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Integrating custom mapping and structure preplanning with gis for emergency responders

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Integrating Custom Mapping and Structure Preplanning
with GIS for Emergency Responders

Zachary Michael Hittie

A thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

In

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Integrated Science and Technology

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Abstract

Accurate information can mean the difference between life and death for emergency responders and the people they serve. At the Harrisonburg Fire Department, laptops with customized databases for street maps and building preplans are one source of information for first responders. Another available resource is a Geographic Information System for the City of Harrisonburg and Rockingham County. However, ESRI's ArcGIS® software is far from user-friendly in a mobile atmosphere. The objective of this research is to develop new software that integrates the ArcGIS® tool suite with custom street map files and structure preplan databases into a single application on a mobile platform for first responders that allows them to take advantage of the benefits of GIS. This new software is specifically designed for use on laptops or tablets where a touch screen is the primary input device, thus no keyboard or mouse is necessary to use the system. The software development cycle begins with a needs assessment and requirements analysis conducted with users at the HFD, and continues with system design, testing, deployment, and maintenance. The solution implements many resources into one software package, featuring GIS maps with searchable address and street layers, the ability to import and search files such as building floor plans, documents, hazardous materials instructions (etc), and identify and display structure preplans with fire apparatus assignments, property owner contact information, sprinkler system connections, and much more. Integrating these tools into one robust application literally puts vital information at the fingertips of emergency services personnel by making GIS more accessible, and helps them respond more effectively and quickly to emergency calls while improving incident management.

I. Introduction & Background

Emergency responders rely on information for effective and timely responses. When the alarm sounds in the fire station, within seconds any number of fire apparatus is en route to an emergency call. One of the first pieces of information a first responder requires is a location; a place to respond to. This is without question one of the most critical pieces of information for any incident regardless of whether it involves police, fire, rescue, public utilities, etc. When responding to an emergency, the responder(s) must know exactly where to go. As little as five years ago, the way Harrisonburg Fire Department found a specific address was by looking it up on a street map drawing on a piece of paper in one of several large binders. These maps were and continue to be drawn using drawing software such as Microsoft Visio, Adobe Photoshop, Microsoft Paint, etc. Maps are updated periodically by fire department personnel as buildings are built or demolished (See figure 1 for a sample map). Each of the four fire stations in the City of Harrisonburg is responsible for maintaining maps within their “first due”. The first due area is the area for which a given fire company would be the first unit dispatched to respond to a 911 call. A basic street map drawing would have all the addresses and apartments for that street block listed on it, as well as nearby fire hydrants and any other critical information that might be pertinent to an address. In most cases such a simple drawing did not depict much additional information, typically ignoring road curvature, elevation changes, fences or boundaries, etc. With over 600 streets or street blocks in the city, it took at least two 5” binders to store all the map hardcopies (sorted alphabetically).

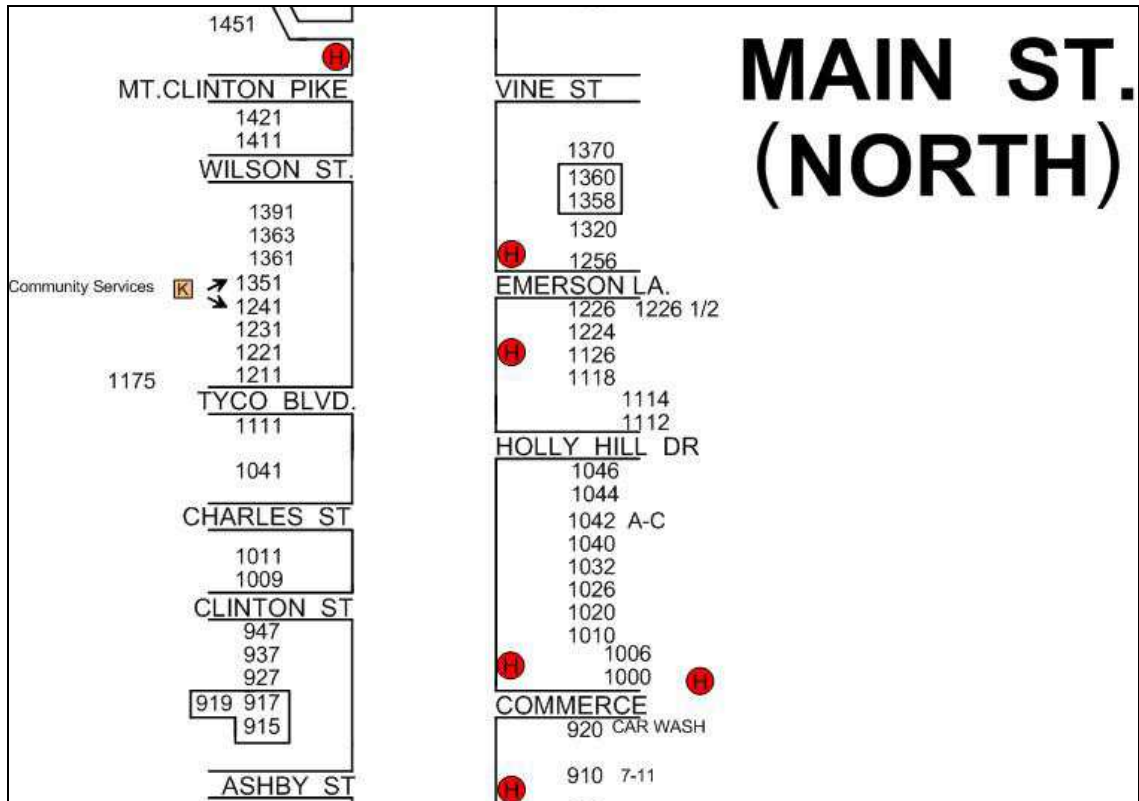


Figure 1: Sample street map printout – North Main Street Harrisonburg

For many addresses in the city there is another important resource a fire department looks to for information called a preplan. A preplan is a pre-incident plan that identifies response actions as well as hazards that may endanger the first responder and those they are trying to protect at a specific location. The City of Harrisonburg is slightly smaller than 20 square miles containing thousands of addresses. Since it is impossible to preplan every single address, the fire department preplans locations that bear potential for high loss of life and property. Large buildings and high occupancy buildings such as strip malls, apartment complexes, industrial sites, schools, churches, etc are typically targeted for preplanning. A preplan contains information such as specific assignments for each company responding to the emergency, property owner and contact information, building construction data, sprinkler system information (if applicable), where to find building keys (if applicable), hazardous materials data (if applicable), floor

plans or drawings of building layouts, and more. A hardcopy of an example preplan form for JMU's Memorial Hall at 395 South High Street is shown in figure 2. Preplans are typed on at least one page, and all preplans are usually accompanied by at least one drawing (such as figure 3).

Date: May 05, 2009	Author: [REDACTED]
Address: 395 S High St	
Business Occupant: Memorial Hall	
Owner: James Madison University	
Contacts [REDACTED] [REDACTED]	
(2):	
Residential Occupant: No	Number of Occupants: Day 300
Number of Apartments: 0	Night 1
Knox Box: Yes	Location: Right side of main entrance
Sprinklered: Yes	Hook-up: A & C Side supply same area. Side B-auditorium. Side D-ROTC area.
Standpipe: Yes	Hook-up: Sprinkler connections at side B and D.
Hazards	
Science lab 3rd Floor, Rm #3315. Geology Rm # 7130-7140. Natural gas service to building (shutoff on C Side at maintenance room).	
Comments	
Sprinkler system does not cover entire building. Auditorium seats 1074 people. Alarm panel in office at main entrance. All rooms have 4 digits; first digit is building number, second is floor level, and last two are actual room number.	
Required Fire Flow: 2,470 g.p.m.	Early Collapse? No
Approximate Square Footage: 247,000	HAZMAT Available?
Roof Construction Type: Rubber membrane over metal roof decking	
Building Construction Type: Type III - Exterior walls are noncombustible, interior any permitted material	
Response Actions:	Alarm Assignment: E28 E23 E25 TW1 C40
E28 Utilizing hydrant on West Grace Street, take main sprinkler, Side A, near main entrance. May need to supply handlines.	
E23 Stage at hydrant off High Street, near main entrance, until directed otherwise. May need to connect to additional sprinkler and supply hand lines.	
E25 Manpower.	
TW1 Stage at entrance off High St.	
C40 Manpower.	

Figure 2: Sample preplan form for 395 South High Street

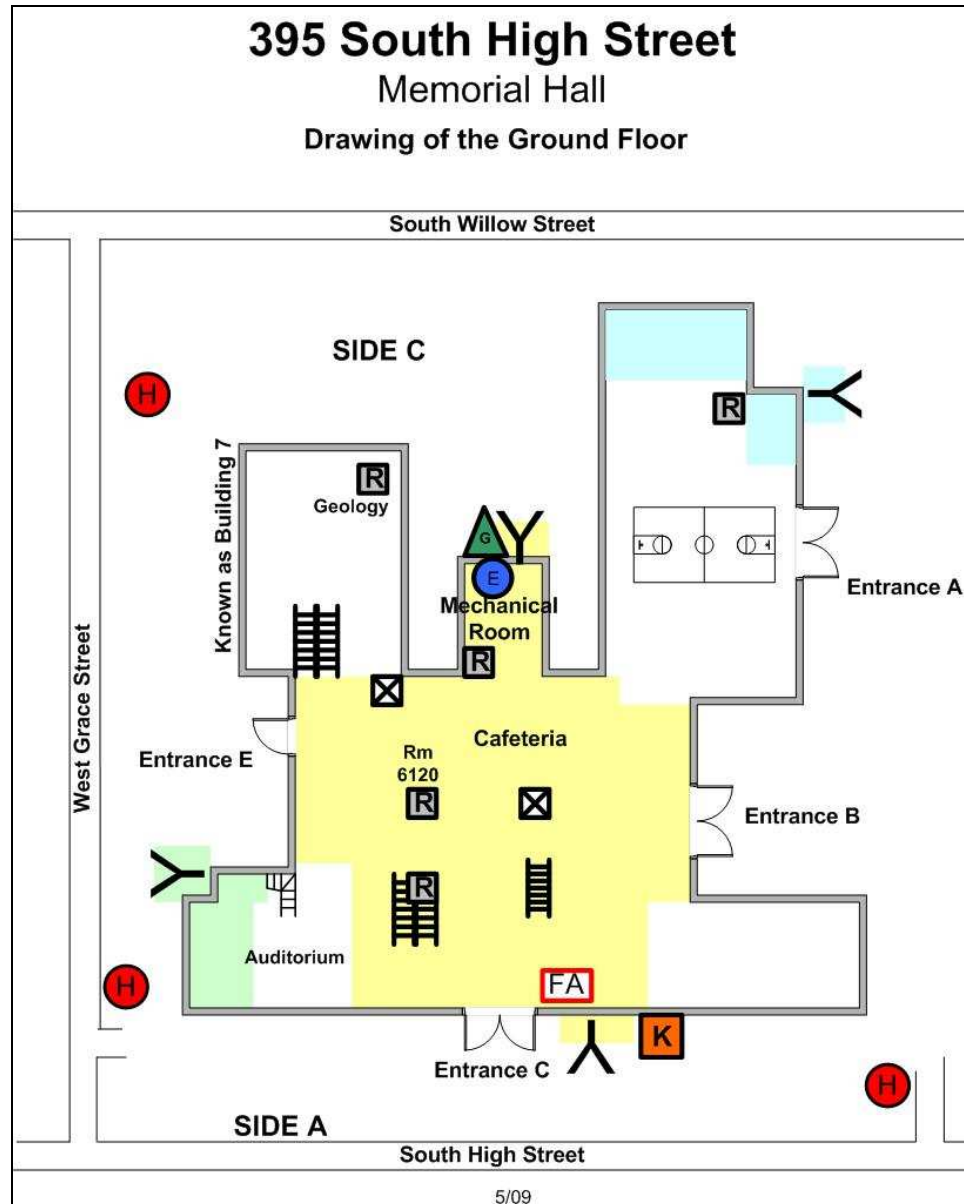


Figure 3: Preplan drawing for 395 South High Street

Preplan drawings provide responders with a map of the site showing critical details such as stairways, fire hydrants, building utilities, elevators, sprinkler connections, etc. Over time preplans have progressed from handwritten actions and drawings, to typed with a typewriter, to word processed and drawing software, and currently to databases. Much like street maps, first due preplans are maintained by each fire company. With about 850

preplans for city, several more large binders worth of preplans and drawings were loaded on to each piece of city fire apparatus (figure 4).

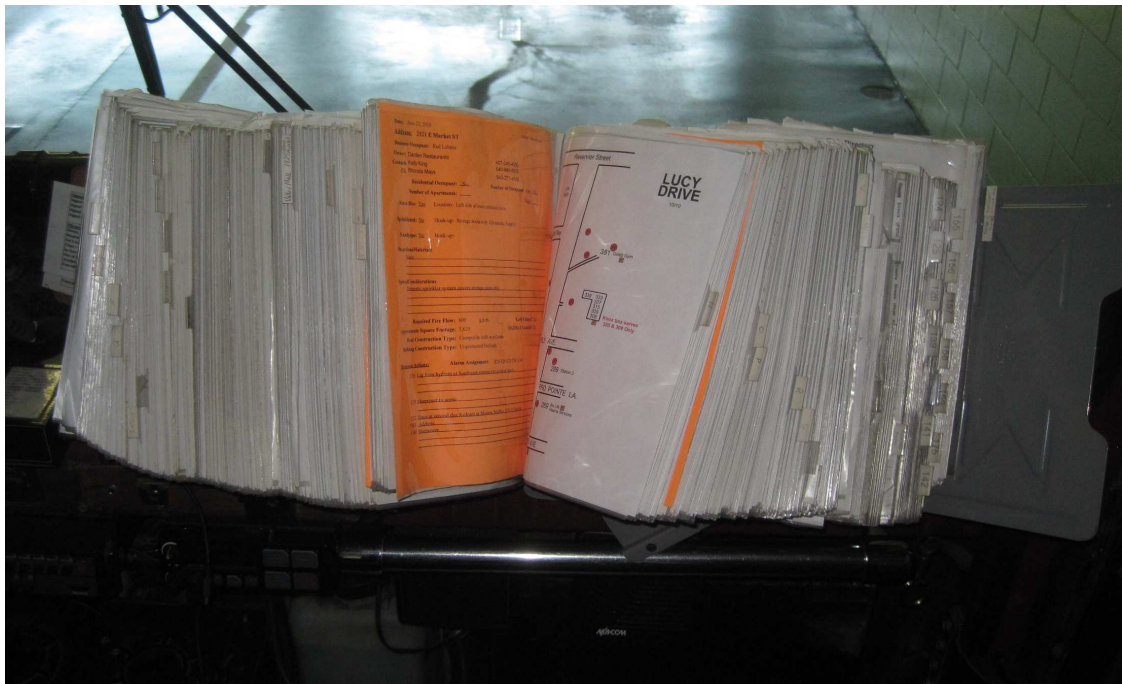


Figure 4: Maps and preplan "parts-book" in HFD fire apparatus, circa 2006

In late 2007 the Harrisonburg Fire Department purchased and installed ruggedized laptops in most of the city's fire apparatus using grant funds provided by the Department of Homeland Security (figure 5). Electronic data replaced stacks of papers and binders, and provided firefighters a means for quickly and efficiently accessing the information necessary for responding to a call for service. Touch-screen enabled toughbooks in fire engines, ladder trucks, and staff vehicles store a FileMaker Pro® database containing all of the street maps and structure preplans in the City of Harrisonburg.



Figure 5: A laptop replaces paper maps and preplans in HFD fire apparatus, 2007

HFD STREET MAPS			
1000	1199	BLUE RIDGE DR	
		BLUE STONE HILLS DR	
		BLUEBIRD CT	
0	99	BLUESTONE DR	JMU
100	199	BLUESTONE DR	JMU
200	299	BLUESTONE DR	JMU
* = map not present			
PAGE UP	0-9	A	B
		C	D
		E	F
		G	H
		I	J
		K	L
		M	N
		O	P
		Q	
PAGE DOWN	R	S	T
		U	V
		W	X
		Y	Z
MENU	QUICK SEARCH	Market Street	ALL
		JMU	PREPLAN
			MENU

Figure 6: Screenshot of HFD street map database - FileMaker Pro

The FileMaker Pro database is user-friendly and efficient for storing and retrieving critical information en route to an emergency. Shown in figure 6 above, the

map screen features streets listed alphabetically by block range in large text. It has large buttons for scrolling and navigating the database, and shortcuts to sort and show streets by first letter. Each record listed is a link to a layout (figure 7) that shows a full screen picture of the street map, as well as large text and control buttons to zoom in and out or go back to the map list. Shortcuts on the right side allow the user to display up to 10 pre-programmed streets that intersect that block. Intersections where streets cross a street block are known as “cross streets”, and they are very important in the emergency response process. Cross streets help narrow down incident locations within blocks.

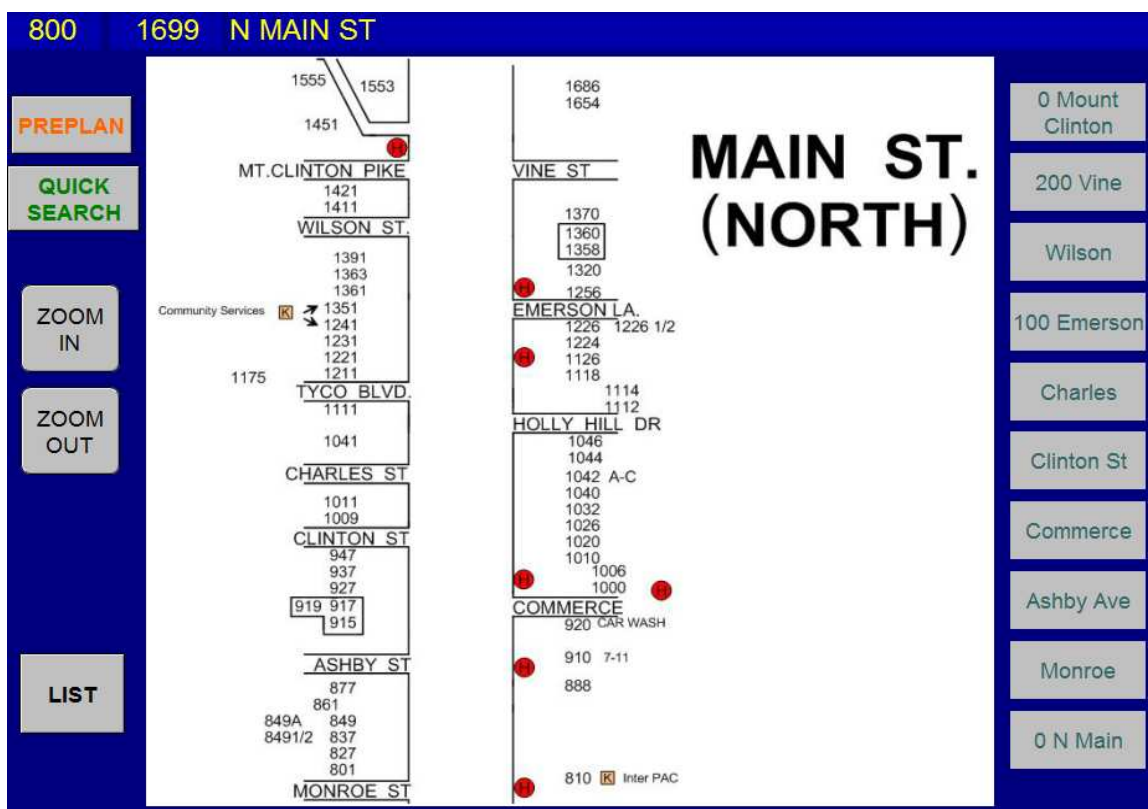


Figure 7: North Main Street map from Figure 1 in the FileMaker Pro viewer

Similar to the street maps database, a second database contains all the preplan data. Shown in figure 8, the preplan database displays a list of preplans available (sorted alphabetically by street address).

HFD PREPLANS		
3160	ABBOTT LA	KNOX BOX
641	ACORN DR	KNOX BOX
880	ACORN DR	KNOX BOX
950	ACORN DR	KNOX BOX
960	ACORN DR	
961	ACORN DR ; 961-963	KNOX BOX

* = floor plan not present

PAGE UP	0-9	A	B	C	D	E	F	G	H	PAGE UP
	I	J	K	L	M	N	O	P	Q	
PAGE DOWN	R	S	T	U	V	W	X	Y	Z	PAGE DOWN
MENU	QUICK SEARCH	Market Street	ALL	JMU	MAPS	MENU				

Figure 8: Screenshot of the HFD preplans list layout – FileMaker Pro

Each record in the list is touchable to display the text portion of the preplan at that address. There are also shortcuts as large buttons for paging and searching for specific preplans from the list, as well as shortcuts for preplans that are labeled as JMU or Market Street addresses. JMU and Market Street preplans make up over one quarter of the preplans in the database. Selecting a preplan record displays the preplan response assignments (figure 9).

