After Andrew
I Need a Map That Shows....

RONALD J. WELEBNY, DIGITAL MATRIX SERVICES, INC.

This is a narrative about events that brought a large and complex GIS to maturity over an 8 week period. The GIS activities are ongoing, but after the first 8 weeks, involve prototyping of experimental techniques. This article is confined to a sampling of those applications which were of actual value, directly related to the response, relief and recovery efforts.

It came as no real surprise. The National Weather Service had been reporting the progress of Hurricane Andrew for nearly a week. The National Hurricane Center in Coral Gables (Miami) predicted with incredible accuracy, the time and place of expected landfall, and even the magnitude of the hurricane winds (but not, necessarily, the tornado winds which, we suspect, were embedded around the eye). Miami Beach underwent the largest evacuation in U.S. history. Night fell, and all was ready. Or was it?

Howard Jacobs, a young Account Executive at Digital Matrix Services, Inc. (Miami) had spent Sunday with his wife Shelly, boarding their two story frame home in Kendall, 6 miles south of the office. They felt reasonably secure. Howard lived just two blocks from an elementary school that was filling with families that had been evacuated from the "real" danger zone to the South and East. That was where, in the final hours, the eye was expected to pass.

At 2am, Howard and Shelly were listening as the radio told of the imminent arrival of this monster. The neighborhood was quiet. By 2:30, the winds had begun and it was immediately evident that this was not going to be a cake walk. The house began shaking and the plywood battens were threatening to tear away from the doors and windows. An announcement on the radio reported that the elementary school being used as a shelter had begun to disintegrate. The roof was being ripped off of the gymnasium, by the winds. Power and phone service ceased. As their house began to come apart, Howard and Shelly grabbed the baby and the dog and went from place to place seeking a spot that might offer protection. They wound up under a concrete stair well adjoining the garage. Daylight broke revealing that the house and all of its contents were a total loss. So was the neighborhood. So were over 85,000 other homes and tens of thousands of businesses. Howard and family (including the dog) were OK. Tragically, others were not. Some 30 people were killed directly by the storm, and upwards of a hundred others (including Howard's grandfather) died as a result of stress, from heart attacks and cerebral hemorrhage. There are still those who suspect that the death toll was much higher, and not accurately reported. Rumors abound regarding the number of migrant farm workers who may have perished. There seems to be no record.

In the Southern Dade County communities of Homestead and Florida City, the devastation was beyond comprehension. Entire subdivisions were leveled. Tens of thousands of people were stranded among rubble that was unrecognizable. The infrastructure was shattered. There was no communication, no food, no health care, and no shelter. Later, evacuees returning to their neighborhoods were unable to find their homes. There were no street signs and no landmarks. In many cases, there were no neighborhoods. Where to begin?

Digital Matrix Services, Inc. (DMS) is the Miami-based software development firm that produces the InFoCAD Geographic Information System. Its offices and labs are located a mile and a half from the National Hurricane Center. Under sustained winds of 168 mph, the radar at the National Hurricane Center blew off the roof, taking the wind meter with it. South Miami was a shambles, and it took four days for DMS staff to finally gain access to their facility. Incredibly, the building was untouched. For no apparent reason, a select few buildings regained electrical power on that Thursday night. Midday on Friday, a weak phone line came to life. DMS was back in business, sort of.

"I need a map that shows locations of all the places where we are establishing emergency facilities..."

Moved by the personal tragedies that had befallen comrades and the community at large, the officers and staff pondered over what, if anything, the company could do to be of service. DMS President Herman Miranda recalled that "we have an ETAK database of the whole south half of the state." We had a digital representation of every street from Palm Beach to the Keys which had been in preparation for a regional client (see figure 1).

