OKLAHOMA TRANSPORTATION CENTER

ECONOMIC ENHANCEMENT THROUGH INFRASTRUCTURE STEWARDSHIP

GPS LOCATION DATA ENHANCEMENT IN ELECTRONIC TRAFFIC RECORDS

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16. ABSTRACT

In this project we developed a new GPS-based Geographical Information Exchange Framework (GIEF) to improve the correctness and accuracy of location data reported on electronic police forms in Oklahoma. A second major goal was to provide a base level of automatic vehicle location (AVL) technology to the Oklahoma Highway Patrol (OHP) to improve operational efficiency and inter-agency asset coordination and to enhance police officer safety. The GIEF was successfully developed and integrated with the existing statewide electronic police forms system and was deployed to a select group of OHP Troopers for beta testing. The beta tests demonstrated that high quality position data were acquired from GPS receivers in the field during actual police operations, were used to populate electronic crash reports and citations, and were automatically transmitted to the main Department of Public Safety (DPS) data warehouse and to the statewide court system. High resolution position data were also acquired on a continuous basis for all of the beta test police vehicles and were stored in a new secure data base created for this project. These data were used to demonstrate real-time AVL functionality that will be evaluated by the OHP to determine how it can best be used in the future to improve police operations and officer safety. The enhanced position data provided by this project will be important to a wide range of traffic safety stakeholders for planning and assessing highway improvement projects, highway safety projects, and law enforcement activities directly in terms of public safety impact. The GIEF is fully upwards compatible with the new PARIS system scheduled for deployment in 2013.

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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	25.40	millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8361	square meters	m^2
ac	acres	0.4047	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.7645	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.4536	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.0394	inches	in
m	meters	3.281	feet	ft
m	meters	1.094	yards	yd
km	kilometers	0.6214	miles	mi
		AREA		
mm^2	square millimeters	0.00155	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectares	2.471	acres	ac
km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME		
mL	milliliters	0.0338	fluid ounces	fl oz
L	liters	0.2642	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
		MASS		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	Newtons	0.2248	poundforce	lbf
kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

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GPS LOCATION DATA ENHANCEMENT IN ELECTRONIC TRAFFIC RECORDS

Final Report

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Executive Summary

Traffic engineers, municipal planners, and a variety of related traffic safety stakeholders have a critical need to perform geospatial analysis of traffic incidents in order to identify problem roadway segments and chronic traffic safety issues, to plan roadway improvement and safety enhancement projects, and to quantitatively assess the effectiveness of these projects directly in terms of public safety impact. Likewise, police supervisors and commanders need to perform similar geospatial analyses in order to plan enforcement activities and assess their effectiveness in terms of quantitative public safety metrics. All of these important public safety activities depend on the availability of correct and accurate traffic incident location data. Unfortunately, missing, incorrect, and/or inaccurate location data reporting due to human reporting errors is a serious and pervasive problem both nationally and in the State of Oklahoma. Substantial federal efforts have been directed towards the improvement of traffic records accuracy and timeliness over the last decade and the National Highway Traffic Safety Administration (NHTSA) Data-Driven Approaches to Crime and Traffic Safety (DDACTS) program has concluded that location data is "perhaps the most important data element in any DDACTS operation." Moreover, NHTSA's Model Minimum Uniform Crash Criteria (MMUC) specification states that a GPS position fix coupled with the name or number of the highway is the optimum method for reporting crash location data.

In Oklahoma, traffic incident location data is currently reported using either paper forms or an electronic system called the Mobile Data Collection Systems (MDCS) that is deployed statewide to the Oklahoma Highway Patrol (OHP) and partner agencies including the Oklahoma County Sheriff's Office, the City of Edmond, and the City of Woodward. Even with the electronic police forms provided by the MDCS, location data must still be manually estimated and entered into the system using one of several antiquated legacy coordinate systems exactly as is done with the paper forms. This manual location reporting system is prone to human reporting errors and fails to leverage the latest available technologies such as the satellite-based Global Positioning System (GPS) deployed by the United States federal government.

The main goal of this project was to develop a new GPS-based Geographical Information Exchange Framework (GIEF) to improve the correctness and accuracy of location data reported on electronic police forms in Oklahoma. A second major goal was to provide a base level of automatic vehicle location (AVL) technology to the OHP to improve operational efficiency and inter-agency asset coordination as well as to enhance police officer safety. During the project performance period, the GIEF was successfully developed, integrated with the MDCS, and deployed to a select group of OHP Troopers for beta testing during the month of December, 2012. The beta tests demonstrated that high quality position data were acquired from GPS receivers in the field during actual police operations, were used to populate electronic crash reports and citations, and were automatically transmitted to the main Department of Public Safety (DPS) data warehouse in Oklahoma City as well as to the statewide court system. High resolution position data were also acquired on a continuous basis for all of the beta test police vehicles and were stored in a new secure data base created for this project and located at the National Weather Center in Norman. These data were used to demonstrate real-time AVL functionality that will be evaluated by the OHP to determine how it can best be used to improve police operations, officer safety, and multi-agency coordination in the future.

The enhanced position data provided by this project will be important to a wide range of traffic safety stakeholders for planning and assessing highway improvement projects, highway safety projects, and law enforcement activities directly in terms of quantitative public safety metrics. Moreover, the GIEF is fully upwards compatible with the new Police Automated Records Information System (PARIS) that is currently scheduled for statewide deployment to the OHP and partner agencies during calendar year 2013.

Chapter 1

1.1. Introduction

Geospatial analysis of traffic incidents such as crashes, traffic violations including excessive speed and driving under the influence of alcohol and/or drugs (DUI) [1], and highway infrastructure issues such as damaged guard rails or pavement is a critical component of enhancing public safety as it is related to all aspects of roadway transportation [2], [3], [4], [5]. Traffic engineers, municipal planners, and a variety of related traffic safety stakeholders routinely perform geospatial analysis with a primary goal of reducing the number and severity of crashes of all types, including fatality, personal injury, and property damage crashes in particular [6], [7] . The results of these analyses are used to identify “problem” roadway segments, to plan roadway improvement projects and enforcement activities, and to assess the effectiveness of these projects and activities directly in terms of their impact on public safety [1], [5].

Unfortunately, geospatial analysis of traffic incidents is difficult for at least two main, closely related reasons. First, in most states the locations of traffic incidents, violations, and roadway infrastructure issues have historically been reported using a myriad of legacy coordinate systems including, e.g., roadway mile markers, distance from a known intersection, or various grid systems [2], [6], [8]. For example, Texas uses three geographic coordinate systems to report crash locations: control sections and mile point markers, street codes for crashes on city streets, and block numbers and street names for crashes on county roads. This mix of coordinate systems makes accurate geocoding difficult and complicates the problem of performing meaningful analysis to improve public safety [6]. Similar multiple legacy coordinate systems are widely used, e.g., in Alabama [8], Kentucky [9], Wisconsin [2], and elsewhere. In Oklahoma, law enforcement agencies manually record location information using Oklahoma Department of Transportation (ODOT) control section numbers and mile markers [10], intersection ID and distance from the intersection, roadway name and mile post, and county grid sections. This reporting system is manual and prone to human reporting errors. Moreover, different agencies often report incidents using different coordinate systems, again making accurate geocoding and analysis difficult.

Second, inaccurate location reporting due to human error is a pervasive and serious problem [8], [9], [11] that is exacerbated by the fact that legacy coordinate system location reporting is typically manual and not automated. Common data entry errors include spelling errors in roadway names, use of unrecognized alternate roadway names, incorrectly entered control section numbers, and incorrectly estimated or incorrectly entered mile markers and offset distances [2]. In Oklahoma, the ODOT Collision Analysis and Safety Branch (Traffic Engineering Division) maintains a significant staff dedicated to manually checking crash reports and correcting location reporting errors where possible.

The last 10 years have seen a significant national focus on using technology to automate crash reporting with major goals to improve traffic records accuracy and timeliness [1], [2], [4], [7], [9], [12]. With the discontinuation of selective availability (SA) in 2000 [13], [14] and the advent of differential systems for improving accuracy even further, the United States government's Global Positioning System (GPS) [15] is a technology that offers the potential to supersede outdated and conflicting legacy coordinate systems, minimize human error by automating and streamlining data entry, and dramatically improve the accuracy and correctness of traffic incident location data [1], [8], [9], [12]. In addition, the deployment of GPS technology in law enforcement patrol vehicles opens the door to a whole range of new automatic vehicle location (AVL) capabilities with the potential to improve logistics and situational awareness, reduce response times, improve law enforcement efficiency and effectiveness, and enhance police officer safety [16], [17], [18].

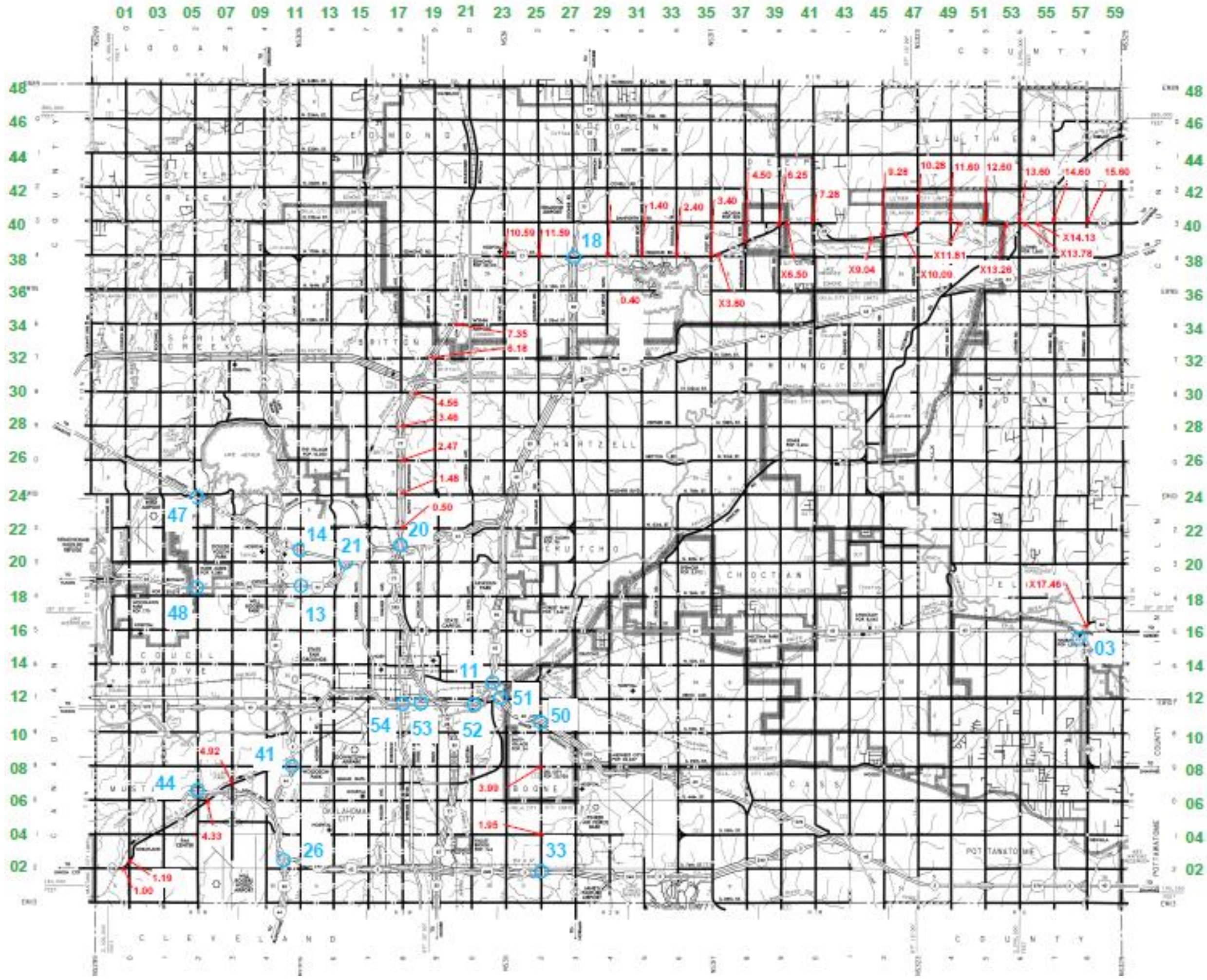

Figure 1. Example of a county grid and control section map used by Oklahoma law enforcement agencies to report traffic incident locations.

