HIGHLIGHT

Use of Image Data to Facilitate Navigation of an Airport Emergency Response System

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An image-based moving map display was created for the Voice Activated Poor Visibility Emergency Response System (VAPERS). VAPERS is a commercial retrofit package designed to enhance the operation of fire fighting equipment deployed at military and commercial airports. The system was designed and tested at Truax Field (Madison, WI) and Tyndall AFB (Panama City, FL). The moving map was based on one-meter digital orthophotography, systematically aggregated to lower resolution displays and organized in a tiled TIFF format. Each resolution layer was enhanced with vector data deemed desirable by emergency vehicle operators. Given the availability of different data sources at each site, the protocols for producing the moving map varied. The successful demonstration of VAPERS is discussed in terms of its future commercialization and potential future enhancements for the moving map.

Introduction

Inclement weather severely hampers the response of plane crash rescue operations at both military and commercial airports. Fog, snowstorms, and darkness often obstruct emergency vehicle operators from efficiently identifying the crash site and coordinating fire-fighting vehicles to the site. Delay in response time significantly increases the chance of loss of life and property damage.

A joint U.S. Air Force/Federal Aviation Administration system design research project focused on equipping emergency vehicles with advanced technologies to significantly decrease response time in inclement weather. Under a 1996 Small Business Innovation Research grant, and teamed with the Astronautics Corporation of America, Orbital Technologies Corporation (ORBITEC) proposed and developed the **V**oice **A**ctivated **P**oor **V**isibility **E**mergency **R**esponse **S**ystem (VAPERS) in 1997. The aim of the system was to improve overall emergency response of fire fighting personnel and equipment to aircraft fires and crash sites, consistent with FAA regulations (FAA Advisory Circular 150/5210-19).

Through the NASA Commercial Remote Sensing Program Office at Stennis Space Center and the University of Wisconsin-Madison sponsored Affiliated Research Center (ARC) program, ORBITEC teamed with graduate students and faculty researchers to develop an image-based *"moving map" demonstration for* VAPERS. VAPERS had already been designed by ORBITEC to use scanned hard copy maps when this joint research project began. The objective of this pilot project was to develop an image-based moving map display to supplement or replace the conventional map data. Instead of scanned hard copy maps, which were not of high enough resolution (1-5 meters) and were hard to read, remotely sensed imagery was suggested as a viable alternative. The team stated that the moving map should be easily read at a glance by the emergency vehicle operator, and it should provide for viewing at a range of scales to respond to emergency situations within a response radius of 30 miles from the base of operation.

VAPERS Capacity and Role of the Moving Map

To aid fire-fighting personnel in responding to aircraft fire and crash

Table 1. The Capacity and Components of VAPERS

Capacity of VAPERS	Components
1. Locate a fire or crash site quickly in all weather conditions.	Forward Looking Infrared (FLIR) Display.
2. Travel the most direct route to the emergency site quickly and safely, avoiding obstacles or non-trafficable terrain.	Differential GPS (with local base station) and a highly accurate map display.
3. Receive critical information while en route to emergency site.	Data Link from each vehicle to the base station.
4. Communicate position of each vehicle to dispatcher and fire chief.	Data Link with Mission Display.
5. Operate the FLIR and other system components via voice activated commands.	Voice Activation and Display System.
6. Access aircraft and hazardous materials databases.	Data Link and Display.
7. Locate "hot spots" and passengers through smoke or fog.	FLIR Display.

incidents in all weather conditions, VAPERS was designed to integrate many components so as to provide real-time navigation and emergency information. Table 1 outlines the capacity of VAPERS with each of its functional components.

For the highly accurate map display, the team proposed that a remotely sensed image base integrated with digital vector information could be used as an effective substitute to hard copy scanned maps, since up-to-date maps with the required spatial resolution of a few meters do not exist for all airport facilities. More (and arguably better) information could be derived from a remotely sensed image, such as the condition of the landscape beyond the roads, location of buildings, etc. Imagery could be updated more easily then a conventional cartographic product, and would be particularly valuable in areas that are developing quickly. Finally, future one meter spatial resolution imagery from commercial remote sensing satellites will make the creation of such maps possible for virtually all military and commercial airports worldwide.