HFD PREPLANS		ASSIGNMENTS				
395 S HIGH ST MEMORIAL HALL						
E28 E23 E25 TW1 C40						
E28	Utilizing hydrant on West Grace Street, take main sprinkler, Side A, near main entrance. May need to supply handlines.					
E23	Stage at hydrant off High Street, near main entrance, until directed otherwise. May need to connect to additional sprinkler and supply hand lines.					
E25	Manpower.					
TW1	Stage at entrance off High St.					
C40	Manpower	5/5/2009				
ASSIGNMENTS	KEY INFORMATION	CONTACTS & OCCUPANCY	BUILDING INFORMATION	LAYOUT	STREETS	PREPLAN LIST

Figure 9: Screenshot of the apparatus Response Assignments layout – FileMaker Pro

The preplan example in figure 9 is the electronic version of the preplan form in figure 2. The database presents the apparatus response assignments first. Buttons across the bottom of the layout allow the user to access more preplan data, such as key (Knox Box) & sprinkler connection locations (figure 10), contacts and occupancy (figure 11), building information (figure 12), and drawings or photos (figure13). The buttons simply display a different layout or panel containing different controls and text containers, performing as if the information was laid out among several different tabs.

HFD PREPLANS
KEY INFORMATION

395 S HIGH ST
MEMORIAL HALL

Knox Box: RIGHT SIDE OF MAIN ENTRANCE
 Yes

Sprinkler: A & C SIDE SUPPLY SAME AREA. SIDE B- AUDITORIUM. SIDE D-ROTC AREA.
 Yes

Standpipe: SPRINKLER CONNECTIONS AT SIDE B AND D.
 Yes

395 South High Street
Memorial Hall
Drawing of the Ground Floor

5/5/2009

ASSIGNMENTS
KEY INFORMATION
CONTACTS & OCCUPANCY
BUILDING INFORMATION
LAYOUT
STREETS
PREPLAN LIST

Figure 10: Screenshot of the Key & Sprinkler Information layout – FileMaker Pro

HFD PREPLANS
CONTACTS

395 S HIGH ST
MEMORIAL HALL

Owner James Madison University

Contacts

Residential Occupant: No

Apartments:

of Occupants: Day
Night

395 South High Street
Memorial Hall
Drawing of the Ground Floor

5/5/2009

ASSIGNMENTS
KEY INFORMATION
CONTACTS & OCCUPANCY
BUILDING INFORMATION
LAYOUT
STREETS
PREPLAN LIST

Figure 11: Screenshot of the Contacts & Occupancy layout – FileMaker Pro

HFD PREPLANS		Building Information				
395 S HIGH ST MEMORIAL HALL		395 South High Street Memorial Hall Drawing of the Ground Floor 				
Required Fire Flow: 2,470 g.p.m.						
Approximate Sq Footage: 247,000						
Building Construction Type:	Type III - Exterior walls are noncombustible, interior any permitted material					
Roof Construction Type:	Rubber membrane over metal roof decking					
Hazardous Materials: Early Collapse? No SCIENCE LAB 3RD FLOOR, RM #3315. GEOLOGY RM # 7130 -7140 . NATURAL GAS SERVICE TO BUILDING (SHUTOFF ON C SIDE AT MAINTENANCE ROOM).						
Special Considerations: SPRINKLER SYSTEM DOES NOT COVER ENTIRE BUILDING. AUDITORIUM SEATS 1074 PEOPLE. ALARM PANEL IN OFFICE AT MAIN ENTRANCE. ALL ROOMS HAVE 4 DIGITS; FIRST DIGIT IS BUILDING NUMBER, SECOND IS FLOOR LEVEL, AND LAST TWO ARE ACTUAL ROOM NUMBER.						
		5/5/2009				
ASSIGNMENTS	KEY INFORMATION	CONTACTS & OCCUPANCY	BUILDING INFORMATION	LAYOUT	STREETS	PREPLAN LIST

Figure 12: Screenshot of the Building Information layout – FileMaker Pro

395 S HIGH ST		MEMORIAL HALL				
BUILDING MAP		395 South High Street Memorial Hall Drawing of the Ground Floor 				
Pic #1 ZOOM IN ZOOM OUT		ZOOM IN ZOOM OUT				
ASSIGNMENTS	KEY INFORMATION	CONTACTS & OCCUPANCY	BUILDING INFORMATION	LAYOUT	STREETS	PREPLAN LIST

Figure 13: Screenshot of the Drawings layout – FileMaker Pro

The FileMaker Pro database solution functions adequately for the fire department. However, it is extremely limited in capability. It is not possible to link to anything outside of the individual record, limiting how much data can be saved in a preplan. FileMaker Pro container fields are limited to JPG image formats only, therefore requiring any drawing or picture to be exported to a JPG format. HFD personnel draw images predominately in Microsoft Visio, which is capable of exporting a JPG file in most cases. However, no other document type can be loaded or linked to the database. FileMaker Pro is also limited in what you can do with scripts. The overall issue with the FileMaker Pro solution is that it cannot expand to include additional functionality the users need or want; it cannot link preplans to maps or maps to preplans, it is unable to perform spatial analysis, and it is complex to administer and update.

Another tool made available in 2008 on these laptops in the fire apparatus is a geographic information system (GIS) for the city. A GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying any form of geographically referenced information. GIS provides a dynamic way to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. Geographic Information Systems can help answer questions and solve problems by looking at data in ways that is easily understood and quickly shared, which is critical for emergency responders. GIS data is represented in different feature layers and can be identified spatially as points, lines, or polygons.

GIS is one way to broaden the sources of information available to first responders. It pulls data maintained by multiple agencies and displays it geographically in ways it can be usefully interpreted. GIS is a way to get information that otherwise exists in filing

cabinets where it is useless to personnel in the field and get it on a map where they can see it and take advantage of it. Having all of this information available will increase the efficiency of emergency management, which will result in saving time. When it comes to public safety, saving time means saving lives.

Harrisonburg's Office of Community Development manages a geodatabase containing vast amounts of GIS data including (but not limited to) utilities (water, sewer, storm, electric, etc), fire hydrants, street centerlines, building addresses, property owners, city limits, etc. From an enterprise level, GIS data of this magnitude is virtually impossible to maintain at a fire department; staff members would spend all of their time constantly updating records. By obtaining the existing data from the city's GIS department not only are firefighters saving time and effort, they're not duplicating data that other departments have already collected and maintained. Having the most up to date data about real estate, available fire hydrant flow rates, newly constructed buildings and streets, etc benefits all first responders. Connecting a GPS receiver to GIS software also allows the capability to dynamically pinpoint and track the exact location of the emergency vehicle. One GIS tool suite called ArcMap contains many basic utilities that allow a user to manipulate a map with tools like zoom in or out, pan, select, identify, measure, and find features in GIS data layers.

However, ArcMap is not that simple. ESRI's ArcGIS software is extremely complex to the untrained user, and nearly impossible to use in a mobile environment. As seen in figure 14, a screenshot of the city's GIS for the fire department circa December 2009 displays feature layers such as address points, street lines, and fire hydrant points, all on top of a digital ortho image (a type of aerial photo) over JMU's Bluestone campus.

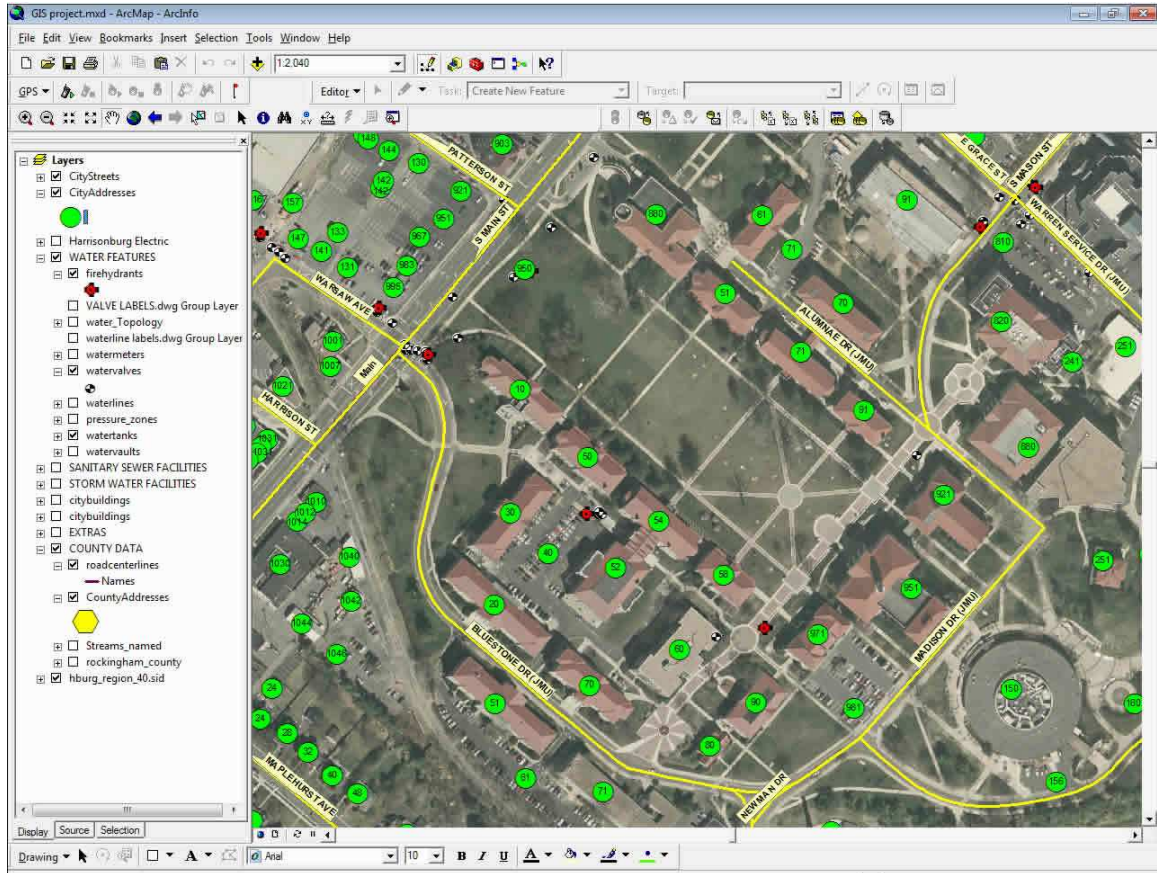


Figure 14: Screenshot of ESRI's ArcMap software

With its small buttons, tool bars, and text, this tool is great for spatial analysis in an office environment, but on a 13.3 inch laptop screen in a fire engine at 3am that feels every bump along the way it is rendered virtually useless. Figure 15 offers a side-by-side comparison of the two software interfaces at the same resolution. The difference in size of the text and controls is plainly visible.

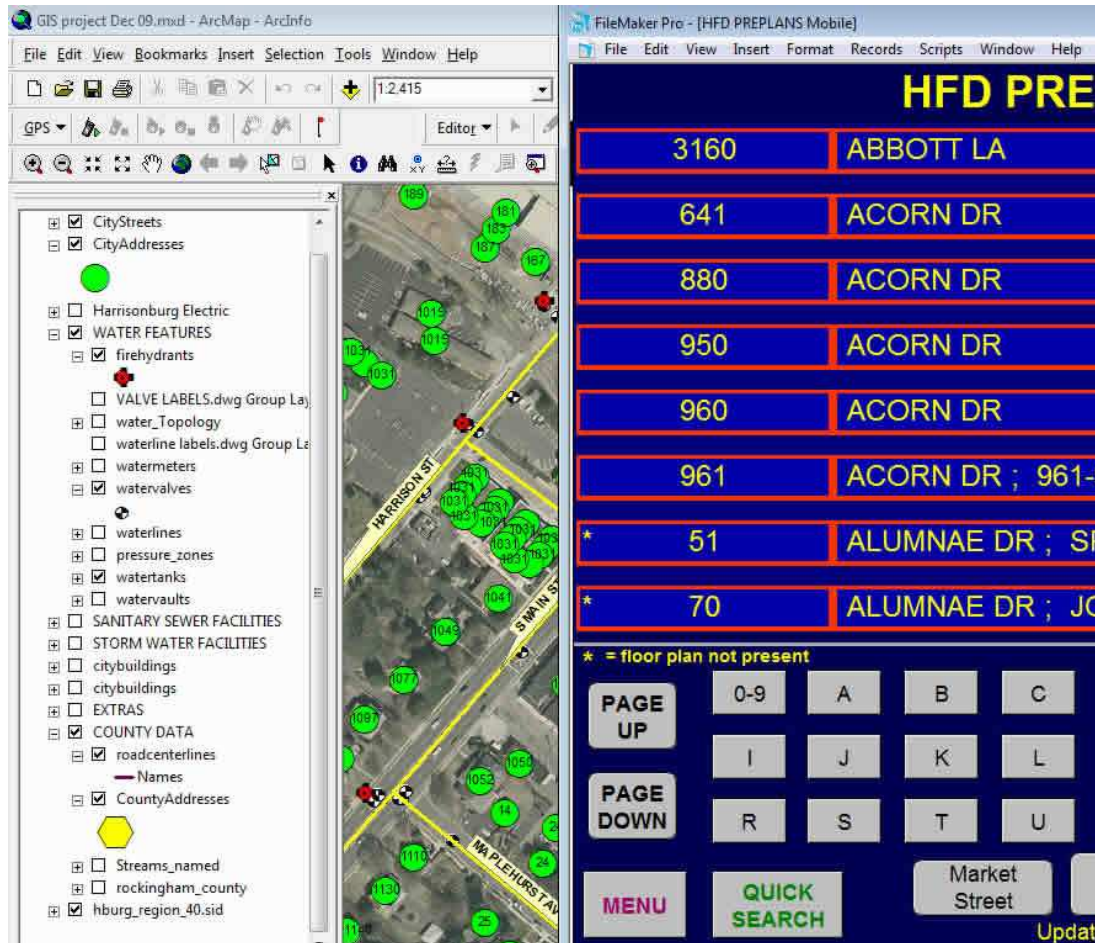


Figure 15: Side-by side comparison of ArcMap and FileMaker Pro user interfaces

To make better use of the information contained in a GIS for emergency responders, a custom software solution is required. This thesis capstone project will detail the software development lifecycle of a GIS-based solution that makes use of ArcGIS Engine and Microsoft Visual Studio to create an integrated solution that functions in a mobile environment. ArcGIS Engine is a tool suite that is a collection of GIS components and developer resources that can be used to create custom mapping applications. The result is a software product that combines multiple critical sources of information into one powerful database not only for the Harrisonburg Fire Department but potentially for other first response agencies. A more detailed account of this process follows in the next chapters, which describe the users' needs assessment, design and

development, data migration, testing, application implementation, user training, system maintenance, and final solution discussion.

II. System Requirements Assessment

Before one line of code is written for any system, it is critical to conduct an assessment with the users of a potential system to facilitate designing the most functional program according to their needs. Since this project integrates multiple systems in use at the Harrisonburg Fire Department, a requirements study was conducted with staff from the city fire stations. There are three 24-hour shifts at HFD; shift A, shift B, and shift C. There are five companies among the four fire stations in the City of Harrisonburg.

Company Name	Station	Station Address
Engine Company 28	Station 1	80 Maryland Avenue
Tower Company 1	Station 1	80 Maryland Avenue
Engine Company 25	Station 2	380 Pleasant Valley Road
Engine Company 26	Station 3	299 Lucy Drive
Engine Company 23	Station 4	210 East Rock Street

Table 1: Harrisonburg Fire Department companies

Each company consists of 4 to 5 fulltime firefighters of varying rank and responsibility. In order to build a list of requirements for this system, all companies on all shifts participated in a consultation to discuss what features and functions they needed in order to carry out their duties. Systems currently in place were assessed for positive and negative feedback, and users were also asked to identify improvements that could be made in order to be more efficient on the job. A-shift was interviewed on May 5th 2010, B-shift was interviewed on June 1st, and C-shift was interviewed on June 2nd.

The most overwhelming feedback was that many features of the FileMaker Pro solution must be available in any solution that replaced it. All text must be in plain font and must be no smaller than size 14. Buttons should be large enough to function on a touch screen, and consider that the user may or may not be wearing some type of gloves during the software interaction. The main input device should be the touchscreen since the laptop is always moving while the vehicle travels down the road, which renders a

mouse, touchpad, or keyboard nearly impossible to use. Since time is of the essence in an emergency, it should only take a few seconds to find and display a map or preplan. The cross street shortcuts in the street maps database was one of the most lauded features of the FileMaker Pro system, and it should accompany any new product.

There were many requests to make improvements where the FileMaker Pro system lacked capability. One of the most frequent complaints pertained to a message box that displays on preplans that warns firefighters about potential early structure collapse due to lightweight construction materials. When a preplan is selected where lightweight construction is involved, a warning message box pops up on the screen warning the responder of the hazard (figure 16). While the warning prompt has good intention, it inhibits the user in several ways. First, it is difficult to clear using the touch screen due to the small size of the “OK” button. Secondly, it hides other critical information for the second and third due company assignments as well as the image thumbnail on the right. It was the consensus that this hazard message alert needed to be implemented in a different way.

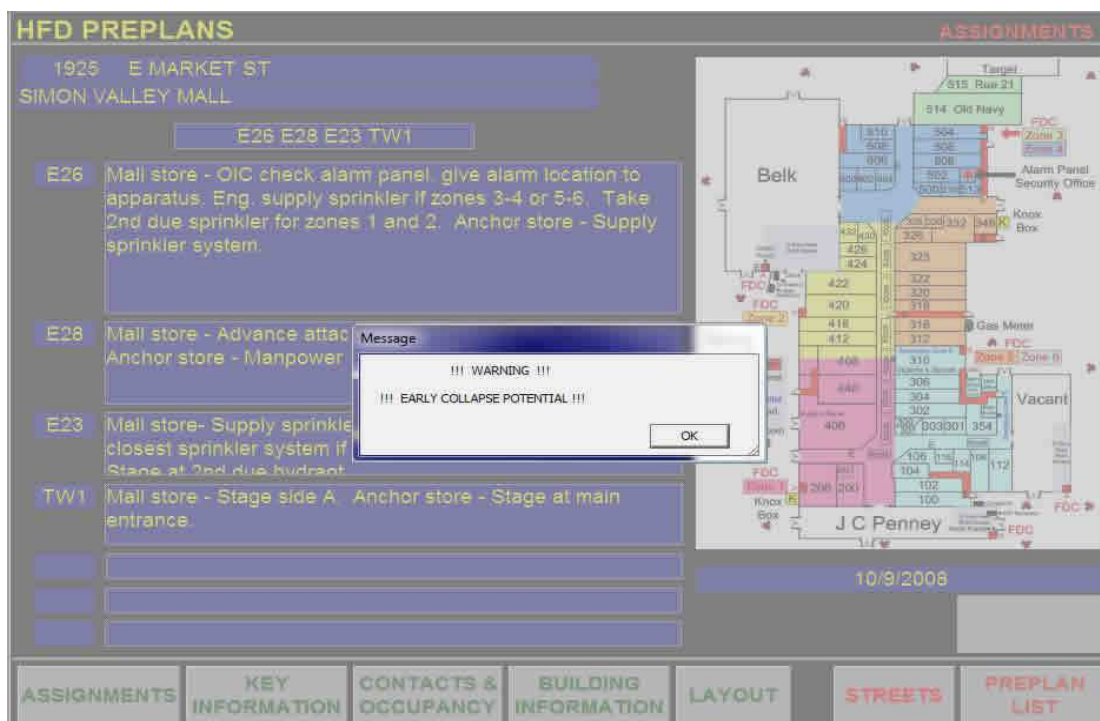


Figure 16: A message box in the foreground hides critical preplan information

There were numerous requests to have the ability to touch an address point on a displayed map image, and automatically have the system search for and display the preplan or other critical information about that address. There's no way to link multiple points of information to a specific point in a flattened image (JPG), thus there's no way to make this function available in FileMaker Pro. However, this feature could be implemented in a GIS program where a tool or function searches for information based on a specific point in space.

Another major drawback to the FileMaker Pro solution is the inability to manipulate images. The software allows the user to view a picture at nearly a full screen size, however there is no way to easily zoom or pan the image. While there are buttons to zoom in and zoom out shown on the layout, the zoom function is not a true image zoom. The zoom feature in FileMaker Pro actually magnifies the entire layout on the screen by a magnitude of 50%; it enlarges all controls such as text, buttons, pictures, labels, etc.

Figure 17 displays a screenshot of a map of East Wolfe Street in the city at the standard 100% zoom level. The address numbers on this map are nearly impossible to read even on a full screen laptop. Using the zoom buttons on the left, the layout is zoomed to 200% in figure 18. Note the standard toolbars on the edges of the screenshots remain the same size, while all other aspects of the layout have zoomed to twice their size.