In this project, a GPS-based geographical information exchange framework (GIEF) was designed and implemented to improve geospatial data accuracy within collision reports, citations, and warnings fulfilled by Oklahoma law enforcement officers in the field. The system was developed in partnership with the Oklahoma Highway Patrol (OHP) Law Enforcement Technology Division (LETD) and was pilot tested by a group of five OHP Troopers. Figure 1 shows an example of the type of map that OHP Troopers currently use to estimate East and North grid and control section coordinates when completing collision reports, citations, and warnings. Grid locations are accurate to within 0.10 mile and serve as a primary means to calculate the location of collisions that do not occur on the interstate or highway system. Control sections are used to locate collisions that occur on the US and State highway systems and are accurate to within 0.01 mile [10]. All map-based collision location reporting systems such as this one are susceptible to human error. One of the main goals of this project was to provide a new location reporting mechanism to ameliorate this problem. In the Model Minimum Uniform Crash Criteria (MMUC) specification [19] developed by the National Highway Traffic Safety Administration (NHTSA) and the Governors Highway Safety Association (GHSA), it is stated that a GPS position fix (location) coupled with the name or number of the highway is the optimum method for reporting data associated with the location where a collision occurred. For this reason, this project was focused on the development of a new GPS-based system for reporting, storing, manipulating, and exchanging location data in the OHP and DPS.

The resulting GIEF is composed of server and client application components. The server components provide services for real-time Trooper location and a web site for mapping and display. The Microsoft Windows-based client application components are designed to assist officers in reporting geographical information for collisions, citations, and warnings in an automated modality that improves accuracy and correctness in reporting incident locations. The locations may subsequently be displayed on a real-time map to support AVL and on-the-fly analysis functionality. With this new GIEF, state agencies such as OHP, OHSO, ODOT, and the Emergency Medical Services Authority (EMSA) as well as local municipal emergency response administrators will be able to utilize a web-based application to search the data and correlate the results with agency specific datasets for use in process and enforcement planning. In addition, the real-time location asset map will provide an important resource to improve fleet and inter-agency coordination and resource management for agency administrators.

1.1.1. Problem Statement

As described below in Section 1.1.2, the OHP currently uses a computer-based electronic system for reporting collisions and enforcement activity. Although this system leverages computing, communications, and information technology to provide a comprehensive suite of electronic police forms including an electronic crash, citation, and warning, the location data must still be determined manually using grid and control section maps like the one shown in Figure 1 – just as it was in the past when paper forms where still in use. Thus, human reporting errors are unavoidable with this system. Moreover, the total number of incident locations reported agency-wide by the OHP on an annual basis is large. Consequently, the collisions and enforcement activity reported by the OHP (and by other law enforcement agencies throughout the state) contain many cases of missing or erroneous location data. In addition, the location of emergency response resources are not available to managers, communication officers who direct their activities, and other officers assigned to the same or neighboring geographic areas. This lack of universally accurate location data presents a problem for data analysis, resource coordination, and efforts to improve officer safety and situational awareness by the many involved agencies.

The issues associated with missing and inaccurate location data on law enforcement reports have driven efforts to associate the collision and enforcement data by targeting enforcement to reduce traffic fatalities [1]. Oklahoma is one of many states participating in a national effort to improve the accuracy of collision data collected by law enforcement officers [20]. Collision data collected by the Oklahoma DPS and other county and municipal police agencies are used by state and federal data analysts in efforts to improve traffic safety.

A related but distinct issue is that a growing number of studies have consistently documented numerous benefits associated with providing law enforcement administrators, dispatchers, and officers with the real-time location of officers deployed in the geographical areas they are responsible to oversee or patrol. Some benefits include efficient asset coordination and an observable increase in officer safety and situational awareness. Efficient asset coordination is realized by decreased response time [16] and/or a decrease in fuel cost and other operational expenditures [21]. The greatest benefit realized by implementing technology to display the real-time location of police officers is increased officer safety [16].

1.1.2. Background

Since 2005, the University of Oklahoma (OU) Intelligent Transportation System Laboratory (ITS Lab) has partnered with DPS, OHP, and OHSO to develop an electronic mobile data collection system (MDCS) to improve traffic records accuracy and timeliness on a statewide basis in Oklahoma. This system provides a comprehensive suite of electronic police forms, up-front data checking and validation, activity reporting, supervisor and administrative tools, and query and analysis capabilities. On the back end, the system interoperates with DPS mainframe computer systems and with the statewide court system for rapid transmission of incident and violation records. Currently, the MDCS is deployed to approximately 600 OHP Troopers, 50 Oklahoma County Sheriff's Office (OCSO) deputies, 30 Woodward Police Department (WPD) officers, and 6 Edmond Police Department (EPD) officers. Deployment of the crash reporting component to the Oklahoma City Police Department is planned for 2013. The county and municipal agencies are currently integrating the data collected through the MDCS into their respective records management systems.

The MDCS is composed of hardware and software components that cooperatively interact to facilitate accurate and timely reporting of collisions, vehicle impounds, warnings and citations. The system consists of laptop computers deployed to individual OHP Troopers and police officers, a recommended combination magnetic strip and 2D barcode scanner, a cellular communication device, and a recommended cellular antenna booster with an integrated GPS receiver. A third party product called TraCS [22] that was developed by a consortium of 14 US states and two Canadian provinces [23] is used as the core software engine to collect and validate information entered into the electronic forms, while a larger custom software system developed in-house at the OU ITS Lab is used to communicate between the mobile police units and a central server located at the National Weather Center (NWC) in Norman, Oklahoma. In addition to providing an integrated platform for the TraCS engine and transmission of electronic data to the NWC and subsequently to DPS and the courts, the custom software also implements functionality for user administration, searching and statistical

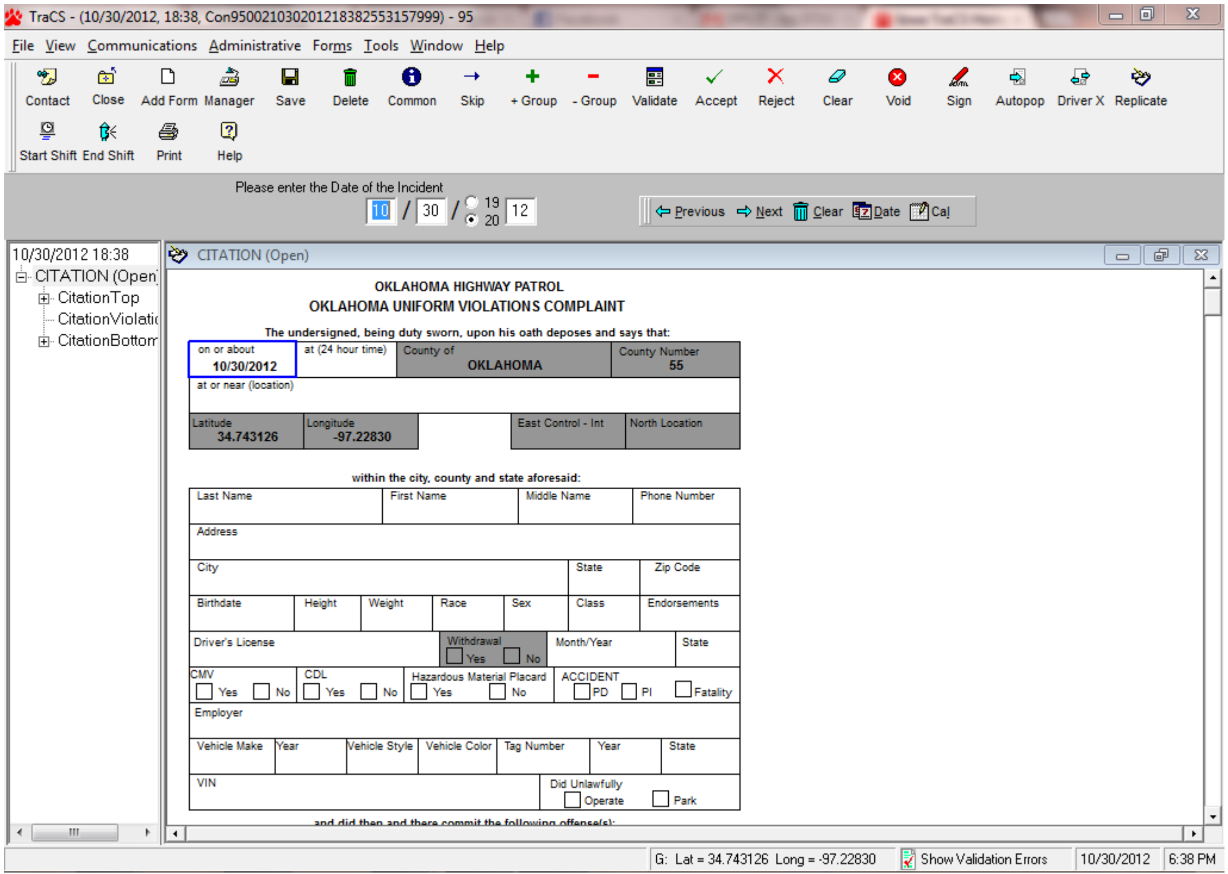

Figure 2. The MDCS data entry wizard, depicting an Oklahoma Highway Patrol electronic citation form.

analysis of historical data, supervision of OHP Troopers including forms approval, and analysis of Trooper performance and productivity

Figure 2 is a screenshot of the MDCS TraCS-based electronic police forms component. The image shows the OHP electronic citation data entry wizard that is used by law enforcement personnel to enter and validate information associated with the location, drivers, passengers, and vehicles reported on the citation record. A navigation bar appearing at the left side of the figure is used to jump between major sections of the citation to allow out-of-order data entry. The gray boxes indicate that the field is unusable or unnecessary in this particular case based on the data that has already been entered or is auto-populated by the application. With this system, the time required for a collision report to become an official DPS record is based only on the time required for a supervisor to approve the collision report. Prior to deployment of the

MDCS, the average turnaround time for collision reports had been approximately 55 days. With the MDCS, this has been reduced to an average collision turnaround time of only five days. Citations and warnings are now automatically transmitted from the laptop computer, which is referred to as the *mobile unit* in this context, to the NWC within five minutes of issuance. Citations are then forwarded to the appropriate county court within 30 minutes of arriving at the NWC. Overall, the implementation of the MDCS in Oklahoma has resulted in significant improvements in the timeliness and accuracy of all data reported in collision, citation, warning and impound reports.

