Alaska Department of Transportation & Public Facilities

Intelligent Specialty Vehicle System

Pilot Program Report

March 26, 2007

Preface

This report presents a project overview, challenges and lessons learned from implementation of Intelligent Specialty Vehicle System (ISVS) technologies at the Alaska Department of Transportation & Public Facilities.

In completing the assessment process, we reviewed the planning, procurement and implementation process used in completing the ISVS pilot project.

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1. Acronyms

ADOT&PF	Alaska Department of Transportation & Public Facilities
PGPS	Precision Global Positioning System
HUD	Heads-up-display
ISVS	Intelligent Specialty Vehicle System
ITS	Intelligent Transportation Systems
LMRS	Land Mobile Radio System
RTK	Real Time Kinematics
RWIS	Road Weather Information System
UoM	University of Minnesota
GIS	Geographical Information System

2. EXECUTIVE SUMMARY

The **Intelligent Specialty Vehicle System (ISVS)** is equipped with Precision Global Positioning System (PGPS) technology which is delivered in the form of Real Time Kinematics (RTK) to the vehicle from a single dedicated GPS base station. The vehicle mounted system has integrated collision avoidance radar technology designed to provide the driver a means to maintain desired lane position and avoid collisions with obstacles during periods of low visibility. The PGPS provides position information to the vehicle which can be as accurate as 3 cm. Distance from the PGPS determines the final accuracy, the further the ISVS is from the PGPS, the lower the accuracy.

This project is motivated by the fact that specialty vehicles often must operate under inclement weather conditions. The driver assistive system improves safety for the specialty vehicle operator by providing the necessary cues for lane keeping and collision avoidance normally unavailable during poor visibility conditions. The driver assistive system, when placed in snow and ice, control vehicles, improves safety by facilitating all-weather road services which keep roads open and passable for other emergency vehicles and the general motoring public.

A snow blower and snowplow are the primary vehicles of the ISVS project for the Alaska Department of Transportation and Public Facilities (ADOT&PF). The project implemented, operated and evaluated all necessary infrastructure components, in-vehicle sensing technology, in-vehicle processing including algorithms, and driver-vehicle interfaces. Testing of these systems took place on state highways using state vehicles under all conditions including low-visibility conditions such as snow, blowing snow, ice fog, and night.

The ADOT&PF through partnership with the University of Minnesota (UoM), Intelligent Transportation Systems Institute developed the project design, installation and field evaluation procedures. Project results are used to inform decision makers and the general public of the improved safety and productivity benefits to the transportation system. The UoM is working directly with the Federal Highway Administration and the Minnesota Department of Transportation on similar technology projects.

To achieve the greatest benefit, the supporting PGPS infrastructure needed to support the ISVS project**.** The system designed is compatible with a system that is planned for the City of Valdez. When these systems are integrated, the PGPS coverage in the Valdez area will increase by 72%. This system uses the same basic technology with the addition of a Virtual Reference Station network, which uses a series of base stations linked together to create seamless coverage over a greater area. The City of Valdez proposes to use the system for resource management of city services, especially Police, Fire, and EMS. By integrating the two systems, City of Valdez and ADOT&PF will both benefit from the expanded coverage into areas that would otherwise be unserviceable.

The GIS mapping and model development efforts in this project will integrate with the ADOT&PF GIS Departments base maps. The GIS Department will benefit by receiving more accurate centerline road data which will accelerate the highway inventory and feature location process in the area. Furthermore, the GIS Department will have the necessary template to generate additional models if the ISVS or other applications for virtual modeling are expanded into other portions of the state.

The RTK Guidance System provides the greatest value when used in conjunction with Land Mobile Radio System (LMRS) and Road Weather Information System (RWIS). Equipment operators will be able to directly download RWIS data via LMRS in the field and reprioritize duties as necessary. The total technology package will mean greater equipment efficiency and a quicker response to rapidly changing environmental conditions. This will ultimately translate into more lane miles per dollar spent for snow clearing operations.

The AKDOT&PF also plans a new project next year at Deadhorse/Prudhoe Bay, AK and south toward the Brooks Range. This location provides some unique opportunities to test the system at one of the Northern most and remote locations in the United States and still be on the connected highway system in Alaska. This project will improve safety for commercial trucking which supports the oil production camps by equipping two road graders with PGPS.

3. Technical Approach

3.1 Background

The Alaska Department of Transportation and Public Facilities would like to thank the University of Minnesota for material used in the Background, Project Description and Equipment Installation Synopsis.