ARC

Organizationally, the ARC program is designed as a 6-9 month no-exchange of funds partnership between businesses and ARC program universities, where technical, organizational, and financial aspects of the introduction of geospatial information technologies are examined on a pilot-project basis focusing on an objective defined by the commercial partner. It is hoped that these short-fused projects stimulate the partner commercial firm to become further interested in procuring and/or developing goods and services employing appropriate spatial data and technologies. The University of Wisconsin-Madison ARC program is administered by the UW Environmental Remote Sensing Center (ERSC).

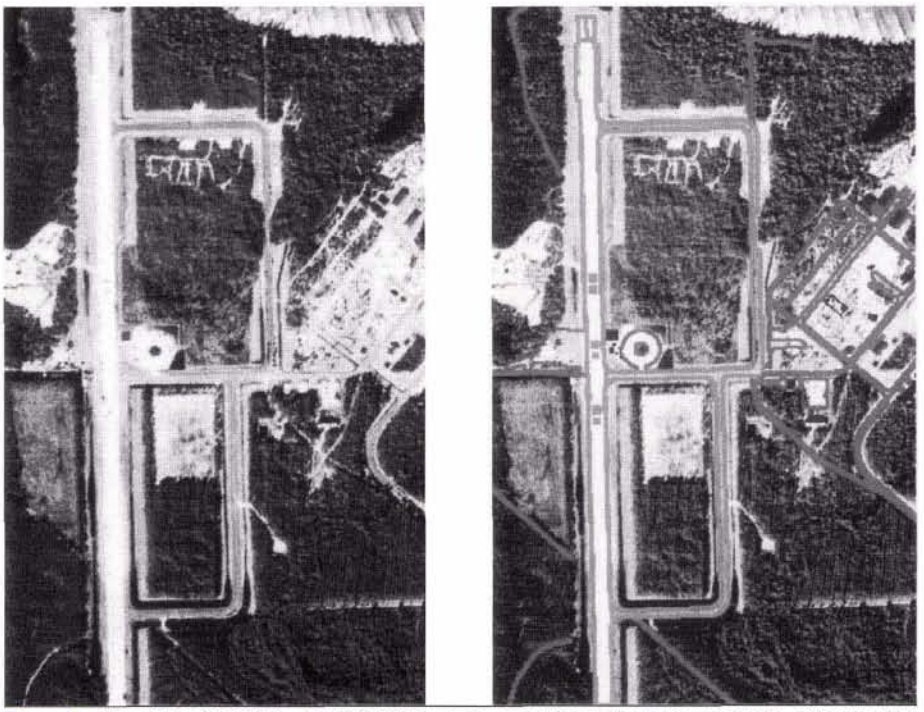

Figure 1. The original DOQQ for Tyndall AFB featuring the Silver Flag test area (left), subsequently classified and enhanced to create the moving map (right).

Test Site Locations

The system was tested at two sites - Truax Field (Madison, WI) and Tyndall AFB (Panama City, FL). Truax Field was chosen as the initial development site given its proximity for validating system components. Tyndall AFB was selected because it is the location of the Air Force Fire Research Group, and serves as both a research site and training facility for aircraft fire fighting personnel nationwide.

Moving Map Preparation and Design

The development and demonstration of the moving map occurred in three phases: 1) project preparation and planning, 2) development of a demonstration map product for Truax Field, and 3) development of a demonstration map product for Tyndall AFB. The moving map preparation and design ran in parallel with the definition and development of the hardware and software integration involved in the overall design of the VAPERS system. Given this, the overall hardware and software environment for this demonstration was fixed by the original VAPERS design.

Project Preparation and Planning

Critical elements in the preparation and planning phase included the identification of appropriate raster and vector data, review of VAPERS' hardware and software system capabilities, interviews with fire fighting personnel, and identification of appropriate software for creation of the moving map.

