

Automated Vehicle Location using Global Positioning Systems for First Responders

Mr. Daniel Portillo

**Institute for Information Technology Applications
Technical Report Series**

February 2008

Approved for public release. Distribution unlimited.

ABOUT THE AUTHOR

Danny Portillo

Danny Portillo is currently the Director for Geospatial Laboratories at the Air Force Academy and also serves as a geospatial technician/researcher for the Geospatial Technical Center. He has worked with geospatial technologies for over 20 years. He has been conducting research related to Global Positioning System asset tracking for more than two years.

Comments pertaining to this report are invited and should be directed to;

Sharon Richardson
IITA, Director of Operations
HQ USAFA/DFPS
2354 Fairchild Drive, Suite 4L35F
USAF Academy CO 80840-6258
Office: (719) 333-2746
Email: sharon.richardson@usafa.edu

Table of Contents

Background Information	4
Project Significance and/or Relevance	5
Research Methodology	6
Hardware Installation	7
Frequency use and approval	8
Re-radiation of GPS data	9
Repeater antenna installation	10
Data storage and distribution	11
Conclusions	12
Future Research	13

Background Information:

Automatic vehicle location (AVL) is a means for determining the geographic location of a vehicle and transmitting this information to a point where it can be stored and used with certain software and database applications. A common practice is to stand up a centrally located server that is connected to a network and the server acts as the gathering point where data is received and stored in a database.

Most commonly, vehicle location is determined by using a Global Positioning System (GPS) device, and the transmission mechanism of the data is a satellite, terrestrial radio or cellular connection from the vehicle to a receiving satellite, radio receiver, or nearby cell tower.

Originally designed for fleet management, AVL systems have been in use for over 20 years to increase the accountability of field personnel and boost the efficiency of an organization's dispatching procedures. The integration of AVL data into a geospatial information system (GIS) combines the concepts of dynamic geospatial location, intelligent geographic data and situational awareness.

The added information of vehicle tracking information into an existing geospatial information system provides a comprehensive approach for decision making and asset management. The aggregated information makes the system extremely useful since the data is updated on a minute by minute basis to provide real-time applications.

This paper summarizes a project conducted by members of the Air Force Academy Geospatial Technical Center (under the direction of the Institute for Information Technology) in collaboration with the Colorado Springs Traffic Management Center, AF Space Command, USAFA Fire Department and the 10th Communications Squadron during the summer of 2005.

Initial AVL work and applications were first established by a federal grant for Congestion and Mitigation and Air Quality for the Colorado Springs region in 2001. The City of Colorado Springs Traffic Management Center approached the Colorado Springs Fire Department in 2004 about collaboration on an AVL project to study and develop a solution aimed at aiding emergency response and efficiency.

Military installations were later included under the "Coordinated Responders Program" including the U.S. Air Force Academy (USAFA).

Project Significance and/or Relevance

AVL technology is assisting decision support, situation awareness, and emergency response situations. It is well known that the most critical time factor is the availability of basic information such as the location of an incident, location of emergency resources, distance to a certain location and travel time.

Aside from emergency response support, AVL technology provides improved response time, resource management, schedule adherence and increased productivity on a day to day application. The use of this technology can support many activities such as fleet management, snow plow routing, garbage truck tracking, and mobile workforce management.

The value of dynamic geospatial information is extremely powerful especially when it is integrated with existing static geospatial information because of the added capability it provides. Knowing where “something” is located as it moves along the earth’s surface, gives you the ability to predict, react, and respond accordingly. By having the authority or ability to change the direction of a moving vehicle, certain users are essentially “enabled” to make more efficient use of these valuable resources in real time.

In response to a previous accident, Peterson AFB established a satellite based GPS tracking system in 2003. The system was designed to monitor missile transport using GPS, satellite communication and web based mapping capabilities. This same tracking system was later installed on emergency response vehicles to provide the similar capabilities including incident management. The Air Force Academy (AFA) Fire Department was a recipient of this system that was offered to all military installations in the region.

Shortly after installation, it was discovered that although the GPS tracking system was efficient for tracking missile transport vehicles, it did not meet Emergency Management response requirements because of the eight to ten minute latency in data transmission.