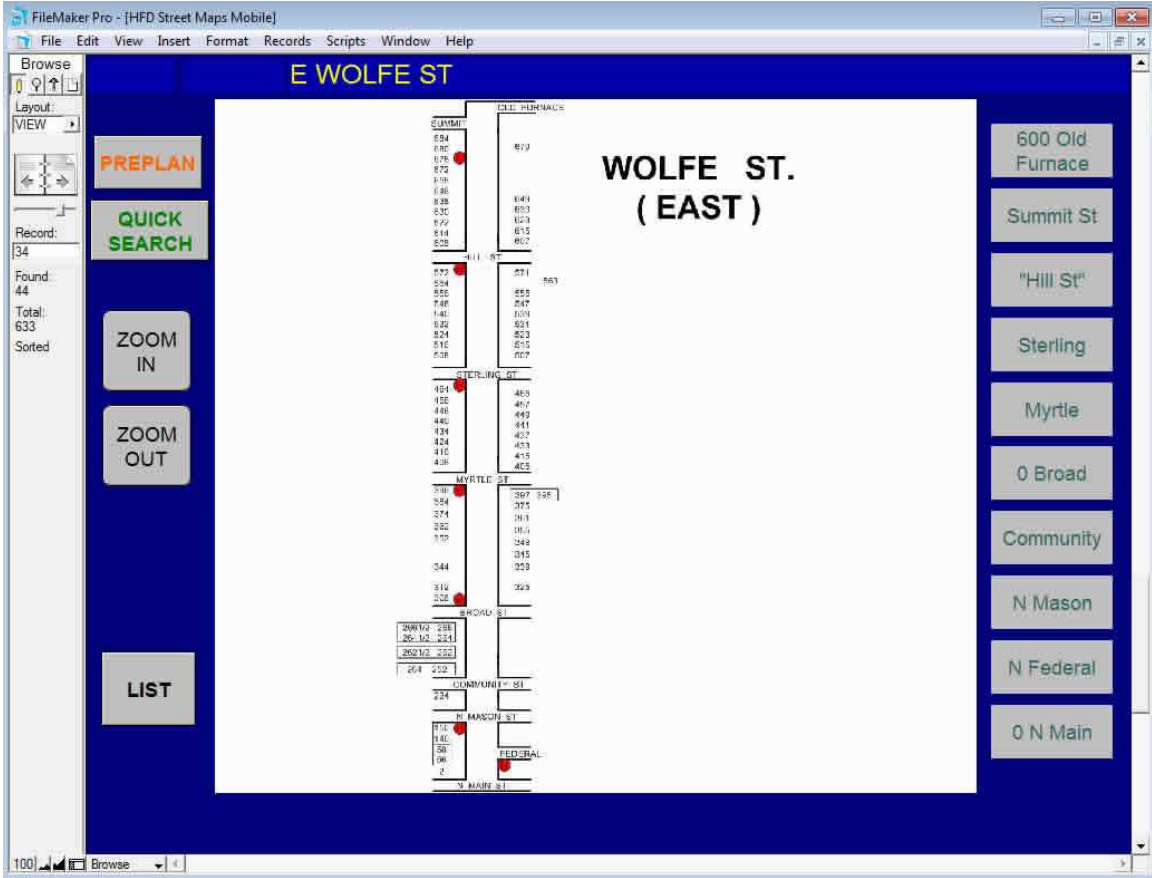


Figure 17: FileMaker Pro 100% zoom level – East Wolfe Street

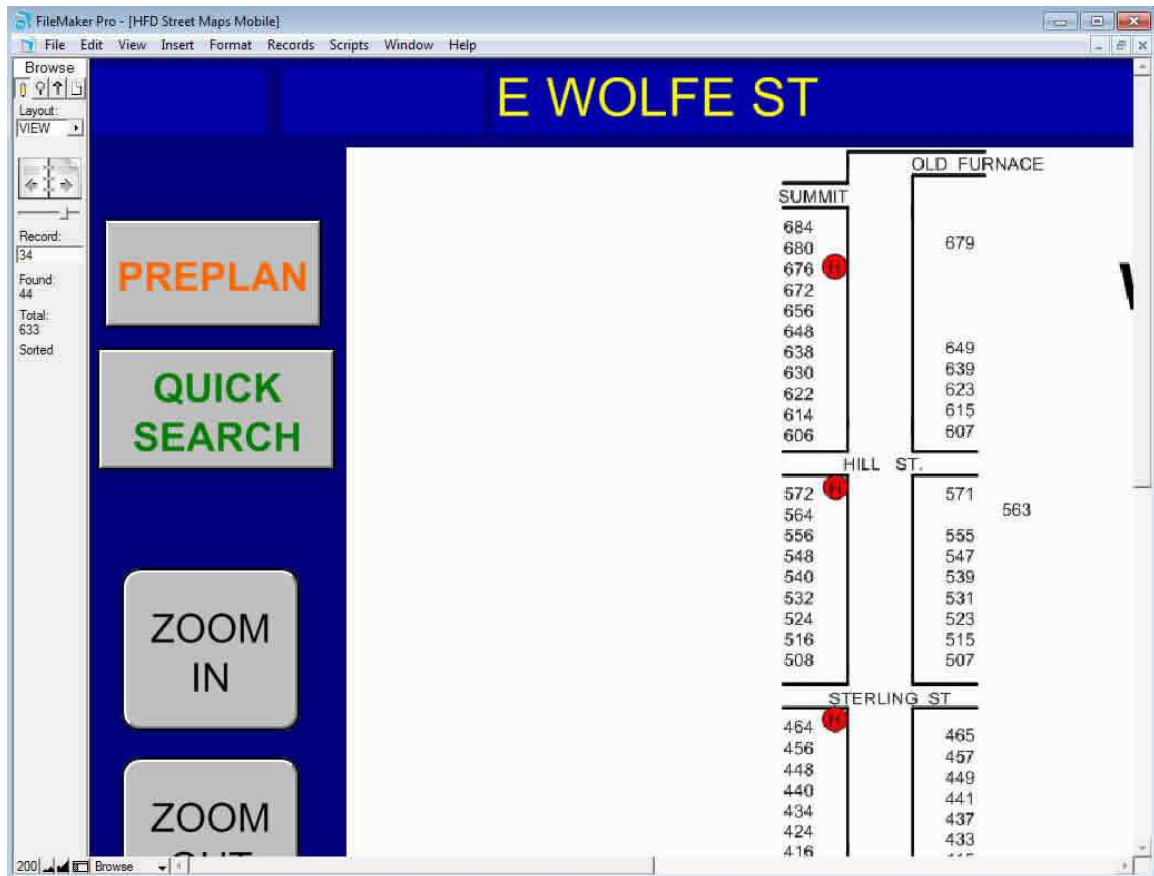


Figure 18: FileMaker Pro 200% zoom level – East Wolfe Street

While the image is now viewable at 200%, there is a new problem. In order to pan an image up, down, left, or right, the user is forced to use standard windows scrollbars on the right and bottom sides of the touch screen. A standard scrollbar is narrower than the body of a typical ink pen, thus a scrollbar is certainly not finger-friendly when it comes to a touch screen. The way the program is setup, touching a image sets the layout zoom at 100%, so accidentally touching the image instead of the scrollbar zooms the layout back to 100%, forcing the user to start over with the zooming process.

Given the difficulty with viewing and manipulating images coupled with the fact that over half of the HFD FileMaker Pro solution is implemented in order to view map images and building preplan images, it is critical to design and deploy a solution with the

capability to zoom and pan various formats of pictures. The fire department would also like the capability to use file formats other than JPG. Given that the majority of the HFD staff creates drawings in Microsoft Visio, a viewer that could read those types of files would simplify the process by saving time converting files. Other file types such as PDF, TIFF, BMP, DOC, GIF, etc would also be beneficial but not be critical.

An improved search feature was also a request. The FileMaker Pro system allows the user to search for a street name in the maps database. However, in the preplan database a search is broken up in two separate fields; one for address number and one for street name. This is somewhat restrictive if the user is unsure of the address or would prefer to type in the building or business name instead. Also, searching for a preplan does not simultaneously search for a street map in the street database. Likewise, searching for a street map does not simultaneously search for preplans in the preplan database. While the latter is less likely, the former is very important in case a company is arriving on the incident location and needs to find another cross street to access the emergency, another hydrant, block off the incident scene, etc. Having the maps of the streets nearest an incident without having to waste time searching for them would be a drastic improvement.

There were many complaints about the usability of the ArcMap GIS software. While the tool was a great asset, it was impossible to use while responding to an emergency. The toolbar buttons were too small to touch (figure 19), the text was too small to read, and without hours of formal training nobody knew how to use the program. One of the best features about the GIS was that it made addresses in Rockingham County available to the city fire department. While not conclusive, the city obtained a replicated

file several years ago from the county GIS department containing building addresses and streets layers for most of Rockingham County. This was beneficial since the city companies are more familiar with addresses inside the city limits and their first due than they are for the county or beyond. Using the GPS locator was also a major benefit of ArcMap according to the users. During the major snow storms the previous winter, many companies used the GIS combined with the GPS locator to pinpoint fire hydrants that were buried under many feet of snow alongside roadways so that they could be dug out.



Figure 19: A gloved firefighter struggles to use ArcMap software

There were some other requests during the user assessments that were categorized as “wish list” items that would be nice to have as options as the fire department considers future systems. Turn-by-turn directions might have been one of the most frequent feature requests. Portable GPS navigation systems such as Garmin or TomTom are restrictive in

that the streets and the addresses in these over-the-counter units are not the most up to date. Using a portable GPS unit is also one more thing a responder has to do while en route to an emergency that uses valuable time. Computer software such as Microsoft Streets and Trips suffer from the same issues. Routing from point to point is possible in GIS. However, at this time neither the City of Harrisonburg nor Rockingham County officials have a routable GIS streets layer. That is not to say a routable streets table does not exist somewhere, however it is not available at this time. A customized software package could have the capability to route a vehicle from one point to another using GIS tools, however the current data sets available to the city do not support it.

Text-to-voice capability was suggested, particularly for directions so that the computer would speak the directions to the user. Taking that a step further, the laptop's audio-out port could be interfaced with the fire apparatus headphone system so that the driver and all riders could hear anything the computer would communicate.

One final user's request that would make a new system stand out from any other product was a Computer-Aided Dispatch (CAD) interface between the fire apparatus and the Emergency Communications Center (ECC). Integration with CAD could allow the 911 center to dynamically push an address point to the fire department laptop, essentially requiring no address or location input from the user. When a company is dispatched for an emergency the map and preplan would already be displayed on the laptop screen allowing the responders more time to efficiently assess the available information while en route to an incident.

With over 20 hours of initial interviews, user's requirements were taken into consideration. All needs were prioritized according to request frequency for a

development timeline. Basic usability needs were considered at first and throughout the development process. Incorporating existing functionality along with improvements requested was also given high priority. Since integration among several databases and systems was the goal of this thesis, this was the focal point of the development process. Upon successful integration of the GIS, maps, and preplans, more usability requests and features could be considered. “Wish list” items such as routing and CAD integration would require the coordination of multiple agencies and is outside of the scope of this thesis. However, it is critical to have these requirements in mind as development begins and progresses in case the software development continues.

III. System Design & Development

Prior to beginning the software development process, a period of several weeks was spent in preparation. As a result of the requirements analysis, it was determined that a .NET solution would be developed using Microsoft Visual Studio 2008 Professional. Incorporating ArcMap tools would be made possible by utilizing ESRI's ArcGIS Engine, which is a collection of GIS components and developer resources that allows developers to create customized mapping applications. A development environment including Visual Studio and ArcGIS Engine was setup on a custom 2.2 GHz AMD desktop computer. Reference materials and programming guides were gathered, including Bradley and Millsbaugh's *Programming in Visual Basic 2008*, and Burke's *Getting to Know ArcObjects*.

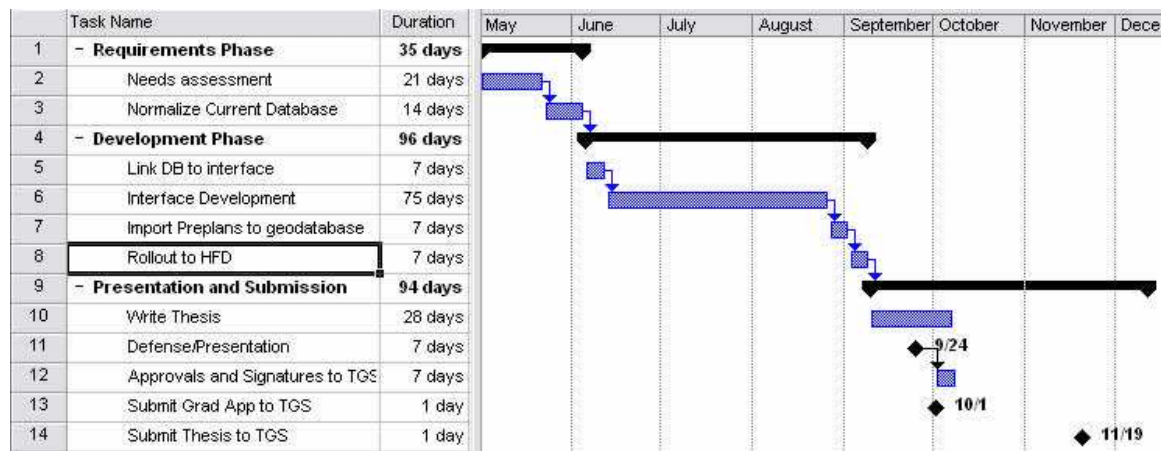


Figure 20: Proposed project timeline

Figure 20 outlines the proposed timeline for the thesis project. Development of an integrated software solution began on June 6th. Several forms, layouts, and controls were experimented with. The best layout employed a tabbed approach similar to the way the FileMaker Pro preplan database functioned by using different buttons to change between various layouts. Tabs across the top of the application included a tab for a menu or options panel, a tab for maps that would implement the FileMaker Pro street maps

database functionality, a preplan tab that would implement the preplan database functionality, a search tab to facilitate GIS searches, and a GIS tab that would contain ArcMap components.

The main form was customized for the Harrisonburg Fire Department by adding their logo to the title bar of the main application window. Within one week the basic layout was more defined. The “Menu” and options tab was moved to be the first tab, and a “Directions” tab was added. The directions tab would facilitate the future development of turn-by-turn routing for driving directions, featuring a split view with two ArcMap controls. One map control is for the current location map based on a GPS receiver point, and the incident location map to display the destination point. Instead of beginning with GIS functionality first, development began with the street maps search and display functionality as one way for the developer to become reacquainted with the programming language.

Street Map Integration

The initial week of development involved creating the functionality of the street map file viewer and the methods associated with it. The maps tab would need the capabilities to search and list available maps as well as display the picture of the map file. This tab would be implemented with several panels: a file results panel, a file viewer panel, and later a file search panel. A panel is simply a control that is used to provide an identifiable grouping for other controls. Panels allow forms to be subdivided for functionality. In this solution, if one panel on a tab is visible then other panels on the same tab might either be invisible or behind the visible panel.

The results panel features a ListBox control that identifies file search results (figure 21). It takes up a majority of the screen in order to maximize the number of file results it can list. The ListBox can display 12 results at a font face of Microsoft Sans Serif 24. Paging up and down buttons for the results list were essential due to the narrow scrollbars on the side of ListBox controls. The file search method was the key implementation concept on this tab. A search string is passed to a search method, which looks for filenames in a specified directory that match the string. A label below the ListBox displays the count of the results. Clicking (touching) any of the results in the ListBox will try to display the selected file on the viewer panel.

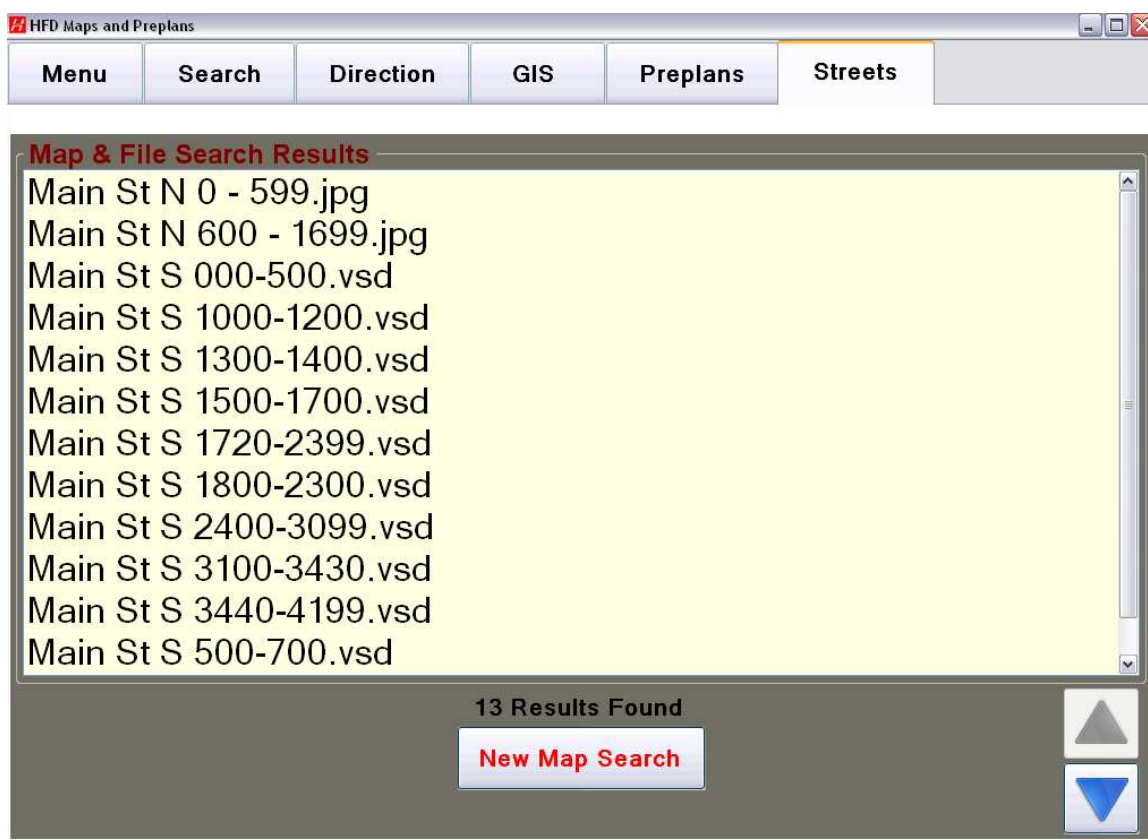


Figure 21: File search results for “Main St”

The method to display the selected map utilizes a select case statement that executes differently based on the file extension. JPG, BMP, GIF, and TIF image formats are

acceptable image formats to display in a PictureBox control. Selecting a PDF file will launch the file in Adobe Acrobat Reader (if the Adobe software is installed).

The concept of viewing pictures or drawing files sounds simple but the implementation was no easy task. One panel contains a PictureBox control and needed zooming control buttons, labels, and panning functionality to manipulate images. However, Visio files presented a challenge. VSD files will not load in a PictureBox control. Several experiments ensued, including one wild idea to programmatically open a Visio file, invoke an export to a JPG file, and then load that file into the PictureBox control. This unusual approach was not successful. A different Component Object Model (COM) control was necessary to successfully implement this functionality. Continuing research later in the development process revealed that it was possible to incorporate an ActiveX Visio control as a COM module reference in Visual Studio applications. After downloading Microsoft's free Visio Viewer 2010, a Microsoft Visio Viewer 14.0 Type Library COM object was available in Visual Studio. Adding this component to another panel essentially placed a blank Visio document into the application. Programmatically, all that remained was to pass a filename and directory to the object to make a Visio file viewable in an ActiveX control just like a JPG file in a PictureBox control. As an added bonus, the Visio Viewer component already had built in zooming and panning features. Using three button controls for zooming in, zooming out, and zooming to 100% (whole page) was made easy by simply calling appropriate zoom properties on the Visio object (figure 22). A "Map List" button allows the user to go back to the results panel.