We are currently in the process of developing a new system called the Police Automated Records Information System (PARIS) that will supersede the MDCS and eliminate the need for the third party TraCS engine. Simultaneously, PARIS will substantially increase the flexibility and capabilities of the present MDCS. PARIS is a state-of-the-art law enforcement software architecture that is currently under research, development, and testing at the OU ITS Lab and LETD. Once in full production, PARIS is expected to be widely deployed to law enforcement agencies throughout the State of Oklahoma. Certain PARIS components, including most notably the GPS data collection client, were undergoing alpha testing with the OHP during the performance period of this project. There are significant benefits that accompany the integration of latitude and longitude information into all aspects of electronic police reporting. PARIS provides a powerful opportunity to integrate automatically acquired GPS position fixes into Oklahoma law enforcement reports, thereby simultaneously improving the accuracy of the reported location data and reducing the police officer workload associated with manually determining and estimating the location data in the current MDCS.

In recent years, roadway sensors and the instrumentation of law enforcement vehicles have dramatically expanded the scope of data that is available to traffic managers. However, the integration of many of these technologies has lagged behind the technological improvements. This effect has generated disparate data sets and difficulty in integrating these reporting systems. Federal efforts to streamline the reporting of this data and the data consistency and accuracy have generated a higher level of data integration typically at the state level [4], [7], [8].

In many of these systems, the state and local law enforcement agents serve as the primary point of data collection [4], [5]. The data collected generally deal with the nature of the incident for law enforcement and adjudication purposes as well location of the incident. There are several methods by which location is described, including grid/section numbers as assigned by a roadway management agency or state Department of Transportation. Other data used to locate collisions in Oklahoma are the intersection identification number and a measure of the distance and direction from the intersection that is estimated by the reporting law enforcement officer. Often, a police officer's data collection efforts are hampered or constrained by the hazardous roadway environment as well as the limited measurement tools available in the field. However, accuracy can be greatly improved through the use of GPS [1], [8], [9], [12], reducing a variety of common reporting errors such as crash clustering at grid intersections, control sections, and roadway intersections [8], [9]. Identifying the location of collisions that occur in rural areas presents a greater challenge to the reporting officer in that county roads are not part of the state's route and control section system. In Oklahoma, collisions that occur on rural county roads are referenced by the county road grid system and distance from the nearest intersecting roadway. The use of GPS coordinates to locate these collisions can improve location accuracy [12].

Strategic enforcement activities can be geospatially organized around this new data collection effort allowing for a measurable reduction in crashes via enforcement similar to efforts to reduce medical response times through geolocation of ambulance units [17]. Important considerations will include which enforcement goals are to be prioritized, such as enforcement in high-speed/crash corridors or DUI collision reduction; these are distinct problems which demand differing enforcement strategies and resources may be deployed differently depending how the goals are prioritized. For a specific goal such as reducing fatality collisions in a particular problematic corridor, improved location data will facilitate accurate, timely, and meaningful assessment of enforcement activities. This data driven approach has been studied and was found to be cost effective by the National Highway Traffic Safety Administration (NHTSA) Data-Driven Approaches to Crime and Traffic Safety (DDACTS) program [23]. A key finding of [23] is that location data is "perhaps the most important data element in any DDACTS operation."

This project also represents an important opportunity to integrate automatic vehicle location (AVL) functionality into OHP and multi-agency operational procedures. In terms of emergency and disaster response, knowing the location of the closest available response asset is key, especially in scenarios where the roadway system has been degraded by the effects of a natural disaster or by human induced congestion. In cases where the originally dispatched unit is unable to respond in a timely manner, the nearest backup unit can be assigned to respond to the event [24]. OHP dispatchers assign calls to Troopers based on the county, Troop jurisdiction, and the zone that the Trooper has been assigned to patrol. Currently, dispatchers are generally unaware of the locations of Troopers in adjacent troops who may be much closer to the reported incident. AVL systems can display the position of all Troopers near an incident regardless of their assigned area and allow dispatchers to assign the call to the closest unit. Troopers equipped with the same technology integrated into a computer aided dispatch (CAD) system can self-dispatch to calls that occur near the area they are patrolling [25]. Moreover, the benefits of AVL do not end after the emergency event is stabilized: administrators and managers can analyze historical data to increase efficiency through careful strategic and tactical planning efforts [26].

Another critical concern that can be addressed by AVL is officer safety, especially during high speed pursuits. The prevention of police vehicle crashes, particularly between units from multiple agencies which may not have effective radio systems interoperability requires real-time situational awareness including precise knowledge of the locations of all pursuing units and the termination point of the pursuit. In [18], the coordination of pursuit units was identified as a primary benefit of AVL. With the use of AVL, police dispatchers are also able to efficiently route officers to the point where the pursuit was terminated. The use of AVL was associated with a reduction in radio traffic because the officer's position was being updated in real time. This factor allowed officers to focus on operating the emergency vehicle rather than radio communication. Other factors that increase officer safety were identified in [16], including the ability for an officer in distress to be located after signaling an emergency alert to the communication center. The locations of all active units are continually updated, even if the officer is incapacitated and unable to relay his position after the alert.

During pursuit operations, law enforcement supervisors must ensure that the pursuit is being carried out according to department policy and must also identify potential hazards that could compromise officer safety. AVL technology can greatly increase the situational awareness of these supervisors. Violations of policies concerning the number of units involved in the pursuit [18] or pursuit speeds can be easily monitored on a real-time map. Operations involving man hunts and barricaded subjects also benefit from the increase in situational awareness realized from AVL systems. From a remote command post, supervisors can continuously monitor established perimeters to contain a fugitive within a specified area [27]. While GPS is the most widely used core technology for enabling these critical AVL functions, it is not without limitations that must be carefully considered. GPS relies on line-of-sight communication with at least four satellites in order to obtain the position solutions. Line of site can be lost in environments that have overhead clutter such as heavily forested areas or urban centers. Since this technology relies on radio signals, a potential for signal jamming and spoofing also exists [28].

Police agencies and Departments of Transportation in several other states have previously developed solutions for accurately capturing GPS coordinates for purposes of improving crash and violation location data, enhancing and assessing enforcement activities, and strategically planning and assessing roadway improvement projects [29], [30]. It is important to realize that simply capturing a GPS position fix for the patrol vehicle is not sufficient for accurately reporting incident location data, since the vehicle will generally be displaced from the actual incident location. Consequently, these systems typically display a map that is initially centered on the coordinates retrieved from a GPS device in the patrol vehicle. The reporting officer is then able to refine the location by panning and zooming the map as needed and then designating the actual location where the incident occurred, typically via a mouse click. The GPS coordinates are then exported automatically to reporting system where they can be used to auto populate electronic forms such as a collision report, impound report, and one or more citations. The South Carolina Department of Public Safety [31] has deployed a system of this type that provides the reporting officer with a means to capture additional field measurements required for the collision report form. Measurements from the nearest roadway and the route name or number are also collected from the mapping application and auto populate location information on collision report forms.

Commercial fleet tracking solutions [32], [33] are another option that is available to law enforcement agencies for implementing AVL functionality. Commercial applications require a monthly fee for each vehicle using the system. These applications typically use a password protected web-based map to display the location of law enforcement assets. While these systems are typically not specifically configured for police operations, managers and communications personnel are able to view the location of law enforcement assets and assign calls more efficiently. Officers are often authorized to use these systems so that they can view their own location, the locations of other officers, and routing information. Commercial solutions offer a wide range of features including remote vehicle unlock, notification of high speed operation, routing, and reporting. These systems are able to receive data from an integrated GPS device or from optional devices that report the vehicle location independently of an in-vehicle mobile computer system.

Although a variety of system components are available from developers in both government agencies and commercial vendors, we believe that there is no “off the shelf” turnkey application that offers a complete solution to the problems addressed by this project. The technology development funded by this project offers uniquely effective and low-cost solutions to the stated location data problems when used in conjunction with the current Oklahoma MDCS. The developed GIEF has also been designed to ensure seamless integration of this technology into PARIS when that system is deployed in the near future.

1.1.3. Objectives

The high-level objectives of this project were to implement a GPS-based geographical information exchange framework (GIEF) to

- improve the correctness and accuracy of location data reported in electronic police forms filed by Oklahoma law enforcement agencies using the forthcoming PARIS system and the current statewide MDCS,
- provide a base level of AVL functionality for exploratory use by the OHP, and
- ensure upward compatibility of the developed technology with the forthcoming deployment of PARIS,

as well as to beta test the GIEF in an operational law enforcement environment. In order to accomplish these high-level objectives, the project work was organized around the following six task-oriented objectives:

1. Create a client application using the SharpMap [35] open-source mapping library to display a map showing the user's location and the locations of other law enforcement officers and emergency responders on the MDCS/PARIS laptop computers deployed in patrol vehicles.
2. Create a client application to capture position fixes from an onboard GPS receiver on-the-fly and provide them to the MDCS and PARIS for auto populating location fields in electronic police reports, as well as to other GIEF components. This objective includes the development of a map-based tool for refining the position fix acquired from the GPS receiver via a mouse click, which is needed, e.g., for accurately reporting the location of a crash since this is generally not the same as the location of the police vehicle in which the GPS receiver is situated.
3. Create a client application to report the locations of law enforcement and emergency responder vehicles to a new secure database deployed at the National Weather Center (NWC) in Norman, OK, in order to support AVL

functionality. These data are served out to other GIEF components for real-time AVL displays as well as after-the-fact analysis of police operations.

4. Create a secure web-based interface to display the current location of law enforcement and other emergency responder assets on a real-time map.
5. Create a web-based query interface to provide users with spreadsheets and graphical results from queries of enforcement, collision, and roadway data.
6. Coordinate this development with ongoing MDCS and PARIS development activities for the foreseeable future.

Chapter 2

2.1. Development

The project team successfully developed a map-based application to retrieve GPS data from a GPS client application and display the current user's location in real time. Data from the GPS client application are provided to the MDCS and reported via web services by a GPS reporting client. The location records are stored in a secure database hosted on a server located at the NWC. The web services provide secure query and login features. Direct integration with PARIS was not possible during the performance period of this project due to slips in the PARIS project development schedule. However, all of the GIEF components developed for this project were designed for full upwards compatibility and seamless integration with PARIS in the future.

