can be labeled if necessary, in order to enhance the level of detail, but the information provided by the streets database is quite limited. A problem addressed here is that the visualization of crime data needs to be dramatically improved in order to provide opportunities for better communication within and between the varied internal and external constituencies of police departments. A central theme in this project is examination of the utility of aerial photography as an adjunct to, or substitute for, conventional "stick"-type street maps (Figure 1).

Digital crime mapping is developing in the context of rapidly increasing computer processing and storage capabilities, two keys to enhanced visualization, given that graphics applications are extremely demanding in terms of both. Processing is important owing to the large number of instructions per second needed to draw and redraw graphics files at an acceptable speed. Storage is critical owing to the large size of such files. The digital photography "tiles" used in the course of this project, for example, average about 30 megabytes each, when the photograph itself and its associated "coverages" are taken into account. With the complete coverage of Baltimore County needing hundreds of tiles, storage on the order of 6 gigabytes is needed to cover approximately 610 square miles.

When this project commenced, about three years ago, this was a daunting prospect that has since become trivial now that it is possible to buy an off-the-shelf personal computer with a 70-gigabyte hard drive costing only a few hundred dollars. Less than a decade ago, a one-gigabyte drive cost about $1,000. Price per gigabyte has dropped to less than one percent of its decade-ago level, an astonishing development that opens new horizons for memory-intensive applications.

Hence our ability to manage information in graphic form has improved at a more or less exponential rate. As shown in figure 2, the continuum from total abstraction to reality can be represented as a line along which ability to visualize information may be characterized as "some," "moderate," or "rich." As shown, improved computing has meant that it is possible to move to the right along this continuum, although a limit is reached at which point no further progress toward reality is either technologically possible, or even desirable, since it is some degree of abstraction that makes possible the manipulation and portability of the information.

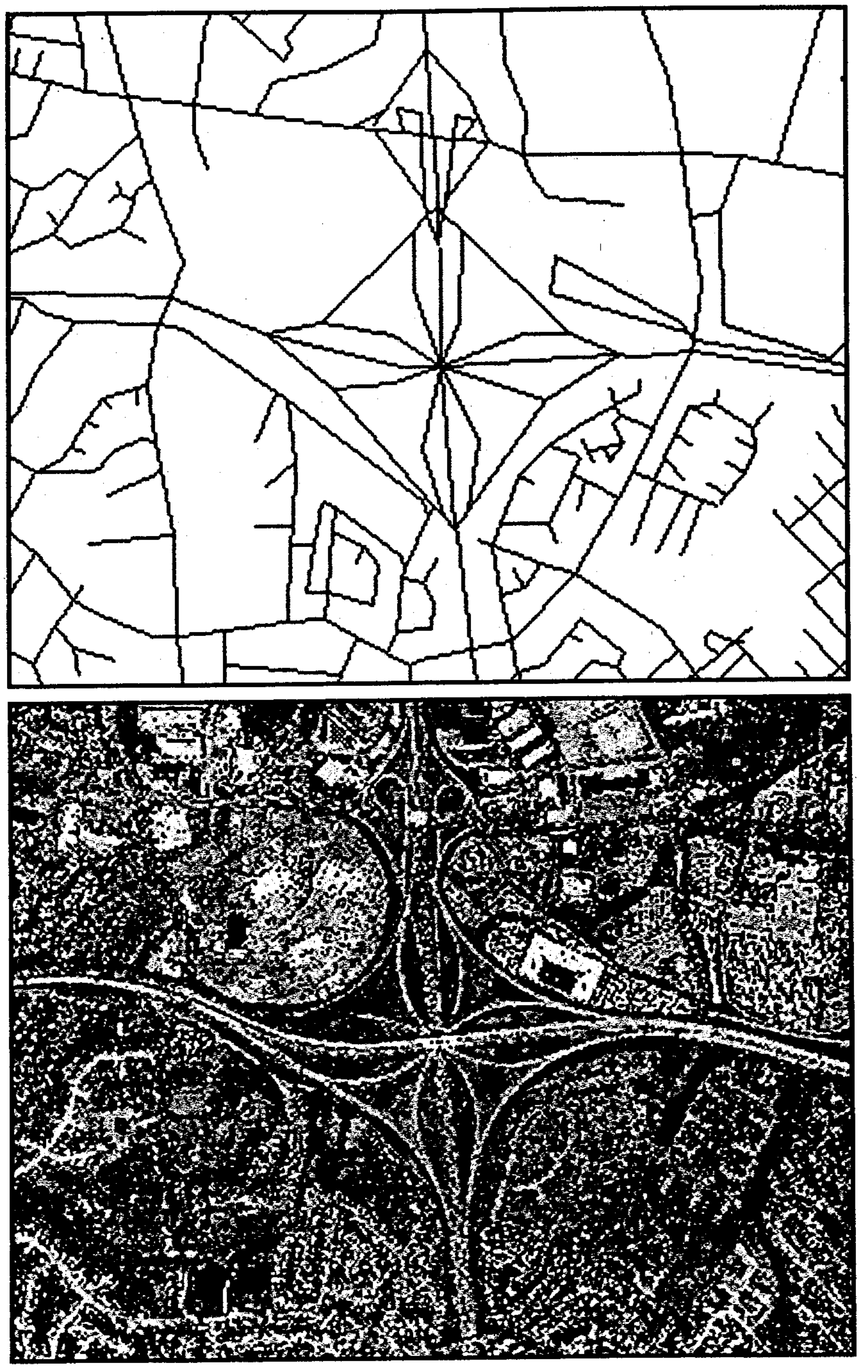

Figure 1. Top: Conventional "stick"-type street map as used in the context of GIS. Bottom: the aerial photo equivalent image, demonstrating typical richness of detail. Source: Harries, 1999.

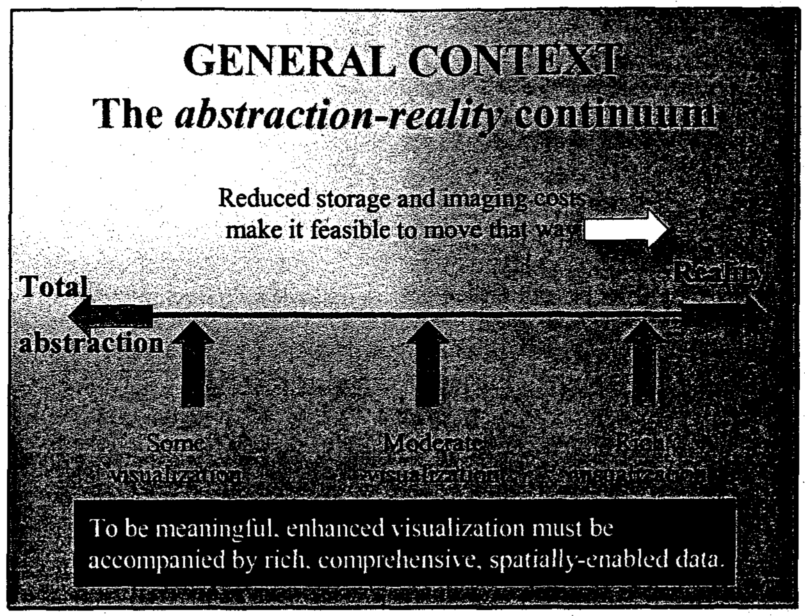

Figure 2. The general context of visualization expressed as a continuum from complete abstraction to reality. Source: Harries, 1999.

A key activity in the course of this project involved adapting spatially-enabled large scale (representative fraction 1:2,400) digital aerial orthophotographs[1] made available through the auspices of the Office of Information Technology at Baltimore County government. Through a labor-intensive process, police boundaries and other selected aspects of the streets base map were registered to the digital photographs in order to correct some underlying inconsistencies. This process permits the relatively accurate portrayal of geocoded crime in its "real" spatial context. It was then possible to identify land uses, landmarks, and virtually any relevant landscape features via direct reading of the orthophoto image.

The vehicle for proving this technology was a demonstration project focused initially on two communities in Baltimore County, Maryland: Essex and Middle River (Figure 3). These communities are roughly synonymous with zip codes 21221 (Essex) and 21220 (Middle River). 1990 Census data for the Essex and Middle River Census Designated Places (CDPs) indicated profiles describing generally modest, predominantly white, working class neighborhoods that historically relied on an abundant local supply of industrial employment. This type of employment was exemplified by plants such as the nearby Bethlehem Steel Sparrow's Point operation. It employed some 50,000 workers (now 8,000) in its heyday. Much of the housing stock in both communities is on the order of 50-60 years old. Between 35 and 38% of residents

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[1] Aerial photographs are subject to three principal types of error: 1. Distortion caused by distance form the lens of the camera. The image is most true closest to the center of the image, perpendicular to the camera lens, and most distorted at the edges, farthest from the lens. 2. Errors attributable to the attitude (as distinct from altitude) of the airplane. If the airplane is not flying straight and level, some degree of tilt will be introduced in the relationship between the camera lens and the ground. 3. Distortion due to variations in topography. Hilltops are closer to the camera, valleys farther away. Insofar as accuracy is in part a function of camera proximity, this has some effect on the image. Thus aerial photos have to be corrected, or rectified, in order to ensure that tiles fit together at the edges. Without rectification, tiles would not match properly. It is this correction that distinguishes an "aerial photo" from an "orthophoto." *Ortho* in this context means perpendicular, as in *orthodontics,* the science of making teeth perpendicular to gums.

had not graduated from high school, according to the 1990 census, a reflection of the relatively low socioeconomic status of the areas, further reinforced by the fact that some 10-13% of residents were below the poverty level.

AREA LOCATOR MAPS

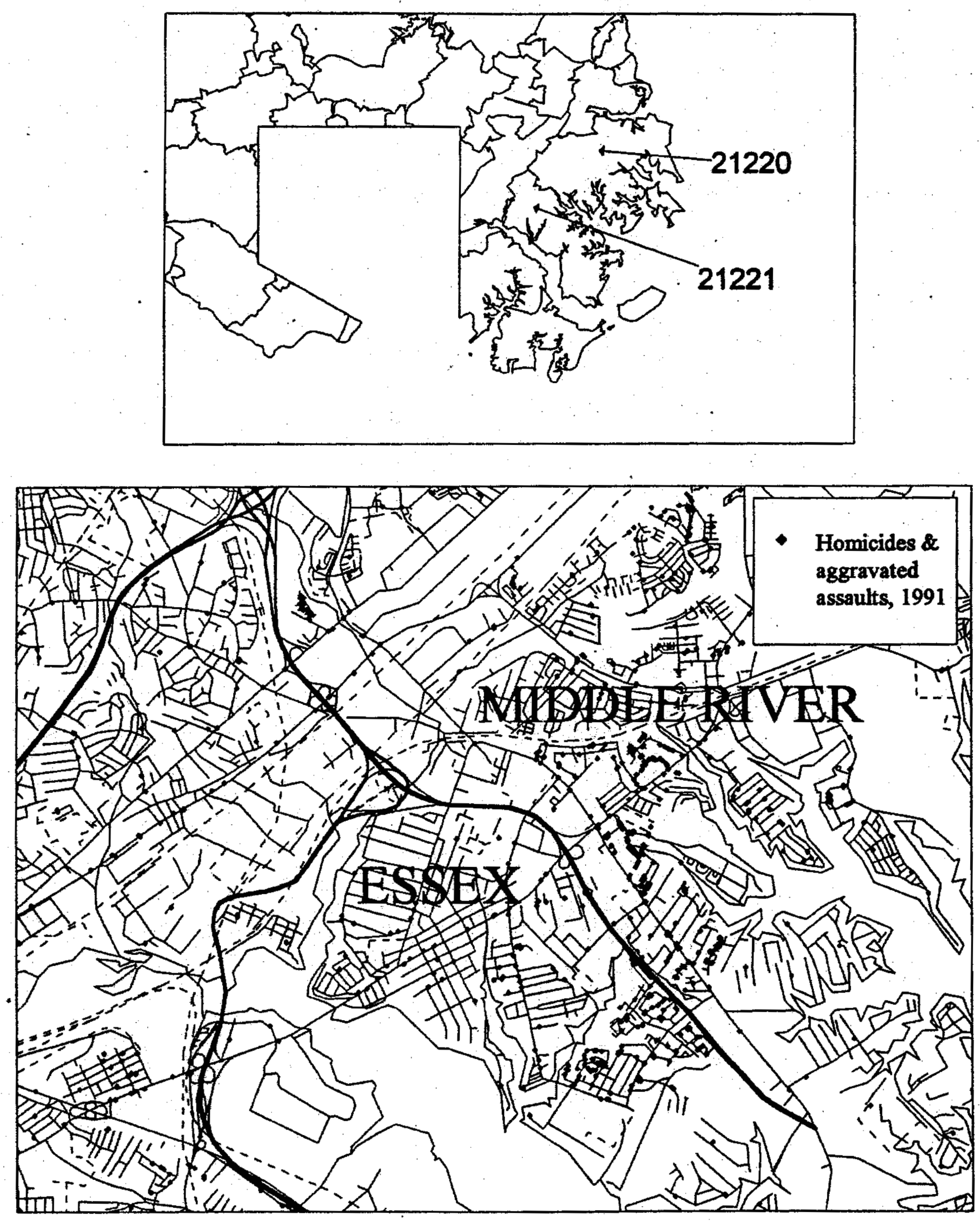

Figure 3. Study area, as originally proposed, in eastern Baltimore County, Maryland, with violent crime locations overlaid. Subsequently, the Dundalk community was included, west of Essex. Source: Author.