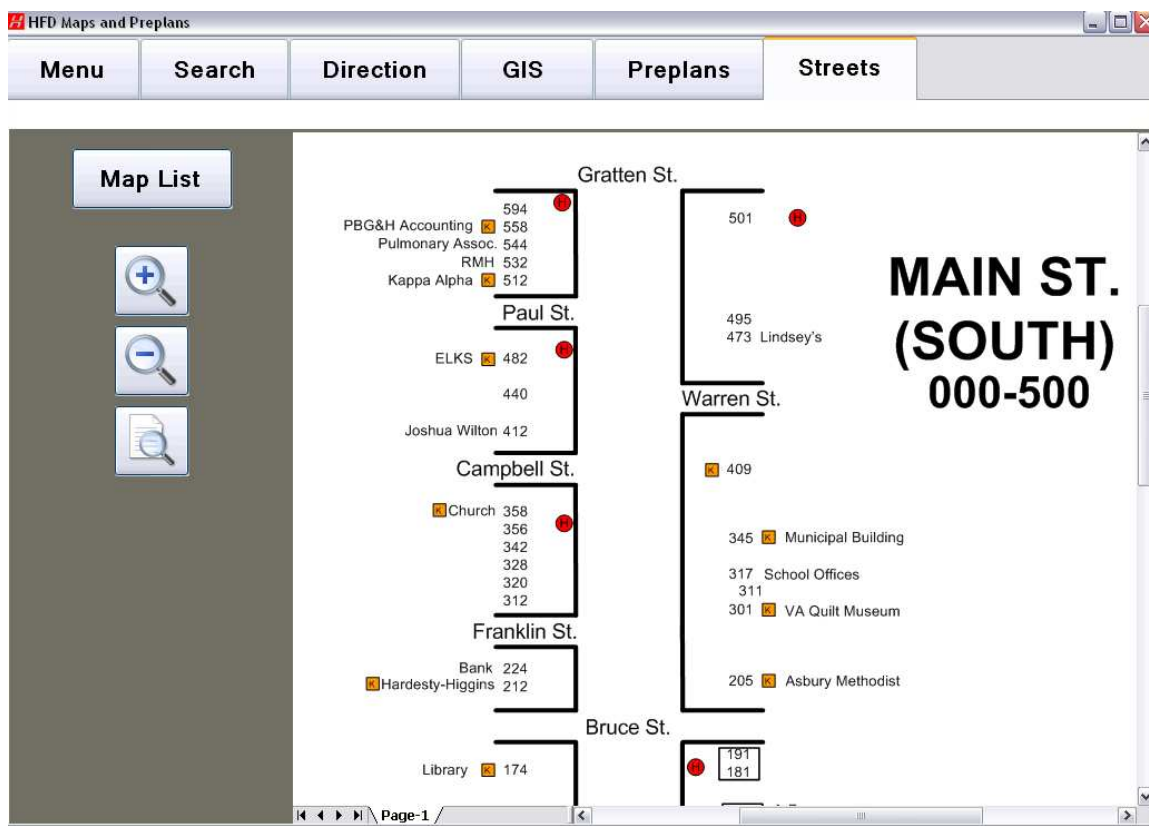


Figure 22: A Visio file loaded into the Visio Viewer component

Zooming and panning a PictureBox control required significantly more programming effort. A considerable amount of time was spent on creating methods that could handle zooming capability. One consistent development problem was that images over a size of about 600 x 600 pixels (just larger than the PictureBox object) were getting cut off. After nearly giving up on the PictureBox control and scrapping the whole approach, the object's properties were closely examined. As it turned out there was a parameter for the maximum size of the image in the PictureBox; the function coding was correct all along and a small parameter was limiting the size of the viewable image. Zooming in or out of an image involves taking the source image dimensions into consideration, determining a target width and height with respect to zoom level for creating a new image, and placing the image into the PictureBox. Scrollbars on the right

and bottom of the image container dynamically update based on the size and position of the image when it is zoomed in or out.

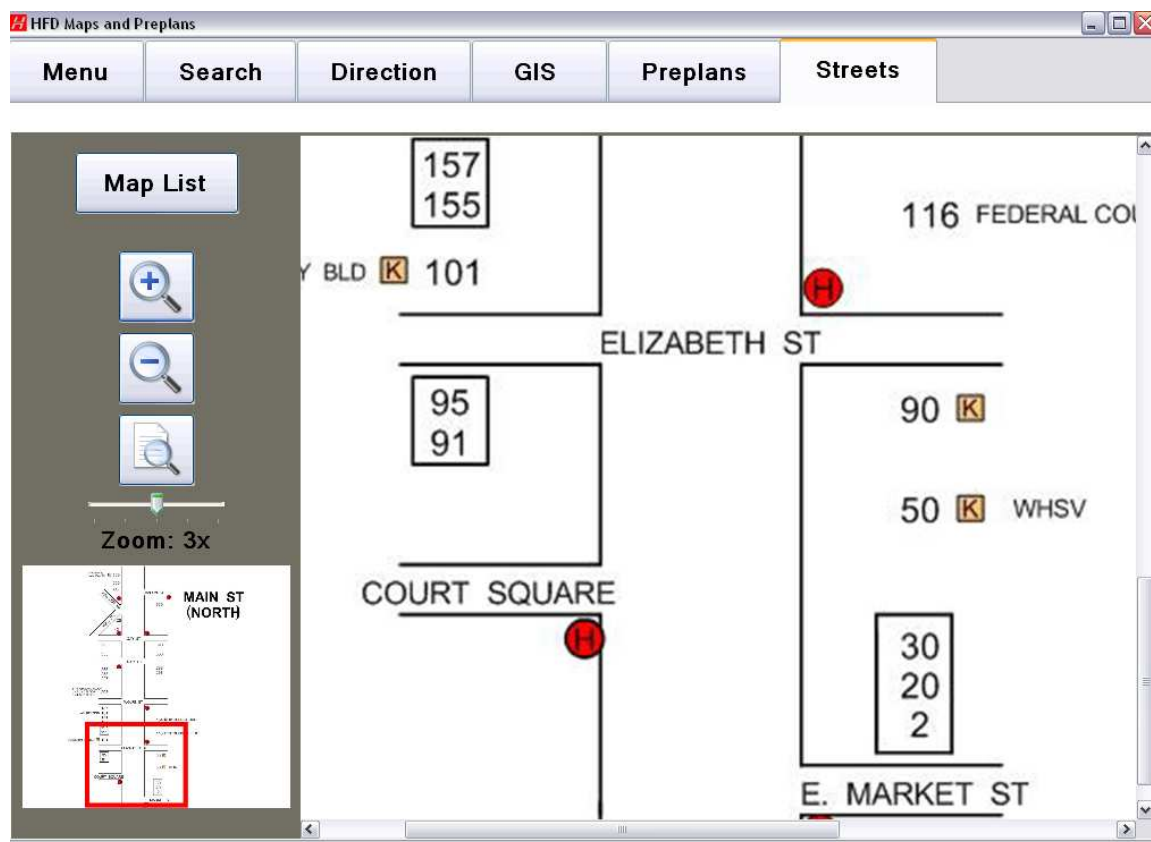


Figure 23: 3x zoom of North Main Street

A feature that was added to the PictureBox panel was a thumbnail of the original image (figure 23). Displayed in the bottom left corner, a thumbnail displays the portion of the image in the main PictureBox view outlined in a red box. Panning an image (dragging or moving the image) was the only remaining critical function to implement on PictureBox control. This involved some creative math that considered the image's dimensions and the X/Y point on the PictureBox that the user clicks or touches on, then scrolling the picture to the proper destination (where the user un-clicks or releases the image). Essentially by clicking the picture, the user is grabbing the scrollbars on the right and bottom of the PictureBox and moving the scrollbars. The thumbnail outline is

updated to place red selection box accordingly. The thumbnail is also selectable in that clicking a point on the thumbnail centers the main PictureBox view to the clicked point on the thumbnail.

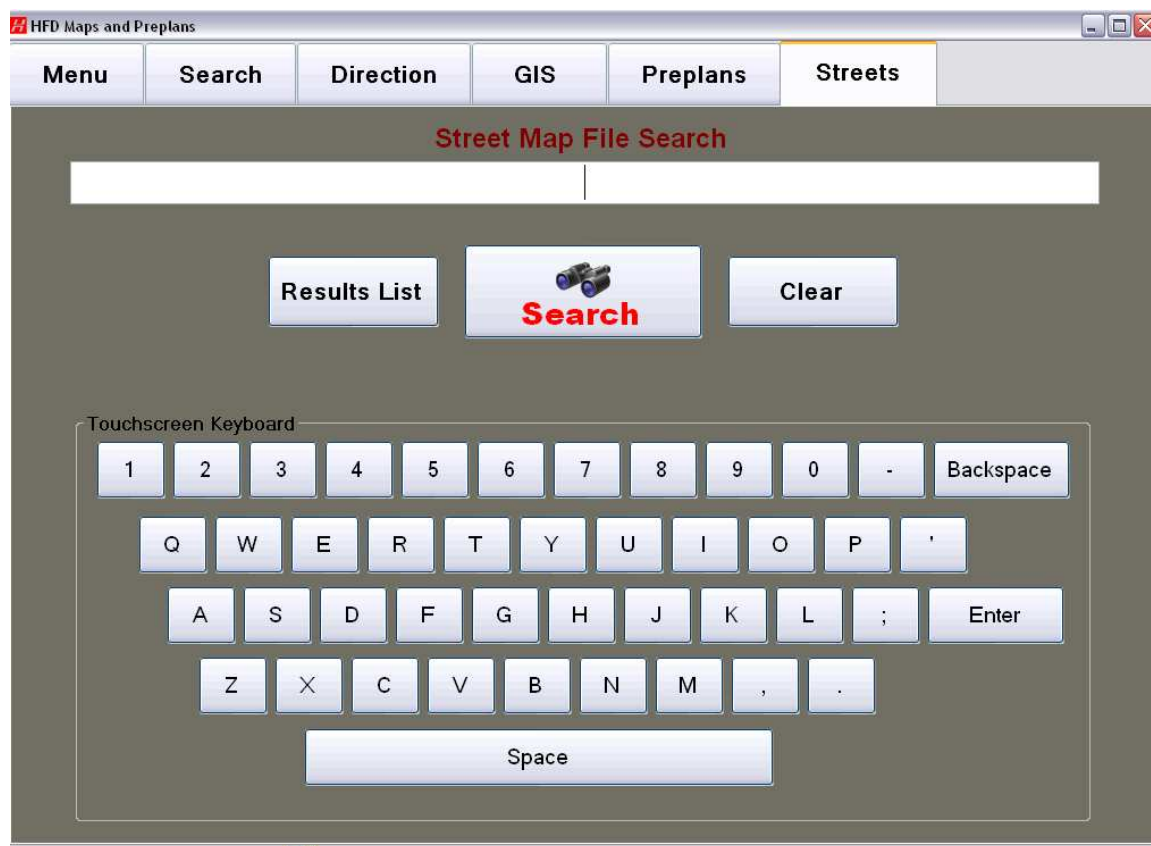


Figure 24: The file search panel

Since the Search tab at the top of the program implements a GIS feature search for the software, another search panel is required to search only for map drawing files. A third panel was added to the Streets tab to conduct a map file search. Seen in figure 24, the panel features a touch screen keyboard for filename input and some other button controls that fully implement the file search and navigation capability. Pressing keys on the keyboard or touchscreen adds the letter to the search string textbox. The Search button invokes the file search method, which accepts the search string as input. The results list panel then displays matching filenames.

These three panels fully implement and improve all available features of the existing FileMaker Pro database that the Harrisonburg Fire Department had in place. The process for updating a street map the FileMaker Pro system used to be that an administrator had to obtain a digital copy of the new map, export a JPG file of the map, upload it to the FileMaker Pro database, manually update street names, block ranges, comments, and cross streets, and then copy the database to a shared network folder. From that point a utility installed on the fire department laptops would periodically synchronize with the network share. With this new application, no administrative support is required. Since the map files are synchronized to apparatus laptops by the same utility that updates the FileMaker Pro system, whenever a map is updated and saved the newer file replicates to the laptop. It is not necessary to update individual records and publish a new copy of the database.

The file search function allows users to search for matching street map filenames more efficiently. A panel containing a scrollable ListBox displays matching file results. The PictureBox panel and the ActiveX Visio panel allow the user to view multiple images file formats. Both viewers fully implement zooming and panning capabilities. The streets tab is implemented with almost 1000 lines of code.

GIS Integration

A GIS tab implements the controls necessary to view GIS data. An ArcGIS map object fills most of the tab, a table of contents object to display map layers is docked on the left side, and a toolbar across the top contains standard ArcMap tools to manipulate the GIS map (figure 25). The map control allows for an ArcMap document (MXD file type) to be loaded into the map object. For this application, a MXD file maintained by

the fire department will be loaded at runtime. The table of contents control displays the available layers of the map object. Both the toolbar object and the table of contents object are linked to the map object in order to control the map object.

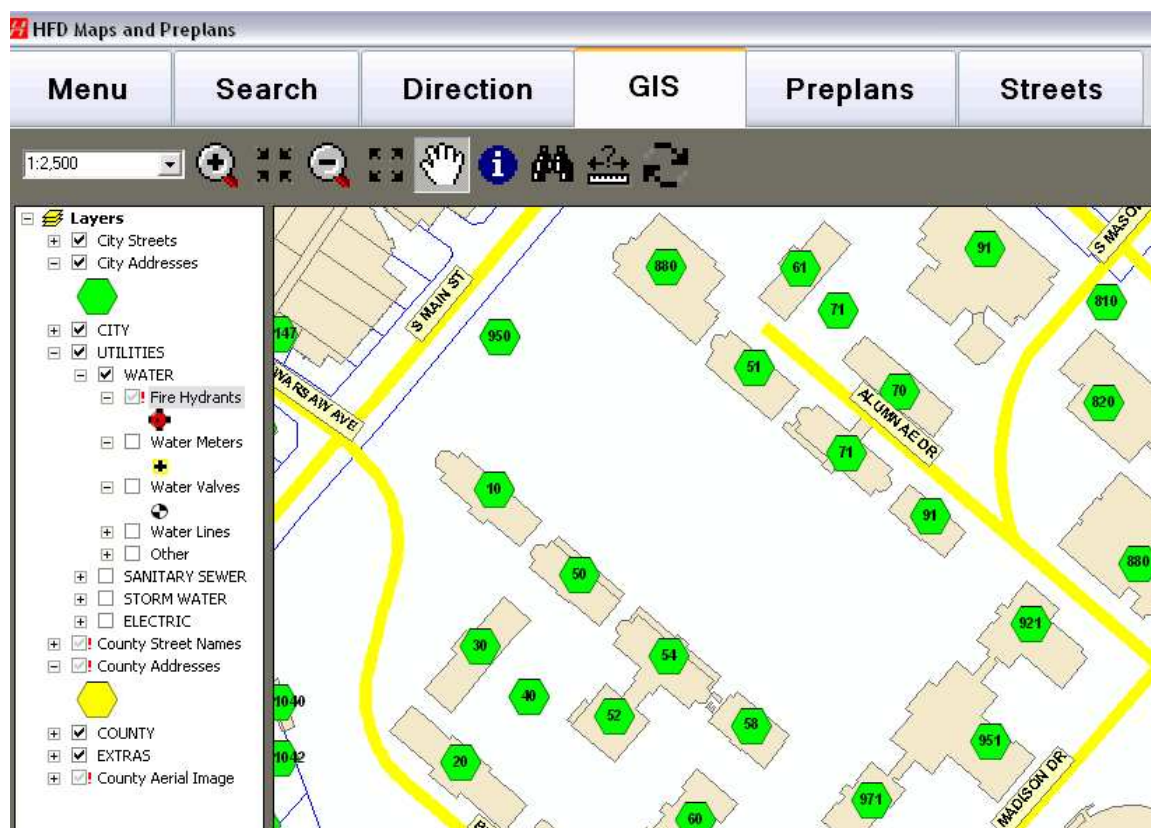


Figure 25: Partial screenshot of initial GIS tab design layout

The utilities available to add to the GIS toolbar were selectable as part on the ArcObject control. Initially several basic map controls were used, including (from left to right in figure 25), map scale, zoom in, fixed zoom in, zoom out, fixed zoom out, pan, identify, find, measure, and refresh. It quickly became apparent that the standard ArcGIS Engine toolbar control would not be adequate for this solution. The buttons were still too small, the map scale control was a standard 10 point font with a narrow dropdown control, and the icons were rather grainy when enlarged. It would be necessary to implement custom button controls to manipulate the map object. These controls would

be researched and implemented later on in the development cycle after some of the core system functions were successfully programmed.

Figure 26 is a screenshot of the first GIS search panel design. It features a textbox control for a search string and numerous button controls that would perform as a keyboard specifically designed for a touchscreen by passing a character to the search string textbox. This panel would later be updated to include several more controls.

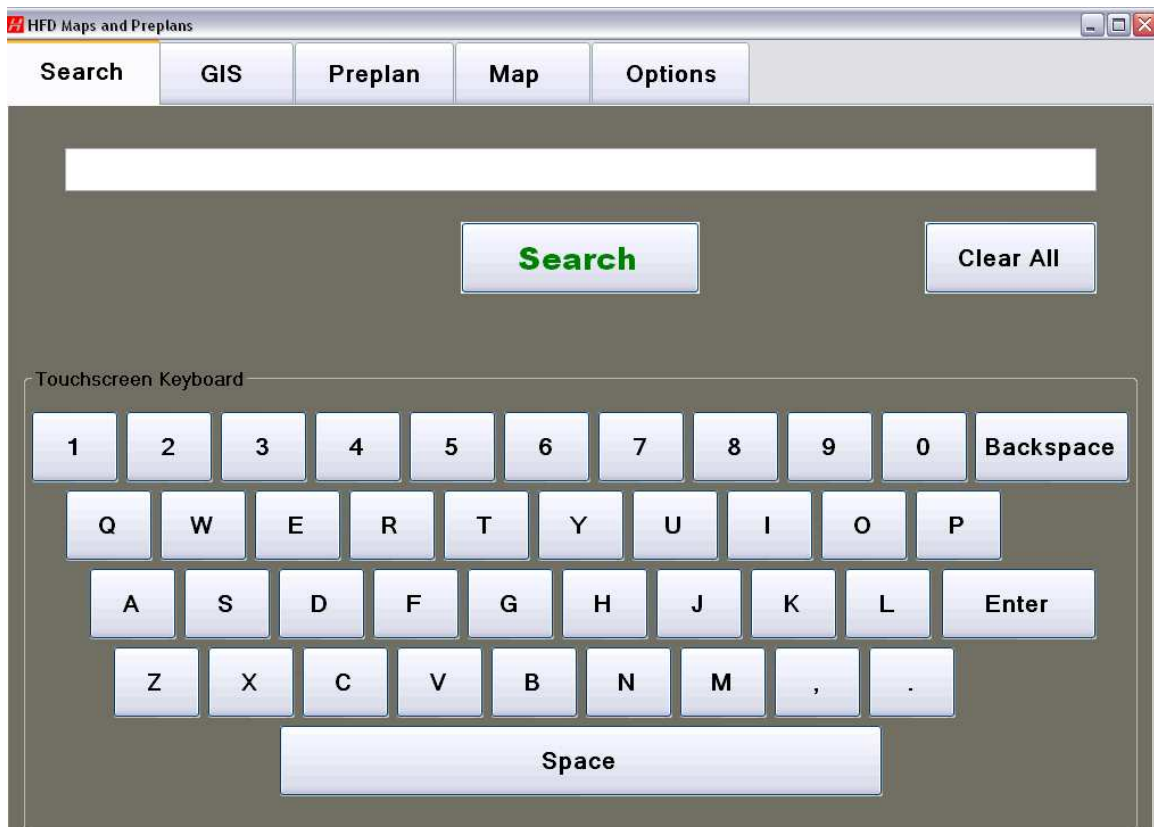


Figure 26: Initial GIS search screen design featuring a touchscreen keyboard

Entering a search string into the textbox and clicking the search button invokes a method to find objects in the ArcMap document on the GIS tab. The function utilizes the ArcMap 'Find' command, passing the search string to find features matching the search string from a specified layer of the GIS map. In this case, the find is performed on the address feature layer. Features that match the search are returned and listed in a ListBox

control on another panel of the search tab. Figure 27 shows GIS search results for “Carrier Dr” entered as the search string on the GIS feature search panel.

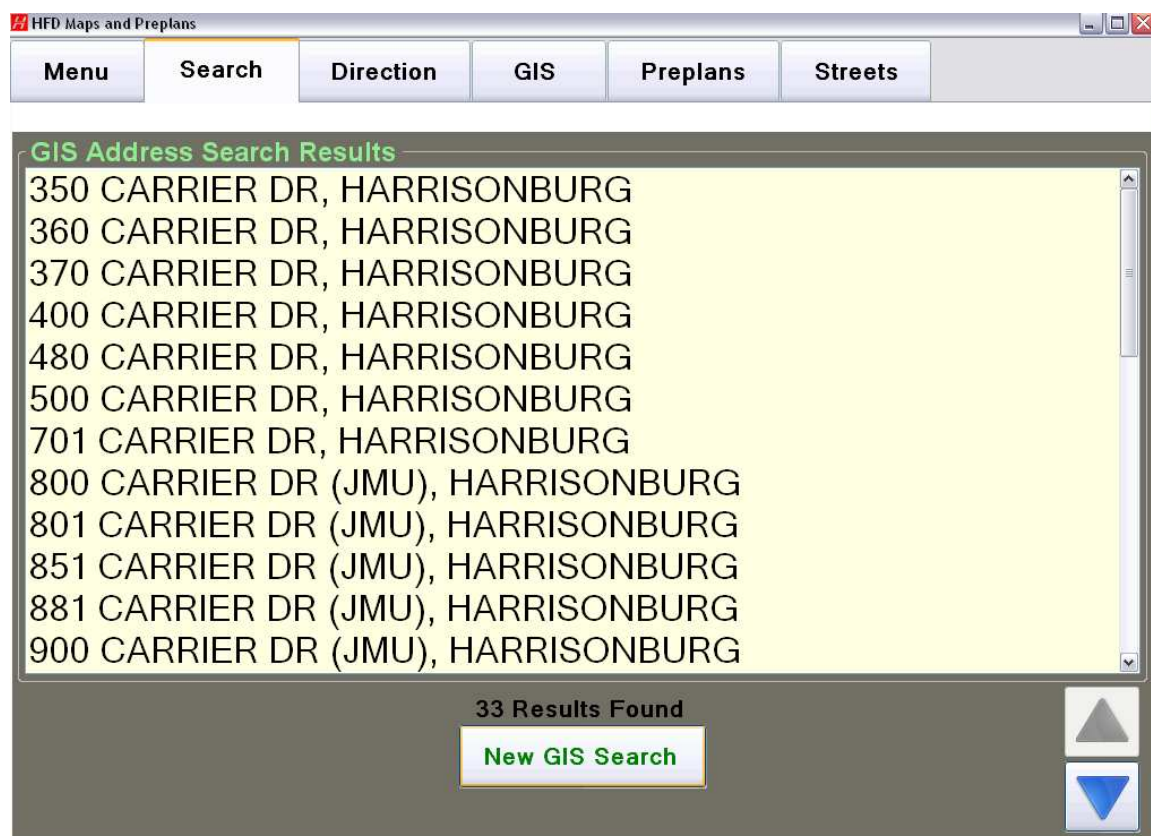


Figure 27: GIS Search results for “Carrier Dr”

Identically to the streets file results panel, the GIS feature search results panels have controls for scrolling up and down the results list and for going back to the search screen to conduct a new GIS feature search. Just as touching or clicking a result in the street file ListBox will load the image into a picture viewer, selecting one of the results from the GIS address search results will pinpoint that address on the GIS map object and display the GIS tab with the selected feature centered on the map. Address points or polygons are identified by a pushpin icon. Street lines are highlighted in another color. Figure 28 is the screenshot that displays the GIS tab that shows for selecting the result “701 Carrier Dr, Harrisonburg” from the results in figure 27.