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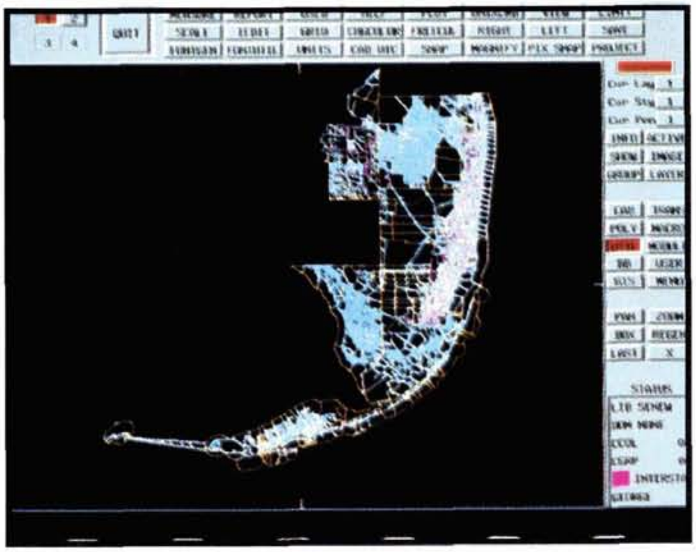

Fig. 1. InFoCAD® screen showing ETAK street network data covering Broward, Dade, and Monroe Counties. Includes every street segment as well as certain cultural features.

There was brief discussion over the immediate value that this might have, and it was decided that the company would offer systems, software, data, and people to assist in the relief effort. The Washington offices of FEMA (the Federal Emergency Management Agency) were contacted, and within 24 hours Jack Bryan, the FEMA Director of Information and Planning in Miami had accepted the offer.

FEMA arranged to have the Army Special Forces transport two workstations, an X-terminal and a pen plotter. These were moved to the Command and Control Center at Miami International Airport, just a few miles north of DMS's offices (no small undertaking given the amount of rubble in the streets). The company had volunteered the equipment and software, as well as the efforts of three full time support specialists for a month. DMS contacted ETAK, Inc., of Menlo Park, Cal., to secure the use of their commercial data in this effort. Bill Folchi, ETAK's vice president for sales immediately approved the request and offered whatever other help the company could provide.

One hour and thirty minutes after the plugs went in the wall at FEMA, a guy came into the facility wearing a white baseball cap emblazoned with the words "The White House." He said, "I need a map that shows the coordinates of neighborhoods in Homestead and Florida City. Can you do that?" It seems that the White House Task Force had arranged to have the Goodyear Blimp station itself over neighborhoods where people were stranded, and flash messages in both English and Spanish on the sign boards with directions to get aid (field hospital 1 mile North - field kitchen 2 miles East, etc.). While there were local maps available, there was no way to navigate from them, especially at night. The first spatial query and analysis performed at the Command and Control Center resulted in the determination of latitude/longitude coordinates. This allowed the Blimp Captain to use his on-board global positioning system to place the machine where it needed to be.

"I need a map that shows locations of all the places where we are establishing emergency facilities..." On the evening of the first night, databases were prepared by geocoding (using the software to assign geographic coordinates to) addresses where mission specific facilities were being established. Representatives from each of the participating agencies provided lists containing the address and information pertinent to each site. This information was entered at the keyboard and the software searched the ETAK street network database for a match. InFoCAD then dynamically panned and zoomed to the selected location and displayed a tag showing the site and selected database information. The software interpolated the address value to place the tag at a location on the segment reflecting its probable distance from the nearest intersection. Via even or odd address number, the appropriate side of the street was determined and selected. A record was then stored in the database relating to the facilities.

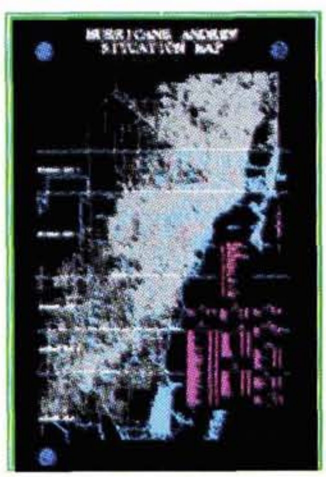

Fig. 2. A daily situation map depicting the location and nature of mission specific sites covering the entire operation.