The dominant ethnic affiliation was German, with Irish as the second most often selected ethnic identity. With the sharp decline in industrial employment, these communities have struggled economically as relatively uneducated workers have attempted to find employment in an increasingly competitive workplace. One side effect of the economic distress has been fairly high levels of crime, as illustrated by the pattern of homicide and aggravated assault for 1991 shown in Figure 3. The combination of relatively high-density urban development and rather high levels of crime made the Essex/Middle River communities ideal for the proposed demonstration project.

II. COORDINATION WITH STUDY AREA PRECINCT COMMANDERS

Communication with the Baltimore County Police Department precincts in the study area was in integral element of this project. Initial meetings were held with Major McCleese, and Captains Johnson (Pct. 11, Essex) and DiPaula (Pct. 12, Dundalk) on March 16 and March 30, 1998. The March 16 meeting, held at police headquarters in Towson, was inconclusive owing to an emergency situation that forced an abbreviated meeting. The second meeting (March 30), held between the PI and the same commanders, involved a detailed review of data archive elements, with discussion of their appropriateness (or otherwise) and feasibility. It was primarily on the basis of this meeting that Table 1 was finalized. It was also agreed at the second meeting that the PI should ride along on 7am-3pm and 3pm-11pm shifts in both precincts in order to develop a better understanding of the geographies of each and the issues of most interest from the perspective of officers in the field. The PI offered to assist in the preparation of project-related materials that the commanders might find useful for community meetings or other salient purposes.

The ride-alongs planned with the precinct commanders occurred on April 15, 1998 (7am-3pm, Precinct 11, Essex); April 22 (3pm-11pm, Precinct 11, Essex); April 29 (7am-3pm, Precinct 12, Dundalk); and May 6 (3pm-11pm, Precinct 12, Dundalk). These ride-alongs were extremely useful in familiarizing the PI with the (complex) geographies of the precincts, and also for building rapport with several officers, including shift supervisors, and for beginning to understand the accuracy of the automatic vehicle locator (AVL) systems in patrol vehicles. In order to evaluate the latter, the PI asked officers to drive to specific intersections, whereupon a radio call was made to the dispatcher requesting a location reading. In virtually all cases, the dispatcher was able to provide the location, at least after the necessary (short) interval for positional updating. It was also useful to ride with officers with varying degrees of experience, from rookies to officers with many years of service. The PI derived a better sense of how the OPRA archive might be effectively deployed at the precinct level. It was encouraging to hear that officers would indeed use such an archive, and this anecdotal evidence was later supplemented by a formal survey documented elsewhere in this report.

III. PROJECT PHASES: OVERVIEW

1. Proving The Digital Orthophoto Quadrangle And Data Integration Technologies

This was done through the acquisition of the necessary digital orthophotography in the appropriate format. These data were supplied under contract by Baltimore County Government. Crime data came from the Baltimore County Police Department. Other data were acquired on an *ad hoc* basis depending on availability and compatibility. Data sets were integrated using the facilities of the geographic information systems (GIS) and cartography laboratories at the University of Maryland Baltimore County, as well as the in-house capabilities of the Baltimore County Police Department and the Department of Geography at Towson University.

2. Demonstrating The Utility Of The Orthophoto And Data Integration Technologies

In consultation with the Baltimore County Police Department and other interested agencies, applications were developed, demonstrated, and evaluated. As the project proceeded, more of its content was subsumed by the RCAGIS[2] project, as noted elsewhere, thus contributing to virtually total data integration in that context. Concepts developed in OPRA were ported over to RCAGIS to become a seamless part of that effort.

3. Testing Geocoding Technology

In this phase, conventional address matching was compared with sub-meter accuracy GPS and recreational (hand-held) GPS, in terms locational precision.

4. Developing A Web Page

This part of the project lagged owing to various logistical difficulties within Baltimore County government, including personnel changes and some degree of concern in relation to the content of the web page. As of this revision, work is essentially completed (see Appendix IV).

5. Evaluation

In order to assess the impact of improved visualization via orthophotography at the precinct level, project collaborator Philip Canter undertook a formal survey of 24 officers in the study area's Essex precinct. While it is recognized that 24 constitutes a small sample from a purely statistical perspective, the interviews were extremely time-consuming and this relatively small number exhausted available resources. Nevertheless, the PI and Philip Canter believe that the results of the survey are at least indicative if not definitive, and provide substantial encouragement for more widespread adoption of the technology.

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[2] Regional Crime Analysis Geographic Information System

IV. ENRICHING MAPS OF CRIME

1. Overview

In cooperation with the Scanning and Forecasting Team of the Baltimore County Police Department, and the Office of Information and Technology of Baltimore County Government, large scale digital aerial orthophotography was acquired and integrated with crime and numerous other relevant data bases including census data, liquor license locations, drug market data, injury locations, housing and zoning code violations, and other data relevant to the needs of community policing.

Thus any available data base can now be visualized in its actual environmental context, permitting a more vivid and information-saturated portrayal than has hitherto been the case, and facilitating a large number of applications and supplementing, if not supplanting, the use of "traditional" streets base maps in many of the applications where such maps have typically been used, as noted above: criminal intelligence and crime analysis, crime prevention, public information, and community policing.

- Police officers can now more easily recognize and contextualize information, whether that information is crime locations or various social or environmental problems. High resolution imagery provides an extremely detailed visualization that serves to convey almost any detail of interest to the reader. This capability is in the process of being provided to officers at the precinct level, pending upgrade of the departmental wide area network.

- Police dispatchers (increasingly likely to be civilians relatively unfamiliar with the detailed community geography of the city) have the potential to enrich dispatching information since they may now be able to refer to digital images and use landmarks as reference points if necessary. This is a potential application, as yet untested.

- Crime prevention officers, analysts, commanders, and police administrators can present more persuasive visual evidence of problems in order to better communicate with legislative bodies, community groups, and their professional colleagues. This was dramatically illustrated in the case of the Palczynski incident in Baltimore County in April, 2000, in which quick access to orthophotography, coincidentally provided by this project, was useful at the tactical level for assessment and planning.

- Planning is generally enhanced since proposed actions can be seen more vividly in their real world context and perceptions of the size and scope of proposed actions will tend to be more realistic and accurate.

- When appropriate, community residents can pick out their individual dwelling units or apartment buildings and see how the locations of crime incidents or other incivilities relate to their own locations even if they have no first hand experience of the events. This capability must be tempered by concerns for privacy in situations involving juveniles or victims of sex crimes.

The orthophotographic imagery consists of 20 "tiles" acquired from the Baltimore County Office of Information Technology. The 20 tiles cover the areas of southeast Baltimore County identified as problem areas by BCPD commanders a meeting with collaborator Philip Canter on September 10, 1997.

Tiles were selected to provide complete over-coverage of each area identified in this meeting. The tiles include a monochromatic photo (1:2,400 scale, usually referred to as "200 scale" as 1" = 200'), plus some 20 "coverages," or digitized environmental features, such as planimetrics (hydrography, buildings, roads, rail lines, cultural features, vegetation, topography, and cadastral features. These tiles were obtained on two CD-ROM media providing a permanent archive. (Tiles are between approximately 28 and 34 megabytes each, with coverages, for a total storage demand of about 620 megabytes for the 20 images.)

Census data (ArcView compatible digital maps and selected attributes) were obtained from the CIESIN/DDCarto[3] web site for tracts, block groups, and blocks. Philip Canter, the project collaborator at the Baltimore County PD compiled data at the block level incorporating crime and local features such as shopping malls, schools, liquor stores and taverns, and other cultural elements. It was not possible to acquire all preferred databases. Housing inspection data, for example, were not available and were not likely to become available. The patchwork quilt of data availability within Baltimore County government pointed to inconsistencies in access to what might be considered public information. However, these were problems that could not be solved within the scope of this project.

The unique Maryland *Property View* database for Baltimore County was also acquired for demonstration purposes only (due to license limitations). This database contains assessors' real estate records, including owners of record, (raster based) property line (cadastral) maps, and LANDSAT and SPOT images to provide context. Each rasterized property contains a hot spot that, when clicked on, produces all data base elements, of which there are about 75 per property. This can be a useful resource for community policing and could be integrated with the geoarchive under construction. At the time of writing this report, however, it is unclear whether access will be licensed for RCAGIS. The sought-after data elements (that go far beyond those proposed in the original proposal as funded) are listed in the attached table. As noted, most have now been incorporated.

The most serious difficulties encountered in the early stages of the project *conversion of maps between coordinate systems* and *conversions from one software platform to another.* Coordinate conversion generally needed to be from decimal latitude-longitude to NAD 83, the coordinate system of the ortho tiles. At the time, this was done successfully in ARC/INFO; today, however, this type of manipulation could be done most easily using the projection extension in ArcView. Conversion between software platforms generally involved translation from MapInfo to ArcView. This has been problematical, despite the existence (and employment) of conversion utilities such as "MIFSHAPE." While this type of translation has not been done in the later stages of the project, it is understood that later versions of both

[3] See: http://sedac.ciesin.org/plue/cenguide.html

MapInfo and ArcView make such translations a relatively easy matter, most recently though the use of Universal Translator in Mapinfo.

2. Pop-Up Pictures

A project enhancement performed without additional funding involved substituting a digital camera for the originally-proposed computer printer in order to permit the "hot linking" of ground-level pictures to land use maps and/or the orthophotos themselves. Thus by clicking on the map (or photo), a ground-level view will appear concurrently with the map/photo. This will permit users to connect to the more familiar "street" perspective while simultaneously seeing the broader view. Digital pictures are taken in the field, with the resulting image files read directly into the computer. This skips the intermediate (and in the case of processing, expensive) steps of film processing and scanning, and provide substantial graphic flexibility.[4]

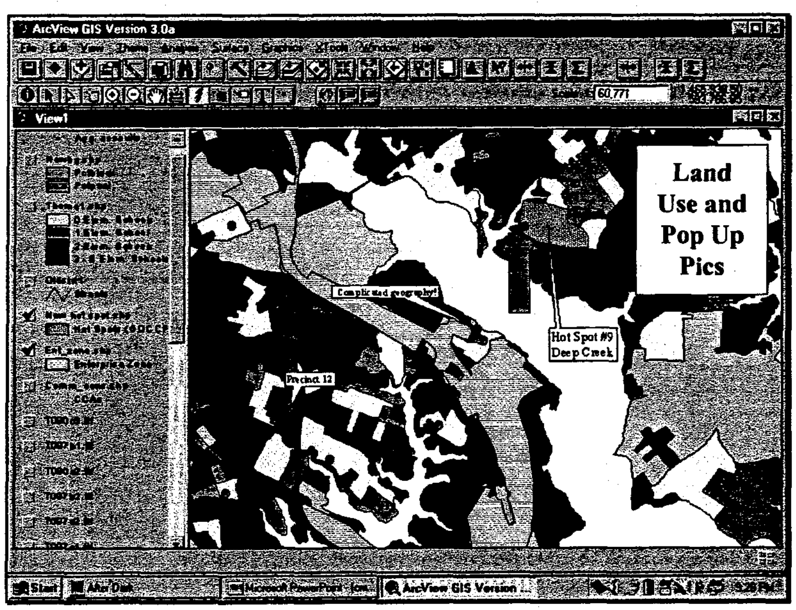

Figure 4. Ground-level digital photos can enhance visualization through hot links to a database, such as land use. The user clicks on a point to activate the pop-up. Source: Author.

[4] A Sony Mavica digital camera was purchased from grant funds and used to take pictures of representative neighborhoods and landmarks in the study areas. These were then incorporated into the land use coverage as "pop-up" elements. The method was as follows: a new column was added to the land use file. Symbols were placed on the land use map to represent places where ground level pictures had been taken. In the new column in the land use file, the path and file name of the relevant picture were placed in the appropriate table row. Then clicking on the symbol on the map pops up the image of that location.

Figure 5. The ground-level image pops up. Such digital photos could be used for training purposes as well as planning and tactical applications. Source: Author.

3. Experimentation With Quick Time Virtual Reality (QTVR) Visualization

Consistent with the overall goal of the project to enhance visualization of crime and its contextual data, an experiment was conducted in order to produce a *Quick Time Virtual Reality*[5] image of a selected location in the study area. *Quick Time* is proprietary software available free through Apple Corporation and commonly used to express virtual reality and streaming video and audio data. The particular mode of presentation prepared here was a 360 degree panorama than can then be "replayed" on a computer or embedded in Microsoft PowerPoint with a hyperlink that plays the graphic on demand. Images of this type have many potential applications in the criminal justice field, such as providing visualization for a jury to show detailed elements of a crime scene or neighborhood, training, community presentations, and other situations where a highly flexible mode of visualization is useful, such as legislative proceedings. This technology may have applications in community policing in conjunction with orthophotography and the "pop-up" ground-level imaging now incorporated in OPRA project ArcView coverages. For example, this technique is in some respects more flexible than video since it can be treated as both still and movie photography

QTVR has both advantages and disadvantages when compared to ordinary videotape. The principal advantage is that within the image, the user can tilt up and down and pan and zoom at will, in order to bring attention to specific details. Another advantage is that the image uses little disk storage space compared to video, which is extremely memory-intensive. The main disadvantage is that production of the image is relatively complicated, as noted below.