A web site was also developed to provide access to location data reported by OHP Troopers. This web site was designed primarily as an access point to be used by external data subscribers but can be used by any authorized users to search for reported roadway damage and graphical reports of enforcement data. Authorized OHP users will use the web site to view the locations of Troopers on a real-time map and to perform after-the-fact analysis of police operations.

2.1.1. SharpMap Client

A client application called the MapInterface was developed in Microsoft Visual Studio 10 using the C# programming language. The MapInterface relies upon the open-source SharpMap library as its mapping engine. It was designed to utilize data from either flat shape files or location data stored in a geospatial database. The visual schema was created so that the map image is not overly cluttered at any zoom level. The base map data are organized into layers based on the roadway or feature characteristics of the dataset. The map application currently utilizes 11 static layers. These layers include political and administrative boundaries of the State of Oklahoma, municipal boundaries, road and rail transportation networks, and lake and river water features.

In addition to the static layers, three dynamic layers were also implemented in the MapInterface. These layers represent the position of the logged-in user and the locations of all other mobile users visible at the selected zoom level. The third dynamic layer displays a unit identification number next to the icon denoting the officer's location. A timer was implemented in the MapInterface to update the image while the user is travelling. While the timer is activated, the map displays a bounding box around the user's location which displays fine-scale roadway details. The timer remains enabled until the user selects one of the map tools created for the interface. Tools were implemented to pan the map, zoom to a user defined box, incrementally zoom in or out, zoom to a troop or county bounding box, or zoom to a statewide view.

Figure 3 shows a screen shot of the MapInterface graphical user interface (GUI). The image contains an icon representing an OHP unit travelling northbound on Interstate 35 in Purcell, OK. Since the unit is travelling, the timer is active and fine-scale roadway details are displayed. The unit number is suppressed in this display mode. The base map contains other features such as U.S. Highways, county roads, city streets, and a segment of the South Canadian River. The status of the GPS receiver and the current latitude and longitude coordinates are displayed on the application's status bar and icons for the tools are shown in ribbons across the top of the window.

The MapInterface application provides authorized users with administrative functions for user maintenance including adding, deleting, and modifying users as shown in Figure 4. Administrative capabilities also include ability to add, remove, and modify organizational units such as divisions and troops and define supervisor relationships between users. Access to the administrative functions is controlled through a system of privileges that can be individually granted (e.g., turned on) or denied for each user account. In addition to granting administrative rights, other privileges were implemented in the GIEF to control access to system features such as login rights for the GIEF Web Site where all OHP unit locations are displayed in real-time. While not implemented during the performance period of this project, additional privileges will be

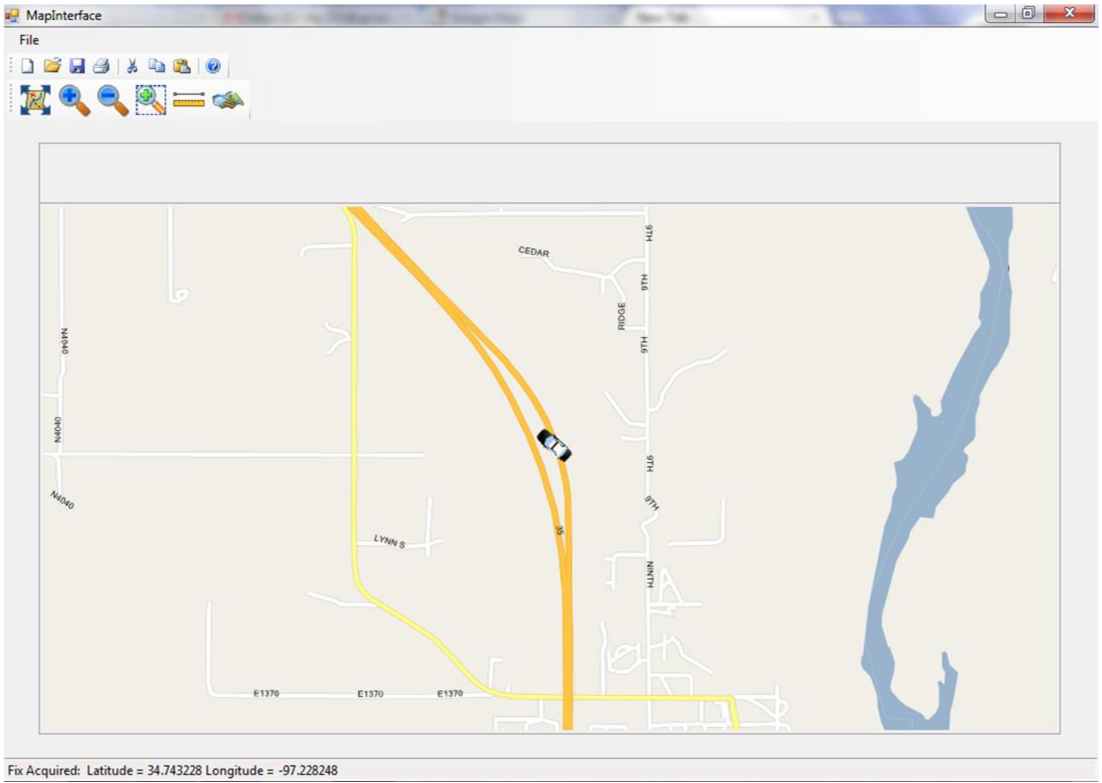

Figure 3. Screen shot of the MapInterface client graphical user interface showing an OHP unit travelling northbound on I-35 in Purcell, OK.

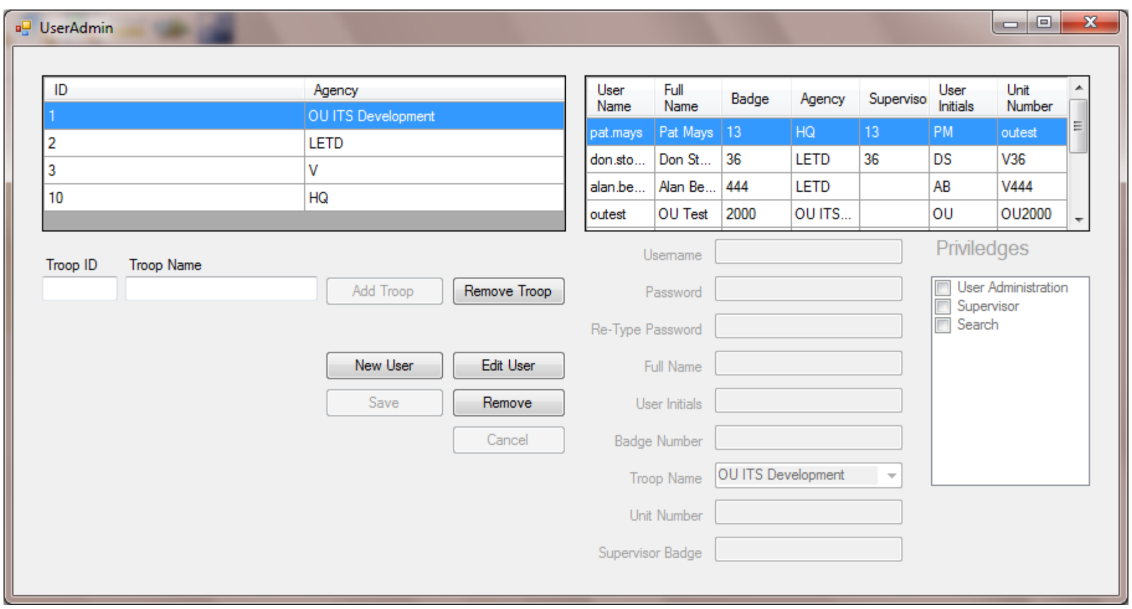

Figure 4. User administration application graphical user interface.

added in the near future to control access to the real-time mapping application. The software design accommodates addition of new features as the need arises.

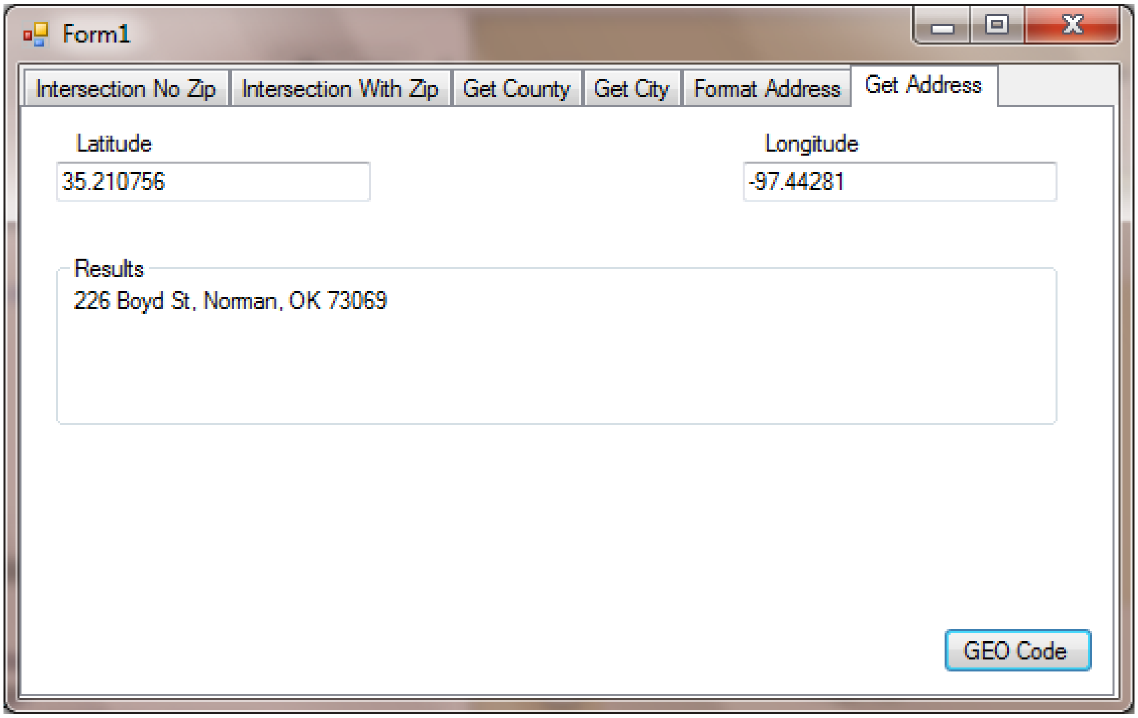

Figure 5. Standalone test bench application developed for validating and testing PostGIS geocoding services.