At first, there were records developed for some twenty kinds of sites that included: FEMA Disaster Application Centers, Red Cross Service Centers,Tent Shelters, Army Field Kitchens, Disaster Medical Assistance Team Locations, and others. By morning, a situation map had been prepared showing locations and proximities of everything, with a legend that had been generated as a result of database query (see figure 2).

DMS's original plan, to donate its own equipment and the services of three staff members to assist with the GIS needs quickly proved inadequate. By the end of the first week, the system had grown to include a network of 8 Unix workstations, with some 15 DMS volunteers providing round the clock operations. Several of those volunteers (Howard included) had their own homes destroyed by the hurricane. The company called on its vendors and colleagues for hardware support, and they responded with an outpouring of boxes. Hewlett Packard donated a file server, several X-terminals and a high resolution scanner. Data General provided a workstation and a 486 PC (which also doubled as a workstation in X-terminal mode), Digital Equipment Corporation loaned a large workstation for devel-

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opment work and both CalComp and Xerox/Versatec furnished E size color electrostatic plotters. Both CalComp and the Louisiana State Department of Natural Resources loaned thermal color screen copy devices.

"That's not a map; It's a bunch of lines."

The GIS network grew to considerable proportion. The databases eventually occupied some 5 gigabytes of disk storage. An on-line linkage was established with Metro-Dade GIS, the county agency providing GIS support for local agencies as well as peripheral support to FEMA and the other participants. DMS enlisted the voluntary aid of Science Applications International Corporation of San Diego, Cal., who provided technical and operational support as the workload increased. Rob Henion, of Digital Graphics Services, Inc. of Ashville, NC, worked nonstop for two days to code (program) a missing plot driver.

"That's not a map; It's a bunch of lines." said one skeptical operations manager, pointing to the computer display of ETAK's carefully crafted and richly attributed street network. The DMS volunteers were then taken upstairs to the third floor where the Army Special Forces staff had mosaiced the walls with 7.5 minute USGS quadrangle maps. The maps were covered with large sheets of acetate, and literally dozens of soldiers were plotting on them with grease pencils, to outline areas and portray site locations. "That's a map," said the ops manager.

It was quickly realized that "GIS types" were overly familiar with the lines and symbols that have been the mainstay of GIS since its inception. It was evident that for non-technical people to make use of the technology without training, a better display mechanism was required.

ASI to the rescue. A phone call was placed to David Lewis of Analytical Surveys, Inc., Colorado Springs, Col. ASI has large format color scanners suitable to capture quadrangle maps in their entirety. The firm readily volunteered to scan the quads covering the affected area, and almost overnight shipped tapes containing the appropriate image files.

The quads were scanned at 150 DPI (dots per inch). This preserved the clarity inherent in the original paper maps. The images, when received at the FEMA Command and Control Center, were geocoded by simply setting the InFoCAD software to receive data into the Universal Transverse Mercator (UTM) projection. Each corner of each image was then tagged (by mouse pointer, see figure 3) with the published latitude/longitude coordinate. Thus, each pixel in each image took on a geocoordinate value. Images files were cropped to retain only pixels contained within each map's neat lines (borders). This was to have provided a seamless edge match between images.