[5] Available at: http://www.apple.com/quicktime/download/indext.html

In order to prepare the QTVR panorama sample,[6] the PI and a colleague from the Department of Geography and Environmental Systems at the University of Maryland Baltimore County (UMBC) established a vantage point on Avondale Road in the historically African-American community of Sollers Point (in the Dundalk community in the study area). This location is of particular interest owing to the existence of a crude wall, built originally as a barrier to separate neighborhoods. A series of approximately 18 slightly overlapping pictures was taken in a precisely calibrated circle, and then "stitched" at the edges of each image using proprietary software (already available at UMBC) in order to produce the 360 degree picture. By mouse or keyboard manipulation, the viewer can explore the image, as noted, rotating through 360 degrees, tilting up and down, and zooming in and out. The National Gallery of Art, for example, uses this technology to permit virtual viewing of exhibits. Selected images used for the panorama are shown in Figure 6. These images were spliced together, edge-to-edge, to form the panorama. (See following page.)

[6] June 16, 1998. This experiment involved no additional project cost, and was done with the digital camera acquired for the project, plus a specialized tripod already owned by UMBC. Expertise was provided on a voluntary basis by Thomas Rabenhorst, Department of Geography and Environmental Systems, UMBC.

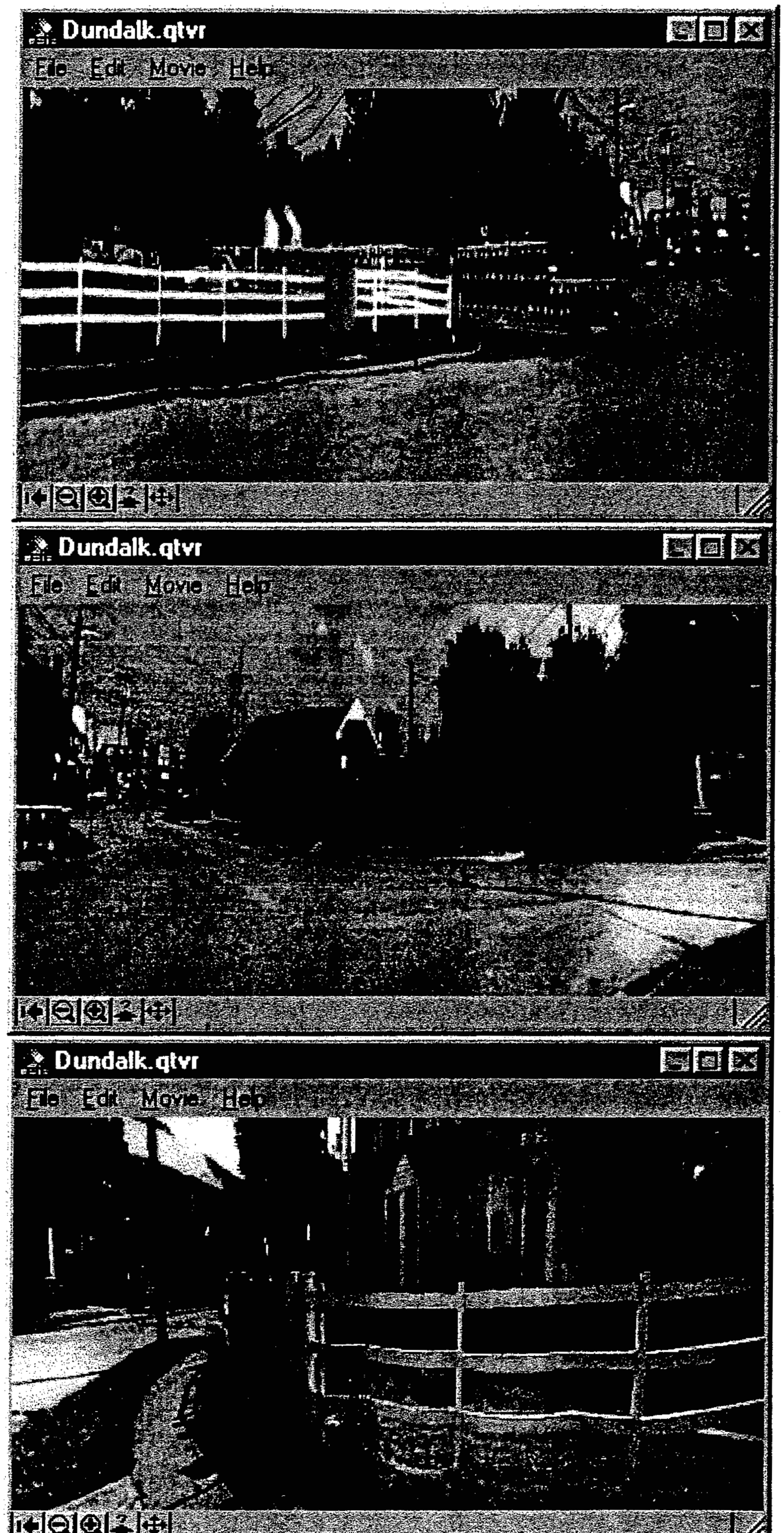

Figure 6. Images used to produce a Quick Time panorama in the Dundalk area. The right side of the top image was spliced to the left side of the middle image. The right side of the middle image was spliced to the left side of the bottom image. This process was continued for all 18 images. Source: Author.

V. DATA INTEGRATION

1. Need For More Integrated And Spatially-Enabled Data

A major effort in the initial stages of this project involved assembling spatially-enabled databases that would assist the process of improving the context in which crime analysis is performed. These efforts are summarized in Table 1. Over the course of the more than three years of the project, a major development occurred providing synergistic benefits. This collateral advance was the multi-year construction of the *Regional Crime Analysis GIS* (RCAGIS) project by a programming team at the Department of Justice, in collaboration with the Baltimore County Police Department and Baltimore City Police Department. A natural evolutionary development was the incorporation and further development of some concepts from this (the OPRA) project into RCAGIS. These developments included the embedding of orthophoto capability and easy access to contextual databases including those shown in Table 1 and Figure 7. It was originally anticipated that the data integration effort would be essentially free-standing, but the advent of RCAGIS has meant that data integration has been subsumed under the RCAGIS rubric, thus effectively (and constructively) superceding efforts made in the OPRA project.

Figure 8 represents current versus idealized modes of data integration. At present, each agency at each level of the criminal justice system maintains its own records. Generally, agencies are extremely reluctant to share data, owing to a complex of reasons including territoriality, longstanding rivalries between agencies and individuals, fear of consequences arising from the use or misuse of the data by others, and a need for confidentiality relating to juvenile status, sexual victimization, or doctor-patient relationships, as in the case of offenders undergoing treatment for addictions. The extreme fragmentation of agencies in the U.S. makes cooperation and data integration quite difficult and renders a project of the scope of RCAGIS remarkable in that the reality of regional integration is exceptionally hard to achieve.[7] Given that misconduct in the compilation of law enforcement data is not unknown, an additional problem is that a secondary user of data has no way of verifying that information. Clearly, it is not beyond the realm of possibility that data could be inappropriately manipulated before being passed on to a secondary user.

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[7] In 1999, there were 13,524 local police departments and 3,088 sheriffs departments in the U.S. When the 49 state police departments were included, the total number of agencies (excluding those with federal jurisdiction) was 16,661, or approximately one department for every 17,000 people.

TABLE 1. DATA SETS ACQUIRED AND INTEGRATED AS PART OF THE OPRA PROJECT AND NOW AVAILABLE IN RCAGIS

Description	*B*oundary, *S*treet, *P*oint, *A*rea	**Application**	**Source**	**Notes**
Accident hot spots	Area	QOL/Planning	BCPD	Acquired
Arrestees' addresses	Point	QOL/Risk	BCPD	Acquired
Bus stops	Point	Mobility/risk	MTA	Acquired
Census geography: tracts, block groups, blocks*	Area	Social indicators & QOL	Various	Acquired
Clients in drug treatment	Area (Aggregated to tracts)	Health/QOL	Parole and probation	Access restricted
Community Conservation Areas & Enterprise Zones	Area	QOL/Community Planning	Planning (CCAs) Economic Development (EZs)	Acquired
Banks	Point	Risk	Balto. Co.	Acquired
Convenience stores	Point	QOL	Balto. Co.	Acquired
Fast food	Point	QOL	Balto. Co.	Acquired
Pawn shops	Point	QOL	Balto. Co.	Acquired
Drug markets Existing & emerging	Point	Hot spot	BCPD	SATS (Substance Abuse Tracking System)
Hot Spots	Area	Md. Hot Spot Communities & Operation Spotlight Sites	Gov. Comm. of Crime Control & Prevention	Acquired
Housing Code violations	Point	QOL/Community planning	Unavailable	Unavailable
Land use	Area	Hot link to pop-up pictures	BC	Acquired
Liquor licenses	Point	Buffer/QOL	BC	Acquired

Parks	Area	QOL/Risk.	BC	Acquired
Parolees Probationers	Point	Hot spot	Parole and Probation	Restricted
Part I Crimes	Area (Blocks)	1992-96 N = 226,103	BCPD	Acquired (BCPD)
Precinct bdys.	Line		BCPD	Available
Rest/Bar, ShopCtr, Mall, Tavern, Package, Schools (E,M,H)	A (Blocks)	Reference/Risk/ QOL	Various	Acquired (BCPD)
Section 8 housing	Point	Risk	Unavailable from any source	Unavailable
Registered Sex Offenders	Point	QOL	Parole and Probation	Restricted
Strategic Objective Areas	Point	PD Planning	BCPD	Acquired
Streets	Line	Reference	Various	Acquired

QOL = Quality of Life
*The Census category included some 200 variables.
Source: Author.

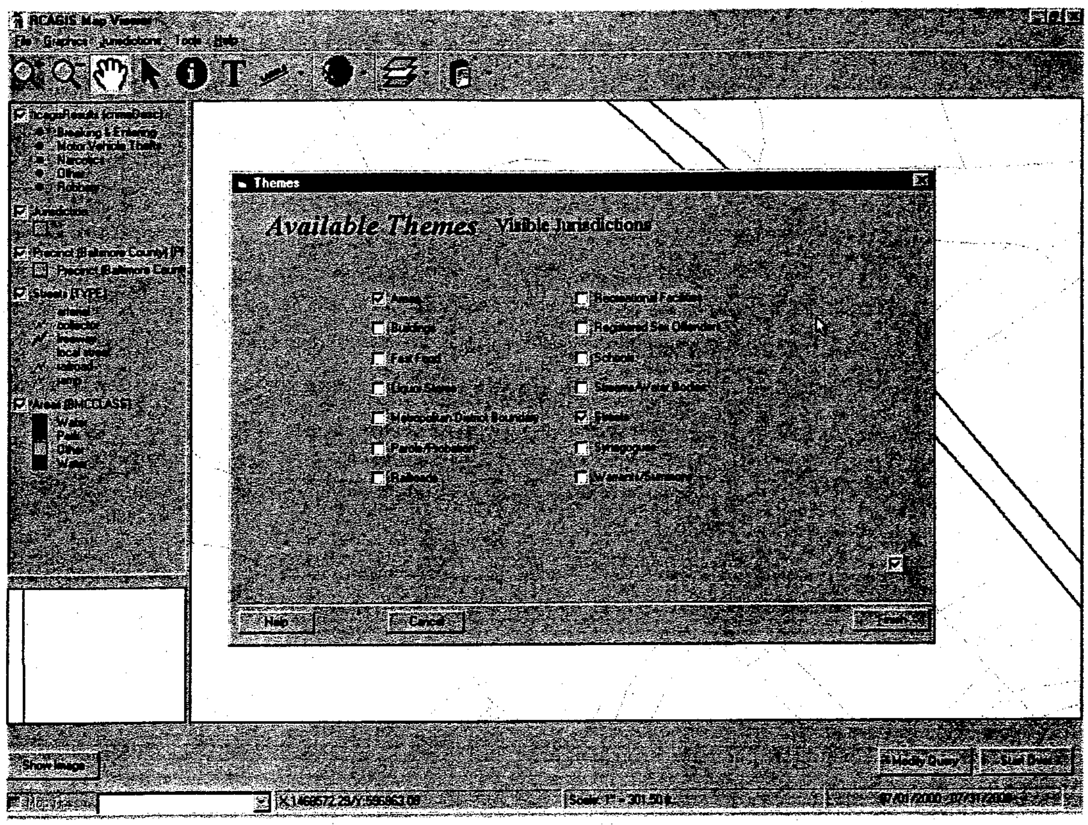

Figure 7. RCAGIS interface providing access to contextual variables. Only selected variables extracted from a larger list are shown. Source: Philip Canter, Baltimore County Police Department.