To improve the tracking capabilities, a web-based tracking system had been developed; however, many of the application features were very basic with minimal interactive capabilities that did not allow the dispatcher or user change or add information. As a result of these shortcomings, the project was shelved indefinitely.

As part of a follow-on project in 2004, the City of Colorado Springs Traffic Operations Center developed a tracking system that used Global Positioning System (GPS)/radio frequency (RF) based AVL system. This system utilizes radio frequency repeater antennas, GPS re-radiator equipment and self contained vehicle AVL GPS tracking equipment. Because the re-designed AVL

System was intended for First Responders, it needed to meet these requirements:

- Radio Frequency communications based for quicker refresh rate
- Higher accuracy
- High resolution imagery and higher fidelity maps
- Integrated with legacy systems such E-911 and other dispatch tools

The database model developed to collect AVL GPS data is consistent with industry standards and capable of producing data that can be consumed by GIS systems that are common throughout the AF Geobase program. The integration of AVL GPS data as another mission dataset holds the potential to enhance Geobase capabilities for AF installations that subscribe to the Geobase data model.

This initiative involved several participants that provided guidance, insight and assistance to make AVL a reliable and well integrated capability in the Colorado Springs, Colorado region. Participants included:

- AFA Deputy Fire Chief
- AFA Command Planner/Architect
- AVL Design Engineer from City of Colorado Springs Traffic Operations Center
- Automated Vehicle Location Engineer from City of Colorado Springs Traffic Operations Center
- Software Engineer from City of Colorado Springs Traffic Operations Center
- Peterson AFB Geobase Integration Officer
- USAFA Geobase Integration Officer
- AFA Security
- AFA IT Project Management for 10th ABW
- 10th MSG/LGR Responsible Transportation
- AFA Security Forces Manager
- AFA Spectrum Manager
- AFA Lead First Responder
- Chief of Logistics Readiness Division

Research Design or Methodology

A systematic approach to the design and implementation of the AVL system required the following steps:

- 1. Hardware installation in vehicles** - Installation of GPS/RF equipment into AFA Fire Trucks. Modification of emergency response vehicles to accommodate installation and use of GPS/AVL tracking equipment

required a vehicle modification letter that was approved by the Vehicle Management Flight.

2. **Frequency use and approval** - Before GPS/RF equipment could be turned on, approval to use selected frequency range was acquired from the FCC and AFA Spectrum manager. Use of the 902-928 MHz frequency bands that are currently in use by the Colorado Springs Traffic Management Center (CSTMC) required coordination and approval.
3. **Re-radiation of GPS data** - To further refine vehicle location when the emergency response vehicles are inside the fire stations, GPS re-radiation equipment was installed at three different fire stations. The re-radiation of GPS data is used to establish immediate location of fire trucks while in the fire station or prior to leaving the fire station. This is necessary because it can sometimes take up to ten minutes for a GPS location to be established once a fire truck leaves the station. The technical specifications of GPS re-radiation antennas met stringent Federal Communications Commission (FCC) and National Telecommunications & Information Administration (NTIA) requirements and were allowed to operate under a special purpose license.
4. **Repeater antennas** - Installation of repeater antennas on USAFA grounds. This required submittal of AF332 for site survey, dig permit, utility location and installation of antennas. Antenna location was determined by view shed analysis and Academy grounds survey.
5. **Data collection, storage and dissemination** - Vehicle location data is transmitted to the Colorado Springs Traffic Management Center (CSTMC) via radio transmission to the radio towers located in downtown Colorado Springs, CO. Data is stored in a central server where various software applications have the capability of deploying the data in a web-based map
6. **Data distribution to PAFB** - Redirection of AVL data from CSTMC Center to Peterson AFB servers under the management of the PAFB Geobase Integration Office and 21st CS. Database server configuration is similar to CSTMC's with geodatabase architecture used.
7. **Data distribution to USAFA** - AVL tracking data was made available as a web service and stored in an AVL data server for further processing and integration with research applications.

As previously mentioned, the USAFA AVL project was a subset of the overall Colorado Springs Automated Vehicle Location system that was designed to address emergency response and preparedness. The configuration of the overall

network was centrally located at the CSTMC because it is one of the primary hubs for fiber communication in the city (FIGURE 1). The layout and configuration of data transmission was designed so that the data would be collected on an MS SQL server and then further distributed to other locations such as Peterson AFB and USAFA (FIGURE 2).