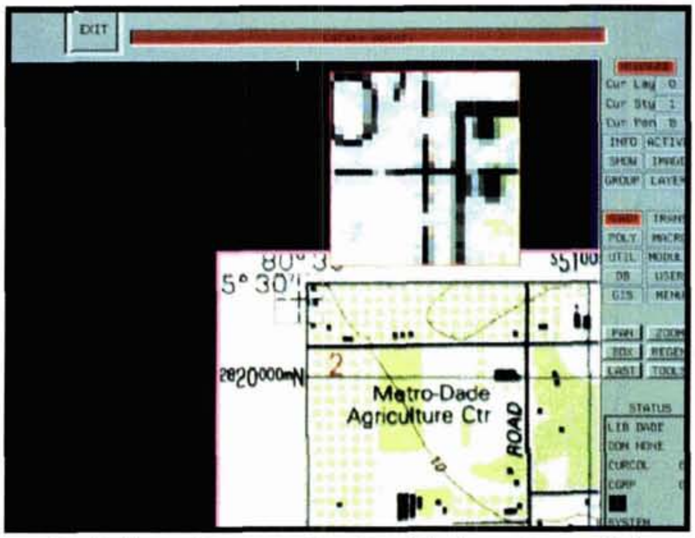

Fig. 3. The software provides the utility to produce a pixel level image of the area in consideration, enabling an exact placement of the cursor to assign the selected coordinate value.

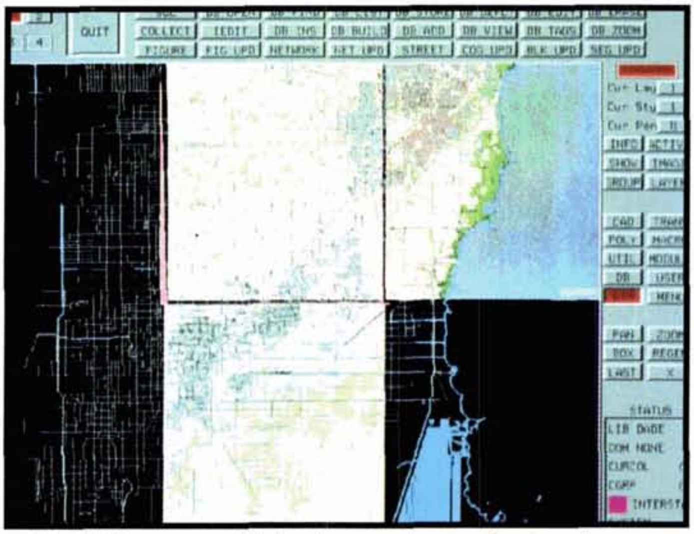

Fig. 4. These are adjoining images, shown after transformation to the UTM projection. The street network files prove a correct geo-reference. The edges have "split apart" owing to the re-projection. This is further proof of the correctness of the coordinate transformation process.

It was interesting to discover there were break lines between the image files. It was determined that while each quad had a UTM grid, the planimetry (physical details) was projected in the Florida East Transverse Mercator Projection. The image file contained data from two different projections and something had to give. Since there is no topology (logical connectivity) between pixels, the reshaping produced the apparent splits. The grids, however, matched perfectly with their neighboring files.

Nonetheless, this provided a very pleasing "sort-of seamless" backdrop (see figure 4) for the GIS functions to operate on and produced a high degree of user satisfaction. There was no

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time (nor any real need) to repair the "cracks in the Earth" and users were quite satisfied.

The introduction of a "quad map backdrop" to the GIS environment proved valuable. The user agencies now received output which looked and felt like maps they were accustomed to using.

The U.S. Army Corps of Engineers contracted with Continental Aerial Surveys, of Alcoa Tennessee to obtain large format (23cm) black and white vertical aerial photography at 1:9600 (1" = 800') of the most heavily affected areas. This block of photography was flown in an East/West orientation and resulted in some 400 images. The flight was planned at 30 percent forward lap frame to frame and 30 percent side lap strip to strip. Full monoscopic coverage was achieved. Prints were available within days of the incident, and soon the walls on the second floor were covered, floor to ceiling with paste-ups of assemblies of contact prints. Soon the paste-ups were covered with acetate. The acetate, in turn, became covered with crayon marks as specialists from the Army Corps performed manual spatial analysis.

When it became known that DMS had a small (8.5 x 14") Hewlett-Packard Scan Jet on line at the FEMA Command and Control Center, a request was made to scan the aerials. The intent was to "use" them in the GIS that the Army Corps was setting up on the second floor. File sizes were a concern, so it was requested that the images be scanned at a resolution of 300 dpi. The 1:9,600 contact prints yielded pixels each representing 32 inches of ground. This resolution proved less than satisfactory to sustain detailed damage analysis to structures, but more than adequate to provide a general idea of damage patterns (see figure 5).