The final feature added to the MapInterface during the project performance period is the ability to geocode a latitude and longitude pair into a corresponding street address, city limit, and county. This functionality is needed to facilitate interoperability between GPS coded location data and those coded in terms of the legacy coordinate systems. The geocoding is accomplished with a PostGIS [36] database loaded with 2010 TIGER line shapefile data generated by the United States Census Bureau [37]. PostGIS also includes a function to normalize addresses to a standard format. An address string is parsed into component parts after being passed to the normalize_address [38] function. This feature will aid in the transition to using normalized addresses in PARIS. Address normalization provides for more consistent address reporting and will provide users with greater search capabilities while performing location-based queries for traffic incidents. A standalone test bench program was developed to validate and test the GeoCoding services, as shown in Figure 5. In the depicted test, the latitude and longitude delivered by the GIEF GPS Reporting Client are being reverse geocoded into an address string. Reverse geocoding is accomplished by means of the PostGIS reverse_geocode function [38].

2.1.2. GPS Collection Client

In its original implementation, the MapInterface described in Section 2.1.1 established a direct connection to the local GPS receiver to acquire position fixes. However, this design turned out to be incompatible with the overall GIEF concept of operations since another process would also have to connect to the GPS receiver to provide position fixes for additional GIEF components such as the web-based AVL interface and the handoff of location data to the MDCS and PARIS for auto populating electronic police forms. The solution that emerged was to develop a dedicated GPS Collection Client that would be the sole GIEF component capable of making a direct connection to the GPS receiver. The GPS Collection Client can then provide position data acquired from the GPS receiver to all of the other GIEF components. This new approach required a redesign of the MapInterface to make it capable of obtaining GPS position fixes from the GPS Collection Client rather than directly from the GPS receiver.

As initially conceived, the GPS Collection Client was to be implemented as a Windows operating system service. However, during prototyping it was determined that security features associated with named pipes in the later versions of Microsoft Windows would place undesirable limitations on the GPS Collection Client and prevent it from running as planned. These security features were introduced in Windows Vista and persist in Windows 7. Consequently, development of the Windows operating system service was abandoned and another redesign was undertaken to implement the GPS Collection Client as a user mode process instead.

Once the redesign and implementation were completed, data integrity checks were developed to validate and test both the acquired GPS data and the handing off of these data from the GPS Collection Client to other GIEF components. To facilitate this testing, a device configuration and data validation GUI was added to the GPS Collection Client as shown in Figure 6. This GUI allows developers and testers to change the com port and baud rate. With the port properly configured, the raw data stream from the GPS receiver can be displayed directly as ASCII text in the device configuration and

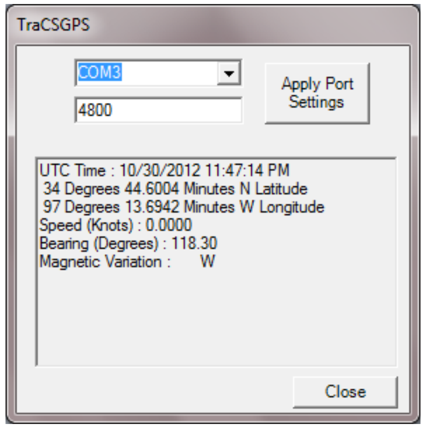

Figure 6. Screen shot of the GPS Collection Client device configuration and data validation GUI used for testing. The raw data stream from the GPS receiver is displayed as text while the GPS Collection Client is operational.

data validation GUI while the GPS Client is operational between the GPS receiver and other system component such as the MapInterface.

The GPS Collection Client device configuration and data validation GUI was implemented to support testing during development. Hence, it would never be visible to users in the operational GIEF system. However, discussions with LETD Troopers from the alpha test group revealed a strong desire to have some kind of simple status indicator in the operational system to inform users whether or not data is successfully being acquired from the GPS receiver. To support this need, a color coded icon was implemented in the Windows operating system Task Bar. The icon displays blue when a GPS data stream is detected and red when no GPS data is being received by the GPS Collection Client. With this simple indicator, users are able to verify that the GPS receiver is operational and data are being acquired by the client side GIEF components.

Finally, a reporting feature was added to the GPS Collection Client to hand off GPS location data to the TraCS engine of the MDCS and to PARIS for auto populating electronic police forms such as crash reports and citations. This is accomplished by having the GPS Collection Client continuously write the position fixes acquired from the GPS receiver out to a GPS.ini file which is readable by TraCS and PARIS. When the user opens a new contact to begin preparing a crash report and/or citations, warnings and other forms, the most recent record written to the GPS.ini file is imported. For crash reports, some citations, and other electronic forms such as the stored vehicle (impound) form, this approach works because the police vehicle is stationary in a location near the site of the incident when the import occurs.

However, as discussed in Section 1.1.3 relative to Objective 2, the location of the police vehicle is generally not the same as the location of the incident and the imported GPS fix must be refined in order to accurately report the true location of the incident. To accomplish this, the MapInterface component of the GIEF described in Section 2.1.1 provides a capability to import the most recent record from the GPS.ini file. A map is then displayed centered on the imported position fix. The user can pan and zoom the map as needed and designate the true location of the incident with a mouse click. With PARIS, this refined location can be used directly to auto populate forms. With the TraCS engine of the MDCS, the refined location data must be written out to the GPS.ini file again to make it accessible to TraCS. In order to prevent this refined location data from being overwritten, the GPS Collection Agent must temporarily suspend the writing of new GPS position fixes to the GPS.ini file.

For other types of citations and warnings such as speeding, the location that must be reported is that of the radar contact (or other observation of excessive speed). This is typically dramatically different from the location where the actual traffic stop occurs and the new contact is opened in the MDCS or PARIS. With PARIS, a hotkey will be implemented on the laptop computer in the near future to trigger import and storing of a position fix to the MapInterface when the radar contact is first made. After the stop, this stored position can be retrieved and refined as described above, providing the added benefit that the MapInterface is available for AVL functionality during the chase in the event that a partner is present in the police vehicle in addition to the driver. With the MDCS, opening a new contact is the only way to trigger importation of a position fix to TraCS. Obviously, this is not practical for a police officer who has just made a radar contact and needs to begin the pursuit immediately. Thus, with the MDCS the best option is for the officer to open the contact after the stop and use the panning and zooming features of the MapInterface to correct the position fix back to the location where the radar contact was actually made.

To conclude this section, we should point out that TraCS provides two built-in features for acquiring and importing GPS position fixes but they were not used for this project. Like the GIEFS GPS Collection Client, TraCS is capable of interfacing to a GPS receiver and writing the position fixes out to a GPS.ini file. However, this mechanism has long been problematic for the Oklahoma MDCS. These comments apply to TraCS 7.3, which is the most recent version that has been integrated into the Oklahoma MDCS. The current production version of TraCS is 10.05. However, migration to TraCS 10 was deemed by MDCS program managers to be cost ineffective for Oklahoma in view of the impending conversion to PARIS.

With TraCS 7.3 certain events including a computer crash while TraCS is open, other applications accessing the GPS device, a crash of the TraCS engine itself, or temporary loss of connectivity to the GPS receiver can cause the TraCS GPS.ini file to be permanently marked as "in use." This renders the file permanently inaccessible until an expert technician can touch the computer and clear the "in use" flag. The result is that all future attempts to import a GPS position fix revert to the last position that was successfully imported. Since this position is generally one that was imported in conjunction with a completely different previous incident (perhaps weeks in the past), and since a typical user has no obvious means of detecting the problem, this condition has led to serious location reporting errors in Oklahoma when earlier versions of the MDCS attempted to use the built-in TraCS GPS features directly. The other TraCS built-in feature is a turnkey interface to an add-on GIS-based incident location tool (ILT) that was developed by Iowa State University and is capable of interfacing to a GPS receiver [30]. However, program managers at the cognizant funding agencies made the decision that Oklahoma would not subscribe to the ILT due to cost considerations. Thus, use of the ILT was not an option for this project.

2.1.3. GPS Reporting Service

The GPS Reporting Service is a GIEF component that was designed and implemented to continuously report the locations of OHP units to a dedicated secure database housed at the NWC. It consists of a Windows operating system service resident on the laptop computer located in a police vehicle and a web service resident on a server at the NWC. Both services were designed and implemented specifically for this project. The Windows service receives GPS position fixes from the GIEF GPS Reporting Client and transmits them in real-time to the web service over a secure wireless communications link at 30 second intervals. In addition to latitude and longitude, the username and vehicle heading are also reported. Reporting begins when the laptop is started and continues as long as the computer is running. These data are time stamped upon insertion into the database. While the web service and database were designed to store historical data records for an arbitrarily long time period to support after-the-fact AVL analysis of police operations as described in Objective 3 of Section 1.3.3, only the most recent record for each unit was actually retained during the beta testing phase of this project. A screen shot of the location data reported by the GPS Reporting Service during the beta test is given in Figure 7, where the time stamps are truncated to show only the date.

The GPS Reporting Service also provides position and heading data to the MapInterface described in Section 2.1.1 and the GIEF Web Site described below in Section 2.1.4. The positions and headings of all active OHP units are updated when the map is refreshed by local timers in each application. The unit number is used to populate a dynamic label layer within the MapInterface to facilitate easy visual identification of individual units when the MapInterface is operating in AVL modes. Future enhancements will support use of the data record time stamps to provide visual alerts concerning the status of the units displayed on the map. If the GIEF is deployed to non-police emergency response agencies then the locations of their assets can be logged and displayed as well, although this was not done in the scope of this project.

	latitude double precis	longitude double precis	unitNumber [PK] characte	heading double precis	time timestamp wi
1	35.210756	-97.44281	OU2000	0	2012-12-12
2	36.015157	-95.981296	V259	87	2012-12-10
3	35.471872	-97.46634	V36	15	2012-11-12
4	35.5042235	-97.4749923	V444	0	2012-12-14
5	34.74324666	-97.2281983	V95	312.29	2013-01-06
*					

Figure 7. Screen shot of the location data reported by the GPS Reporting Service during the beta test phase of the project. In this view the time stamps are truncated to show only the date.

2.1.4. GIEF Web Site

The GIEF Web Site was developed to deliver real-time AVL functionality over a secure Internet connection to OHP supervisors and commanders who are not currently running the MapInterface GIEF component and may be located at a command center or remote site rather than in the field. A screen shot is shown in Figure 8, where two OHP vehicles identified by unit number are visible. In addition, the GIEF Web Site will be a primary means of delivering AVL functionality to authorized external users outside the DPS. The GIEF Web Site was implemented using ASP.net and the same shape files as the MapInterface. It is hosted within the publicly visible segment of the PARIS network, where a suitable user authentication system has been implemented to prevent unauthorized access. After the operational deployment of PARIS, this web site will provide access to a query builder interface that will be used to search for specific types of location information associated with collisions and enforcement activity. Users will be able to view the formatted query results and create printed maps and spreadsheets, although this was not implemented within the performance period of this project.