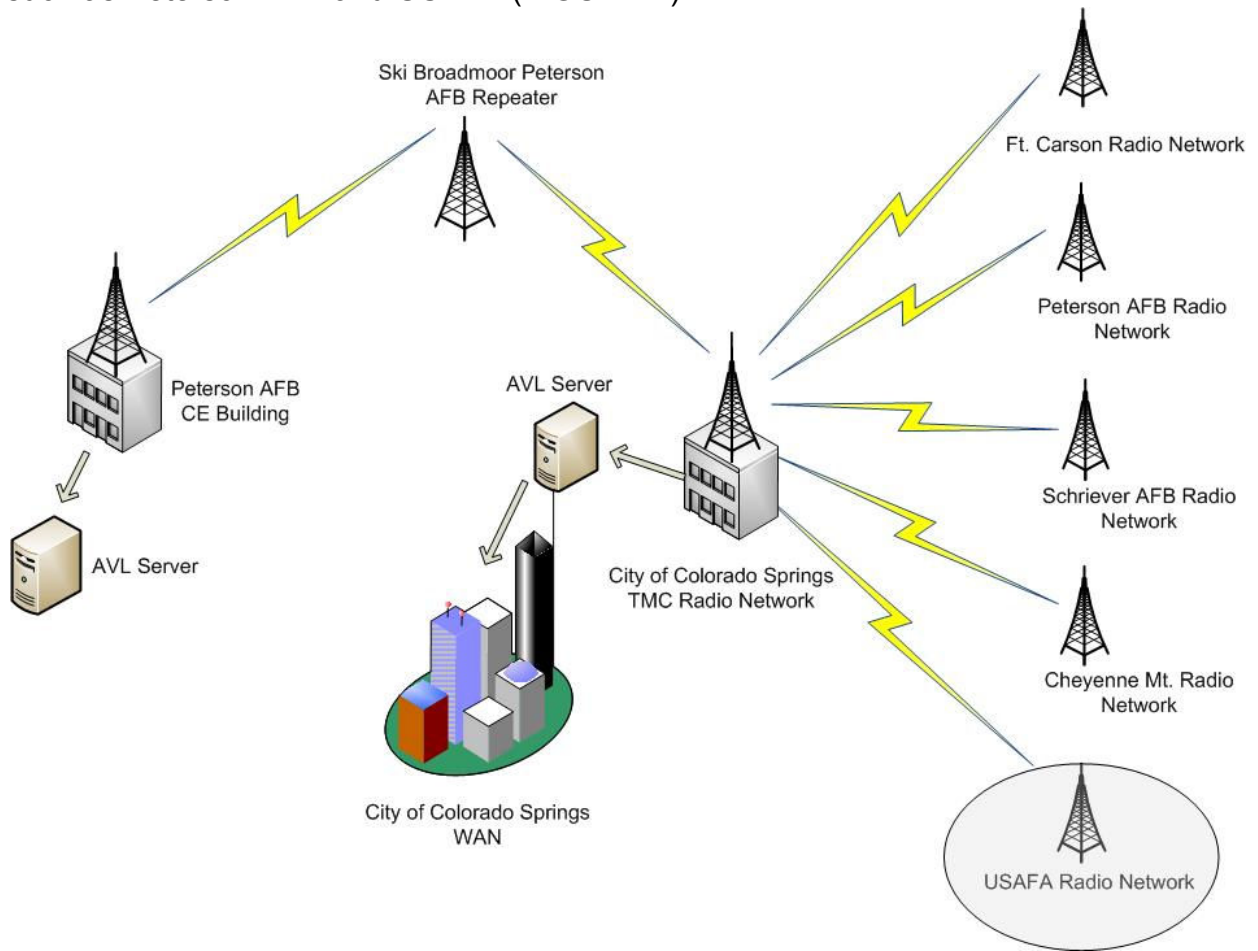


FIGURE 1
Fiber communication for city's wide area network is directly connect to the Traffic Management Center