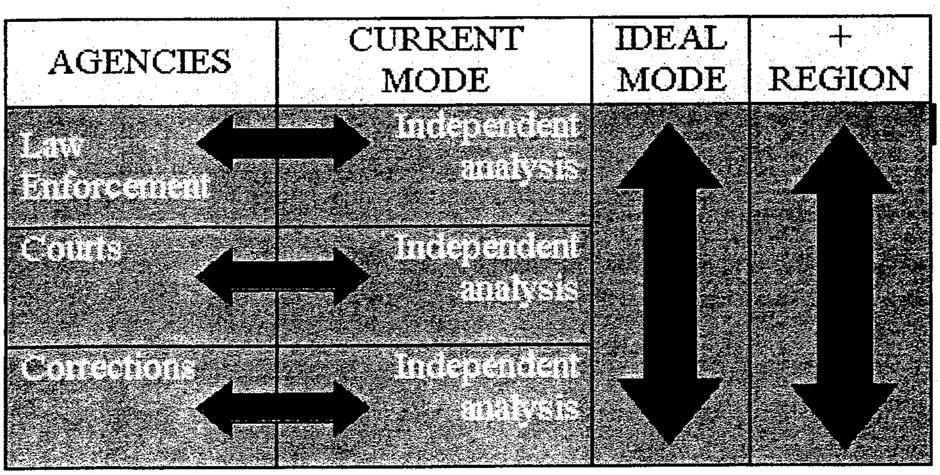

Figure 8. Cross-level integration – current and ideal modes of operation with respect to data integration. Source: Author.

The underlying assumption driving the need to integrate datasets of substantial breadth and scope is that law enforcement touches virtually every aspect of life in some way, and therefore needs access to data about virtually every aspect at one time or another. Clearly, access to such wide-ranging data is not needed on a daily basis, but the point is that such data is like an encyclopedia – you may not need to look up a specific item very often, but when you do need information you need it right now. In law enforcement, timeliness is everything, given the urgency of so many incidents and situations.

VI. USING A GLOBAL POSITIONING SYSTEM TO IDENTIFY CRIME LOCATION COORDINATES[8]

The purpose of this demonstration project was to evaluate whether digital orthophotographs improved an officer's ability to read and interpret a crime map. The primary benefit associated with aerial photographs is its realistic perspective. As noted earlier, traditional centerline or "stick" maps lack the detail needed to relate crime to its surrounding environment. Crime locations accurately placed over an aerial photograph could enable an officer to relate criminal activity to other map features such as buildings, parking lots, and wooded areas.

Most point locations are placed on a map using an address matching procedure available in a Geographic Information System (GIS). The geographic accuracy of a point location as defined by its respective x-y coordinates is dependent on the digital and attribute accuracy of the basemap. The digital accuracy of a basemap can be influenced by a theme's geometry, scale, and projection. For example, a map attempts to represent, as realistically possible, the earth's surface. A criticism often directed at the traditional centerline or "stick" map is its rigid, linear representation of smooth or rounded features such as interchange loops or curvilinear streets. Assume the point location appears to be accurately placed on the map as determined by its relation to some control point, say an intersection. The same point coordinates located on a new, better aligned centerline map may not even appear on the street. The point, when displayed over an aerial photograph, may be located in a pond or woods.

Considerable attention is given to the cosmetic appearance of a map and its ability to visually communicate graphic information. The geometry and alignment of suitably scaled features such as roads and streams is an important component in determining map accuracy. The geographic accuracy of a digital map file, while important, is useless for geocoding unless the digital map file has good attribute information. An "attribute" contains information about a map feature used for geocoding. Most crime locations are geocoded using the incident address. The incident address has to be matched against the same attribute information attached to a digital map file. For example, the attribute information associated with a digital map file used for geocoding crime locations by address typically consists of a street segment containing a street number range corresponding to the left and right sides of a street, a street name, and street direction. In the most simplistic example of address matching, a crime location identified by a street number and street name is matched against the attributes in a digital map file. The coordinates are determined by relating the matched road segment to the digital map. Digital map files with inaccurate or missing attribute information will result in a low geocoding rate, or an inaccurate coordinate.

Since the geographic accuracy of point locations determined by address matching against a 2000 scale centerline file was questionable when displayed over a more accurate digital orthophotograph, it was necessary for purposes of this demonstration project to obtain coordinates using a Global Positioning System (GPS). A coordinate determined by a real-time differential GPS more accurately represents a point location on the earth's surface.

[8] This section was contributed by Philip Canter.

Two types of GPS were used: Magellan GPS ProMark X-CM with an Ashtech BR2 Beacon Receiver for real-time differential GPS, and a recreational Magellan GPS Colortrak model. The GPS equipment was calibrated and checked for accuracy with assistance from the GPS vendor and a geography student from UMBC. The GPS point coordinates were entered into a special data field within the Regional Crime Analysis Program (RCAP) data table for subsequent analysis.

Comparing geographic coordinates obtained through address matching relative to coordinates determined by a GPS

Geographic coordinates obtained through address matching against a 2000 scale digital map file will not relate directly to a basemap or image developed at a larger scale. Of interest was the amount of difference between coordinates derived by GPS and point coordinates determined by address matching. Differences between the two coordinate pair values would be expected, but large differences would suggest that significant problems exist with the smaller scale basemap. The types of problems could reflect inaccuracies in the digital map or the attributed information attached to the basemap.

A total of 350 cases were initially examined; 13 of the 350 cases (3.7%) were deleted from further analysis because the address could not be addressed matched (7 cases or 2.0%) or because the address information was incorrect (6 cases or 1.7%). Distances between the two coordinate pair values were computed using the distance function in *MapInfo*. The remaining 337 cases show the distances to be positively skewed towards lower values (skewness=3.0). The minimum distance between coordinates determined by geocoding, compared to GPS was 10.7 feet. The median distance was 117 feet. The following are descriptive statistics for distances measured between geocoded versus GPS coordinates.

	Distance in feet
N of cases	337
Minimum	10.666
Maximum	1125.696
Median	117.005
Mean	162.865
Standard Dev	155.677
Skewness(G1)	3.035

Although distances between the two coordinate pairs were somewhat less than expected as indicated by the positively skewed distribution, the last quartile was comprised of distances greater than 190 feet.

Distances also remained skewed regardless of the type of crime. The median distances for robbery cases (114.89 feet) was slightly less than residential burglary (118.19 feet) and motor vehicle theft (121.8 feet). Kruskal-Wallis One-Way Analysis of Variance revealed no statistical differences in distances between any of the three crime types.

The distances calculated between point locations represented by coordinates determined through address matching (geocoding) and GPS are indicative of the problems encountered in projecting the earth's surface on to a two-dimensional map. The problems are compounded by differences in scale, geometry, and attribute information associated with a digital map file used for geocoding. The value of determining accurate coordinates using a GPS as opposed to address matching, and then locating those coordinates on to a geographically accurate two-dimensional surface can reveal important information about environmental factors contributing to a crime event. It is also important to recognize that inaccurate coordinates placed over a digitally corrected map or aerial photograph can mislead an analyst or investigator.

Figure 12 demonstrates both issues: making inferences about factors possibly contributing to a criminal incident (motor vehicle theft) based on an inaccurate point location, and the possible benefits realized by accurately locating a point over a 200 scale digital orthophotograph. The motor vehicle theft occurred around July 9th in a residential area. The circle shown on the orthophotograph represents a point location (motor vehicle theft) determined by address matching against a 2000 scale centerline file. The square identifies the theft location determined by GPS coordinates. The victim was asked to identify the car's location prior to it being stolen. The distance between both point locations is 348 feet.

The location determined by address matching places the theft at the end of the street near a heavily wooded area. The theft location is also outside of the apartment complex. One response may be to advise people not to park in a dark, secluded area. Perhaps no parking signs would be posted if auto thefts became a recurring problem in the area; or street lighting might be installed, particularly if it was assumed that people were parking along the street because of parking shortages in the apartment complex. In fact, the car was not stolen at the location shown on the aerial photograph. The GPS location clearly shows the car was parked within the apartment property in a parking space located on the southwest side of the complex. Police would probably interview possible witnesses who reside in buildings around the actual theft location (there are not many possible witnesses surrounding the wooded location). There may also be possible design (lighting, landscaping, etc.) or security issues that could be considered if the auto theft problem is recurring. It is interesting to note several officers mentioned during the evaluation phase of the demonstration project that it was helpful to see where a car was parked when it was stolen.

Figure 13 shows two robbery locations, one determined by address matching (represented by a circle) and the other by a GPS (square). The robbery occurred on June 19th on Eastern Boulevard. The distance between both point locations is 496.6 feet. The robbery location determined by address matching places the point outside of the shopping center identified as the crime location by GPS, across the street (Eastern Boulevard), and on to another commercial property. The robbery actually occurred near the store's entrance as the victim was walking towards their car parked on the shopping center lot. Distances calculated between address matched point locations and locations determined by GPS for robberies occurring on parking lots (n=3, median=496.6 feet) were much higher than the median distances reported for cases reported during the study period (n=337, median distance=117 feet) and other robberies (n=37, median distance=114.9 feet). The large distances in actual (GPS) versus interpolated (address matched) parking lot robberies suggests considerable mapping error is being introduced by address matching.

Figure 9. Motor Vehicle Theft Locations determined by GPS (Square) and address matching (circle). Source: Philip Canter, Baltimore County Police Department.

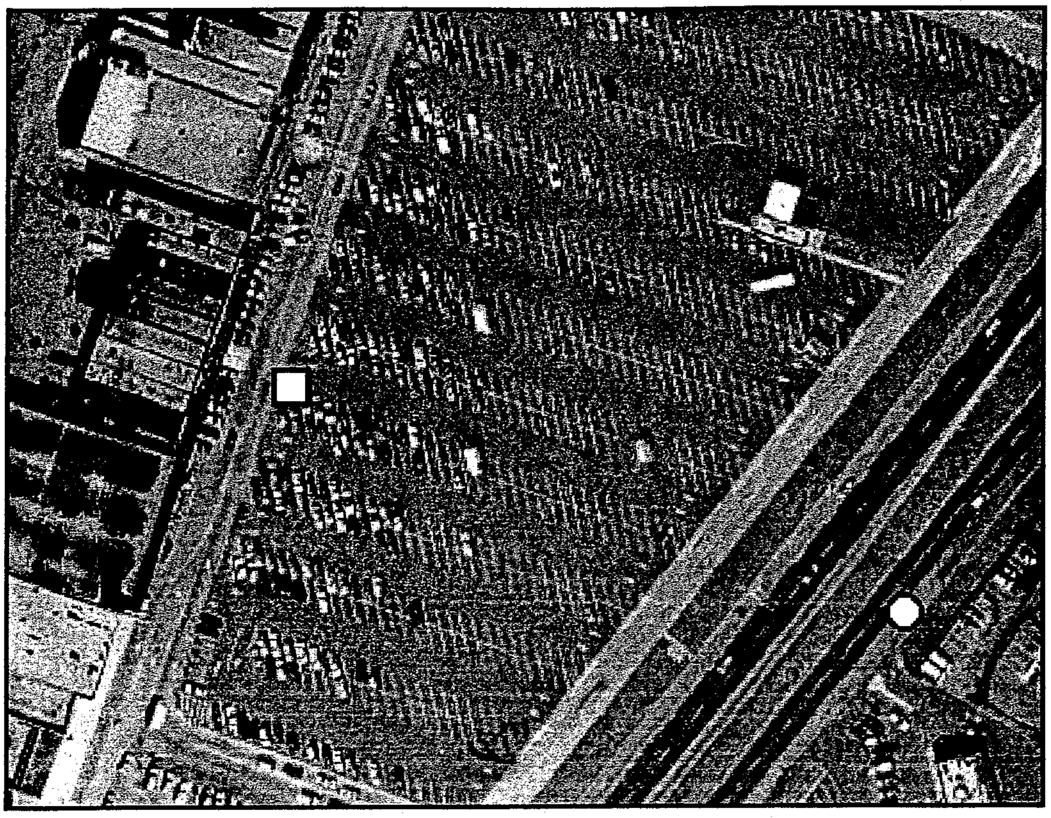

Figure 10. Robbery Locations determined by GPS (square) and address matching (circle). Source: Philip Canter, Baltimore County Police Department.

The relative distances calculated between a pair of point locations (GPS versus interpolated coordinates) is low in Baltimore County, suggesting differences between digitally corrected orthophotographs and 2000 scale base maps used for address matching are not too significant. Interpolated point locations using conventional GIS procedures are adequate when viewed relative to centerline or "stick" maps, provided digital and attribute issues are satisfactorily addressed. Problems can result, however, from mapping address matched point coordinates against a digitally corrected image or basemap. Point locations determined by address matching (or geocoding to any other basemap using centerlines or polygons, including Cadastral files) should not be construed as representing the actual crime location. Overlaying interpolated point coordinates against a digitally corrected image or basemap could be misleading. The potential for problems in interpreting a crime map can occur if interpolated point locations are viewed in relation to more accurate basemaps or aerial photographs.