The resulting image files were geo-rectified using InFoCAD's imaging capabilities. Control points were selected by mouse pointer from a window displaying georeferenced data from the street network, and applied by mouse pointer to the corresponding point on the photo image (see figure 6). Given the incredible time constraint and the modest requirements for high orders of spatial precision, only four points per photograph were selected. Each image thus became geo-referenced, and warped to conform with the underlying spatial geometry. Figure 7 shows the original image shape in white, and the resultant image shape after geo-rectification.

Finally, InFoCAD's Image Crop utility was used to simply box the desired area of each image, and edge-match the adjoining boxes. Figure 8 shows two images side by side after cropping in concert with the vector data representing the streets. A match line can barely be detected running vertically down the center.

Fig. 7. Here is the same photo after rectification. Notice the alteration from the original perfect square.

Query and analysis could then be performed directly on the photo-images (see front cover). These image files remained in residence on FEMA's InFoCAD GIS, where they were in constant use in support of analysis and assessment.

A Reserve Lieutenant Colonel attached to the Army Corps of Engineers was directed to the Command and Control Center. He

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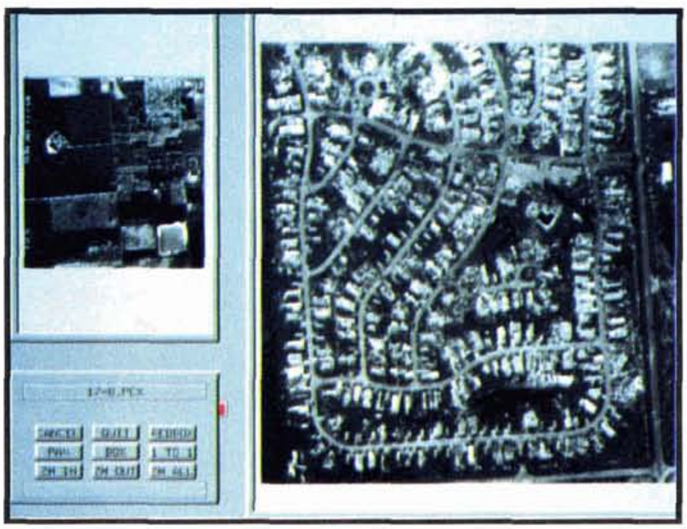

Fig. 5. The software provides the ability to zoom and pan on the entire frame, shown in the left window. The zoom area is displayed in the larger window to the right. Note the level of destruction evident in the housing development.

Fig. 6. In order to geo-rectify each photo, the software provides a window (upper left) in which known ground truth can be displayed. In this example, the street network is shown. Note that the areas in each display are similar. Selection of a

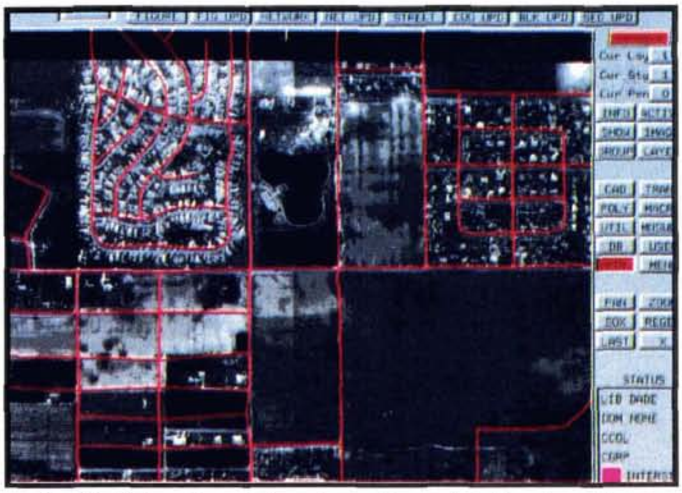

Fig. 8. This enlarged view shows the match line down the center of the display. Again, the vector overlay proves that the rectification process has been successful.

was to obtain detailed, point specific site locations of thousands of portable toilets and trash bins located in the field. With some 30,000 soldiers billeted in tents, sanitation was a major consideration. The dynamic nature of the operation had military units constantly on the move (no pun intended). This fellow, who jokingly billed himself as "Generalissimo Du Caca" took his mission quite seriously, and had a real problem. The toilets and trash containers followed the troops wherever they went. The vehicles assigned to daily service, in many cases, could not find them. The Colonel's staff spent untold hours trying to plot locations on enlarged copies of local street maps, but with unsatisfactory results.