VAPERS was designed to incorporate map layers at different spatial resolutions to assist with the response to emergency situations ranging from on-site to within 30 miles of the base station of operation. Emergency vehicle operators could toggle between maps with greater or lesser spatial detail, enabling them to zoom in and out to readily identify landmarks. The system was originally designed to provide scale change in multiples of two (for example, layers could be configured to have spatial resolutions of 5, 10, 20 and 40 m, or alternatively 3, 6, 12 and 24 m). Initial experiments were conducted using combinations of image data sets from multiple sources (for example, Landsat TM 30 m data in combina-

tion with 10 m SPOT® data). However, the dramatically different reflectance characteristics between these different data sets (in large part due to temporal differences) proved to be hard for to the emergency vehicle operator to read (or interpret) as suggested. The team finally decided to use data nominally at one meter resolution and set synthetically generated images with lower spatial resolution. This eliminated any variation in the spectral characteristics of the data at the various spatial resolutions.

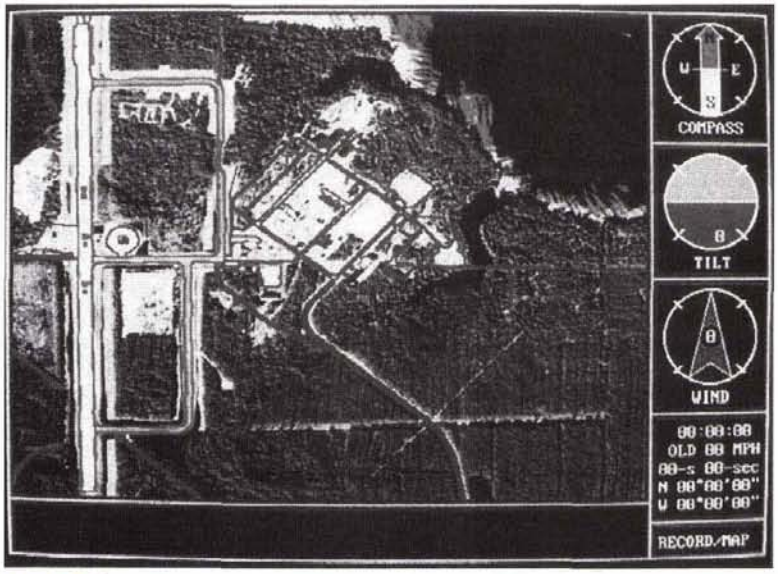

Figure 2. **The moving map as integrated into VAPERS and displayed on the LCD screen.**

For Truax Field, a ready source of one meter panchromatic digital orthophotography data existed from the Dane County Regional Planning Commission (DCRPC). The data were organized by township and nine townships were included in the demonstration project. Vector data were also available from the Land Information and Computer Graphics Facility (LICGF), University of Wisconsin-Madison. A review of this data set revealed that only the left edges of roads had been digitized (versus the centerline), and that significant urban areas of the county were not covered by the data. This caused additional digitizing and manipulation of the vector data files. For Tyndall AFB, color infrared orthophotography from the Florida Resources and Environmental Analysis Center (FREAC) was found, and an AutoCAD data base from the base engineer's office at Tyndall AFB was used.

Early in the project, the team reviewed VAPERS' hardware and software system components to determine what they needed for the creation of the moving map. In general, they found that:

- There was a limited screen extent (180 x 280 pixels) for map viewing (subsequently modified to 526 x 425 pixels);
- The radiometric resolution of imagery was limited to one byte (256 possible colors), with 240 colors available for the imagery and 16 colors available to the vector data;
- Zooming capacity, as discussed, was available in multiples of two;
- The MS-DOS based software only supported raster data; and,
- Tiled TIFF formatted data was required.

As a result, many information exchanges and modifications were made, with implications both for the final software and mapping products. The biggest change needed was to incorporate the vector data with the imagery. Vector data had to be "burned into" the imagery at each spatial resolution. This greatly increased processing time because the thickness of the lines and the size of the features had to be produced specifically for each layer of imagery.