The availability and use of inexpensive GPS equipment can significantly improve crime mapping. The officer assigned to take GPS readings was enthusiastic about using the less expensive, hand-held recreational GPS equipment (coordinates from the hand-held unit were very accurate, and comparable to coordinates obtained by the more expensive differential GPS). The value of examining crime locations relative to an aerial photograph or accurate planimetric map cannot be overstated. Officers surveyed in Baltimore County recognized the value of relating crime locations to an aerial photograph and building footprints, particularly when the map was displayed at a large-scale view. The use of digital orthophotography and planimetric maps significantly improves the visualization of crime data.

VII. EVALUATING THE USE OF CENTERLINES, AERIAL PHOTOGRAPHS, AND BUILDING FOOTPRINTS FOR NEIGHBORHOOD AND COMMUNITY SCALED MAPS[9]

In 1990 the US Bureau of Census created the first digitized map of U.S. streets called TIGER (Toplogically Integrated Geographic Encoding and Referencing files). Most commercially available digital map files used for address matching and display either resemble or are derived from TIGER files. As computer crime mapping gained wider acceptance among police, crime incident locations were often mapped against abstract centerline or "stick" streets based on a TIGER format. Although generally easy to read and understand, centerline maps are not very effective in visually communicating a realistic representation of the mapped area.

As police become more experienced with using GIS for crime mapping, the possibility exists that additional information such as building footprints and other planimetric features will be used to provide a more visually appealing map. An unintended consequence, however, may be a map that is more complex to read and interpret. The question is whether aerial photography and building footprints improve visualization of mapped crime data; and whether the improvement, if noted, was independent of map scale. To our knowledge, no comparable studies had been conducted on this topic.

Methodology

A total of 24 police officers from one precinct were individually interviewed. Each officer was shown a series of maps covering a part of their precinct. All of the officers were able to immediately recognize the area shown using a basic centerline map. The maps were displayed at two different scales. The first group of maps was displayed at a large (neighborhood) scale equal to 1:2,697; the second group of maps was displayed at an intermediate (community) scale equal to 1:12,500. The neighborhood scaled map closely corresponds to the department's reporting area, an areal unit of police geography typically associated with a residential subdivision, shopping center, park, or recreational area. The community scaled map approximated an area covered by 2-3 police cars. Major streets were labeled on all maps. Each map group (large and intermediate scale) consisted of four maps showing the location of robberies, residential burglaries, and motor vehicle thefts. Geographic coordinates were obtained using a Global Positioning System (GPS). The GPS improved the geographic accuracy of crime locations shown in relation to map features such as building footprints, parks, streams, and aerial photography. Each interview lasted approximately 25 minutes.

The first map showed street centerlines commonly referred to as a "stick map". The second map showed street centerlines and building footprints color-coded by land use. The third map displayed street centerlines and an aerial photograph. The fourth map was a combination of

[9] This section was contributed by Philip Canter.

the previous three maps (centerlines, building footprints, and aerial photograph). Police were asked a series of questions designed to measure the utility of GIS for crime mapping at different map scales.

Officers had definite opinions about which types of maps they preferred when seeing crime locations at the neighborhood scale. Initially, officers viewed centerline maps favorably, although several commented that it was difficult for them to relate crime locations to other map features such as parking lots and buildings. At best, officers used a centerline map to determine whether certain types of crimes were occurring in particular neighborhoods or blocks. Officers tended to find a neighborhood map more useful when additional information, such as building footprints and aerial photographs, were introduced to the display (Figure 12). Several officers began to relate crime locations to other map features such as the type of land use, parking lots, and proximity to wooded areas when viewing crime with an aerial photograph or building footprints as a background.

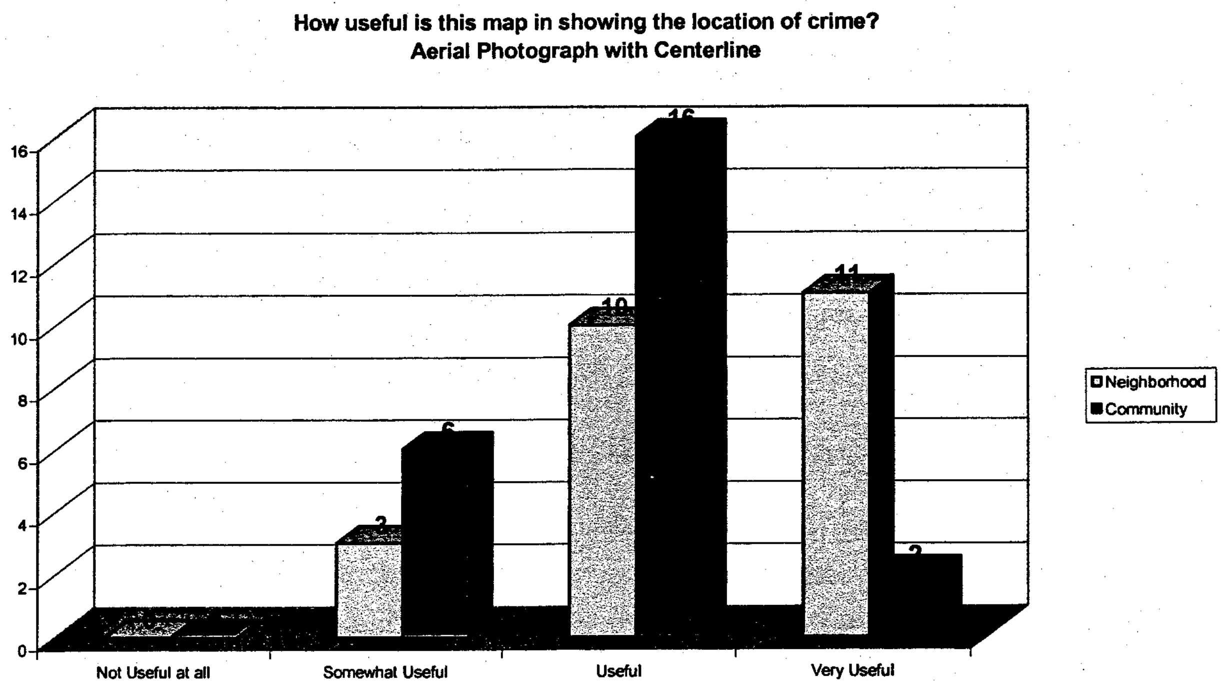

Figure 11. Aerial photos with centerlines were found useful at both neighborhood and community scales. Source: Philip Canter, Baltimore County Police Department.

The opinions of officers regarding the types of features displayed on map at a community scale were more varied. Some preferences became apparent by comparing responses for different map types for each scale. For example, a larger number of officers preferred a centerline map for viewing a crime map at a community scale compared to a neighborhood scale; whereas, the use of building footprints on a map tended to be viewed more favorably at the neighborhood scale. Most officers, however, still preferred to use a combination map for displaying crime locations at the community scale (Figure 13).

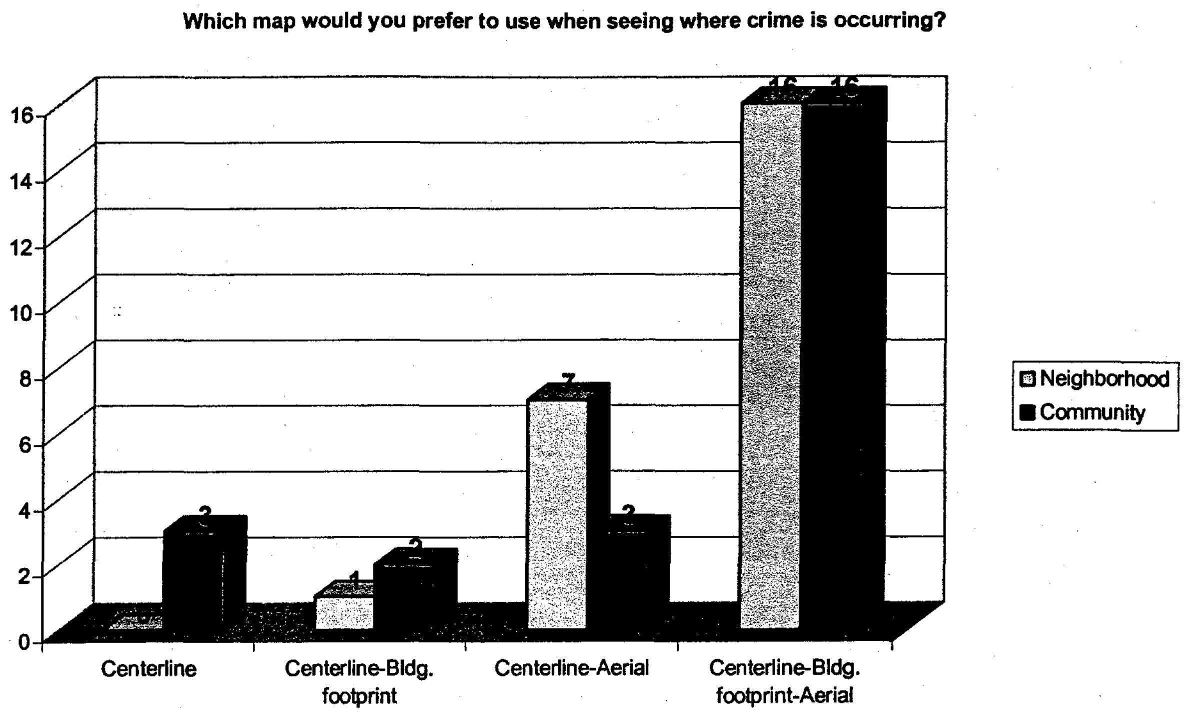

Figure 12. Combination representations were preferred by officers. Source: Philip Canter, Baltimore County Police Department.

Officer Responses

Conclusions based on the survey findings should be viewed with caution due to the relatively small sample size (n=24). Attempts to test differences in responses relative to map scale were influenced by low expected cell values, even after categories were merged to increase the number of reported cases. Survey responses, therefore, may very well be due to chance. It is apparent, however, that officers tended to believe that:

- The interpretation and use of large-scale crime maps can be improved when aerial photography and building footprints are introduced to the display.
- Officers were able to relate the location of a crime incident to other map features such as buildings, wooded areas, and parking lots.
- Officers generally believed that aerial photographs and building footprints improved their ability to read and interpret a crime map.
- Centerline maps tended to be more useful when displayed at an intermediate, community scale.
- Aerial photographs improved the visualization of mapped crime data, particularly when displayed at a large scale.

There are methodological issues associated with the survey. Officers were only presented with two scaled views: a large scale, neighborhood view (1:2,697) and an intermediate, community scale (1:12,500). A progressively increasing view from neighborhood to community may be better in ascertaining scale effects on map interpretation.

In summarizing survey findings two important factors appear. First, officers universally recognized the value of GIS for crime mapping. Several officers, unaware of the capabilities of a GIS, commented about the need to see information on a map associated with a crime location or map theme. In response to this point, the interviewer would use a GIS to demonstrate the ability to label map features or obtain information about crime locations after the survey had been completed. In several instances, officers after the interview asked to use or see further examples of GIS. Many officers expressed interest in having access to a GIS in their patrol cars. A comment commonly made during interviews was an interest in seeing street blocks and buildings labeled with addresses. Officers believed this information would greatly assist them in finding an unfamiliar building or location in response to a 911 call.

A second factor pertains to an officer's individual training and map interpretation skill level. The survey was intentionally structured to introduce a series of maps in a given order to simulate the use of a GIS for crime mapping. Officers in Baltimore County comfortable with using GIS for crime mapping will generally construct a crime map starting with a centerline view, and gradually introduce additional information such as building footprints and aerial photographs as needed. There are practical reasons for this process, such as the greater amount of time needed to display graphically intensive images such as aerial photographs for small scale maps. In training on the use of GIS in Baltimore County, officers are encouraged to construct a centerline map first, followed by the introduction of aerial photographs, building footprints, and other planimetric features as needed. Officers liked the option of introducing other sources of information to a map display, but in the end it depended on the purpose for making a map and the personal preferences of the officer.

VIII. SUMMARY

This project leads to the conclusion that the use of digital orthophotography and planimetric maps improves the visualization of crime data, and these tools can be further enhanced through the use of GPS instrumentation. The utility of these tools can be further enriched if a comprehensive community database is spatially enabled permitting the overlay of any selected element on a conventional digital streets framework or an orthophotograph. Since the commencement of this project, orthophotography has become more widely available and the adoption of this type of imagery has become increasingly commonplace in law enforcement (see Appendix II). The principal findings of this research were as follows:

- The acquisition and deployment of aerial photography in support of law enforcement are feasible.

- The integration of aerial photography, digital street maps, and collateral supporting data can be accomplished relatively easily without the need for additional software or other systems.

- Global Positioning Systems (GPS) technology can provide accurate positional data and would be most useful in situations in which conventional street address data are not available, such as shopping malls, parks, and other open public spaces. GPS technology may permit skipping the geocoding step in GIS, although further research is needed to evaluate this issue.