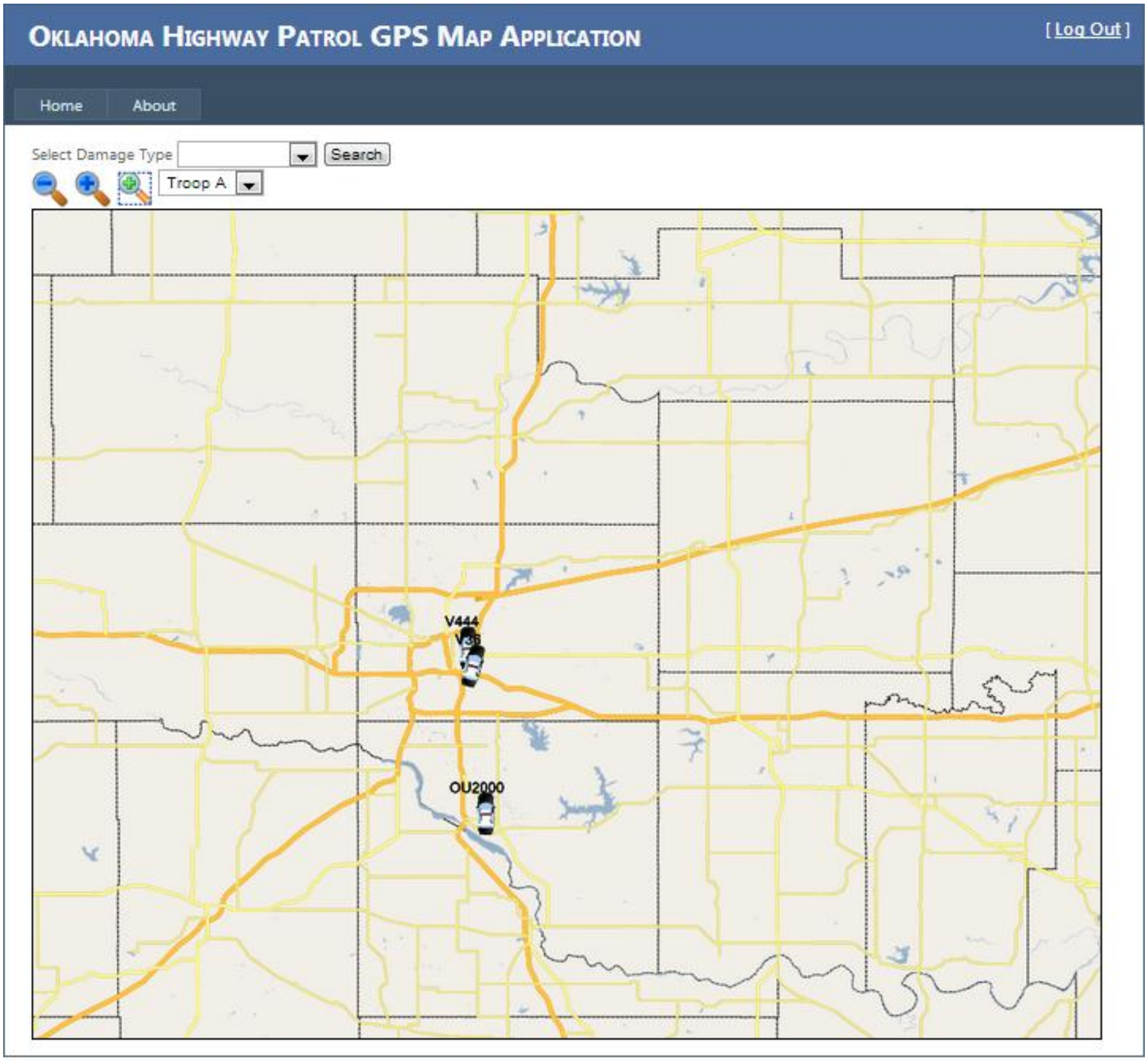

Figure 8. Screen shot of the GIEF Web Site that delivers AVL functionality to users who are not running the MapInterface GIEF component.

2.1.5. GIEF Web Services

The GIEF Web Site and the GIEF components that are resident on the laptop computers deployed in police vehicles all use the GIEF Web Services to communicate with the server and secure database located at the NWC. The GIEF Web Services provide a secure communications interface between the client-side components and the server. They are also used for client login authentication, assignment of user permissions, and the reporting of location data. In addition, these services provide the actual data that are displayed in the dynamic unit layer of both the MapInterface and the GIEF Web Client. Three web service clients were developed for this project. The UserLoginService provides for user administration and adds a layer of security to both the client-side and web-based components. The GeoLocationService reports user locations to the PostGIS database described in Section 2.1.1 and retrieves location data for the MapInterface and the GIEF Web Site. The GeoCodeService is used to geocode latitude and longitude values in terms of legacy coordinate systems such as control section and mile post and the county grid system.

Versions of the GIEF Web Services which are interoperable with both the PARIS and the MDCS public and private networks as well as with the MDCS and PARIS central databases were developed. However, because of slips in the PARIS development schedule, the GIEF could only be beta tested with the MDCS during the performance period of this project. Figure 9 illustrates the GIEF network architecture as it will be after the operational deployment of PARIS. The PARIS private network at the NWC is shown on the far right side of the figure and contains the PARIS MySQL database, which stores all of the data and electronic forms transmitted by PARIS users. This includes the electronic forms data from collisions, citations, warnings and impounds, as well as user administration data, user login information, and any information collected regarding roadway damage and infrastructural issues. A firewall separates the private and public PARIS networks to prevent malicious attacks against critical PARIS system components. The public PARIS network is responsible for hosting the PARIS web services that are used to facilitate secure and efficient communication between all users of the PARIS system and the PARIS database.

2.2. Testing

Testing of the GIEF was performed throughout the 15-month project performance period by two test groups and was carried out in three phases: functional testing, alpha testing, and beta testing. In the context of this project, *functional testing* refers to testing performed on each developed software module to verify that the relationship between inputs and outputs conformed to the system requirements and design specifications.

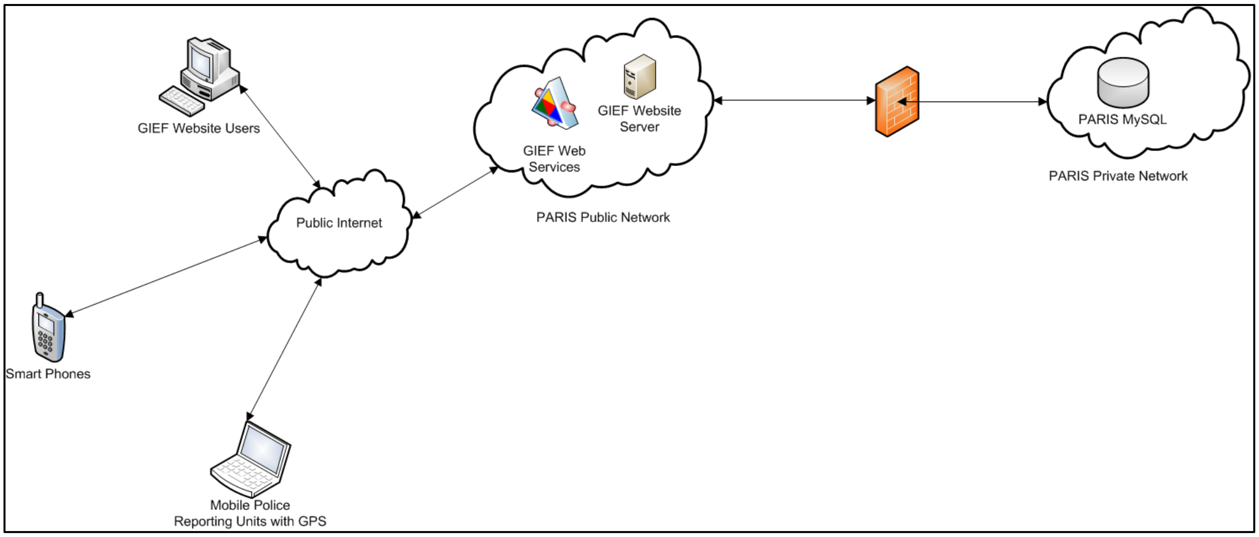

Figure 9. Overview of the GIEF Network Architecture after operational deployment of PARIS.

Functional testing was performed by the OU ITS Lab staff on a continuous basis throughout the performance period as each testable module of the GIEF was developed. This is illustrated by the two examples of functional testing that were described in Section 2.1.1, which revealed the need to redesign the MapInterface GIEF component so that it would not make a direct connection to the GPS receiver as well as the need to implement the GPS Collection Client GIEF component as a Windows user mode process rather than a Windows operating system service.

2.2.1. Alpha Testing

Subsequent to functional testing, alpha testing was carried out for each major GIEF component as prototype versions were completed. These major components include the MapInterface, GPS Collection Client, GPS Reporting Service, GIEF Web Site, and GIEF Web Services described in Sections 2.1.1 through 2.1.5. The alpha test group consisted of five Troopers from the OHP Law Enforcement Technology Division (LETD). Members of the test group exercised each GIEF component in a standalone mode and in an office setting with the objective of identifying usability issues and evaluating the suitability of the component for deployment in an operational law enforcement environment to enhance police officer productivity, efficiency, and effectiveness. To the extent possible, the alpha testers were also asked to evaluate the potential of the component for contributing to achievement of the high-level project objectives articulated in Section 1.1.3. Like functional testing, alpha testing was carried out on an ongoing basis throughout the project performance period as each GIEF component was developed. The GIEF system requirements and design specifications were revised based on feedback received from the alpha test group, leveraging the extensive field experience of the Troopers to create a continuous cycle of system improvements. Illustrative examples of cases where alpha testing made an impact on the final GIEF system design include the following:

- In Section 2.1.1, it was mentioned that the MapInterface display changes to a bounding box around the police vehicle that is automatically zoomed to portray fine-scale roadway details when the vehicle is in motion. This “zoom and follow” feature was not part of the original MapInterface design specification, but rather evolved directly out of MapInterface alpha testing.
- Also during MapInterface alpha testing, the Troopers felt that it would be useful to have predefined map views corresponding to counties and troop jurisdictions. The development team created a library of county and troop boundaries to support this and implemented predefined views for all 77 Oklahoma counties and all 13 OHP field troops.
- The color-coded GPS status indicator which displays blue when the GPS Collection Client is receiving position fixes from the GPS receiver and red when the GPS receiver is off line, as described in Section 2.1.2, resulted from Trooper feedback provided during alpha testing of the GPS Collection Client and was driven at least in part by the problems that had been experienced with the TraCS built-in GPS features as also described in Section 2.1.2.
- The detailed structure of the GIEF user administration features and the user permissions and privileges were defined almost entirely through an iteration between the OU ITS Lab developers and OHP testers during alpha testing of the MapInterface and GIEF Web Services.

2.2.2. Beta Testing

After all of the major GIEF components were implemented and alpha testing was completed, beta testing was conducted to test the system as a whole and in an operational law enforcement environment. Thus, unlike functional and alpha testing, which were performed on an ongoing basis throughout the project performance period, beta testing was conducted only during the final month of December, 2012. The beta test team consisted of the same five LETD Troopers who conducted the alpha testing. The GIEF was designed to be fully interoperable with both the existing Oklahoma MDCS and with PARIS and it was initially envisioned that the GIEF would be beta tested with both PARIS and the MDCS. However, this was not possible during the project performance period due to slips in the PARIS development schedule. Therefore, beta testing was conducted with the MDCS only.