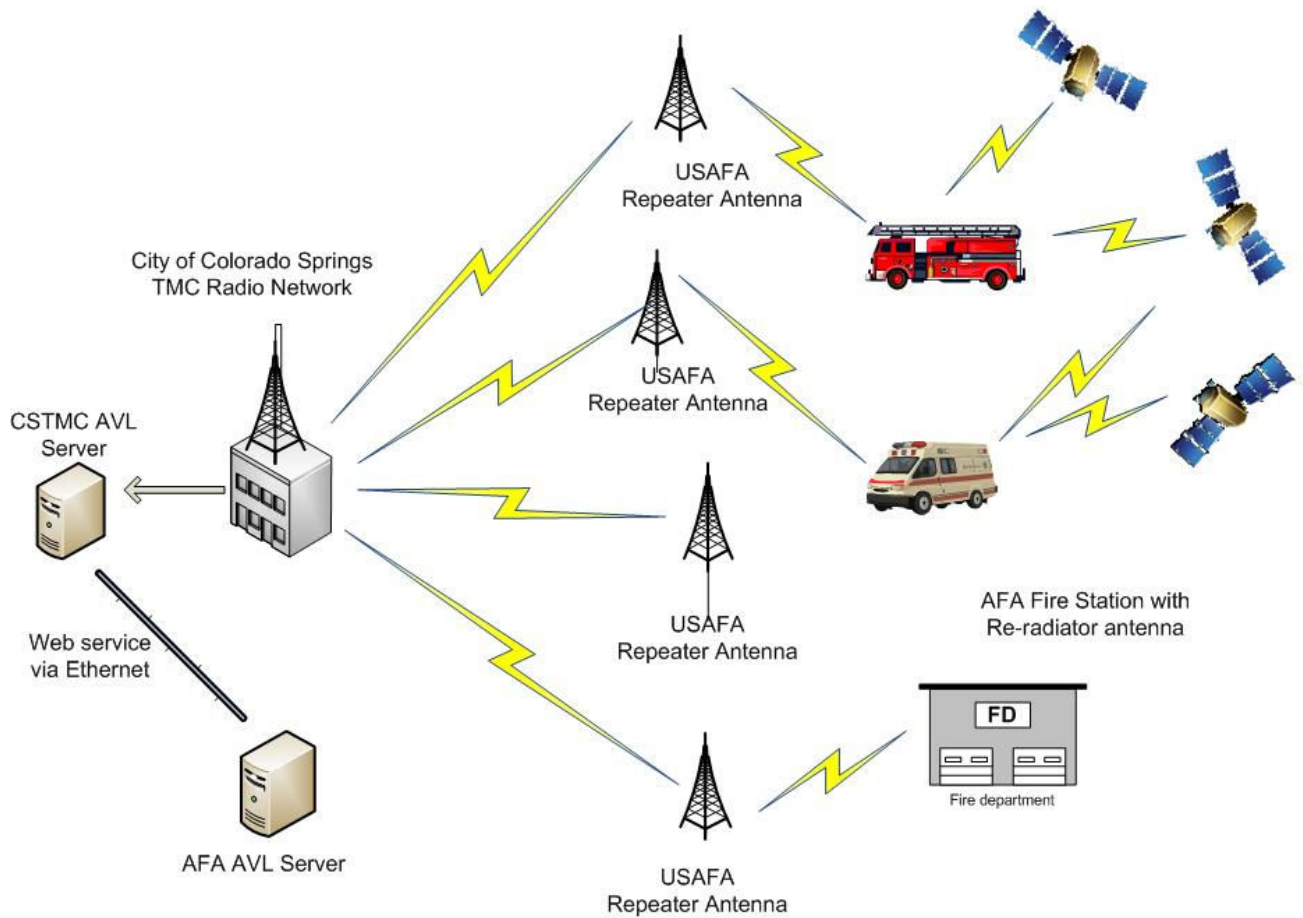


FIGURE 2

AFA AVL tracking system shows the repeater antennas that service the Colorado Springs region and includes the use of the re-radiator antennas.

Hardware Installation in vehicles

Installation of GPS tracking equipment on AFA Fire trucks and AFA Fire Chief vehicle included GPS antenna, radio transmission antenna (Figure 3 & Figure 4) and the GPS receiver (Figure 5).



FIGURE 3

Hole drilled into the roof of fire truck and cabling routed to the receiver inside the fire truck.



FIGURE 4

Magnetic mounted antennas provide “best placement” ability on roof of vehicle.



FIGURE 5

Modification to the vehicles allowed installation of the GPS receiver units under the passenger seat with easy access to electrical power supply.