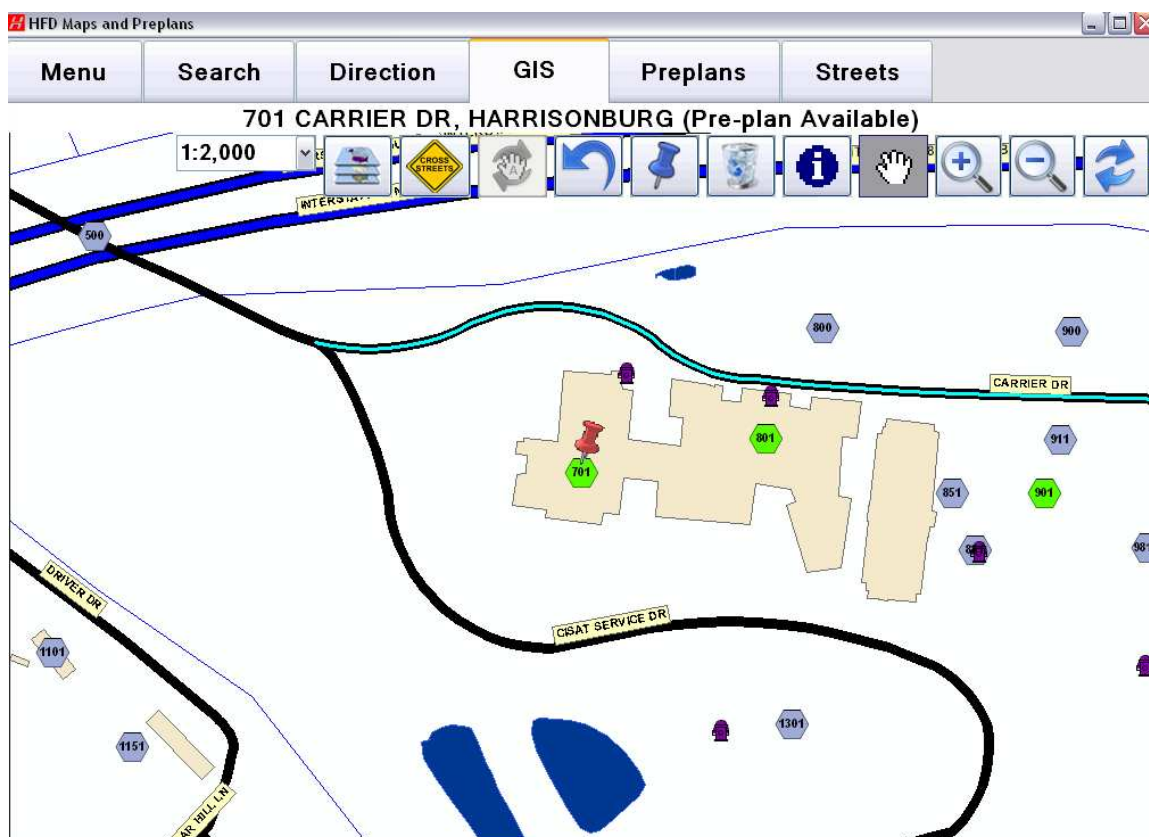


Figure 28: GIS result for “701 Carrier Dr” pinpoints the ISAT building

As mentioned previously, GIS features can be identified as points, lines, or polygons. Figure 28 shows the City of Harrisonburg’s GIS address points and fire hydrants are represented as point features, streets are represented as lines, and buildings and lakes are represented as polygons. All features have shape, size, and color properties that can be customized in the ArcMap file; this is just one way to represent GIS data.

More designs and updates during the development process implemented some changes to the GIS tab. A label for the GIS street address appears along the top of all panels. Eventually the table of contents control was defaulted to invisible in the interest of maximizing the GIS map object real estate. The default toolbox object was replaced by customized tool buttons on the top of the GIS map object. The tools available on the top of the GIS tab are displayed in figure 29. Table 2 identifies the tools by name.

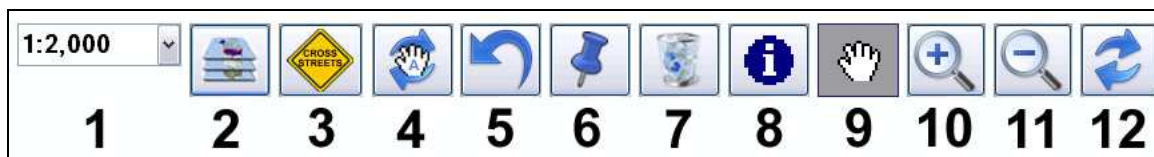


Figure 29: GIS tab tool button controls

Control Number	Control Name
1	Map scale
2	Table of Contents (on/off)
3	Display cross streets
4	Auto-pan map (on/off)
5	Back to previous feature
6	Select address (on/off)
7	Clear selected features
8	Identify features (on/off)
9	Pan GIS map (on/off)
10	Zoom in
11	Zoom out
12	Refresh map

Table 2: GIS tab tool names

The map scale is a drop-down ComboBox control that contains various map scales. The higher the map scale, the larger the area shown on the GIS map object.

The table of contents button toggles the ArcMap table of contents on and off. The table of contents is docked on the left, and allows the user to turn map layers on or off based on a checkbox, thus the button control icon representing layers (table of contents is displayed in figure 25). Tools that toggle on and off will appear flattened or pressed when they are on. For example, the pan tool (labeled #9 in figure 29) is toggled on while the rest are off.

The cross streets button displays a panel containing a ListBox of GIS cross streets results. During a GIS feature search, streets that intersect a selected incident street block are identified and stored as cross streets. Like a GIS feature or file results list, selecting one of the cross street results in the ListBox displays the street on the GIS map.

The Auto-pan button toggles whether or not the GIS map screen will automatically pan (track) the position of the vehicle. Vehicle location is made possible by a GPS (Global Positioning System) receiver connected to the laptop. If Auto-pan is on, the GIS map will automatically pan to the vehicle's location and keep the vehicle within the map screen. When the vehicle drives off of the map, it automatically pans and re-centers the GIS map back on the GPS point. The auto-pan control becomes disabled if a GPS receiver is not installed to the computer. The auto-pan control is also stopped any time a GIS search is performed to locate a street or address. If it were not stopped, the map would focus on an address point and then immediately pan back to the current GPS location.

The back to previous feature button performs similar to an internet browser history, taking the user back through points previously selected on the GIS map. This is particularly useful if a user selects one or more cross streets to display, then needs to return to a previous point.

The select address feature button allows the user to pinpoint an address on the GIS map. It is equivalent to performing a feature search from the search tab, but works simply by touching an address point in the GIS map view. The function attempts to find an address point within the vicinity of where the user touched or clicked on the map. If an address is found, then a GIS feature search ensues that will center the address, search cross streets, load a preplan, and search for street map files. This allows the user to quickly search for maps or preplans for addresses already in view on the GIS tab.

The clear features button clears the GIS map of selected streets, pinpointed addresses, system address labels, displayed preplans, and sets the search and streets tabs

to their respective search panels. Clearing a map selection essentially gives the user a clean slate for searching GIS features.

The identify button invokes the ArcMap Identify tool. The Identify tool is how the user examines feature details in a GIS map. By touching a point, line, or polygon on a GIS map while the Identify tool is active, the table of all data contained in the GIS database is displayed for the selected feature. Figure 30 displays a screenshot of some of the fields and values from the city's GIS for 701 Carrier Dr.



The screenshot shows the 'Identify Results' window in ArcMap. The 'Layers' dropdown is set to 'Real Estate'. The 'Real Estate' layer is expanded, showing a feature named '85 A 3'. The 'Location' is given as '(11379003.790303 6841223.201326)'. Below this is a table with the following fields and values:

Field	Value
LBSC	10
DESC_12	College Property
LIVE_FSQFT	0
Shape_Leng	8488.402221
date_of_la	<null>
proposed_z	M-1
land_use_2	PUBLIC SEMI PUBLIC
Count_	1
OID_	8898
acctnum	085 A 3
owner_jan1	COMMONWEALTH OF VA VISITO
owner_cur	COMMONWEALTH OF VA VISITORS OF JMU
address1	
address2	ACCOUNTING AND REPORTING
address3	HARRISONBURG VA
zipcode	22807
tyear	2010
Shape	Polygon
GlobalID	{CF414701-ADBF-42A6-BF30-11ED4940D9F6}
acreage	68.309807
propertytype	Industrial
statecode	Exempt State
usecode	Exempt State
exlanduse	SCHOOLS, COLLEGES, AND UNIVERSITIES

Figure 30: Identify results for '701 Carrier Dr'

The last few tools are pretty simple GIS controls. The pan tool allows the user to move the GIS map up, down, left, and right simply by dragging the map. The zoom in and out tools magnify the GIS map accordingly by a factor of 500. The refresh button invokes a GIS map refresh in case the map hangs while redrawing.

The GIS search feature is the bread and butter of this customized solution. In less than 10 seconds a user can enter an address on the search tab, perform the search, select a result, and display it on a map. During those few seconds the software performs all possible searches; the address is pinpointed and centered on the GIS map, the block of the street involved is selected and highlighted on the GIS map, a cross street search is performed for streets intersecting the selected street block, an associated preplan will be loaded (if available), and a streets file search is performed for map files matching the address street name, all with the touch of one button. The same searches would have taken up to several minutes using previous systems at HFD.

Preplan Integration

One of the final development steps was to implement preplans. Incorporating the functionality of the preplan database for FileMaker Pro was pretty straightforward. The existing database contains almost 850 preplan records for addresses in the city of Harrisonburg. The FileMaker Pro solution allows firefighters to search and view those records. Since the record search is conducted during a GIS search, all that needs implemented is the viewing capability. The preplan tab offers a panel with its own tabbed layout to view all parts of the preplan. The preplan tab contents are laid out exactly as they were in the FileMaker Pro system (compare figures 9-13 with figures 31-35). The lightweight construction collapse warning is implemented as a GIF image featuring a hazard sign with a flashing exclamation point on all preplan panels. Since hardcopies of preplans for Knox Box locations were printed on orange paper, the burned-orange background color signifies that there is a Knox Box for that location. Numerous textbox controls on these tabs display the preplan record data.

HFD Maps and Preplans

Menu Search Direction GIS Preplans Streets

1925 E MARKET ST, HARRISONBURG (Pre-plan Available)

Assignments Knox & FDC Contacts & Occupancy Building Info Attachments Hazmat

E26	Mall store - OIC check alarm panel, give alarm location to apparatus. Eng. supply sprinkler if zones 3-4 or 5-6. Take 2nd due sprinkler for zones 1 and 2. Anchor store - Supply sprinkler system.
E28	Mall store - Advance attack lines to fire area. Anchor store - Manpower
E23	Mall store- Supply sprinkler if zones 1 or 2. Supply second closest sprinkler system if zones 3-4 or 5-6. Anchor store- Stage at 2nd due hydrant.
TW1	Mall store - Stage side A. Anchor store - Stage at main entrance.

Updated: 10/9/2008 12:00:00 AM

Early Collapse Potential

Figure 31: Preplan Assignments tab

HFD Maps and Preplans

Menu Search Direction GIS Preplans Streets

1925 E MARKET ST, HARRISONBURG (Pre-plan Available)

Assignments Knox & FDC Contacts & Occupancy Building Info Attachments Hazmat

Knox Box: Side A at Ruby Tuesday Rest. and Side C at S.E. entrance. [Yes]

Sprinkler: See map for connection locations [Yes]

Standpipe: Mall office fed from Zone 5. Victoria Secret fed from Zone 6. [Yes]

Updated: 10/9/2008 12:00:00 AM

Early Collapse Potential

Figure 32: Preplan Knox Box and Sprinkler tab

HFD Maps and Preplans

Menu Search Direction GIS Preplans Streets

1925 E MARKET ST, HARRISONBURG (Pre-plan Available)

Assignments Knox & FDC Contacts & Occupancy Building Info Attachments Hazmat

Occupant: Simon Valley Mall

Owner: Simon Property Group Inc.

Contacts:

Residential Occupancy? No

Number of Apartments:

Number of Occupants

Day:

Night:

Updated: 10/9/2008 12:00:00 AM

Early Collapse Potential

Figure 33: Preplan Contacts and Occupancy tab

HFD Maps and Preplans

Menu Search Direction GIS Preplans Streets

1925 E MARKET ST, HARRISONBURG (Pre-plan Available)

Assignments Knox & FDC Contacts & Occupancy Building Info Attachments Hazmat

Required Fire Flow (GPM): 37200 Early Collapse? Yes

Approximate Sq Footage: 186000

Roof Construction Type: Bar joist w/ rubber membrane covering

Building Construction Type: Unprotected Ordinary

Hazardous Materials:

Natural Gas - Shut off side C see map.

Special Considerations:

Lightweight roof with skylights. Mall store's alarm panel side C at security office. Anchor stores have second floor with roof access. Anchor store alarm panel in each store. Interior roof access behind mall office at S.W. entrance.

Updated: 10/9/2008 12:00:00 AM

Early Collapse Potential

Figure 34: Preplan Building Info tab

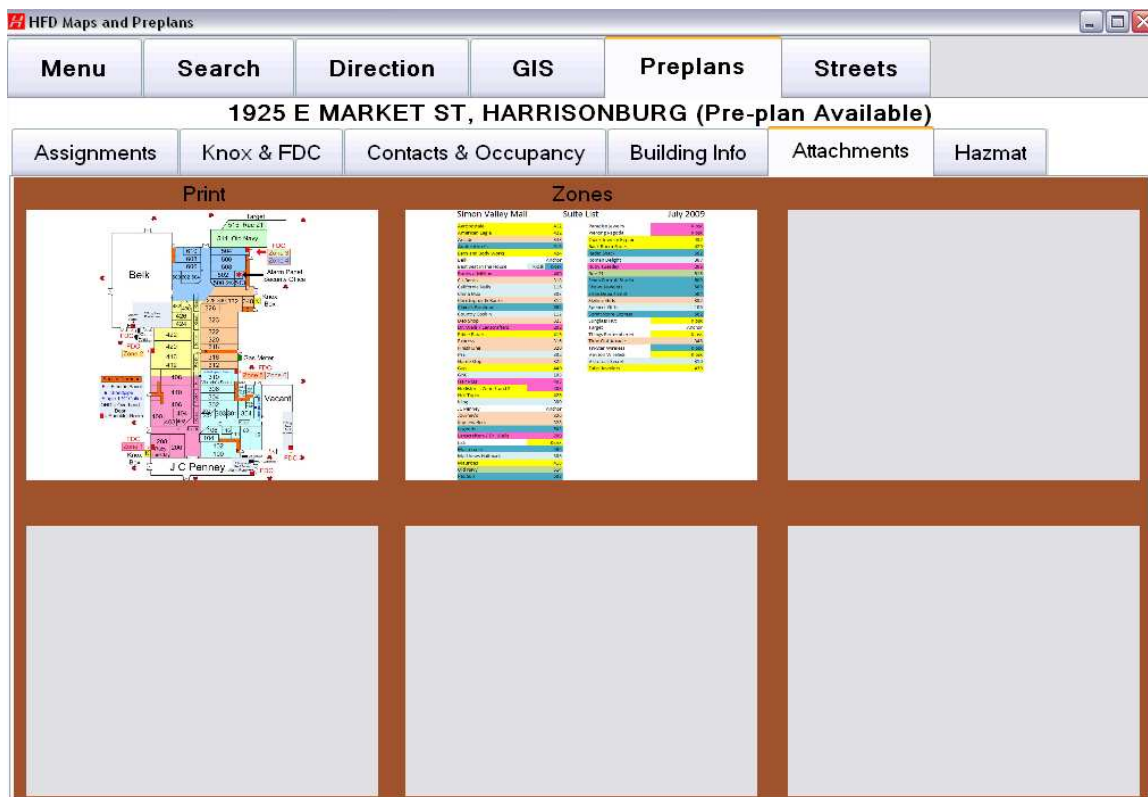


Figure 35: Preplan Attachments tab

The attachments tab allows up to six images to be attached to a preplan, which is an improvement from the FileMaker Pro system that until recently was configured to handle only one. Similar to the street map file implementation, JPG, TIF, GIF, BMP, and VSD file formats are acceptable attachments. Touching any preplan thumbnail of a drawing enlarges the pictures to an image viewer (figure 36). Preplans with documented hazardous materials on site can incorporate material safety data sheets (MSDS) as a hyperlinked attachment. Figure 37 shows a preplan with blue text indicating a hyperlink to a MSDS document. Touching the link will open the file containing the MSDS information. This was a feature that was not possible to implement with FileMaker Pro. The preplan tab only populates when there is a preplan record for an address. If there is no preplan record, a label indicates that no preplan is available for that address (figure 38).