The purpose of beta testing was to exercise all of the features of the GIEF in an operational environment to identify any problems and/or usability issues still remaining after the completion of alpha testing. The full beta version of the GIEF was integrated with the MDCS and deployed to the beta test group early in December, 2012. For the remainder of the month, the beta test Troopers used the MapInterface to report GPS latitude and longitude coordinates on their crash reports, citations, warnings, and stored vehicle reports and tested the MapInterface AVL functionality in actual daily police field operations. The GPS Reporting Service and GIEF Web Services were also operated continuously during the beta test period to capture the beta test Troopers locations and store them in the secure database located at the National Weather Center in Norman. These tests demonstrated 100% successful end-to-end system performance. High-quality position fixes were acquired from the GPS receiver on-board each Trooper's vehicle and were used to auto populate crash forms, citations, warnings, and stored vehicle reports with the result that GPS-based locations were reported and ultimately propagated all the way to the mainframe data warehouse located at DPS headquarters in northeast Oklahoma City as well as to the statewide court system. ***This is probably the most significant result of the entire project, since it represents a clear and***

feasible means for achieving the first important project objective articulated in Section 1.1.3.

Due to time and logistical constraints, the remaining GIEF AVL functionality – specifically, the functionality to support multi-unit and multi-agency coordination – was beta tested in simulated scenarios but not in actual "live" law enforcement operations such as man hunts or high speed chases. During these tests, the positions of the beta test Trooper's vehicles were successfully reported by the GPS Reporting Service, captured by the GIEF Web Services, and recorded in the GIEF secure data base at the NWS in Norman. In real-time, the positions of all vehicles were transmitted via the GIEF Web Services and displayed on each Trooper's laptop computer by the MapInterface. Simultaneously, the Troopers' positions were also displayed in real-time at the OHP Command Center and at a remote location using the GIEF Web Site. ***Thus, these tests represent the second most important result of the project because they fully demonstrated all of the real-time AVL capabilities that were envisioned for the GIEF system.***

Feedback received from the beta test Troopers resulted in minor changes to the system, including most notably several modifications to the MapInterface map layers and user interface. The following three major issues also emerged as a result of the beta testing phase:

- The first major issue that emerged during beta testing was that the GIEF UserLogin web service was blocked by the DPS firewall. During normal operations, the MDCS, PARIS, and the GIEF connect to data bases and services on the DPS private network via a NetMotion VPN connection through the DPS firewall. LETD, DPS IT personnel, and the OU ITS Lab development staff collaborated to modify the firewall by opening new ports and revise the GIEF Web Services to resolve the conflicts. After these modifications, the GIEF Web Services were fully operational and beta testing continued as planned.
- It became evident during beta testing that the client-side laptops in the Trooper's vehicles had issues managing the memory required to process the shape file

data used by the MapInterface. The most significant symptoms of this problem were sluggish performance and unacceptable delays in displaying the real-time positions of multiple vehicles. To help ameliorate this problem, future work on the GIEF should include an investigation of alternate data sources for the SharpMap library. Potential solutions include using server-based tiled images created from the shape files rather than reading the shape files directly. In this regard, it should be noted that fee-based commercial tile sources are available for use with the SharpMap library.

- An integrated, automatic installer and software updating application was created as a system enhancement in the later phases of beta testing. The Microsoft ClickOnce installation framework was considered and then abandoned due the size of the data in the required shape files. In the final beta test version, the shape files represented over 70 megabytes of data which was too large to be downloaded on a recurrent basis over the air card connections utilized by the test Troopers. Therefore, the updater application was converted to a local installer package so that the shape files would not have to be downloaded over the air card connection after initial installation of the GIEF client-side software. This installer was developed to deliver the required libraries without the data files which are not subject to frequent changes.

Chapter 3

3.1. Technology Transfer

The GIEF development efforts described in Section 2.1 resulted directly in the production of new, deployment-ready technology that is specifically designed to achieve the high-level project objectives given in Section 1.1.3. The beta tests carried out in December 2012 and described in Section 2.2.2 represent significant transfer of this technology to the Oklahoma Highway Patrol that was successfully achieved during the performance period of this project. Today, the GIEF is online, operational, and deployed to the OHP beta test group.

In the near future, the GIEF will be fully integrated with PARIS and will see widespread operational deployment as part of the planned statewide PARIS rollout. The agencies currently scheduled to receive PARIS and the GIEF in calendar year 2013 include the Oklahoma Highway Patrol, the Oklahoma County Sheriff's Office, the Oklahoma City Police Department, and the City of Woodward Police Department. Although the City of Edmond Police Department is also currently using the MDCS, it is our understanding that they plan to transition to a commercial for-profit system instead of PARIS sometime in calendar year (CY) 2014. Opportunities to deploy PARIS and the GIEF to other agencies in the near future will be available and could be initiated with a deployment decision from the relevant program managers at DPS, OHSO, and the OHP. In terms of realizing the high-level project objectives in Section 1.1.3, deployment to the City of Tulsa and the Tulsa County Sheriff's Office would be desirable.

While it is clear that rapid deployment of the GIEF on the widest possible scale would be the fastest way to achieve the high-level project goal of improving the correctness and accuracy of location data reported in electronic police forms in Oklahoma, it must be realized that deployment is not without costs. For example, deployment to an additional agency requires that LETD expend potentially significant resources to provide training.

The Oklahoma state Office of Management and Enterprise Services (OMES) and/or DPS must allocate potentially significant resources on a one-time basis to make the initial installation as well as on an ongoing basis to provide a reasonable level of technical support for the police officers in the field. For the MDCS or PARIS, the OU ITS Lab or a third-party vendor must develop agency specific forms and customization (e.g., violation tables and codes to support the agency-specific electronic citation) and must develop back-end interfaces to integrate the new electronic forms with existing agency-specific records management systems and with the courts.

Thus, the public safety benefits of rapid deployment to additional agencies must be balanced against the real costs and resources required to accomplish this. For the foreseeable future, the OU project team is committed to working closely with managers, stakeholders, and command staff at the OHP, DPS, and OHSO, as well as with the Oklahoma Traffic Records Council to identify additional agencies for PARIS and GIEF deployment and to determine the most beneficial timeframes for rolling the GIEF out to these agencies. As the OHP continues exploratory use of the GIEF AVL functionality and begins to formalize AVL operational procedures, technology transfer of the GIEF through deployment to additional non-police agencies such as EMS is also expected.

Chapter 4

4.1. Conclusions

Over the course of this project, the OU ITS Lab team developed the proposed Geographical Information Exchange Framework (GIEF) and deployed it to a select group of five Troopers from the Oklahoma Highway Patrol (OHP) Law Enforcement Technology Division (LETD) for beta testing. The beta tests were carried out during the month of December, 2012, providing both a successful technical culmination to the project and a concrete and significant technology transfer achievement. In specific relation to the six task-oriented objectives given in Section 1.1.3, which are repeated verbatim below, the completed work includes the following:

1. *Create a client application using the SharpMap [35] open-source mapping library to display a map showing the user's location and the locations of other law enforcement officers and emergency responders on the MDCS/PARIS laptop computers deployed in patrol vehicles*. **100% achieved.** The client is called the GIEF MapInterface. Development of the MapInterface is described in Section 2.1.1, while testing is described in Section 2.2. Alpha and beta testing with PARIS could not be achieved during the project performance period due to slips in the PARIS development schedule. However, PARIS functional testing was completed with all existing PARIS components and the MapInterface is ready for full integration with PARIS.
2. *Create a client application to capture position fixes from an onboard GPS receiver on-the-fly and provide them to the MDCS and PARIS for auto populating location fields in electronic police reports, as well as to other GIEF components. This objective includes the development of a map-based tool for refining the position fix acquired from the GPS receiver via a mouse click, which is needed, e.g., for accurately reporting the location of a crash since this is generally not the same as the location of the police vehicle in which the GPS receiver is situated.* **90% achieved.** The GIEF GPS Collection Client described in Section 2.1.2 acquires the position fixes from the GPS receiver and makes them available to the MDCS and PARIS, while the GIEF GPS Reporting Service described in Section 2.1.3 transmits the locations to a

secure database located in the National Weather Center (NWC) for dissemination to other GIEF components such as the GIEF Web Site described in Section 2.1.4. The map-based position refinement tool was developed and functional testing of the tool was successfully completed. This tool is ready for deployment with PARIS. However, due to the level of effort that would have been required to achieve full and seamless interoperability with TraCS 7.3, compatibility with the MDCS was not developed within the performance period of this project and the position refinement tool was not beta tested with the MDCS.

As an alternative for the MDCS, a web-based service was created that allows a police officer to manually refine the position using Google Maps, display the latitude and longitude, and manually cut and paste them into a form using the mouse. In order to comply with Google software licensing requirements, this service is fully visible to the general public. While this MDCS alternative does not provide the convenience and level of automation envisioned for the final GIEF position refinement tool, it nevertheless made it possible for the beta testing to go forward and fully demonstrate the GIEF system objectives with the MDCS. The fully functional and fully automated position refinement tool is ready for beta testing and deployment with PARIS.

3. *Create a client application to report the locations of law enforcement and emergency responder vehicles to a new secure database deployed at the National Weather Center (NWC) in Norman, OK, in order to support AVL functionality. These data are served out to other GIEF* components *for real-time AVL displays as well as after-the-fact analysis of police operations.* **95% achieved.** The location data are reported to the secure database by the GIEF GPS Reporting Service described in Section 2.1.3. The secure database was deployed at the NWC and is currently operational. The location data are served out to other GIEF components for AVL functionality by the GIEF Web Services described in Section 2.1.5. Beta testing with non-police emergency response agencies was not conducted during the project performance period. However, the testing that was done by the OHP beta test group demonstrates

that the GIEF AVL functionality will work with the assets of such non-police agencies when the GIEF is deployed to them. It should be noted that development of some new icons for easy visual distinction of police and non-police vehicles such as EMS will probably be desirable when this occurs. Similarly, although after-the-fact analysis of police operations was not part of the formal beta testing, the fact that the locations of the beta test group police vehicles were successfully stored in the secure database at the NWC demonstrates that this functionality can be supported by the current GIEF implementation; a query engine to retrieve the historical location data from the database will have to be developed in the future in order to make this capability operational.

4. *Create a secure web-based interface to display the current location of law enforcement and other emergency responder assets on a real-time map.* **100% achieved.** This objective is fully achieved by the GIEF Web Site described in Section 2.1.4.
5. *Create a web-based query interface to provide users with spreadsheets and graphical results from queries of enforcement, collision, and roadway data.* **0% achieved.** This objective was not achieved during the project performance period. However, the design of the current GIEF implementation fully supports this functionality and it will be straightforward to add it to the system in the future.
6. *Coordinate this development with ongoing MDCS and PARIS development activities for the foreseeable future.* **100% achieved.** The GIEF was fully integrated with the MDCS and was beta tested with the MDCS. Functional testing with existing PARIS components was performed to the extent possible given slips in the PARIS development schedule and was 100% successful. The GIEF is ready for full PARIS integration as soon as PARIS itself is ready for beta rollout.