- Police officers generally react positively to the availability of orthophotography in concert with other coverages, such as building footprints. However, small sample size in the survey conducted on this question makes strong conclusions inappropriate.

This project has systematically explored and evaluated the pros and cons of enhancing spatial data in law enforcement by bringing together maps, imagery, contextual data, and GPS-enhanced crime data. While it cannot be claimed that these technologies will provide cost-beneficial advantages to all law enforcement agencies, it is clear that the tools can make a positive contribution in a wide variety – if not all – circumstances.

Reduced costs of imagery (often by utilizing orthophotography obtained by local government for other purposes) and the removal of selective availability in the GPS signal have meant, in conjunction with much cheaper digital storage, that the tools reviewed here are within the reach of more law enforcement agencies. Access will improve as these tools become accepted as necessary components in the law enforcement repertoire. The release of 2000 Census of Population and Housing data in the near future in combination with the advent of the Census Bureau's *American Community Survey* will also assist agencies in building timely data to assist the understanding of social processes affecting the dynamics of crime in small areas.

In less than a decade it is not unreasonable to expect that police officers, as a matter of course, will have wireless access to needed databases, including orthophotographs, as well as wearable GPS units capable of superceding geocoding processes in units responsible for geocoding. This, in turn, would make crime data available in a more timely manner, enabling field commanders and managers to make decisions about resource allocation on a nearly real time basis. This should improve crime prevention and generally reduce lag times in the deployment of resources caused today by delays in data coding and processing.

The issue of costs versus benefits in connection with the implementation of the technologies examined here warrants additional investigation. Clearly, the universal adoption of these tools is unnecessary. Some methods will see more rapid and more widespread adoption than others. Digital aerial photography is widely used by local governments, and acquiring access to such imagery will in many cases involve little more than a request from the police department to another unit of local government. Even specialized software, beyond basic GIS capability, is unnecessary, since GIS programs accept so-called "raster" files (represented by digital imagery) and can manipulate them as layers like digital maps or other spatial data. GPS is a little more problematical, although the removal of selective availability, as noted elsewhere in this report, has meant that cheap, hand-held units provide a level of accuracy acceptable for most law enforcement purposes. Whether miniaturization[10] and cost reduction will result in universal adoption remains to be seen. At this time, it seems unlikely that GPS will become part of every police officer's uniform, but it is likely that GPS will find niches of utility where "value added" will justify cost, such as recording locations that have no street address. Similar observations apply to imaging. In-vehicle video cameras, for example, are finding widespread use for monitoring patrol activities and providing fairly definitive evidence of the actions of officers and the public they deal with, and it is this type of niche use that other modes of imaging will be used to support. While universal adoption would not be cost effective, niche uses, with limited outlays of hardware, software, and technical expertise, possibly shared among agencies, may justify costs.

[10] GPS wristwatches are now on the market at a cost of less than $500. See, for example: http://www.casio.com/watches/product.cfm?section=14&market=4&product=3682

APPENDIX I

Key Word "Demonstration": The Lecture And Seminar Component

Summary Of Presentations With Total Or Substantial OPRA Content

Given that a key word in the title of this project is "demonstration," it is appropriate to document the occasions on which this project has been the sole or partial subject of a paper at a professional meeting or an invited presentation, commentary, or publication. In another NIJ project, for example, a book was prepared as a primer on crime mapping for crime analysts. Parts of that publication contained various discussions and illustrations of materials derived from the OPRA project. This publication appeared in late 1999 (*Mapping Crime: Principle and Practice*. Washington D.C.: U.S. Department of Justice, National Institute of Justice, Crime Mapping Research Center). While there is no reliable way to measure the effect of various presentations, the PI has made strenuous efforts to convey to a diverse set of audiences in three countries the potential utility of aerial photography, and allied technologies such as global positioning systems (GPS). These audiences have included cadets in multiple sessions of the Maryland Police Corps, and the FBI Academy, Quantico, and at the annual conference of the Crime Mapping Research Center, trainees at several police academies in India, including the National Police Academy in Hyderabad*, and professional meetings of criminologists, geographers, and psychologists. A list of these 30 presentations follows:

1997. Applications of geographic analysis in policing. Lecture presented by invitation to the 1st session, Maryland Police Corps, Linthicum, MD, September 26.

1997. Cartography: From pins to contours. Two workshops co-presented (with J. LeBeau, Southern Illinois University) at *Exploring the future of crime mapping: A national symposium on the use of GIS in criminal justice research and practice.* Denver, CO, October 5-7.

1997. Integrating and visualizing data using geographic information science: Concepts and applications. Lectures presented by invitation to combined classes in *Applied research methods in law enforcement* and *The practice of crime analysis* to the 190th session of the FBI Academy, Quantico, VA. October 20.

1998. Lectures dealing with crime mapping and analysis were delivered in India by invitation at the following institutions (February):

- Department of Sociology, University of Madras
- Department of Criminology, University of Madras
- Police Training College, Chennai [Madras]
- Department of Geography, S.P. Chowgule College, Margao, Goa
- Department of Geography, University of Rajasthan, Jaipur
- Rajasthan State Institute of Public Administration, Jaipur
- S.V.P. National Police Academy, Hyderabad
- Vellore College of Engineering, Vellore
- Regional Institute for Correctional Administration, Vellore
- Department of Sociology, Pondicherry University, Pondicherry

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*A graduate student in criminology at the University of Madras, Chennai, India, was prompted to write his Ph.D. dissertation on crime mapping as a result of one of these presentations advocating enhanced visualization. The Madras [Chennai] Police Department is now in the process of adopting some of the techniques demonstrated in the dissertation.

- Dr. Ambedkar Government Law College, Pondicherry

1998. Orthophotos and community policing. Lecture delivered by invitation to the National Institute of Justice, Cluster Conference on the Development of Spatial Analysis Tools. Washington D.C., February 26. With Philip Canter.

1998. Applications of digital orthophotography in community policing. Towson GIS: 11th Annual GIS Conference, Towson University, Towson, MD, June 3.

1998. New approaches to crime mapping: Applications in crime analysis. Lecture delivered by invitation to the annual conference, International Association of Crime Analysts, San Diego, CA, November 5.

1998. Applications of orthophotographic representation in community policing. Lecture delivered by invitation of the National Institute of Justice, to the National Conference on Community Policing, Arlington, VA, November 9.

1998. Innovative approaches to the enhancement of crime visualization. Plenary address, delivered by invitation to the Second Annual Crime Mapping Research Conference, Arlington, VA, December 10.

1998. Cartography: From pins to contours. Two workshops co-presented (with J. Szakas, ICPSR and USDOJ) at *Mapping out crime: Second Annual Crime Mapping Research Conference*. Arlington, VA, Dec. 11, 12.

1999. Automated Mapping: New opportunities in law enforcement. Lecture delivered by invitation to the Maryland Police Corps, Linthicum, MD, January 28.

1999. Approaches to the enhancement of visualization in GIS and crime analysis. Annual conference, Association of American Geographers, Honolulu, HA, March 28.

1999. Data visualization and integration in criminal justice. Presentation by invitation to the Summer Assembly of the University Consortium for Geographic Information Science, Center for Urban and Regional Affairs, Hubert H. Humphrey Center, University of Minnesota, Minneapolis, MN, June 24.

1999. Principles of crime mapping. Two workshops delivered by invitation of the Crime Mapping Research Center, National Institute of Justice. International Conference on Crime Mapping Research. Orlando, FL, December 13, 14.

2000. Violence against women in Baltimore City. Lecture delivered by invitation to symposium: *Four disciplines, four community perspectives*. Annual meeting, Eastern Psychological Association, Baltimore, MD, March 24.

2000. Applications of mapping in law enforcement. Lectures delivered by invitation to the

Maryland Police Corps, Linthicum, MD, May 2 & 17.

2000. Interview for National Public Radio program *Public Interest*. September 26.

2000. Enhancing the visualization of crime data. Lectures delivered by invitation to the Maryland Police Corps, Linthicum, MD, October 18 & 23.

2001. Spatial data in crime analysis: improving visualization and locational precision. Lecture delivered by invitation to the Department of Geography, University of Maryland, College Park, MD, October 11.

APPENDIX II

Compilation Of Listserv Responses To A Question Requesting Suggestions For Uses Of Aerial Photograph

(Some responses lightly edited to conserve space. Relevant text is highlighted in yellow.)

These messages were mostly in response to the following request by Trina Cook on the CRIMEMAP LISTSERV.

```
-----Original Message-----
> From: Trina Cook [mailto:TCook@ci.tukwila.wa.us]
> Sent: Wednesday, November 29, 2000 7:13 AM
> To: crimemap@aspensys.com
> Subject: [CRIMEMAP:4599] Orthophotos: how to use
>
>
> I am lucky enough to have access to aerial photos that I can
> use in ArcView. They're brand-spanking new (to us) and I am
> eager to put them to use.
>
> The Chief has asked me to make a short presentation to
> command staff to introduce them to this new technology and
> talk about different ways to use the photos. I can think of
> some (warrant service tactical stuff, showing drug zones,
> etc.), but am polling the group to see if you have used
> aerial photos in your work or if you have ever thought, "Boy!
> If I just had aerial photos, I could ..."
>
> Thanks for any suggestions. I have seen mapping on street
> files on top of orthophotos (go King County SO!), and would
> love to hear other suggestions.
>
> -Trina Cook
> Police Information Analyst
> Tukwila PD, WA
> tcook@ci.tukwila.wa.us
```

RESPONSES

Subject: [CRIMEMAP:4624] Re: Orthophotos: how to use
Resent-Date: Thu, 30 Nov 2000 12:36:04 -0500 (EST)
From: John Kaiser <jkaiser@typhoon.sdsu.edu>
Reply-To: crimemap@lists.aspensys.com
To: crimemap@lists.aspensys.com

Trina:

A quick reply to your comments about aerial imagery and ArcView for crime analysis. Our University recently conducted an exploratory study in conjunction with the Omega Group (CrimeView) and the City of Carlsbad, CA to explore the used of remotely sensed imagery for crime analysis and law enforcement. Many things came out of the study. First the use of imagery as backdrop to ArcView views such as streets, points of interest, landmarks, etc can be very useful to the patrol officer in viewing all of their beats. Clearly patrol officers know the beats from experience, but the imagery allows them to see behind building, over fences and into areas not normally visible from a street perspective. The use of imagery in conjunction with land use maps and crime events is very useful in locating areas that attract various types of crime. We found that some land uses attract crime when they are associated with certain urban features, but are devoid of crime when these urban features are absent. We also plotted crime events by land use type and found that a very few land use types accounted for a very large percentage of repeat crime events. Assessing these parcels using aerial imagery often gives clues as to why they attract crime. We also Performed a nighttime study where we mapped light patterns and studied the distribution of crime events during the day and at night for the same areas. Light can clearly deter some forms of crime, but has little effect on others. The use of aerial photography and remotely sensed imagery is an area of study you will find quite useful. It clearly adds another dimension to understanding crime events. Talking with your patrol offices, and investigators will generate many different potential applications ranging from traffic, drugs, gang activity, etc.
Good luck

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Email: jkaiser@typhoon.sdsu.edu

Subject: [CRIMEMAP:4623] RE: Orthophotos: how to use
Resent-Date: Thu, 30 Nov 2000 12:34:17 -0500 (EST)
To: "'crimemap@lists.aspensys.com'" <crimemap@lists.aspensys.com>

Besides the obvious tactical value, showing ingress, egress avenues of approach, location of cover and concealment, positioning of spotters or observation post, you can use it to help show relief (DEM or DTED and/or the way shadows fall in the image) long term planning for facilities. They can be used as a base map to plot various types of crimes, then run some of the spatial functions and determine a correlation. With the results you can do some community policing (I saw an example where a police station mapped out the hate crimes, and determined specific things associated with those crimes, a little community policing plus increase in those areas of man power and the crimes dropped) You could us it to plot and track sex offenders. Pretty much if it is archive imagery (not taken that week or earlier) it will be best used as a base image to plot current activities or as an analytical aid to determine (using the spatial functions) what factors have to be present for a particular crime (in the case of the hate crimes, once they were plotted out on a map, the majority of them fell near a retirement community and two high schools and a street that ran through the three). If you have access to current imagery, depending on what kind of camera they are using you can search for marijuana gardens, I.D. suspect vehicles, determine what kind of activity is occurring (locating chemical barrels near a house in an area residents have reported strange smells?......hmmm meth lab maybe?) or such. I hope I have helped and not confused you.

Douglass A. Setting, Staff Sergeant, U.S. Marine Corps
Imagery Analysis
JTF-6 J2 Topographic and Imagery Cell
DSN 978-8234/Comm (915) 568-8234
douglass.setting@jtf6.bliss.army.mil

Subject: [CRIMEMAP:4625] RE: Orthophotos: how to use
Resent-Date: Thu, 30 Nov 2000 12:38:09 -0500 (EST)
To: "'crimemap@lists.aspensys.com'" <crimemap@lists.aspensys.com>

Trina

I have been involved in the use of aerial photos in GIS for many years, however we are just applying photos and satellite images to conservation law enforcement.