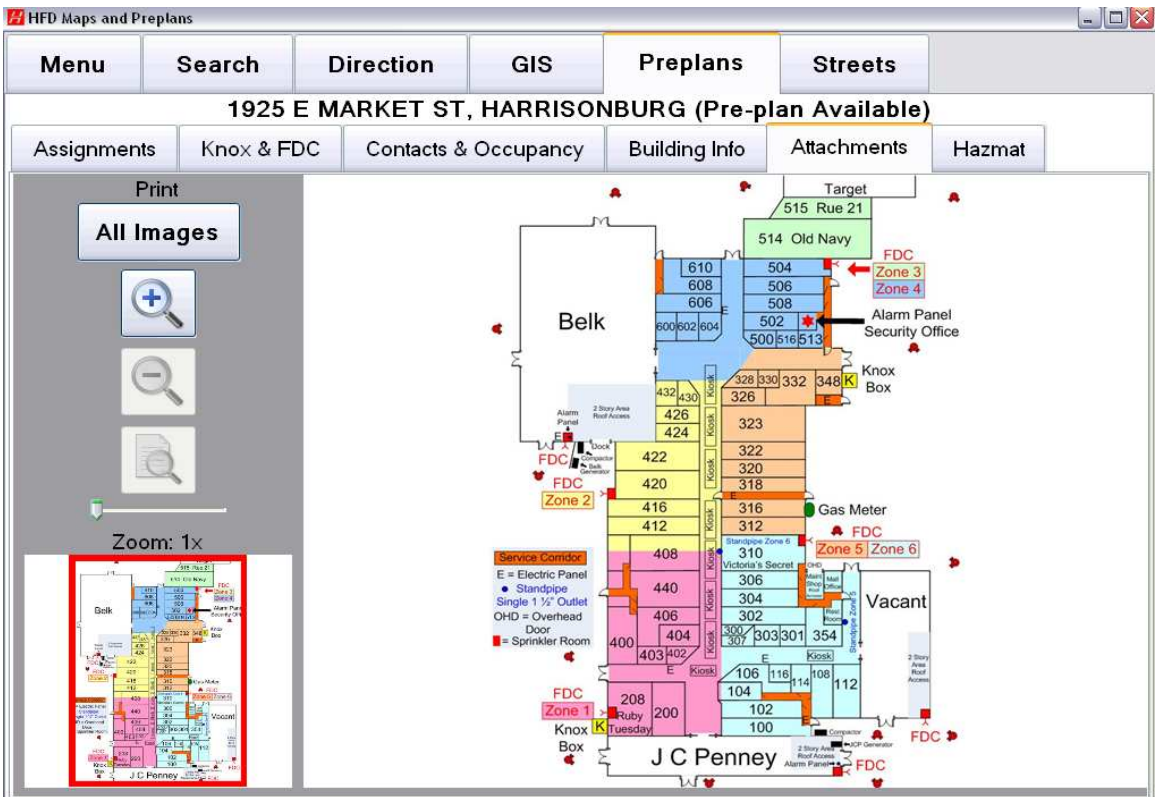


Figure 36: Preplan Attachment viewer panel

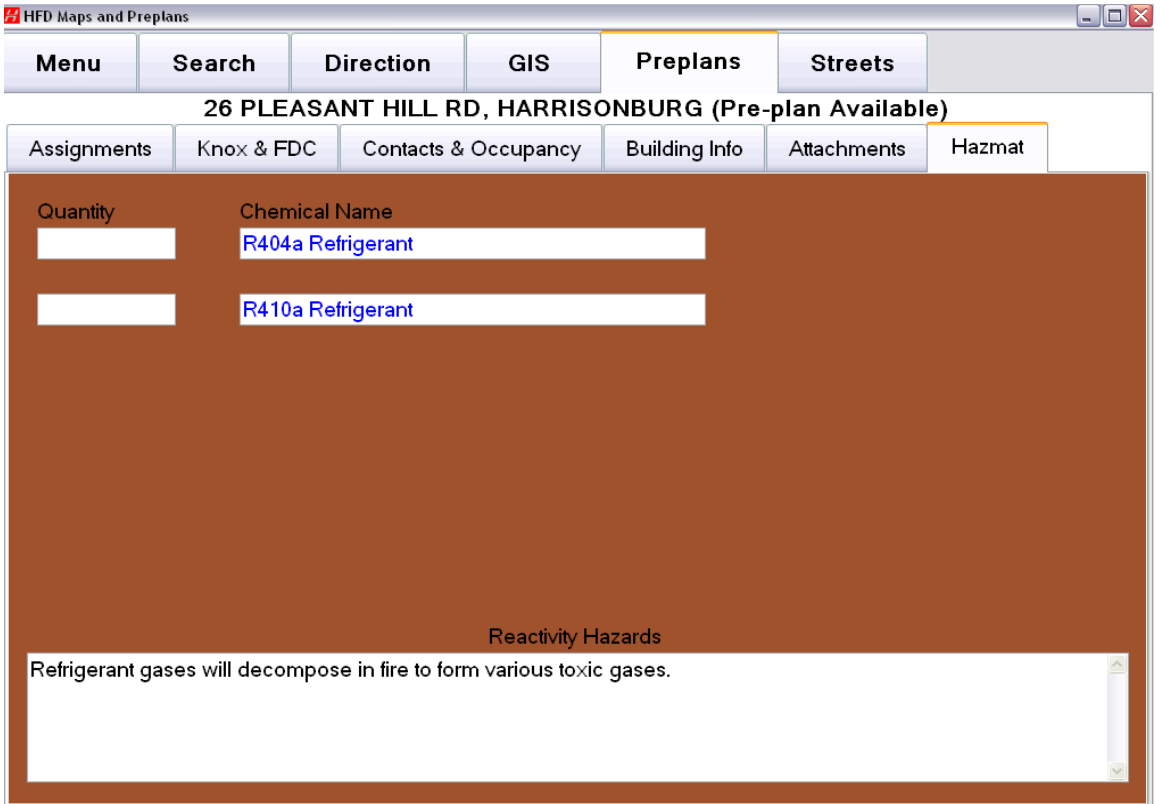


Figure 37: Preplan HazMat tab featuring hyperlinked MSDS data

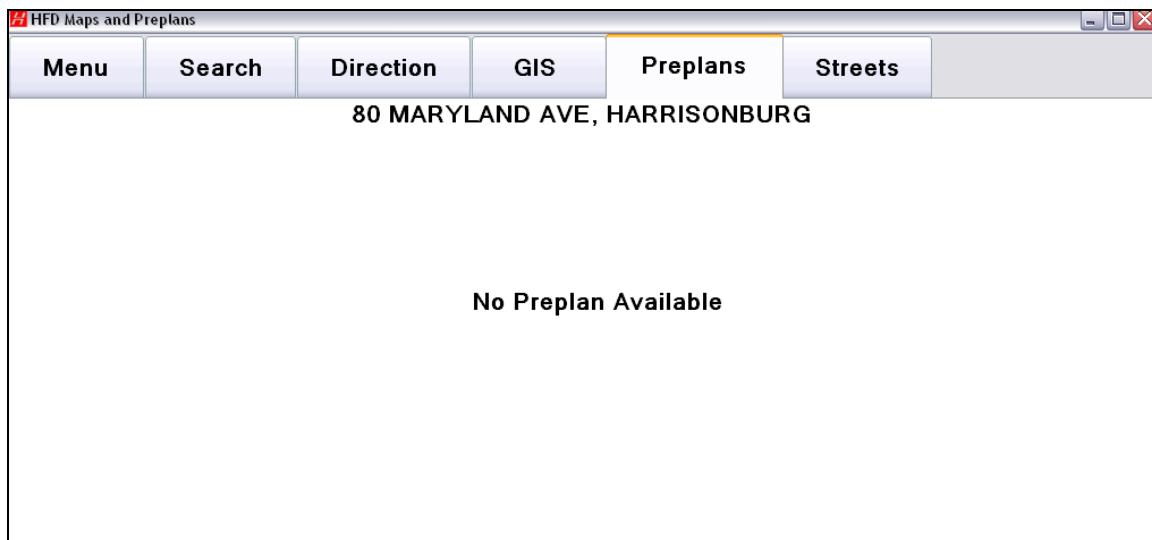


Figure 38: An address that does not have a preplan record

The methods required to implement the preplans tab are pretty straightforward. Data for a preplan record is simply copied into the appropriate textbox control. The textbox controls are cleared of all data every time a new GIS search occurs. Having already determined how to implement PictureBox features for zooming and panning for the maps files, similar functions were written to handle clicking, zooming, and panning preplan image containers. While this explanation might make the preplan implementation sound easy, there are over 1300 lines of code that pertain to the preplans tab. It is a very significant module of the solution.

Other Features

There are several other features implemented during the design and development stages that are worth mentioning. Figure 39 displays a home or menu tab that features several button controls. The search, GIS, and maps button simply display the corresponding tab. Controls for manipulating the GPS receiver appear on the home screen. The system will automatically attempt to start the GPS receiver if the hardware is

available at runtime. A status bar along the bottom of the form displays the GPS receiver status, identifying if the connection is open, closed, receiving, or not receiving a signal.



Figure 39: The Menu tab

Remaining controls include an Exit button, an About button, and a Settings button. The “Settings” button opens a form to save and modify all application settings (figure 40), including GPS hardware settings, file folder paths, GIS document and layer data, apparatus unit name, etc. The “About” button shows a form containing application data including the title, version, author, and details of the system (figure 41). The “Exit” button presents the user with a yes/no confirmation box to close the program (figure 42).

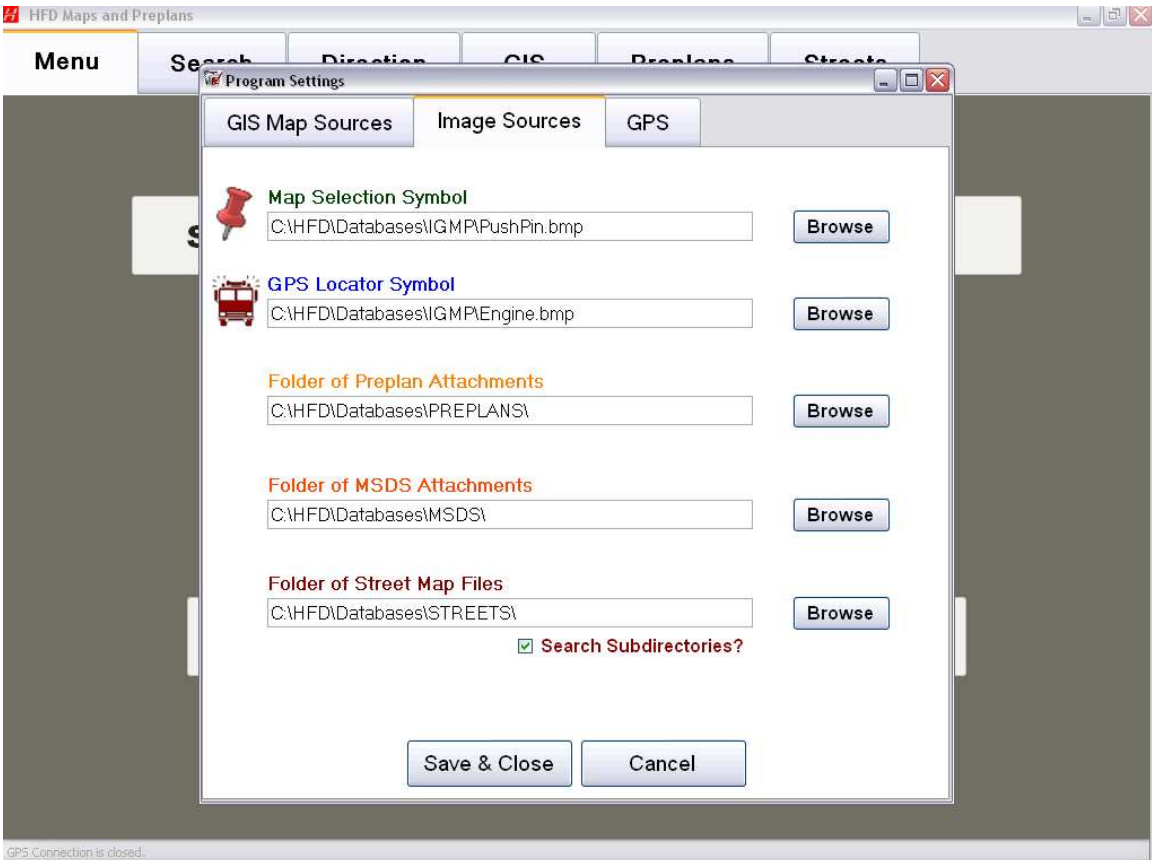


Figure 40: Application settings form

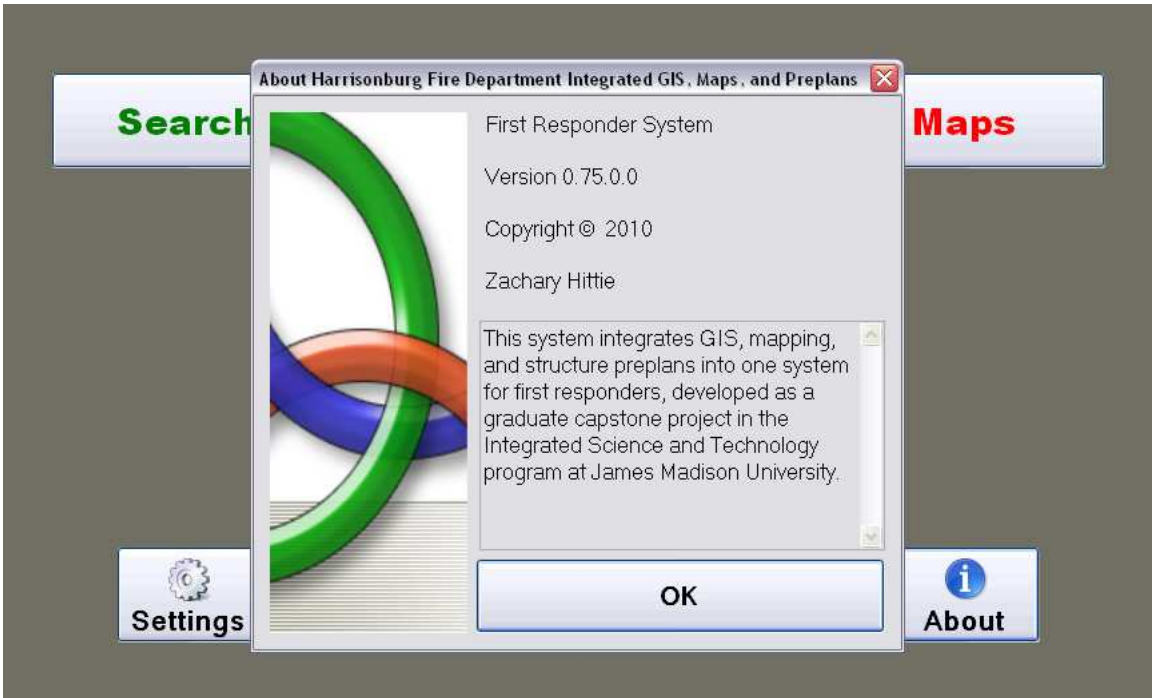


Figure 41: Information about the application

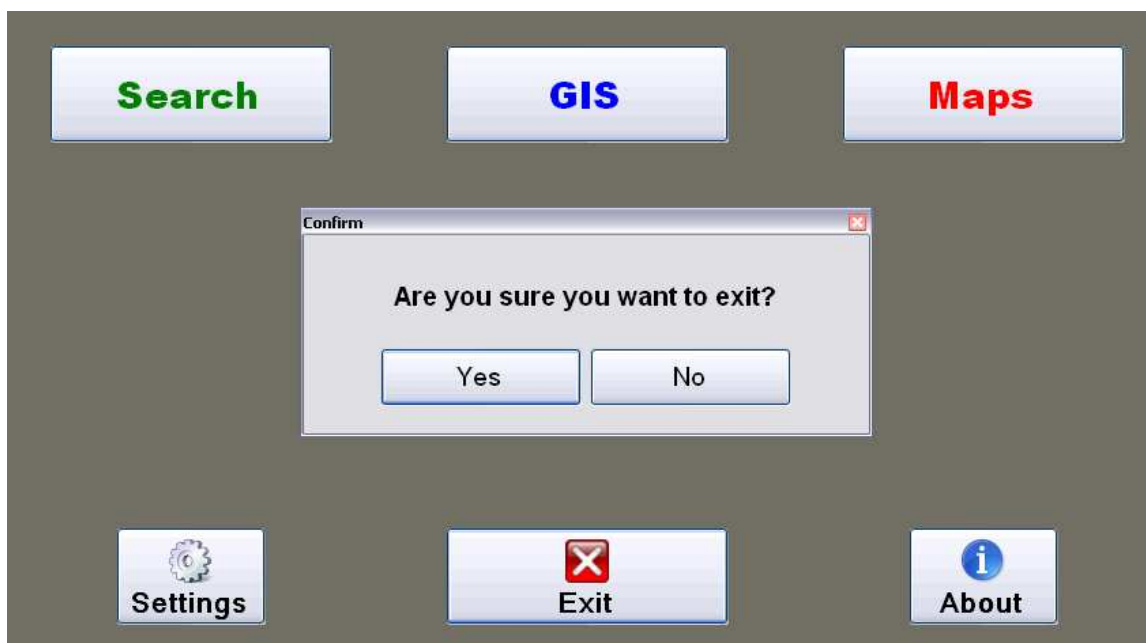


Figure 42: Exit application confirmation

Finally, the directions tab simply identifies a split screen view with two map controls (figure 43). The left map is connected to the GPS receiver and always auto-pans, thus the apparatus location is always in view. Location is identified by a moving point marker on the map. The incident location map functions like the map on the GIS tab; a GIS feature search pinpoints the incident address and centers this map on that location. Both maps use the same GIS document, have only zoom in and zoom out capability, and do not have a table of contents to change what GIS features are displayed on the map. The document only has address points, street lines, fire hydrant points, and building shapes on the map to minimize overcrowding the map. A textbox at the top of the tab would implement turn-by-turn directions to an incident location. Again, since the city's GIS is not routable, this capability is disabled. In the version released to HFD this textbox control is not even on the directions panel anymore; the two map objects split the panel in half to provide a view of the apparatus current location versus the incident location. This proves beneficial particularly in cases of emergencies outside of the city

limits where a user can use the second incident map control on the directions tab to manually obtain directions for the apparatus driver without having to change the incident map on the GIS tab.

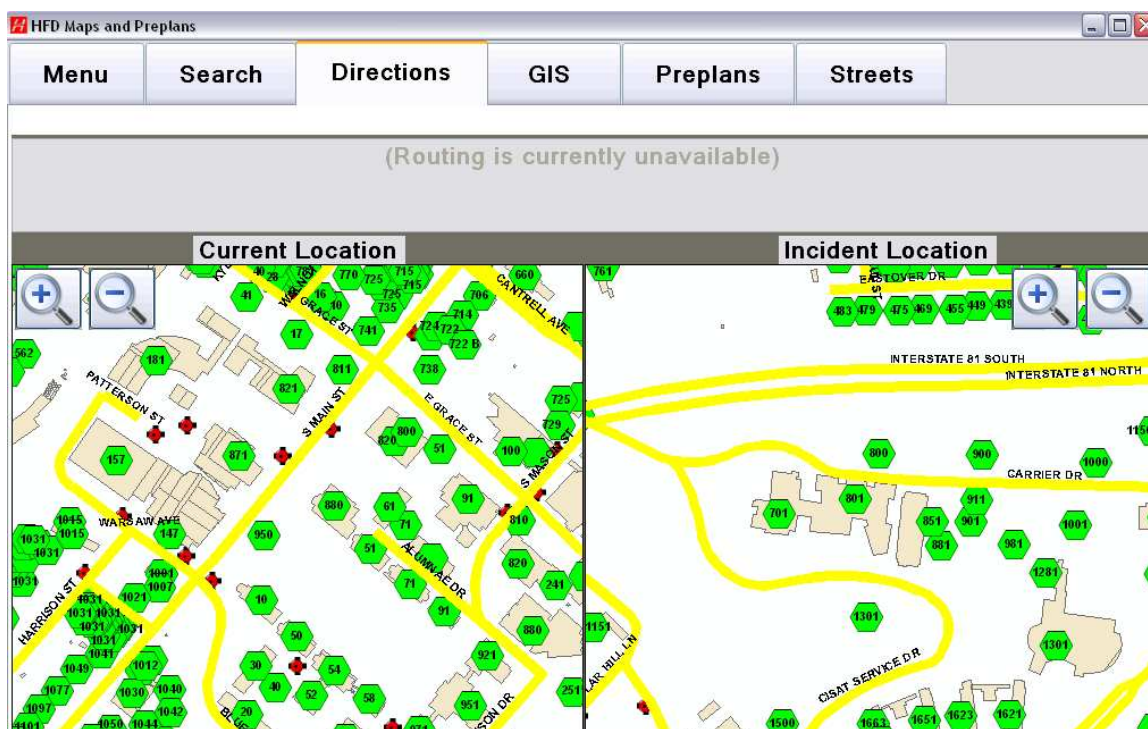


Figure 43: One design concept of the directions tab

One thing the user does not see is a system log feature allows the application to capture critical information behind-the-scenes and write it to a text file. This is especially beneficial for catching and logging program exceptions so that a fix can be implemented for potential bugs in the software. It is also useful for logging what the users have been searching for. For this new system, successful GIS searches are just as important to log as any exception that might be captured.

This chapter summarized the design and implementation of the features requested and required by the Harrisonburg Fire Department to integrate several systems into one application to handle mapping and preplanning capabilities. Data migration, system testing, implementation, training, and maintenance are discussed in the next chapters.

IV. Data Migration

Before any data can be searched for and extracted from this system, valid input data is necessary for the application to function. The three critical components of the solution involve street map files, preplan records, and GIS data. The first critical step for proceeding into the system testing stages was to have proper input data by auditing all three parts of the solution. There were several issues that arose in development in all three systems that would require some attention. Since GIS is the cornerstone of this solution, the streets and address feature classes were the first for review.

GIS Data Audit

The city's street feature class needed some maintenance to be of any use. The first problem was that a street name was contained in one single field of the table. For example, the GIS property for FullRoadName might have records for E Market St, N High St, S Main St, Port Republic Rd, etc. However, to be useful a database should have the street names enumerated in separate fields by prefix direction, road name, and suffix. In order to parse these records appropriately, a script was written to execute in ArcMap to extract both the street prefix and suffix out of the FullRoadName field. Using a field calculator, records containing a N, S, E, or W as a single first letter were put in the RoadNamePr field, and the remainder of the road name string was added to a temporary field. A second script captured suffixes using if-then statements to try for acceptable data such as St, Dr, Ave, Rd, Blvd, etc. Street suffixes were parsed according to the recommended official two, three, or four letter standard suffix abbreviations established by the U.S. postal service. Using the field calculator on the temporary field resulting from extracting the road prefixes, the suffixes were captured in a RoadNameSu field and

removed from the temporary string. All that remained of the temporary string was the road name (without prefixes or suffixes), which was calculated into the RoadName field. After deleting the temporary field, records of the street examples above might appear similar to the partial example in table 3.

ObjectID	FullRoadName	RoadNamePr	RoadName	RoadNameSu
0	E Market St	E	Market	St
1	N High St	N	High	St
2	S Main St	S	Main	St
3	Port Republic Rd		Port Republic	Rd

Table 3: Partial sample of GIS street feature records

As of this document's writing, there are 1791 street block segments in the GIS. Using field calculator to parse the streets of the city's GIS not only made it usable for this thesis project, it benefited every other department and citizen that uses GIS in the City of Harrisonburg. The audit also revealed numerous street name misspellings. All of these records were committed to the city's central geodatabase.