Changing to remotely sensed imagery for the moving map meant that the team had to explain it to the emergency response vehicle operator. Typically, a single person operates the vehicles, so any technological innovation must be easy to understand and use under the most challenging conditions. The Fire Chief and his staff at Truax Airport described their operating procedures and present capacity for addressing emergency situations. A series of meetings and demonstrations helped define the important features to highlight on the moving map. For example, color schemes helped identify major versus minor roads, airport runways, selected buildings and landmarks. Fire fighters listed useful point features such as fire hydrants; emergency crash gates, fuel farms, and ammunition depots that could be GPS referenced and included on the moving map. Other themes, such as high-resolution contour information to determine the flow of leaking airplane fuel, were beyond the scope of the demonstration project, but were noted as desirable information in future generations of the system.

Three commercial software packages, Imagine® by ERDAS, Arc/Info®, and Arc/View® by ESRI were used to process the data, along with an UW/ERSC in-house remote sensing software package. Supplementary programs were developed to convert Imagine formatted images to tiled TIFF format.

Development of a Demonstration Product for Truax Field (Madison, WI)

Image layers featuring ground resolutions of 1, 2, 4, 16, 32, and 64 m were created from the one-meter digital panchromatic orthophotos and combined with road and hydrographic GIS layers. Additional ground feature information was digitized from the imagery by UW/ERSC

researchers and verified with ground positions collected using a Trimble GeoExplorer® GPS unit. The following processing steps were performed at each spatial resolution given the VAPERS requirement for raster information:

- The image bases from nine Dane County townships were imported into Imagine®. Each pixel corresponded to a 1m ground resolution and each township contained 128 megabytes. These files were mosaiced and then sub-setted to the area of interest. The resultant image was projected from the Dane County Coordinate System to UTM coordinates, Datum WGS84. The pixel values were re-scaled to a range of 0 to 239.

- The creation of multi-scale image data involved using the one meter orthophotography to synthesize 2, 4, 16, 32, and 64 m pixels. This process included running one-meter data through a low pass filter of appropriate size, then sub-sampling the resultant image to the appropriate resolution. Using a low pass filter provided a sharper image than one from sub-sampling the original image to each spatial resolution.

- Vector data were imported into Arc/Info® and these coverages were converted to raster files. Each feature (including main highways, county roads, runways, airport access roads, hydrography, airport emergency crash gates, airport hydrants, fuel stations, ammunition depots, and the fire station) was processed separately. Features important to firefighters were enlarged to be easily identified on the moving map. After converting the Arc/Info® vector data to a raster file, filters were run over the raster file to thicken lines or increase the size of a feature.
- Each feature was assigned a color when it was integrated with imagery at each resolution. The digital values of the feature colors were greater than the digital values assigned to the imagery. Then the imagery data was overlaid with each feature at each spatial resolution. The maps at each spatial resolution included imagery came from the panchromatic DCRPC orthophotos with accompanying color-coded features of varying line thickness (for roads, etc.) and different sizes (fire station, etc).

A P-19 fire truck outfitted with VAPERS.
Note the FLIR device directly behind the water cannon on the top of the vehicle's cab.

- Final images were converted to tiled TIFF format to be used in VAPERS.

Development of a Demonstration Product for Tyndall AFB (Panama City, FL)
As mentioned earlier, the available data for the demonstration product for Tyndall AFB site was different than that available for Truax Field. This meant some revisions of the data processing protocol were needed. The primary sources of data for Tyndall included

- 1 meter color infrared (CIR) digital orthophoto quarter quadrangles (DOQQs), created from 1994/95 NAPP photography with an assumed accuracy of 10-13 meters

- AutoCAD® files, created from 1990 aerial photography (scale: 1:23,760) that included coverage layers for roads, flight paths, buildings, etc.; and,

- GPS post-processed control points.

In contrast with the one meter panchromatic orthophotos used for the Truax field demonstration product, the team was concerned that there would be problems reading the one-meter DOQQs because in the CIR imagery, healthy vegetation was represented in shades of red. The emergency vehicle operators did not relate well to the concept of interpreting "red grass" and other vegetation in the imagery. An unsupervised classification of the CIR images was done at each spatial resolution and differing tones of green were assigned to the various vegetation classes.