First, as conservation law enforcement is predominately a rural crime task force, officers tend to use photos for understanding the lay of the land. Forest patches, stream corridors, the like. They often use a photo to aid the tracking and potential path of violators to parking locations. As we are in the south with little to no snow, tracking can often be difficult especially in dry times. Secondly, they will use photos to reduce search areas. Case in point. Last year, random timed shots were being heard in an area of Lowndes Co. MS. Officers worked several nights to narrow the area that the shots were coming from. One officer searched the Microsoft terraserver for the reduced area and found 3 trailers that were located near some agricultural areas with the search radius. He set up on those trailers the next night and caught the individual. He had a mental model of what was happening (night shooting of deer), and what the terrain should be to facilitate the crime. With that he narrowed his search region rapidly using the photos and found what he was after. I feel the same can apply to other law enforcement as well.

As a researcher, I am using photos and satellite images to conduct profiling of crimes. It is my belief in conservation law enforcement, that profiling will be a useful tool. It is slightly different from WHat I think of as "normal" profiling in that the profiling is based more on the environment than the individual. We use these tools for measurements of sight distance, vegetation types etc.

The US Fish and WIldife Service has started using photos as back drops to gps located evidence for court cases. GPS'ing the location of crimes, the trails from foot prints and vehicles to subdivisions, or other areas has given them highly influential evidence in the court room. Jurors can really relate to a real world picture with evidence shown on it.

Just a few of our ideas. Hope this helps.

Rich
Richard B. Minnis
Research Scientist
Department of Wildlife and Fisheries
Box 9690
Mississippi State University

Subject: [CRIMEMAP:4622] RE: Orthophotos: how to use
Resent-Date: Thu, 30 Nov 2000 12:32:28 -0500 (EST)
To: "'crimemap@lists.aspensys.com'" <crimemap@lists.aspensys.com>

Hi Trina,
I buffer the parcels of all schools, daycare, housing projects and churches. I often overlay Tiff aerial photos in ArcView.
When one of our narcotics agents makes a buy within the prohibited buffer zone, 1,000' or 200' for a housing project, I generate a map which is provided to the State's Atty. and used as evidence for enhanced penalties. So far, the maps have been questioned extensively in depositions, but have yet to be tested in court. (Defendants plead out at a high rate, of course) I usually generate two maps, one with, and one without the images. There are some parts of our county in which the images don't line up properly with the street file.

Here is another potential use: Providing the agents with an aerial photo of a parcel upon which a search warrant is to be served. Additionally, this could be taken to the Judge when petitioning for the warrant. It reveals all structures on the parcel to be searched, if the trees aren't in the way. Tactical plans can be made based on these photos as far as how to approach the house and where to position agents, etc.

I wish you the best,
Linda Slavin
Crime Analyst
Volusia County SO (FL)

Subject: [CRIMEMAP:4621] Re: Orthophotos: how to use
Resent-Date: Thu, 30 Nov 2000 12:30:45 -0500 (EST)
To: crimemap@lists.aspensys.com

Hi Trina -

Orthophotos may be used for CPTED (Crime Prevention Through Environmental Design) --- we've used Orthos help reconfigure problem parking lots. We also have migrant liaison officers using these data out in the field to identify locations of migrant worker camps. Of course, they are useful for court exhibits and traffic accident reports. In general, anything requiring visualization of building footprints, in particular for school safety issues, Orthos are a necessary data layer, especially if the building footprints have not been digitized.

Regards.....Deena

Deena Bowman-Jamieson, ISA III
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Subject: [CRIMEMAP:4619] RE: Orthophotos: how to use
Resent-Date: Thu, 30 Nov 2000 12:28:46 -0500 (EST)
To: "'crimemap@lists.aspensys.com'" <crimemap@lists.aspensys.com>

We use aerial photos here in our Crime Analysis Section.

Most of the requests so far have been from our Tactical Section (to see escape routes, entrances, etc.) and Traffic (e.g., for accident reconstruction).

I've found that the end product with aerial photos is really nice.

JD Alston
CAS
Edmonton Police Service

Subject: [CRIMEMAP:4656] Re: Orthophotos: how to use
Resent-Date: Mon, 4 Dec 2000 09:19:54 -0500 (EST)
To: crimemap@lists.aspensys.com

Hi all,

I've managed to get my hands on a pile of raster images that include land
use variables, census information (Canadian tracts and enumeration areas for
Vancouver and surrounds (Southern British Columbia). Ortho photos themselves underneath vector data points are an excellent way to promote contextual sensitivity in one's analysis. For example, an image of land use may help readers interpret clusters or 'hot spots'. I look at bars and night clubs and CAD /emerg 911 calls for police service. Having an image of where major parking lots exist, and natural pathways (alleys,

non-geocoded lanes, etc.) might help to understand why so many "hundred block" calls occur for a given street segment.

Regards

Bryan Kinney

Ph.D. Candidate,
Sr. Research Manager,
Crime Prevention & Analysis Lab, Inc. (CPAL)
School of Criminology
Simon Fraser University
8888 University Drive
Burnaby, B.C. V5A 1S6

Subject: [CRIMEMAP:4655] Re: Orthophotos: how to use
Resent-Date: Mon, 4 Dec 2000 09:16:50 -0500 (EST)
To: crimemap@lists.aspensys.com

Hi Trina: I see there's several good reply's already posted on the list. I would add you can use orthos for developing realistic training scenario's as well as visualizing tactical problems and mapping actual crime scene relationships and remote evidence locations. I've used orthos's quite effectively to show vegetation disturbance by converting gray scale of B/W aerials to red-yellow/bluegreen reverse color ramps -- also used photoshop to rubber sheet non-georeferenced scanned aerials into arcview as a theme coverage etc.

We've got sequence ortho's from year 2000 back to 1930 for parts of King County, all of the City of Seattle area , Renton and Tukwilla on my box at work. Sequence photos are quite handy for viewing pre- existing landscape and building/street placement etc in old cases, where urbanization, new roads, subdivisions etc have substantially altered the community layout. Give me a call if you'd like to look at what we have. Were at Third and Columbia, downtown Seattle. I'd be happy to help you work up a couple of scenario's for your presentation--36" to 48" printers are available--but you'd have to supply some sample crime data to overlay the orthos with.

regards,

Glenn Brooks
Geocode 2000
Seattle Public Utility

email: Glenn.Brooks@ci.Seattle.wa.us

phone: 206-615-1214

Subject: [CRIMEMAP:4638] Re: Orthophotos: how to use
Resent-Date: Fri, 1 Dec 2000 08:12:15 -0500 (EST)
To: crimemap@lists.aspensys.com

Dear Trina,

Funny your posting should come in my e-mail this morning. I just printed an aerial of an intersection where we had a fatal accident occur a couple nights ago. The investigator can use it to help re-create the scene in a prosecutor's or juror's mind. Maybe even transpose his measurements of the scene onto the photo.

We have used the orthos for many purposes. The Secret Service likes them when they come to town with a protective detail for a presidential candidate. We've used them for searching a wooded area for an armed murder suspect. It gave our tactical guys an idea as to the lay of the land (especially when combined with a contour overlay). The same application could be useful in lost person searches.

We've also used them in court. Prosecutor's have presented aerials of crime scenes for demonstration purposes. Witnesses can better visualize where they were standing, what direction they were looking, etc. Jurors have a clearer understanding of what the scene looked like without being taken there by the court.

I'm sure I haven't listed all the possible uses and I'm anxious to see what
others use theirs for.

Sincerely,

Det. Rob Drewry
Battle Creek, MI P.D.

Subject: [CRIMEMAP:4637] Re: Use of aerial photography
Resent-Date: Fri, 1 Dec 2000 08:08:13 -0500 (EST)
To: "'crimemap@lists.aspensys.com'" <crimemap@lists.aspensys.com>

I frequently provide aerial photo print-outs for local officers for a number of tasks. When embellished with map data, they're particularly useful in helping to 'visualise' rat-runs, proximity to specific landmarks, etc. Large aerial photo print-outs (A1 or even A0 size) are also an excellent, and sometimes more geographically tangible, alternative to the standard intelligence map.

JOHN CHAPMAN
GIS Analyst/Crime and Disorder
Hampshire (UK) Constabulary Secondee
Southampton (UK) City Safety Team

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EMail: J.Chapman@Southampton.gov.uk

Subject: [CRIMEMAP:4618] Re: Orthophotos: how to use
Resent-Date: Thu, 30 Nov 2000 12:28:44 -0500 (EST)
To: crimemap@lists.aspensys.com

Hi Trina,

Greetings from sunny South Africa!

I have used digital aerial photographs to plot body dumps of a serial killer as well as using it for mapping routes which the accused took when indicating crime scenes to the police, this is very handy in our informal settlements where maps are non-existing. Coupled with a GPS you have some powerful display stuff.

Cheers
Peter Schmitz
GIS Specialist
CSIR, South Africa
pschmitz@csir.co.za

Subject: [CRIMEMAP:4996] Drug Free School Zones
Date: Wed, 31 Jan 2001 09:07:49 EST
From: BILL FERRETTI <BILL.FERRETTI@CO.MO.MD.US>
Reply-To: crimemap@lists.aspensys.com
To: crimemap@lists.aspensys.com

I am looking for feedback from listserve members who have made attempts with mapping Drug-Free School Zones for use by patrol officers as a tool for placing charges - specifically how they were implemented, and how successful were subsequent prosecutions?

Laws providing specific charges and enhanced penalties for "Drug Trafficking within 1000 ft of a school" were passed in Maryland more than ten years ago. A quick statistics check revealed that in Montgomery County, charges under this law (Article 27, Sc 286D) were brought less than a dozen times a year. In order to make more effective use of this law, I have been working with the county's GIS staff to create a simple tool that both patrol officers and narcotics detectives could use to aid in deciding if charges under this statute should be filed. What follows is a basic outline of the steps taken to create this tool.

Creating A Drug-Free School Zone Mapping Tool in Montgomery County, MD

1. Listing of all public schools was obtained from the county school board (A GIS layer already existed). Listing of all Approved private and church exempt schools in the county was obtained from the State Department of Education.

2. Point layers were made for the private schools and then combined with the public schools. The combined school point file was then overlayed with the county's property layer to identify all "school" parcels, and a new polygon layer was created. Digital Orthophotography was used as part of a quality assurance

check.

3. 1000 ft buffer zones were then created around the school's polygon layer.

4. Maps were generated as pdf's - showing school property - 1000 ft zones, and roads.

5. Everyone of our officers is issued an ADC Map book. There are 42 pages covering the county. The Drug Free Zones pdf's were made to match these pages. The pdf's were placed in a virtual map book on our Intra-net.

6. When an officer makes a felony arrest for cds, he can use the ADC index to find the correct page, open that page on the intranet and then make a determination it the location of the crime was in a 1000 ft boundary of a school. (In order to avoid entrapment issues, we have meet with our prosecutors to determine in what circumstances it would be inappropriate to use this charge (ie - traffic stops).

7. As we move toward court, maps overlaying the drug zones and digital orthophotogarphy will be used to make our cases (The error rate in the data has been considered).

This is a simplification of the process. I also considered using ArcIMs and may move that was in the future, but I wanted to get the maps out there and considered ease of use and speed of access as the two key factors in their success.

APPENDIX III

Sample Project-Related Presentation : PowerPoint Lecture Delivered At The University Consortium For GIS, Minneapolis, MN, June, 1999

Slide 1

DATA INTEGRATION AND VISUALIZATION IN CRIME PREVENTION AND LAW ENFORCEMENT

Keith Harries

UCGIS, Minneapolis, June 24, 1999

- **Integration inches forward at all levels**
  - Data
  - Interagency
  - Geographic
- **Integration at all levels critical because**
  - Data needs are diverse and unpredictable and cross agency lines
  - Complementary agencies have unequal access to data (e.g. police, parole/probation)

Slide 2

INTEGRATION AND VISUALIZATION (CONTINUED)

- Integration impeded by logistical and political problems, e.g.
  - Charles County, Maryland rivalries
  - GPS data difficulties
  - Disparities in technical capacity between agencies
- Enhanced visualization feasible, and would offer the following advantages:

Slide 3

- ***Officers in Policing, Parole, Probation***
  - will generally more easily recognize and contextualize information, problems.
- ***Hot spot relationships***
  - are better visualized, e.g. connection between a commuter parking lot and auto thefts.
- ***Microenvironmental elements***
  - become visible, e.g. a path behind an apartment complex leading into a wooded area.
- ***Community residents***
  - will be able to see environmental context.
- ***Synergy***
  - between GPS-GIS-ORTHOS.
  - all three are most useful when used together.