A similar audit and parse was performed on the city's address feature class. Each address record had one single field for the address point street name. The address number and suite/apartment (where applicable) were in two separate fields already. To be able to search for corresponding street features in GIS, the address point's streets need to have a matching street name enumerated by road prefix, road name, and road suffix. As of this document's writing, there are over 22,750 address points in the city's GIS. Each one of these records was parsed to obtain the road prefix, road name, and road suffix to separate fields. Similar to the GIS streets feature audit, numerous conflicts and errors were discovered in the address features resulting in a more accurate product for this thesis as well as other GIS users. Table 4 displays a portion of possible examples of GIS address feature records.

ObjectID	Number	Apt	FullRoadName	RoadNamePR	RoadName	RoadNameSu
0	1925	101	E Market St	E	Market	St
1	176		N High St	N	High	St
2	1031	A	S Main St	S	Main	St
3	80		Maryland Ave		Maryland	Ave

Table 4: Partial sample of GIS address feature records

Street and Map Database Audit

With a useful GIS of streets and addresses, it was necessary to individually audit all street map files compiled by the Harrisonburg Fire Department. The FileMaker Pro system contained over 625 records of street images. A lengthy process ensued. In trying to verify what original files existed for street maps, dozens of files were discovered missing. It seemed that over the years staff members have misplaced files, or a computer crashed, or a file was overwritten, etc. So the first logical step was to create an export of all image records existing in the FileMaker Pro system. This was accomplished by writing a script to export the contents of the image container with the filename given to the record and a '.jpg' file extension, such as "Market St E 1100-1500.jpg", "Main St N 0-500.jpg", "Port Republic Rd 600-800.jpg" etc. Note that street directional prefixes are marked after the suffix to keep the filenames in alphabetical order. In cases of long streets where a street may be broken up into several files by block, a block range accompanies the record as well. The export was about 98% successful, with only a few images being corrupted on export. In cases of corrupt files a screenshot of the FileMaker Pro image saved as a JPG would suffice if an original JPG or Visio file did not exist.

The folder of exported map files and the folder of original map files shared at the department were merged into one folder. The next step was to delete duplicate files. Recall that most streets are drawn using Microsoft Visio, but since the FileMaker Pro database could only store JPG images, all Visio files were exported as JPGs. Having a

Visio, JPG, and exported FileMaker Pro JPG is redundant and useless. Since the Visio drawing is a true vector-based drawing and a JPG is a flattened compressed image, the Visio file makes for a sharper picture (particularly in cases of magnification). Zooming a drawing in Visio will never reduce the sharpness or clarity of the drawing but zooming a compressed image in any format will always result in some loss of quality. See figure 44 for a side-by-side comparison of a magnified Visio file versus the same file exported as a JPG, and notice that even magnifying the file by five times there is already a loss of quality in the image.

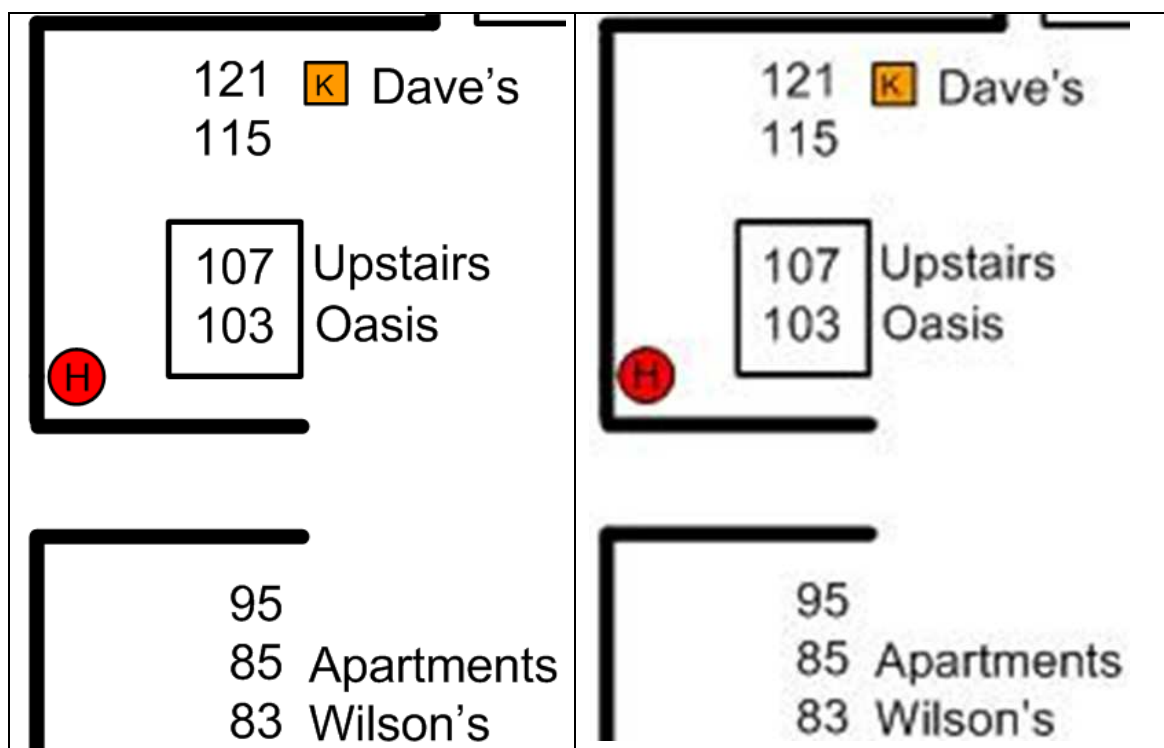


Figure 44: A Visio drawing versus the exported JPG zoomed 5X

In cases where a Visio drawing existed, JPG files were deleted. In cases of duplicate JPG files but no Visio drawing, the newer JPG was retained. In cases where no original drawing or image was available, the FileMaker Pro exported JPG image would suffice.

Finally it was necessary to audit the names of each street map file. A street map filename must match the street name in the GIS or else no match will result. In doing so,

it was important for filename prefixes and suffixes to match exactly what was in the GIS because if a map filename was given a suffix for 'Lane' or 'LA' but the GIS record contained 'LN' then no match would result. This portion of the file audit revealed lots of discrepancies where files were named differently than GIS. Errors were fairly limited to street name misspellings or incorrect suffixes (example: Dr instead of Rd). It is worth mentioning that a separate folder of street maps maintained by fire departments in Rockingham County is available at HFD. Several hundred files in numerous folders were combined into one subdirectory for "County Maps". Since HFD obtains these from outside sources and does not maintain or update them individually, the only work conducted on county map files was to consolidate them and remove duplicate images in cases of VSD and JPG files. The final result was an updated and more accurate share of the street map files used at the Harrisonburg Fire Department.

Preplans Database Audit

The remaining and most difficult audit occurred with nearly 850 records in the preplan database. At design time it was decided that a true relational database would have a table of preplans instead of adding preplan information to each address point in the GIS. Incorporating preplan data with GIS address would unnecessarily add dozens of fields most GIS users do not need or should not see. Instead, having a table where each individual preplan has a primary key (unique ID) would be the proper route. An address point would then be associated with a preplan ID number by adding a field for that ID to the GIS address point feature class. Multiple address points could share the same preplan (many to one relationship) but one address can have at most only one preplan (one to one relationship).

The majority of the work focused on properly modifying the FileMaker Pro system to be as accurate as possible, and then import that database into the GIS. In a stroke of luck, preplan addresses were already separated by address number, street prefix, street name, street suffix, and suite/apartment. This would prove necessary later in the process of mapping preplans to physical GIS address points.

The first issue is that preplans contained one text field for owner information and one text field for contacts information. The most information typical preplans contained were five points of contact, often with two phone numbers per contact. This prompted the addition of new 25 fields. Five fields were added for each of the following (one for the owner, and four for other points of contact): contact name, contact phone1 type, contact phone1, contact phone2 type, and contact phone2. The “phone type” was implemented as a lookup list of text for ‘Cell’, ‘Home’, ‘Office’, ‘Work’, and ‘Pager’. All preplan records were manually parsed to extract names and phone numbers for all owners and contacts. The contacts portion represented a large part of cleaning up the preplan database but there was much more to do. The remaining work was held off until later in development when a few more system requirements would emerge.

ArcGIS 9.3 geodatabases do not have a Boolean data type, thus true/false fields do not really apply for this system. FileMaker Pro has several text fields that could be considered Boolean data types (such as Knox Box, sprinkler, and standpipe availability) that were implemented in different ways. Some had checkboxes, some had yes/no radio buttons, and some were simply text fields with yes or no as dropdown options. To consistently report the Boolean fields, new corresponding fields were created for ‘Yes’ or

'No' text entries. A field calculator was used to populate the fields with a 'Yes' or 'No' entry based on the corresponding field was originally implemented.

ArcGIS 9.3 geodatabases also do not have a container data type that could be used to store drawings, pictures, or other attachments. Therefore it would be necessary to link drawings to preplans. At design time it was decided that the preplan images could exist in one directory (as they do now at HFD), and a GIS preplan record would simply link to the file by uploading the drawing or picture's filename with the preplan. This would also be beneficial because an update to a drawing could be done without having to update the preplan database. Preplans in FileMaker Pro often had one floor plan or site plan JPG in a container. Less than one year ago, the program was updated to include up to five images so very few preplans had multiple image attachments. These pictures were exported to one directory using a script similar to the one used to export street map container contents. In this case, a naming convention was first formulated for each attachment by using the preplan street name, suffix, prefix, address number, and image container number, followed by .jpg (example: Main St N 101 1.jpg, Carrier Dr 701 1.jpg, etc). For each preplan record, if a container stored an image then this filename was calculated in one of five new text fields corresponding to the image container number. Finally a script exported the container image contents with the new filename.

Another piece of the preplan puzzle was the hazardous materials (HazMat) component. The FileMaker Pro solution specified fields for up to five records of HazMat related information including chemical name, quantity, units of quantity, Department of Transportation (DOT) placard (JPG image), DOT division category, Boolean for toxic inhalation hazard, National Fire Protection Association (NFPA) symbol according to

hazards for health, flammability, reactivity, and special hazards, Emergency Response Guide (ERG) page number, NIOSH Pocket Guide (NPG) page number, and MSDS availability as a yes/no field. Maintaining all of that data is time consuming and useless when you consider that everything except the chemical name and quantity is a lookup of other information that already exists. HazMat data is available in tables already with this kind of information based on a chemical ID number. All that would be necessary to maintain in a new system is a chemical ID and the quantity of that chemical or hazard. The name, reactivity, flammability, health, and special hazards, toxicity, ERG number, NPG number, and DOT info are all associated with a chemical ID lookup. That table would be obtained and updated as an extension outside of this project. The only other component to maintain would be an MSDS attachment path so that MSDS could be hyperlinked from the chemical name in the preplans module of the solution.

The first try of the preplan data export uncovered another issue. ArcGIS 9.3 Geodatabase text fields only import 256 characters of text. The preplan database had two fields that exceeded this limit; the first apparatus response action field and the special considerations (comments) field. This makes sense given that these are the two largest fields on preplan hardcopies and FileMaker Pro (refer to figures 9-13 of FileMaker Pro screenshots). In order to accommodate the limitation, it was necessary to split up the whole fields in the FileMaker Pro database. By creating up to three new temporary text fields for both, field calculator was used to trim and calculate 255 characters to field1, trim and calculate another 255 characters for field2, and the remaining characters to field3. Once imported to GIS, ArcMap's field calculator could be used to recalculate these into one single field for response action and special considerations.

Now the preplan database was properly organized and ready to import to GIS. ArcGIS will directly import data from many file types. However, FileMaker Pro is not one of them. The FileMaker Pro database was exported to an Excel spreadsheet. The export was verified by examining the record output for correct number, field type, and spot-checking accuracy. The first row contained the FileMaker Pro system field names, and each record was auto-numbered in column 1 as well. From this point it was possible to use the ArcGIS import single table command to set up and execute the preplan record import. The results were confirmed; about 850 imported records. Some field calculating was necessary to piece the fields previously mentioned back together. This import resulted in the first GIS preplan table to use for testing the software.

The next step was to match preplans with address points according to preplan ID numbers. A temporary field was added to the GIS preplans table for calculating the full street address by concatenating the address number, street prefix, street name, and street suffix. The same field concatenation already existed in the GIS address feature class. By performing a join of the two tables, the preplan records would be matched up with address points and the preplan ID numbers could be saved to the address features. The initial join showed both great and troubling results. In about 850 records, only about 725 actually joined. This was good because a lot of preplans joined to an address but it was bad because a lot did not; more auditing would be required.

The preplans that did not join with an address point were identified by preplan ID number and address. The reasons a preplan did not join with an address were actually limited to one of a few problems. First, the address did not exist in GIS. There were nearly a dozen addresses for which there were no points in the city's address feature

class. In some ways that was troubling because it forces you to wonder how many other points might be missing. However, since there was not much that could be done about it missing addresses would be dealt with on a case-by-case basis as issues came up.

Another problem was incorrect GIS addresses. In some cases the street name was misspelled, a numeric was incorrectly entered, etc. Again this was somewhat unusual so it wasn't a cause for major concern yet. In half the cases, the address was wrong in the FileMaker Pro database. This part is also cause for concern because that's the data the fire department is actively using to respond to emergencies. In most cases, the street name or suffix was incorrectly typed. All of these errors are very minor fixes by updating either the GIS or the FileMaker Pro database to match so that the addresses would join next time. Some preplan records were found to be outdated and were simply discarded from the database, resulting in some "preplan housecleaning". In any case, all preplans that did not match an address were discussed with the first due company responsible for maintaining the preplan. This way the preplan was verified for address correctness by the people responsible for creating it in the first place.

Two more possibilities existed for preplan-address join issues. In cases where multiple preplans existed for complexes with apartment or suite numbers, the join occurred several times but only kept one preplan. Strip malls, for example, often have single preplans per each occupant of the suite or building. Since suites and apartments are not considered in the fields where the join occurred, these cannot be taken into consideration. For example, there are seven records for preplans at Spotswood Square Shopping Center at 1790 E Market St. However when suites are considered, there are separate preplans for Kroger, (former) Office Depot, RMH Corporate Health, TJ Maxx,

Aarons, one vacant suite, and the overall complex. In cases of strip malls or apartment complexes with multiple preplans per suite number or letter, these preplan IDs would have to be manually verified. There are several dozen cases in the city where this occurs.

The final black spot on preplan-address joins was addresses on the JMU campus. The City of Harrisonburg Office of Community Development is responsible for all addressing in the city. When a building permit is issued for a new structure, it is given an address and that address comes from GIS. However, just as the city office is not responsible for addressing outside of the city limits (Rockingham County) it also does not handle addressing on the state property at JMU. According to Sam Hottinger, the GIS coordinator at the City of Harrisonburg, JMU has handled its own addressing since the nineties. In many cases, the address data was informally passed back and forth to city offices to keep records up to date. At some point in the past few years, that informal communication ceased. Essentially, the city GIS did not know what was happening in terms of addressing at James Madison University. Thus when it came to import (approximately 50) preplans for buildings on campus, many preplans did not match up because of new construction, address changes, or incorrect addresses. This issue was brought to light among several agencies for resolution.

On Tuesday August 31, numerous officials including JMU police, JMU facilities management, HFD staff, city GIS officials, and Harrisonburg-Rockingham Emergency Communications Center (HRECC) staff gathered to discuss the JMU addressing problem. The meeting was timely given that several incidents dispatched to HFD that month were to campus addresses that did not exist, the recent acquisition of Rockingham Memorial Hospital, and the University Park construction ongoing at the property along Neff Rd and

Port Republic Rd. All stakeholders brought their issues to the table and discussed the inadequacies of the disconnected communications structure. One member of JMU's GIS department was dubbed the sole point of contact for addressing on the JMU campus, and it would be his responsibility to communicate those updates to Harrisonburg GIS officials. The JMU Police Department and HRECC updated their computer dispatch systems to reflect several address changes as a result of the meeting. At some point this fall the city GIS department will remove all address points from inside the JMU property boundaries and import a new feature class of address points maintained and provided by JMU's GIS department. In the meantime, cases of address conflicts among city GIS and fire department databases were updated according to an official address list provided by JMU. This would reconcile the issues with the preplan import and solve all the addressing problems on JMU's campus.

All these steps were necessary for the first round of the preplan audit. After the GIS updates were completed by the city GIS department and the FileMaker Pro database was updated at the fire department, the preplan import to GIS was performed again for a second and final time. The FileMaker Pro database was exported to Excel and imported to ArcGIS as a table. The preplans and address points were joined. The preplan IDs were added to the address feature class in a PPID field. Verification ensued to find out what preplan IDs were missing. The only cases of missing preplans involved apartment complexes or strip malls. The ID numbers were updated accordingly and committed to the city's central GIS server. Officially, all the Harrisonburg Fire Department's preplan data was finally loaded to the geodatabase and ready for full system testing!

V. System Testing & Implementation

The data migration and conversion steps were a critical part of getting the system ready for full scale user testing. However, long before the solution was presented to its most scrutinizing critics it was tested on a much smaller scale.

Functions and subroutines of the program were tested as they were being written; thus system testing was going on simultaneously with design and development. This “white-box” testing approach tested functions for all possible input and expected output. Button controls that were supposed to behave in a certain way or display different layouts were tested for appropriate behavior. As panel designs began to settle into their “final” layouts, they too underwent testing for proper functionality. The first bout of testing focused on the map search function in which a search string is passed to a function that returns matching filenames in a given directory. Other basic functions such as being able to page up and down ListBoxes and selecting filenames to load into PictureBox or Visio objects were tested as well. Development and testing for zooming and panning images occurred later.

Development and testing of the GIS functionality made sense as a next step for several reasons; the preplan system was not imported to GIS yet, and pinpointing an address was a critical component of the preplan search. The function for searching GIS features underwent intense development and testing. This was tested by searching for known address points from the GIS feature search tab. Testing was conducted on both the address feature layer for the City of Harrisonburg and also the address feature layer for Rockingham County. Numbers of results were tested for by searching for a single city address point, a single county address point, multiple city address points, multiple

county address points, and multiple points in both the city and county. The GIS search is the most critical function for the program. Selecting a feature and moving to it are relatively “simple” ArcGIS tasks that were implemented and tested.

With a functional GIS search algorithm, the first release was published for some users at HFD. Deputy Fire Marshal Captain Arthur Miller is one of the department’s biggest proponents of GIS, and he uses ArcMap on a daily basis at both his office and on his laptop in his vehicle. Capt. Miller received the first release of the system in its early stages to use for finding addresses in his daily field work. Lieutenant Mike Landis, another fire marshal at HFD, also received a release of the system for field testing soon after Capt. Miller. These users were performing “black-box” system testing; they were testing for functionality of the solution as opposed to the internal workings of the program.

Testing continued as more tool buttons began to take their place along the top of the GIS tab. GPS functionality was implemented and tested next. GPS location was first only implemented on the direction tab. Lt. Landis and Capt. Miller were adamant that an auto-pan function with GPS capability was very beneficial in ArcMap and that it should also be included on the GIS tab of the solution. That feedback was taken into consideration, and implemented and tested for the next release.

Panning and zooming came back to the development picture for implementation and testing after some GIS functionality was completed. Full functionality for the streets tab including the search, results, and image viewers was fully tested and completed. With the street file milestone completed, an updated version was released to several more laptops at HFD for field testing. An undesirable condition materialized when the new

release would mysteriously fail to load on some laptops but function on others. Several days worth of troubleshooting revealed unknown prerequisite software requirements for systems running the solution that went unnoticed on Capt. Miller's and Lt. Landis's laptops. Required prerequisite software included Microsoft .NET Framework 2.0, Microsoft Visio or Visio Viewer, and the ArcGIS Application .NET Support package. The .NET support feature for ArcGIS provides the primary interoperability assemblies to use customized ArcGIS applications. This feature seemed to be installed on some machines and not on others. Without any one of these three components, the solution would crash without warning or any kind of descriptive error message. For the purposes of testing and implementation these system requirements would be spot checked. However, in any sort of published or commercial application it would be necessary to provide a setup file that would check for system requirements and install any missing components.

With map-functional software, some of the users were consulted for feedback about the user interface so far. General input was sought on layout, color schemes, button shapes and sizes, appropriate icons, etc. Some suggestions were made for icons but otherwise the system functionality remained the highest priority for the users compared to the look and feel of the system.

Preplan design and testing continued next. This part of development fell somewhat behind because of unanticipated delays with importing the preplan database to the GIS. The GIS preplan table structure and fields were already designed and ready to be implemented. Since no actual data was successfully imported from the preplan system at this point in the testing process, a test table was populated with a few records. This

allowed testing to continue on the preplan record loading function. Obvious bugs were reworked, and the preplan loading functions passed initial testing by August 10th.