The coverage area of the moving map included the Silver Flag test area (used for fire fighting research and training purposes) and the fire station administrative offices. The size of the final computer files at a nominal resolution of 1, 4, and 16m covered a ground area of approximately 8.5 x 6.5 km. The following processing steps for Tyndall AFB were similar to those used for Truax Field:

- AutoCAD® files were converted to Arc/View® coverages then edited and cleaned in Arc/Info®. The coordinate system of the AutoCAD® files was not available, so the files were registered to UTM coordinates, Datum WGS84, via the GPS ground-truth information. Coverages were then converted to raster files for each feature at each resolution. Low pass filters were applied to each raster file to thicken lines or increase the size of point information, and colors were assigned to the various features.

- Four DOQQ files were imported into Imagine®, and contrast stretches were made so that the spectral reflectance of all the images matched. These enhanced images were mosaiced together and a subset of the area of interest was made. The spatial accuracy of the image was confirmed using the GPS ground-truth information. A portion of the original DOQQ is shown in Figure 1.

- As with the Truax demonstration, the mosaiced image was averaged using a low-pass filter and then sub-sampled to create imagery at the various required resolutions. As before, each image at each resolution was classified and assigned digital numbers to emulate 1 true or normal color rendering.

- The integration of the feature data and classified imagery was similar to the Truax Field demonstration. The feature information was overlaid on the classified imagery at each resolution, and integrated with clustered images at each resolution in Imagine® (Figure 1).

- The images were exported from Imagine and converted to tiled TIFF format to be used in VAPERS. Figure 2 shows the final product as displayed by the VAPERS LCD (Orbital Technologies Corporation, 1998).

"Anytime that you can better your vision in a blizard, extreme darkness, or a storm, and (provide) the on-board mapping system that is available within VAPERS to the operator of a vehicle, it is going to allow us to get equipment to the scene quicker. This, in the long run, is going to assist in saving lives."

Fire Chief Richard Heft
Dane County Regional Airport
Truax - Air National Guard Base

The Final Moving Map, Testing VAPERS at Tyndall AFB, and Status of Future Activities

Using the moving map, the vehicle driver was able to:

- Identify his/her DGPS position with a high degree of accuracy;
- Recognize the major land cover features of the area;
- See the major road networks, runways, and buildings; and,
- Flip back and forth on the map display between the various resolutions as needed for a general overview of the region or specific identification of the emergency location.

VAPERS was tested at Tyndall AFB in August 1997. To simulate total blackout conditions, black plastic was affixed to the windows of three P-19 fire-fighting vehicles (see Photo 1 for a picture of the P-19 fire-fighting vehicle). Five fire emergency situations were simulated. In all five situations, the system guided each of the drivers to their specific emergency response location, with vehicles tested at speeds of over 40 miles per hour. Periodically during the five tests, vehicles were stopped and accuracy tests were made to find out whether the vehicle was in the location indicated by the moving map and DGPS. None of the vehicles was ever more than 5 m off of the expected location; and most were about 2 m or less from the expected position. Personnel at the Tyndall AFB considered the demonstration a success, and are in the process of documenting the experience (Kempton, 1998).

To date, VAPERS has been successfully demonstrated at Tyndall AFB, Truax Field, and one major US airport. The system is actively being marketed worldwide, and is a leading candidate for installation at two major US airports. Other government and commercial entities are interested in further demonstrations of the system.

Conclusions

The moving map with an enhanced image proved useful for emergency response in a fire-fighting situation and may be a valuable tool for other emergency and transportation systems. Spin-off applications of the moving map could include everything from transportation logistics to precision farming.

As ORBITEC continues the commercialization of VAPERS, there could be many more technical innovations to further enhance the system. The moving map created for this study was limited by the hardware and software – the use of a Windows-based system and increased computer processing and storage could dramatically increase the capacity of the map, and make it easier to update. Modifications should be balanced against the present cost of VAPERS. Further research and quality control may be needed to understand the cummulative errors through the system as a result of the characteristics of the original source data, the DGPS, and the moving map. Finally, ORBITEC needs to evaluate the results of this project to determine where to obtain appropriate raster and vector data, and how best to create or acquire the moving map data on a production basis.

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For a short video clip of the emergency response demonstration, go to the ASPRS website at www.asprs.org/asprs, click on the October issue of *PE&RS*, and find the link.

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