Frequency Use and Approval

The City of Colorado Springs was already using the 902 – 928 MHz portion of the spectrum for vehicle tracking; however, in order for AFA to participate in the overall CSTMS AVL tracking network, it needed to secure approval from the Spectrum Manager, FCC and NTIA on two particular issues.

The first issue was the installation and use of repeater antennas on the AFA grounds to overcome the problems of inconsistent coverage as a result of the terrain in the region.

Submittal of the installation request with supporting documentation and justification resulted in the approval to use the same frequency band as the CSTMC. The AFA Spectrum Manager determined that there was no frequency conflict and we were granted permission to operate on the requested band for GPS location data transmission to the Traffic Management Center radio network by four repeater antennas that would be installed on the AFA grounds. These repeater antennas would ultimately service the entire Colorado Springs region because of their vantage point.

The second issue was the use of GPS re-radiation antennas on the AFA. The use of such devices is a very contentious issue at the national level because of GPS interference with military and contractor facility. Certain vendors will even produce re-radiation equipment that operates in restricted frequency bands. As a result, there are very strict requirements that have been mandated by the FCC and the NTIA.

Eventually, with the help of the AFA Spectrum Manager we received permission to install three GPS re-radiation antennas, making sure we complied with the NTIA regulations clearly specifying that radiated power must be calculated so that emissions are no greater than -140 dBm/24 MHz isotropic at a distance of 100 ft from the building where the test is being conducted.

Re-radiator antenna Installation

Installation of the re-radiator antennas at Fire Stations 1, 2, and 3 included hardware that was mounted on the roofs of the fire stations with cable installation into the garages. These antennas have the ability to repeat the GPS location of the truck once they enter the fire station garage.

The GPS Repeater kit (GPSRK) is comprised of a GPS Repeater Amplifier and a GPS Repeater Antenna mounted on a pedestal (FIGURE 6)



FIGURE 6
Amplifier (left side), repeater (right side)

A GPS roof antenna (FIGURE 7) and cable are necessary to receive the GPS signal from the outside of the signal. They can be purchased as options with the GPSRK.

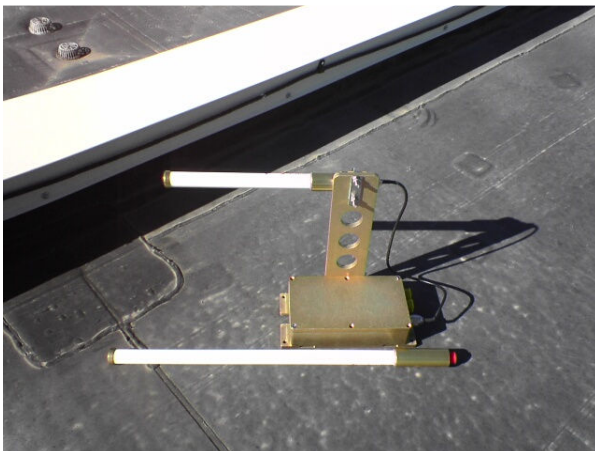


FIGURE 7
GPS roof Antenna

The GPS signal is received by the roof top antenna and routed via a low loss cable to the GPSRK Amplifier Antenna assembly where it is repeated (FIGURE 8). It takes at least three GPS satellites to derive a position and five GPS satellites for position, time, and redundancy. An important thing to remember is that one satellite will keep the receiver almanac and ephemeris data current. Most GPS repeater kits have a range of approximately 100 feet and operate “line of sight”. The radiation pattern is similar to the beam of a flashlight. In some instances multiple GPSRK’s may be needed due to obstacles. With judicious placement the number of GPS repeater kits can and should be kept to a minimum.

The GPSRK is intended for installation and use in areas where the GPS signal is not currently present. The position acquired is normally the roof antenna and therefore is not used for location and/or navigation.