Slide 4

OTHER ADVANTAGES

- ***Planning***
  - scope of proposed actions more realistically represented
- ***Courtroom evidence***
  - more persuasive, realistic
- ***Training applications***
  - learning about the precinct, probation district
  - navigation enhancement
  - steepen environmental learning curve
- ***Dispatchers***
  - could enrich dispatching information

Slide 5

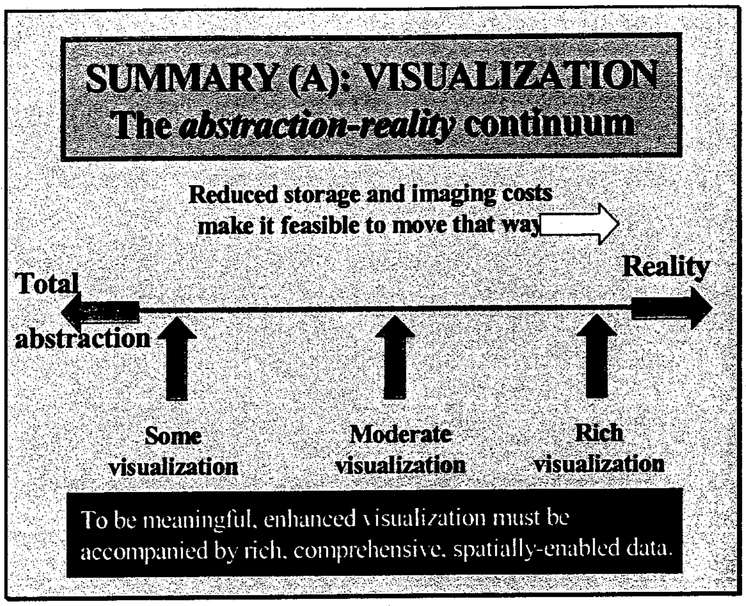
Slide 6

WHAT IS BEING DONE?

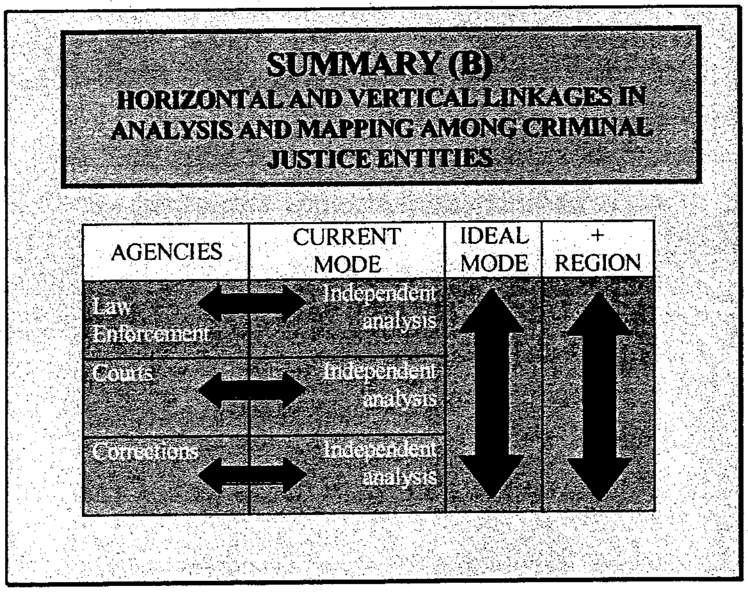
Integrating

- ***Crime data***
- ***Large scale digital aerial orthophotos***
  ("200" scale, i.e. 1:2400, or 1" = 200')
- ***Other appropriate data bases, e.g.***
  - census data
  - liquor license types and locations
  - injury/accident locations
  - housing and zoning code violations
  - banks, ATMs, convenience stores, schools, etc.
  - drug markets
  - other data relevant to the needs of community policing, e.g. aggregated counts of persons in drug treatment

Slide 7



Slide 8



APPENDIX IV

Baltimore County Police Department: Sample Web Pages Developed as Part of the OPRA Project

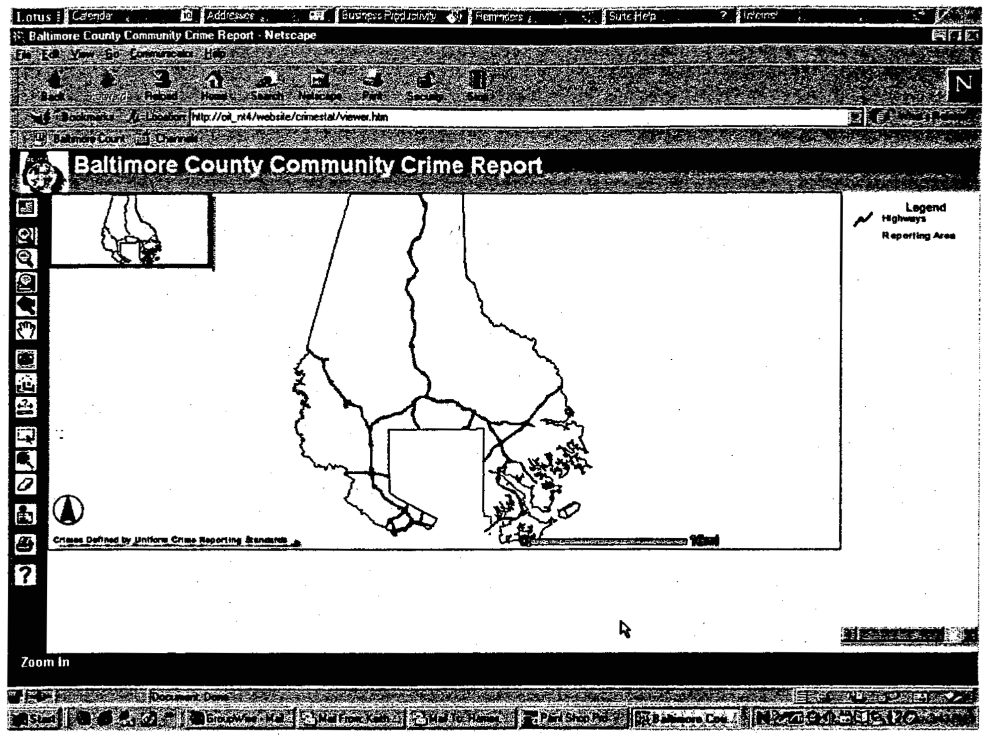


Figure 13. Frame 1 in a sequence of web pages from the Baltimore County Police Department web site.

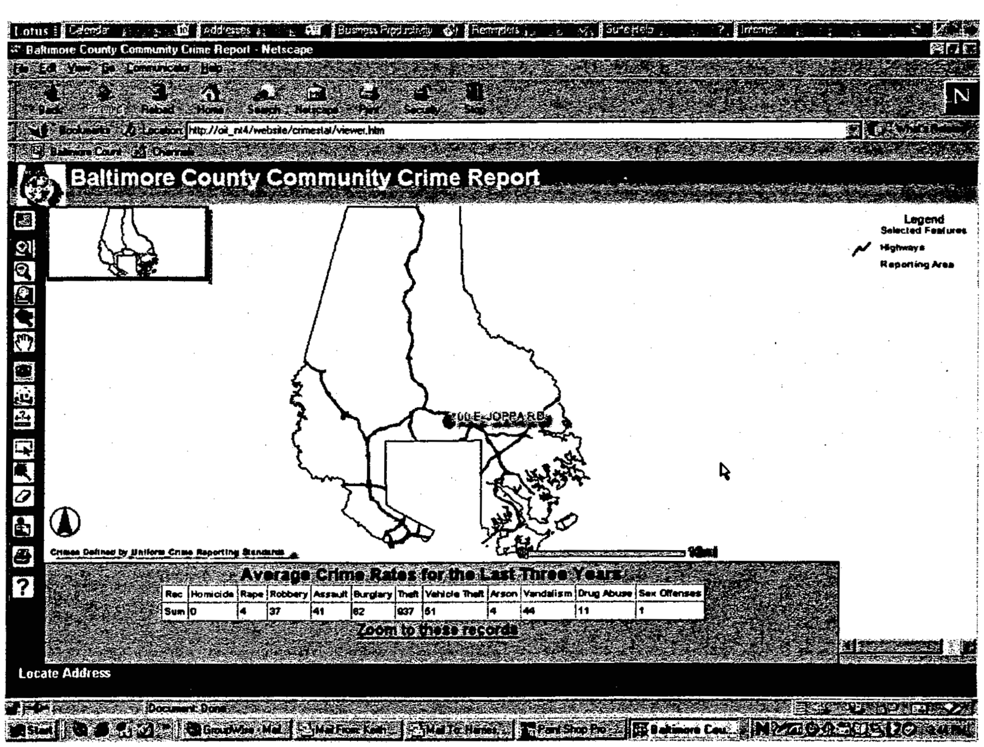


Figure 14. Frame 2 in a sequence of web pages from the Baltimore County Police Department web site.

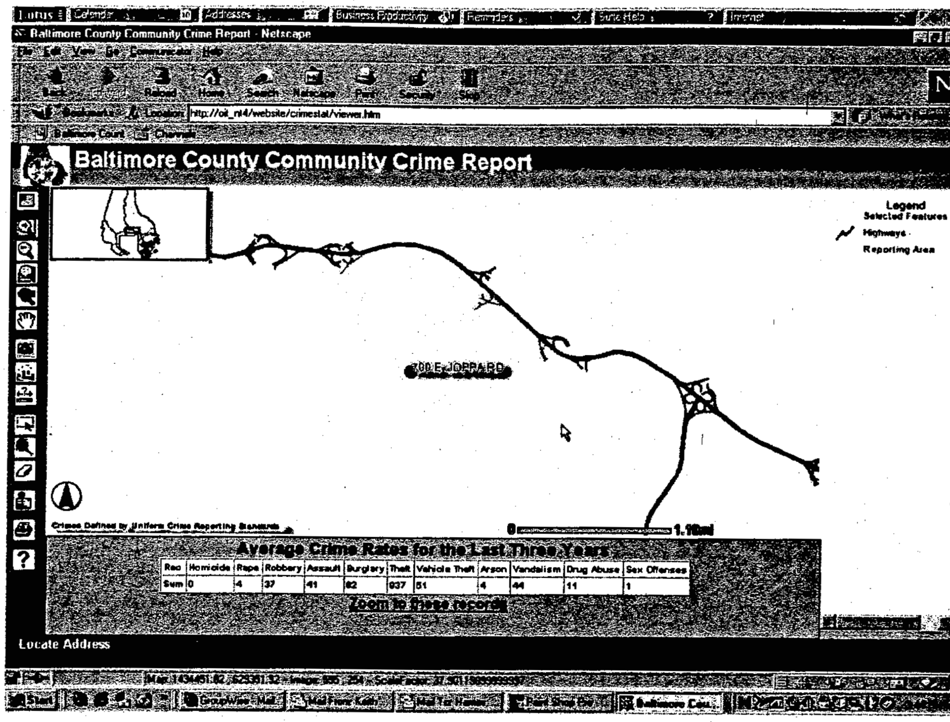


Figure 15. Frame 3 in a sequence of web pages from the Baltimore County Police Department web site.

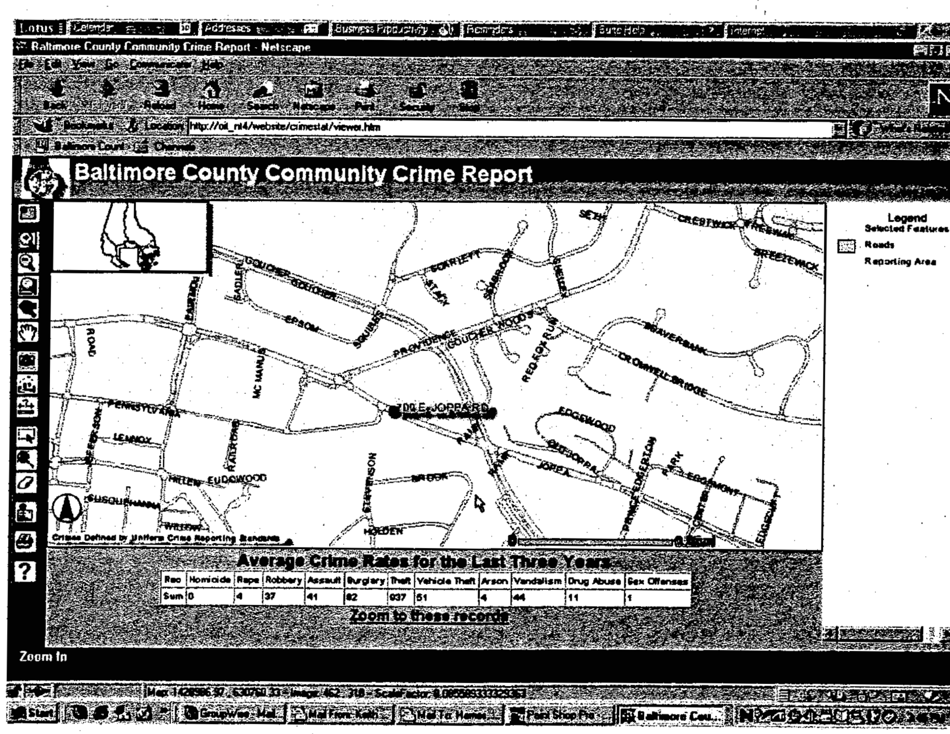


Figure 16. Frame 4 in a sequence of web pages from the Baltimore County Police Department web site.