Coincidentally the first successful preplan table import and partial address join in GIS occurred on August 11th. The system hit the ground running with no significant bugs reported. As mentioned in the last chapter, the main issue was that there were about 125 out of nearly 850 preplans that failed to join with GIS addresses on the first import.

Because there were so many disjointed preplans and addresses, the database was not reliable enough to release the solution for use at HFD by the anticipated August delivery date. As a result more time was spent testing application functions and features, and making sure the laptops had the proper prerequisite software installed in order to run the new system. Since user training was scheduled over a month in advance for August 16th, 18th and 20th, these days were used to present a system demonstration to the users. It was at this point when users saw the system for the first time that they started to think about how it could truly function in their environment and help them shape their emergency response. Several requirements and change requests came up during the demonstration, which meant more development and more testing. It would be another month before almost all of the GIS issues would be fixed and users would gather again for user training on the system. The next chapter outlines the user training on the system and explains that portion of the development process.

VI. System Training

In the original thesis timeline projections from April of 2010, the system was scheduled for release by mid-August. With numerous address complications and preplan issues in GIS, the training timeline would be delayed by a month. This was not completely unexpected and ultimately it was not a significant issue.

User training was scheduled well in advance for August 16th, 18th and 20th. However, since the system was not yet vetted for use these days were used to present the system to the users. C-shift staff was the first to see a demonstration of the system. Feedback was overwhelmingly positive given what they saw, which was limited preplans, duplicated street map files (VSD and JPG), but a solid GIS search platform. They suggested removing duplicate map files (intended to happen anyway), and the ability to touch an address on the GIS tab and have it display the preplan. This feature would be incorporated in a later release.

B-shift was in attendance for the second demonstration. They suggested a pushpin or some sort of icon be used to select an address point and make it visually stand out instead of using the standard ArcMap selection symbol (a blue dot). They also recommended that the table of contents originally docked on the left side of the GIS tab be turned off by default. Functionally this makes sense. Typically a user would turn GIS feature layers on and off infrequently, so it makes sense to just get rid of something they would not be using in order to maximize the GIS map size on the screen. These requests would be implemented in future releases.

A-shift met for the final session of the program demonstration. Their requests echoed what had already been stated by previous shifts. In fact, by the time they had

their training that week most of the improvements previously suggested by the other two shifts were already implemented. All shifts suggested adding some GIS layers for target hazard addresses. Target hazards are addresses that carry very high occupancies (such as hospitals, assisted living communities, etc) and therefore could present a very high risk of human casualties in case of an actual emergency. The feature layer was created and released shortly after the initial demonstrations. Reverting back to implementing change requests and waiting for GIS issues to get worked out, more testing and system improvements were carried out. Another round of user training and orientation was scheduled for a month later to formally go over how to use the system.

While the system was available on all department laptops following the first round of demonstrations and user training in mid-August, the system log files show that it went relatively unused. User feedback cited the fact that the system was not ready yet coupled with unfamiliarity of a new system as reasons for not using the new solution. Given that feedback, individual company training was scheduled for the next sessions as opposed to one training session with all companies so that users could ask questions and get a more personal orientation of the system. September 20th, 22nd, and 24th was the next round of user training. At this release of the GIS, 99% of the preplans had been mapped, with only one address outstanding where adding several GIS address points was necessary. Preplans were also not available for Rockingham County. This was not a major concern however, since there are only five preplans that exist in the city databases for Rockingham County.

B-shift companies were trained on the system on September 20th. Some of their feedback included defaulting the system to the search screen when it initially loads,

defaulting to search for only city addresses (which would cut GIS feature search time in half as well as reduce the number of results), adding town names to the list of address search results, and adding a back button to go back to previous features. They also suggested adding a GIS layer for HazMat address points, differentiating the color of address points that have preplans versus ones that do not have preplans, and they cautioned against using the same colors for different symbols. This comment surfaced because fire hydrants were represented as red circles and target hazard address points were identified as red stars. There were also a lot of blue shades used in the GIS symbology for things like real estate outlines, ponds and rivers, selected roads, Interstates, and waterlines. GIS symbols are easy to represent in other colors and shapes, so this type of feedback is exactly what is needed to make the GIS map more useful. A HazMat feature layer would be added to GIS to show points where hazardous materials were involved, and these points were represented with a NFPA 704 standard placard.

Two days later, A-shift participated in company-level training. Their feedback included suggestions such as flashing the incident address point, changing the GPS identifier shape, and changing the image of the symbol that identified a lightweight collapse hazard on preplans to something that looked less like the cross street icon. Flashing an address point multiple times would help the user identify the GIS point on the screen more quickly. The default GPS locator on the screen was simply a black arrowhead that pointed in the direction of travel. Instead, it was suggested to use a different shape or image, such as a fire engine, or anything that would make it stand out. The feature would be implemented as a user-selectable image, and a fire engine icon would be implemented as the default image. The lightweight construction hazard symbol

was originally implemented as a hazard triangle with some text inside of the triangle. Some users thought that was too similar to the diamond icon used for cross streets. Instead a hazard triangle with a flashing exclamation point was created, displaying the text below the image. Figure 45 displays the original hazard symbol, the cross streets symbol, and the updated choice for early collapse hazards on preplans.



Figure 45: Similar symbols can create confusion

C-Shift participated in user training by company on September 24th. One improvement they suggested was to be able to have a way to display latitude and longitude coordinates, which would be particularly useful to provide landing coordinates to helicopters that often provide emergency patient transport services. The X and Y coordinates should be implemented to give a location in a degrees decimal minutes format. For example landing a helicopter on the ISAT soccer field along Reservoir St to fly a patient to UVA Medical Center would have the coordinates of N 38° 25.868, W 78° 51.407. Another suggestion was to have GIS address results sorted by address number. While the results ListBox controls were all designed to sort results alphabetically, results that begin with numbers are more complicated. For example, a list of addresses containing the numbers 3, 8, 20, 30, and 100 would be sorted by the control in the order 100, 20, 3, 30, and 8. When two values are compared, their leading digit is compared first. Since the 1 in 100 is lower than 2 in 20, 100 will appear before 20. In order for 20

to appear before 100 it would need a leading zero. Since it is not practical to pad every GIS address with leading zeros in the geodatabase, a different approach would be necessary. However, a solution was implemented programmatically pad addresses with zeros to compare address numbers and sort them in order from lowest to highest value.

All of these solutions were considered and prioritized for implementation. One final round of training was conducted on October 18th, 19th, and 20th to update users on some system improvements. At this point, 100% of the preplans were loaded and maintained. GIS sources for all of Rockingham County address features, street features, and utility features were also identified and 100% available. Numerous application features suggested during the previous month's training were also demonstrated. The October update marked a significant milestone in the availability of data and the tools accessible in this integrated solution for first responders at HFD.

Firefighters spend time on the job in training every single day. Whether it is for firefighting techniques, trench rescues, practicing CPR, incident command structure, and yes, even information technology, it is critical for users to continue to train themselves on this solution. The integrated GIS, preplan, and street mapping solution is available on all apparatus and station computers. It is essential for first responders to continue training individually as necessary. The only way to become fluent on a new system is by using it and learning it. Users at the Harrisonburg Fire Department have been given formal training on the basics of the system. Since mid-November, the system logs indicate they are using it more and more in favor of the old FileMaker Pro system, with over 1100 GIS searches logged. Users also continue to offer feedback and suggestions for making the integrated solution better.

VII. System Maintenance

Following the conclusion of the user training and orientation, there were some new requirements and change requests to implement. System upgrades such as GIS feature search history, password protecting system settings for administrators only, modifying the GPS locator icon, and flashing an identified address point were programmed and released.

For the Harrisonburg Fire Department, maintaining the streets and preplan system just got a whole lot easier. Since city street drawings and preplans are centrally located on a network server that is replicated every few hours to all fire department computers, any time a firefighter updates a map or preplan drawing it is automatically copied and updated to all apparatus computers within 3 to 5 hours. No administrator support is required. No paper is wasted. Using the FileMaker Pro system, the firefighter would have updated a map, exported a JPG, emailed or inter-office-mailed it to a deputy chief, the chief would make copies and distribute the map, the IT coordinator would administratively update the map record in FileMaker Pro, save the new database, and overwrite the old database file so that the new map record(s) could replicate it to all laptops. Updating preplans worked the same way; someone would update the text and drawing of a preplan record, send it for approval, once approved it would be disseminated, and the IT coordinator would upload a new database. GIS and preplan updates are now implemented in a different way.

The city has a centrally managed GIS server that is accessible on the city's internal network. One minor issue is that laptops in fire apparatus do not have mobile broadband data connections outside of the fire stations to maintain a direct connection to

the GIS server. Therefore, a local data source is necessary since network access is not available on the road. The way that HFD had been maintaining GIS is by periodically receiving an exported copy of GIS data from the GIS department containing map features (addresses, streets, fire hydrants, utilities, etc). The export process is made very simple by using built-in ArcMap tools. ArcMap has a distributed database feature that allows GIS users to establish geodatabase replicas. In the case at HFD, a one-way replica is established that exports feature layers that the fire department needs to a single database file that can be taken anywhere. Replicas make it simple to update GIS data where network connectivity is difficult to get or maintain. In the one-way replica setup for HFD, only changes from the central database (“parent”) are sent to the copy of the database (“child”). Now at HFD when a preplan needs to be updated, it is updated in the main GIS table and with the click of a button all GIS feature changes and updates are synchronized with the replica in a matter of seconds. The updated replica will download to all laptops within a few hours. The integrated solution does not need to be restarted and the changes are picked up immediately.

Replicas also distribute any updated feature information maintained by the city’s GIS department. If the Office of Community development issues permits to build two dozen new houses and demolish a few others this week, those address points will be added and removed accordingly. If public works adds two fire hydrants on a new street they are building this week, the hydrants and streets will be updated in GIS. If Harrisonburg Electric installs a new high-voltage line this week, the addition will be reflected. If several properties are sold to new owners during this week, the real estate data will get updated. All of these updates and changes are made possible by taking

advantage of a centrally located system that already exists and is maintained by multiple public service entities. Now the fire department has the ability to take advantage of all the information made available by other departments that it would have taken years to maintain themselves.

As part of the updates and additions to the GIS data available to the city fire department, an updated version of Rockingham County's GIS was obtained. A meeting was held with Wes Chappel (a GIS technician at Rockingham County's Office of Community Development) in order to identify sources of GIS that the city fire department could take advantage of. Mr. Chappel indicated that the best way for HFD to obtain GIS data for the county would be to replicate it themselves from the HRECC GIS systems. Sam Hottinger, the GIS coordinator at the City of Harrisonburg assisted in establishing the connections and replication of the HRECC county data. Within a few minutes, the city fire department had a properly maintained and up-to-date GIS collection of Rockingham County data in a separate geodatabase, including addresses, fire hydrants, streets, building outlines, utilities, and more.

The amount of data obtained as a result of this sharing of information is stunning. The previous county GIS sources had no water or other utility features, was missing street centerlines, and often times was missing entire localities in the county address feature class. Implementing a permanent solution to obtaining information outside of the city limits benefits every firefighter that uses the solution, as well as the mutual aid agencies receiving assistance from Harrisonburg Fire Department resources.

VIII. Discussion & Conclusion

This thesis has described the process involved for implementing an integrated mapping and preplanning solution for the Harrisonburg Fire Department. Because an antiquated database system could not expand to meet the needs at HFD, a customized solution was necessary. Integrating and expanding existing systems into one application was the goal of this research. Figure 46 presents an updated timeline of the initially proposed timeline (figure 20).

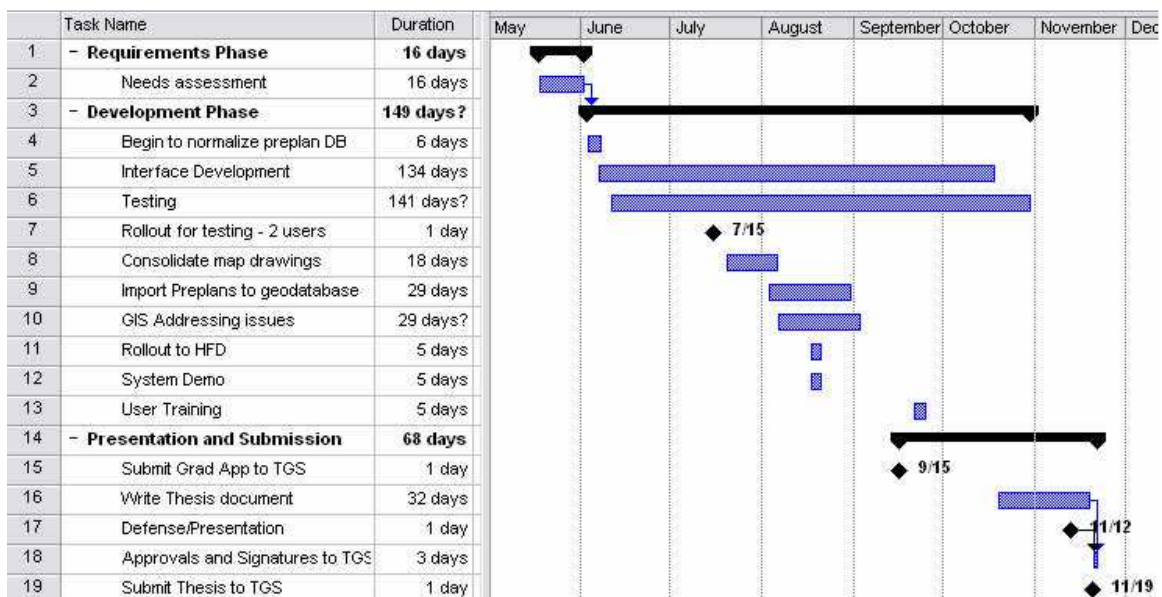


Figure 46: Project timeline - revised

Feedback about the system has been overwhelmingly positive from the first day users were able to use the application. The same day that B-shift participated in user training in September they responded to a structure fire at 1276 Settlers Ln in Harrisonburg that night. Captain Brian Jenkins of Engine Company 26 made the comment on the scene, “That program’s pretty cool once you know how to use it!” Captain Steve Morris of Engine Company 25 also remarked, “It’s great for us because all the information is in one place.” Instead of a large training session with an entire shift,

company-level user training is exactly what the users needed to feel comfortable using the system.

Developing one program to replace at least three others was one of the goals and benefits of this project, but it was not the primary reason for doing so. Gaining access to a usable GIS platform in a mobile environment was the main purpose of this thesis.

Within seconds, one powerful search function can identify an incident address point in GIS, the street block involved, cross streets, a preplan, and custom street map files linked to that address. Finding an incident location is the most critical part of emergency response. Once that location is identified, the focus shifts to finding what resources and hazards exist around the incident. One of the most basic things firefighters will be thinking about is identifying a water supply. Up until recently a fire hydrant was just a dot on a map. Today, in addition to that dot on the map GIS can also tell a firefighter the size of the water main supply line, what pressure zone it's connected to, and what the available pressure and water flow is for that hydrant. Firefighters can save a lot of time if they know a hydrant is connected to the same water main that's already gone dry. Incident commanders at the command post can begin to identify other water sources and save time that way by planning ahead. GIS helps to move information out of binders, shelves, and file cabinets and into a dynamic interactive map that is usable and suitable for emergency responders. GIS enables immediate access to up-to-date information that is critical to make better decisions in an emergency. Taking advantage of GIS opens the doors to information in ways that many people never thought possible.

One of the flexible design aspects about this system is that it is developed to function with any ArcMap data source. The system could theoretically be taken to

another jurisdiction and implemented there so long as there was a GIS available that contained a feature class of streets and addresses and a preplan table. The only catch is that the GIS preplan table would need to be configured with the same field names. Any locality could be provided with a blank table to enter or import their preplan data, and this solution would be ready to use. If a directory of customized map images is available, the street file search would also be suitable as well.

One of the next steps somewhat beyond this thesis is to develop an interface for updating a preplan. Today the FileMaker Pro system is still the primary means for completing forms for new preplans at HFD, then after approval those fields are imported to the GIS table. One way to implement a means for updating GIS preplans could be to create a webpage that would interface with the central geodatabase. Users could simply navigate to a page on the city's intranet to update building preplans and submit them for approval. An approval workflow could be implemented for the proper authorizations. Once approved the updated record would be committed to the GIS and replicated to the laptops. The software itself will not require routine maintenance; it is the data that the application reads that is critical to maintain. GIS streets and addresses, preplan records, and street drawing or other files are necessary to update to give first responders information they need to respond to emergencies. While it is possible to update preplan data using ArcGIS ArcView or ArcInfo, that would require a moderate level of user training. Implementing a method for department members to efficiently update preplans using an online form in their web browser would be simple, and would require very little training to use.

There are many more features for this solution that could be developed beyond the scope of this thesis. Turn-by-turn directions accomplished by GIS routing, computer-aided dispatch integrated with the 911 center, hazardous materials resource lookups, and integrating other apparatus GPS locations onto one map so all units can see each other's positions are just a few things users at the Harrisonburg Fire Department have mentioned that would be very useful in a mapping and preplanning solution. Discussions are already pending with the HRECC for implementing ways that the 911 CAD could instantly push or dispatch address points to computers in fire department apparatus.

There is a potential business venture at stake with this research. Geographic Information Systems contain more and more information that is critical for police, fire, and rescue services can take advantage of to handle emergency situations. There are other enterprise solutions on the market when it comes to mapping software. However, higher operational costs coupled with tighter annual budgets often make complete solutions far too exorbitant for first response agencies all around the country. This solution is a simple application that might suit many departments' basic mapping and preplanning needs.

It is important to note that while the solution is just being implemented it is getting used. In the month of October, the Harrisonburg Fire Department responded to 424 calls for service. By mid-November with 3 months of system availability (and only one of those at 100% potential), the solution has been used to conduct over 1100 GIS searches. This shows that HFD personnel are actively using and training on the system. The application is installed on 13 apparatus toughbooks and a dozen other laptops and desktop computers at the department.

The solution meets the goals of the Integrated Science and Technology Master's program in many ways. It incorporates multiple disciplines including Geographic Information Systems, Computer Science and Software Engineering, as well as Information Management. There are numerous other social aspects involved as well. Many agencies were involved in the culmination of this project, including the Harrisonburg Fire Department, JMU Police, JMU Facilities Management, Harrisonburg Community Development and GIS, Rockingham County Fire and Rescue, Rockingham County Community Development and GIS, and the Harrisonburg Rockingham Emergency Communications Center. The result of many meetings improves communication mechanisms and improves sources of GIS for city agencies and citizens that use GIS daily. Another reason is that knowing what GIS is and knowing how to use it is being implemented and required in fire science curriculums all across the country. By signing up to be a first responder you will need to know how to take advantage of GIS solutions like this one. The solution also supports federal guidelines outlined in the National Incident Management System (NIMS) and the Incident Command System (ICS) for emergency management. These systems are established by FEMA and the Department of Homeland Security to make incident management more efficient. GIS unifies all levels of emergency management disciplines like public safety, hospitals, and communications centers from the local level all the way up through state and federal levels, and cuts across all incident types such as natural disasters, floods, wildfires, HazMat, terrorism, etc. All of these are examples of the social context evident in this solution.

Emergency responders rely on information for effective and timely responses. For fire, police, emergency medical services, and other public safety professionals, getting accurate information within the first few moments of any incident can mean the difference between life and death. Time is the greatest enemy of first responders, and getting to the scene of an emergency is the most critical element of what they do. GIS offers a way to shave seconds, minutes, even hours or days off of obtaining information responders need to make effective decisions. Incident response and management used to be a “shoot from the hip” and “go with the flow” approach for responders to do the best they could with the information they had available. Nowadays information is fed into GIS systems from multiple sources, which helps responders make more informed decisions. Equipped with the solution developed as a result of this thesis project, firefighters and incident commanders at the Harrisonburg Fire Department can respond more effectively and take advantage of the benefits that GIS has to offer.

Glossary

BMP – Bitmap file format (images)

CAD – Computer-Aided Dispatch

COM – Component Object Model

CPR – Cardiopulmonary Resuscitation

DHS – Department of Homeland Security

DOC – Microsoft Word document format

DOT – Department of Transportation

ECC – Emergency Communications Center

ERG – Emergency Response Guide

ESRI – Environmental Systems Research Institute

FEMA – Federal Emergency Management Agency

GIF – Graphics Interchange Format file format (images)

GIS – Geographic Information System

GPS – Global Positioning System

HazMat – Hazardous Materials

HFD – Harrisonburg Fire Department

HRECC – Harrisonburg-Rockingham Emergency Communications Center

ICS – Incident Command System

JMU – James Madison University

JPG or JPEG – Joint Photographic Experts Group file format (images)

MSDS – Materials Safety Data Sheets

MXD – ArcMap GIS document file type

NFPA – National Fire Protection Association

NIMS – National Incident Management System

NIOSH – National Institute for Occupational Safety and Health

NPG – NIOSH Pocket Guide

PDF – Portable Document Format file format

PPID – Preplan ID (number)

SDK – Software Development Kit

TIF or TIFF – Tagged Image File Format (images)

VSD – Microsoft Visio Document (file type)

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