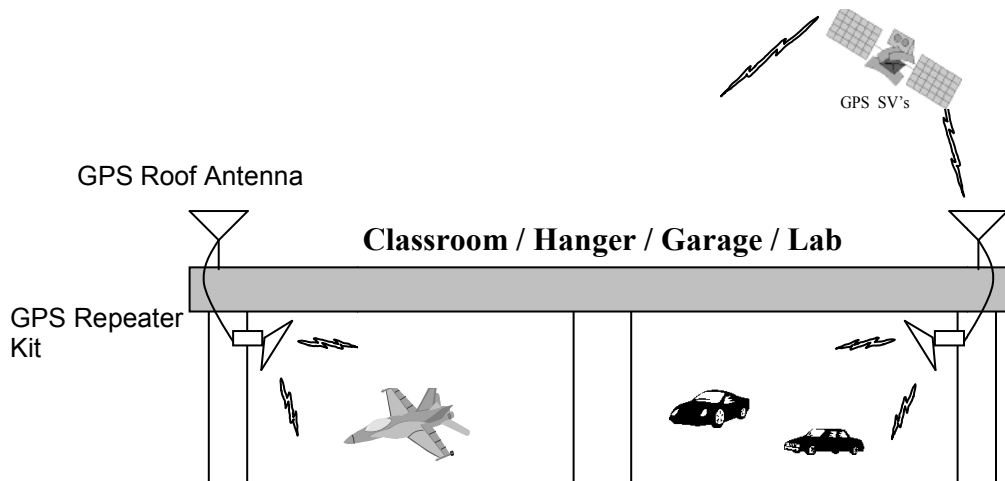


FIGURE 8

Installation:

The GPS Repeater kit (GPSRK) installation is simple.

1. *Mount the pedestal GPS Amplifier Antenna assembly in a corner 8 to 30 ft. high.*
2. *Connect the GPS cable from the GPS roof antenna.*
3. *Plug in the Amplifier Antenna assembly and you're repeating GPS.*
4. *Adjust and point the Repeater antenna across the room at the opposite wall or corner.*
5. *Adjust the pedestal angle for best reception in all areas of the room.*

Repeater Antenna installation

Prior to installing repeater antennas on the AFA grounds, it was first necessary to perform a viewshed analysis of area to determine optimal location.

A viewshed analysis is the study of visibility between points on a terrain surface and is commonly used in visual impact assessments. By using a geographic information system to process a digital elevation model raster data set, the visibility of every cell from the observer cell (or numerous observer cells) is

computed. Visibility is calculated by measuring the tangent from the observer's eye to each cell starting from cells closest to the observer. As long as the tangent increases in the line of site from the observer, the cell is visible. If the tangent decreases, the cell is not visible.

In the case of the AFA, a 5 meter digital elevation model was used. A 50 meter cell resolution was used to perform the analysis and it proved sufficient to determine visibility on the topography of the area.

A “best guess” placement of observation points was used to evaluate various locations until 4 primary locations were selected (FIGURE 9) to provide optimal coverage on Academy grounds and into the City of Colorado Springs.

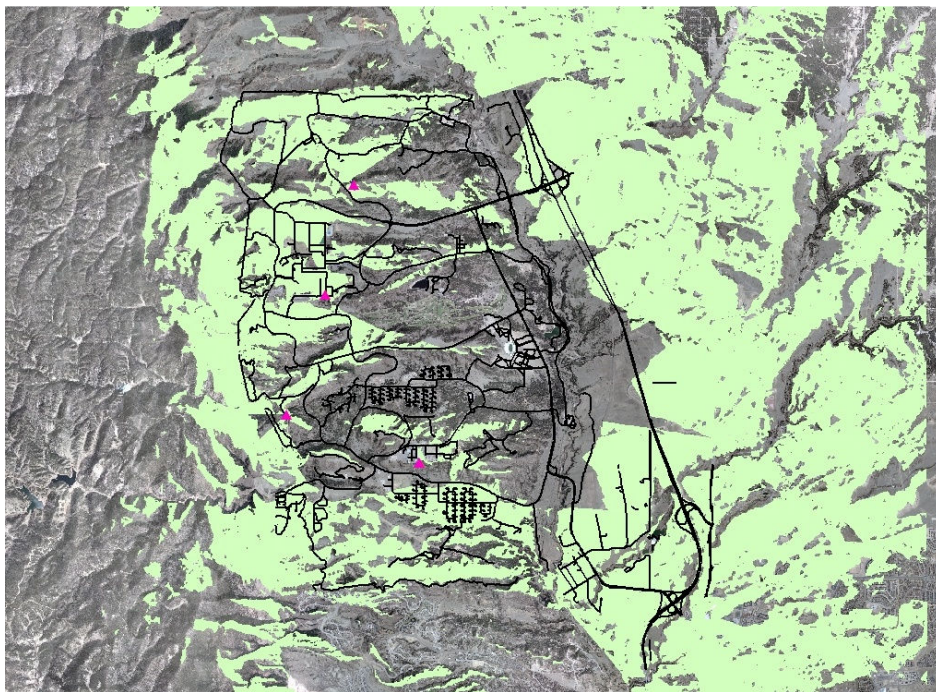


FIGURE 9
Green color depicts areas of coverage.