This application was the first to illustrate to the civilian interests the need of the military to work within the frame of reference of absolute metric coordinates. All of the data that had been thus far gathered was expressed in latitude/longitude or in state plane coordinates. The base data had come in, in reference to the Florida East Transverse Mercator Projection. The GIS, being a COGO (coordinate geometry) based system, had preserved the absolute spatial geometry associated with that projection. Every element of spatially oriented data was thus stored as a cogo point expressed in latitude/longitude as referenced to the above defined projection. New data sets were geo-rectified so that they too, took on this same frame of reference. This included all of the aerial photography.

On his first examination of the GIS, the Colonel said, "what good is this? My soldiers don't know latitude/ longitude. They need metric coordinates." He went on to relate that, "we have metric coordinates for all of the sites (obtained with hand held GPS devices), but have no way of relating them to a map we can use. I need a map that shows all of the locations, their coordinates, and a 1 kilometer grid, annotated in meters. I need it updated every day. Can you do that?"

InFoCAD's Projection Module made short work of converting the entire database to the Universal Transverse Mercator Projection (zone 17), expressed in meters. From that day forward, all of the military units received output as described (see figure 9).

A database was created, containing records for all of the toilet and trash sites, each including metric coordinates. These sites were then reported on the daily situation maps. Field personnel then used portable GPS equipment with the maps to find each site, every day

A bird (full) Colonel from Army Special Forces marched in one evening and bellowed "You the guys with the maps?" Our affirmative response prompted a hearty "well I need a map that shows..."

You may recall that the Hurricane hit on August 24, the day before Primary Day. Sixty-six polling places were destroyed and the State Elections Commission arranged to have the Primaries set back one week, in order to make alternate voting arrangements. At risk of getting someone (mainly us) in hot water, here is what ensued.

On August 30, two days before the rescheduled Primary Election day (8:30 in the evening actually), the Colonel shows up. He had been given a list of street addresses (some of which had place names as in school, church, etc.) where the election officials wanted polling sites established. His staff had worked for hours (possibly days) trying to locate the desired sites, but to no avail.

The street naming conventions simply defied logic. All three of the counties and, separately, all of the cities within the counties involved use the same system of numbering streets and avenues within a quadrant (as; N.W. 188th Ave.). All supplement the street and avenue convention with Lane, Terrace, Court, etc. Thus, N.W. 188th could be street, avenue, lane, court or terrace, any one of which might be found in any of six different jurisdictions.Worse, the jurisdictions use a tremendous number of aliases. North West 8th Street is also State Route 41, and also the Tamiami Trail, both of which are N.E. 8th Street, after they cross Biscayne Blvd. That notwithstanding, there are 8 N.W. 8th Streets in the area that the Hurricane affected.

The DMS volunteers used InFoCAD's geocoding algorithms to find all of the candidate locations for each

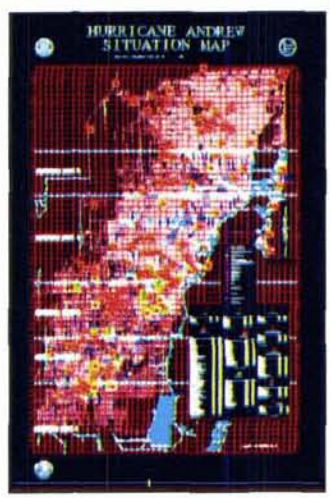

Fig. 9. The daily Official Situation Map as produced in the metric rendition.

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