This completed work also achieves the high-level project objectives that were given in Section 1.1.3:

- A GPS-based geographical information exchange framework (GIEF) was successfully designed, implemented, and beta tested by OHP Troopers in an operational law enforcement environment.
- With both the current statewide MDCS and the forthcoming deployment of PARIS, the GIEF developed in this project provides high quality GPS position information to improve the correctness and accuracy of location data reported in electronic police forms filed by law enforcement agencies on a statewide basis throughout Oklahoma. During the beta tests described in Section 2.2.2, the GIEF was used to acquire high quality GPS position fixes and populate them into actual crash forms, citations, warnings, and stored vehicle reports. End-to-end system testing verified that these high quality location data were successfully and automatically transmitted all the way from the roadside to the statewide DPS mainframe data warehouse located at DPS headquarters in Oklahoma City and to the statewide court system. This demonstrates that the GIEF provides a clear and feasible means to tangibly improve traffic records accuracy in Oklahoma by virtually eliminating the most common types of manual data entry location reporting errors, including spelling errors in roadway names, use of unrecognized alternate roadway names, incorrectly entered control section numbers, and incorrectly estimated or incorrectly entered mile markers and offset distances.
- The GIEF developed and beta tested in this project represents a 100% success in terms of providing a base level of AVL functionality for exploratory use by the OHP for the first time, as demonstrated by the beta tests described in Section 2.2.2. In the immediate future, LETD will lead the efforts to test and further develop this new technology in order to determine how it can best be used to improve police operations, logistics, asset management and coordination, police officer safety, and multi-agency coordination on a statewide basis in Oklahoma. Important tangible and well documented benefits of deploying this type of technology include reduced response times,

improved efficiency, and most importantly, observable increases in officer safety and situational awareness [16], [17], [18]. In the future, the GIEF real-time location asset map will provide an important resource to improve fleet operations and inter-agency coordination and resource management for administrators in non-OHP agencies such as the Oklahoma Department of Transportation (ODOT), the Emergency Medical Services Authority (EMSA), and local and municipal police and emergency response agencies.

- As demonstrated by the functional testing that was successfully completed during this project, the developed GIEF is 100% upwards compatible with PARIS and is ready for full PARIS integration as soon as PARIS itself is ready for beta deployment.

By improving traffic incident location reporting accuracy, the broader impacts of this project will be important to a wide range of traffic safety stakeholders throughout Oklahoma, including:

- safety analysts, traffic engineers, and municipal planners who use location data to identify and localize traffic safety problems, to plan safety and roadway improvement projects, and to assess the effectiveness of these projects, and
- police agencies who use location data to plan and assess enforcement activities in terms of quantitative public safety metrics.

Finally, the GIEF developed and tested in this project provides a real and feasible means to bring incident location reporting technology in Oklahoma into full compliance with the most recent recommendations of the National Highway Traffic Safety Administration (NHTSA) Model Minimum Uniform Crash Criteria (MMUC) specification [19] and Data-Driven Approaches to Crime and Traffic Safety (DDACTS) program [23].

4.2. Recommendations

The beta tests conducted during this project demonstrate that the GIEF technology developed provides the *potential* to realize the high-level project objectives articulated in Section 1.3.3. Fully *achieving* these objectives will depend on the successful wide-scale deployment of this technology and will require a coordinated ongoing effort between the Oklahoma Highway Safety Office (OHSO), Oklahoma Department of Public Safety (DPS), Oklahoma Highway Patrol (OHP), Oklahoma Office of Management and Enterprise Services (OMES), and the University of Oklahoma Intelligent Transportation Systems Laboratory (OU ITS Lab). Participation and buy-in from other stakeholder organizations such as the Oklahoma Transportation Center (OkTC) and Oklahoma Traffic Records Council would also be an invaluable asset, as would the continued cooperation of important partner agencies like the Oklahoma County Sheriff's Office, the City of Woodward Police Department, and the City of Edmond Police Department who are currently using the MDCS and the City of Oklahoma City Police Department who will be beta testing PARIS along with the OHP in calendar year (CY) 2013.

Our main recommendations are that:

1. Development of the full GIEF functionality as originally envisioned should be completed. This will be described in more detail in Section 4.3 below. Certain aspects of this development effort such as reducing the client side memory requirements to improve performance are critical and need to be completed prior to operational deployment.
2. Full integration of the GIEF with PARIS and beta testing with PARIS should be completed as soon as possible. This is primarily a PARIS development issue, as the GIEF was made fully ready for PARIS integration during the performance period of this project. All indications are that PARIS should be ready for beta rollout in the first or second quarter of CY 2013. It is currently envisioned that PARIS beta testing will be conducted concurrently by the OHP and the City of Oklahoma City.

3. In order to achieve the most significant possible impact on traffic records correctness and accuracy, the GIEF should be widely deployed as an integral component of PARIS. The partner agencies currently scheduled to receive PARIS in CY 2013 include the OHP, the Oklahoma County Sheriff's Office, the City of Woodward Police Department, and the City of Oklahoma City Police Department. It should be noted that the City of Edmond currently plans to transition to a third-party commercial product in CY 2014 and is therefore not expected to become a PARIS partner agency. From the standpoint of improving traffic records accuracy and timeliness in the broadest possible sense, deployment to additional agencies such as the City of Tulsa and the Tulsa County Sheriff's Office is *highly desirable*. Wide scale operational deployment of the GIEF with the current MDCS is not recommended because all of the current MDCS partner agencies except the City of Edmond are expected to make the transition to PARIS in CY 2013 and because the cost and level of effort required to make the GIEF position refinement tool work with the TraCS 7.3 engine that is inherent to the MDCS are high. It is our recommendation that technical oversight of the project and leadership in determining future PARIS partner agencies should continue to rest with the OHP Law Enforcement Technology Division (LETD).
4. The Oklahoma Traffic Records Council should assume a clear leadership role in establishing a comprehensive plan for funding future GIEF and PARIS development, deployment, and operations. To date, MDCS development and operations as well as PARIS development have been primarily funded by the Oklahoma Highway Safety Office (OHSO) with generous contributions to the development effort from the Oklahoma County Sheriff's Office, while GIEF development has been primarily funded by the Oklahoma Transportation Center (OkTC). However, a stable and viable long-term funding plan is needed to ensure the long-term success of the project. Since a majority of the stakeholder agencies are members of the Oklahoma Traffic Records Council, it is recommended that the Council should assume the leadership role in establishing the funding plan.

4.3. Future Work

This section describes the additional work that is needed in order to complete development of the full GIEF functionality as it was originally envisioned. This is work that was planned but could not be completed within the project performance period. The incomplete work items include:

1. During GIEF beta testing it was revealed that the client mapping application requires too much memory to remain in continuous use on the laptop computers that are currently deployed agency-wide in the OHP. This is an important outstanding work item because upgrading all of the computers is not cost feasible at this time and therefore the memory requirements will have to be reduced before the GIEF can be operationally deployed on a statewide basis. The most promising approach for solving this problem is to investigate alternate data providers and map display solutions that may alleviate some of the memory issues observed. Specifications for future OHP laptop purchases should include faster processors and additional physical memory. These hardware improvements also represent a feasible but long-term solution for overcoming the technical memory allocation issues encountered during the beta testing exercises.
2. As soon as possible, full integration, functional testing, and beta testing of the GIEF with PARIS needs to be completed. This work is planned for CY 2013 prior to the operational rollout of PARIS. This work includes beta testing of the fully automated map-based location refinement tool with PARIS.
3. The PARIS radar hotkey functionality needs to be implemented and tested. This feature will enable a police officer to punch a hotkey on the computer keyboard when the first radar contact is made with a speeding vehicle. This location will be closer to the site of the actual violation than the location where the violator is stopped and will therefore require smaller refinements with the location refinement tool in order to report highly accurate position data in electronic citations for excessive speed violations.

4. As indicated in Section 2.1.1, a privilege structure needs to be implemented to control access to the real-time mapping applications of the MapInterface.
5. An electronic form needs to be developed for reporting roadway infrastructure issues such as damaged guardrails and pavement and a new data base needs to be developed to receive the forms and make the data available to agencies such as ODOT. This reporting is currently done manually: hand written paper reports are collected at the headquarters of each OHP troop and an ODOT messenger physically visits the troop headquarters to collect the reports.
6. Web services need to be developed to provide authorized users with general queries, including location-based queries, of the secure AVL data base that was deployed at the National Weather Center as part of this project. Options for the query returns should include PDF map-based an tabular text reports as well as spreadsheet files compatible with common programs such as Microsoft EXCEL. These reports will enable authorized stakeholders including, e.g., OHP commanders and supervisors to assess Trooper activities and perform after-the-fact analysis of police operations.
7. The GIEF AVL functionality described in Section 2.1.3 needs to be deployed to non-police emergency responders and non-OHP police agencies in order to study the best use of this technology for multi-agency asset management and operations coordination.

In addition to the incomplete work items described above, the future work issues described in Sections 4.3.1 through 4.3.4 below were identified by the OHP during the GIEF beta testing performed in December, 2012:

4.3.1. External GPS Sharing

The GPS Collection Client demonstrated the ability to share the data stream from a single GPS receiver between multiple applications. In the case of the OHP mobile computers certain software applications outside of the MDCS depend on GPS data. Future work should include development of an application to share GPS data to external applications.

4.3.2. SharpMap Data Providers

The SharpMap library provides functionality for other types of data providers. During this project, the shape files that were used by the MapInterface were read directly from a library installed on the client computer. While the shape file provider allows some functionality of the map application independent of network access, research should be conducted to determine if other providers alleviate the memory issues observed during the beta testing.

4.3.3. Tiling Services and Libraries

Several of the significant SharpMap developers have made reference to the BruTile tiling library [39]. The BruTile library allows SharpMap users to retrieve tile data from a designated server and display them over the map as a tile layer image. Other open source software enables developers to create tile images from local shape files. It is expected that these technologies could allow for high quality maps to be generated for the GIEF with substantially reduced consumption of memory and CPU bandwidth. If implemented, these features would not eliminate or degrade the geocoding capabilities of the system, as the roadway data would remain in the PostGIS database.

4.3.4. Additional Geocoding Methods

The functions available in the current GeoCodeService module of the GIEF should be enhanced to include measurement of distance from the nearest town along the roadway where the location feature was collected. An intersection query should be added so that users can determine their location in relation to intersection locations and their associated Intersection ID Values stored in a PostGIS table. Additional methods that will geocode latitude and longitude values into ODOT control section numbers, offset distances, and East and North grid coordinates should be incorporated into the GeoCodeService module. These features would enhance the location data collected on collision report forms, facilitate translation between coordinate systems, and dramatically improve interoperability between numerous legacy data analysis systems that were based on the older coordinate systems.

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