Repeater antenna installation included solar panels for power supply, the GPS receiver unit and the radio repeater antennas. Installation of a 25 foot pole was necessary at two of the locations (FIGURE 10) to accommodate select areas of coverage.

The Repeater Antennas used were Model Number: FGRO9CSU--Frequency Band: 902-928 MHz--Modulation: GFSK, 144 ~ 188 Kbps--Method: Frequency hopping spread spectrum, FCC ID: KNY-6231812519



FIGURE 10

Stand-alone repeater antenna system overlooking Colorado Springs from the Air Force Academy.

Data collection, storage and dissemination

Once a GPS location is acquired from a vehicle, the location of the vehicle is relayed via repeater antenna to the City of Colorado Springs Traffic Management Center using a 902-928MHz radio network where it is received by a communications multiplexor that sits between the CSTMS radio network and a Microsoft SQL server. The communication multiplexor “unwraps” the packets of information so that it can be parsed into the database.

Once the data has been parsed into the database, viewing the data is done in one of three ways:

1. Viewable through the internet via a Flash client application that places the vehicle location information atop a map.
2. Consumption of a web service from the CSTMC that can further be processed to place the location data either into an additional database or on a customized map.
3. Using internal customized applications that allow direct consumption of the location data via “thick client”.

The three different options of data delivery were able to satisfy the different requirements and intended uses of the AVL data by participants.

AFSPC had decided to have the AVL data redirected to servers located at the Peterson AFB CE building where the data was stored in a similar MS SQL Server. Data was transmitted to the CE building through 2.4 GHz radio link that was repeated through the ski Broadmoor Peterson AFB repeater antenna. This would allow technicians to integrate the AVL data into the Geobase program that is currently in place.

The Air Force Academy decided to receive the AVL data as a web service feed provided by the Traffic Management Center. The secure data feed was directed at a MS SQL Server located at the Academy and further aggregated with GPS data from similar projects that are currently examining the use of GPS location data from various other sources. Because today's computer users are very proficient at using the internet and navigating through web sites, it was determined that the AVL data collected by the Academy would best be utilized through a web based map. The popularity and accessibility of using Google Maps by most everyone at the AFA FD, gave the software developers a different direction in designing the access of AVL data (FIGURE 11).

Rather than relying on the operation of a thick client application such as ArcGIS or similar GIS software, it was determined that the "ease of use" would dictate how often the system would be used and if it could become a part of the information systems that are critical to operations for the first responders.

The system is currently in use and serves as a valuable asset along with existing legacy systems. Although some of the desired features were not integrated at this time, such as E-911 capability, CAD information and the ability to view vehicles en route from a dispatched vehicle, the system has proven useful and reliable.

A shortage of resources, has recently brought the project to closure as Phase I. Further development and experimentation is planned for Phase II and III while making it part of the Common Operating Picture.

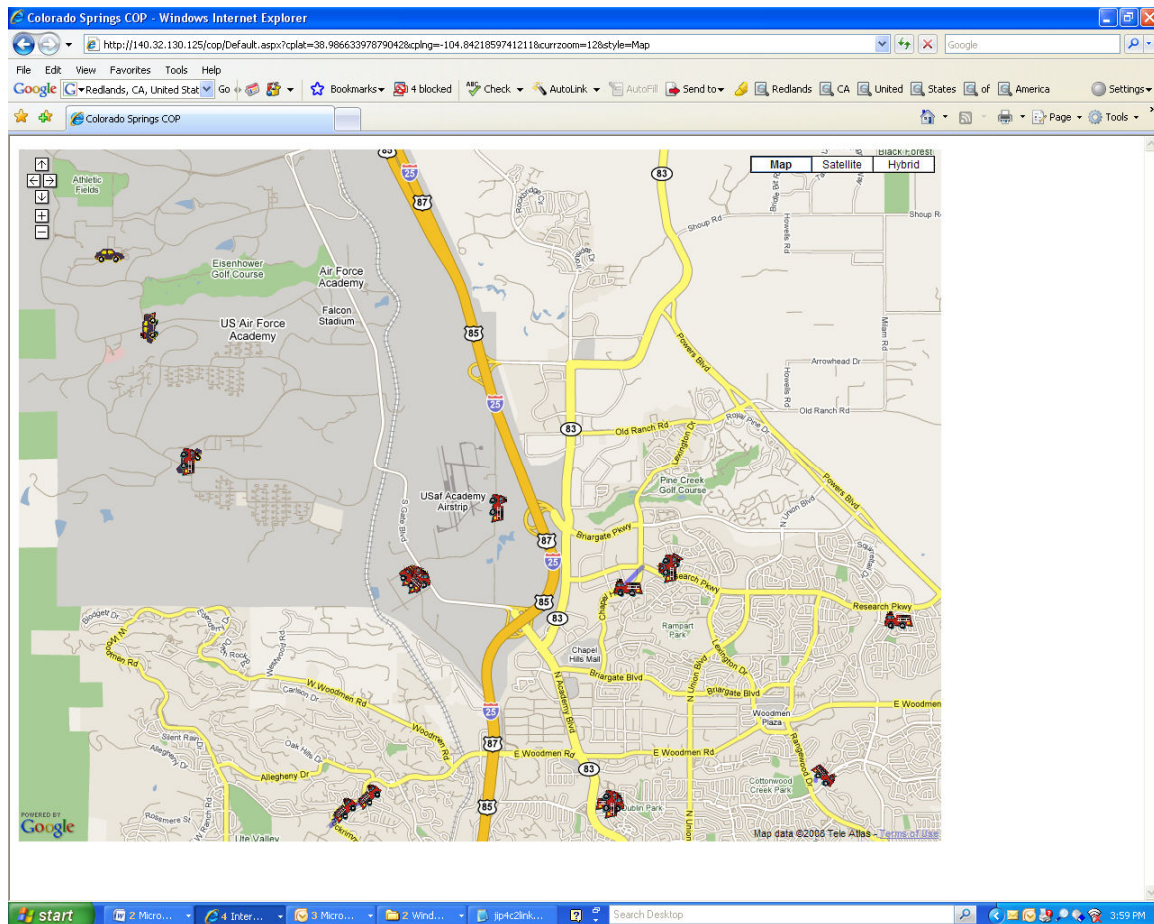


FIGURE 11

Google Maps showing AFA vehicles, AFA fire trucks and Colorado Springs FD trucks. All data was aggregated into a server and configured to display on a common map.

Conclusions

Initial project plans called for a redirection of AVL data from CSP Traffic Network Control Center to Peterson AFB servers configured with a Geobase architecture would be used to store and distribute data to users, including the AFA community.

This portion of the project would have involved oversight and approval by the AFSPC NOSC and the 10th CS. Technical specifications would have to address IP to IP connectivity, protocol definition, security, integration of AVL data into an Oracle database schema, and specifications on how the AVL data would be parsed into the database. Upon further review it was determined that the approval process and establishment of such a system would be prohibitive to the type of research and testing that was conducted by the AFA Geospatial Technical Center and so the data was delivered through a secure web service that could be ingested into a database for further processing.

The popularity Google Earth and its ease of use gave the project a different direction towards the end of the project. As users become more accustomed to using the internet and interactive tools to manipulate information, a web-based interface proved more desirable than working with a thick client application such as ArcGIS. Integration of AVL data into the Geobase program at the Air Force Academy is currently being studied. The consumption of web services and web feature services is already available through ArcGIS and similar GIS software which makes integration easier and seamless.

Future Research

The ingestion of WS and WFS into thin client applications, especially dynamic data such as GPS tracking data has created another dimension for those seeking to have a complete picture for situational awareness and common installation pictures.

Future research will focus integration of GPS tracking data with another research project at the Geospatial Technical Center that provides a Joint Installation Picture that is net-centric and aggregates static data, dynamic data and event data with automated businesses process to create a Command and Control tool that can serve a commander.