Alaska's severe winter weather conditions and the lengthy winter nights can produce some of the most hazardous driving conditions in America. This combination can reduce visibility to the point where the efficiency of snow removal operations is greatly affected and can result in collateral damage to infrastructure (i.e. guardrails, signs, milepost markers, equipment, etc.) as well as increase the likelihood of collision with other vehicles. As the efficiency of snow clearing operations declines there is a corresponding deterioration of driving conditions, which can ultimately result in the closure of highways. Highway closures affect the public's ability to access essential services, prevent public safety agencies from responding to emergencies, and result in substantial economic impact to the affected communities.

The Thompson Pass test site extends from milepost 19 to milepost 39 on the Richardson Highway in South Central Alaska and North of the city of Valdez. The test site includes portions of the highway on either side of Thompson Pass, a 20-mile section of highway characterized as high alpine, in the heart of the Chugach Mountains. This site was chosen because of the severe environmental conditions. Snowfall in excess of 450" annually and winds in excess of 123 miles per hour are common to this section of the Richardson Highway during the winter months.

Snow removal costs consume approximately 80% of Alaska Department of Transportation's winter operating budget. A decline in operational efficiency directly increases snow removal costs per lane mile, quickly depleting limited funds. The ISVS has proven to improve the efficiency and safety of snow removal operations. This permits State forces to continue to provide snow and ice control services during rapidly changing environmental conditions as well as improve the safety of the traveling public. The economic benefits to the state include a reduction in direct winter maintenance costs through improved efficiency as well as a decrease in machine and infrastructure damage. Similar applications of this technology have resulted in a 30% reduction of operational costs. Although difficult to calculate an exact value, the integration of anti-collision technology into the ISVS reduces the potential for accidental collisions with other vehicles, thus substantially lessening the liability exposure to the state.

3.2 Project Description

The Intelligent Specialty Vehicle System (ISVS) is a synergy of different technologies producing the total package. The vehicle-mounted portion of the system combines a recent advancement in, Differential Global Positioning System (PGPS), called Real Time Kinematics (RTK), and collision avoidance technology. The supporting infrastructure includes a base station provide corrections to 20 miles of highway. The system relies on a geospatial database that is generated using Geographic Information System (GIS) based survey methods that depicts the entire infrastructure, hazards, and the highway alignment within the right of way for this segment of the highway.

Vehicle positioning, collision avoidance, and the driver interface constitute the primary components of the ISVS. Vehicle positioning is accomplished through a combination of a PGPS and a geospatial database. Collision warning and avoidance is accomplished with radar sensors and signal processing techniques, which take advantage of information returned by the vehicle positioning system. Finally, information is provided to the driver via the driver interface system, which employs graphical and tactile interfaces to provide an optimal information path to the driver. A block diagram of the driver assistive system illustrating components and signal paths is shown in 6.1. Driver Assist System Block Diagram.

The deployment of the ISVS, which includes PGPS, is particularly timely since the city of Valdez desires its own expanded GPS network. Planned subsequent integration of the two systems will expand coverage by more than 72% for a total of 45 centerline miles. This will improve response times for emergency and public safety services to outlying regions by permitting auto routing and real-time tracking of emergency vehicles in these remote areas. Response will be improved to the following incidences:

- Auto Accidents
- Avalanche Rescues
- Natural Disaster Mitigation
- Hazardous Material Spills
- Medical Emergencies

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The test site also offers the unique opportunity to perform a side-by-side comparison of RTK technology against a wholly different type of guidance system developed by 3M Corporation that is currently being tested in two “smart snowplows”. The 3M system uses magnetic sensing technology that relies on magnetic strips that are inlaid into the pavement and provide a magnetic “trail” to guide the vehicle along an 8 mile segment of Thompson Pass. The magnetic technology provided only lateral positioning data that is communicated to the operator via Driver Haptic Interface (vibratory seat) and Driver Visual Interface (warning lights). This system is simplistic first generation positioning system that is capable of providing limited geospatial position data to the driver. Although the two guidance systems were installed into different types of snow clearing equipment, they both share similar operational techniques and encounter the same severe weather conditions, which limit performance and efficiency. This common environment permitted some performance comparisons. The 3M system is no longer in use by the State.

3.3. Equipment Installation Synopsis:

Intelligent Specialty Vehicle System (ISVS): is a system that uses a form of PGPS technology and interfaces it with forward looking radar to produce a graphical highway model of the highway environment in real time on a heads-up display (HUD). The ISVS equipment consists of two subsystems.

The Base Station is comprised of three major components:
TRIMBLE NetRS Reference Station w/ ZEPHYR Geodetic Antenna
GLB ELECTRONICS Netlink Radio Data System - VHF Transmitter
TRIPP-LITE PR-10b - power supply
A Linier Amplifier to increase Base Station power output to 102W forward installed at the site in February 2006. The addition of the amplifier improved highway coverage by about 30%.

The Base Station monitors local atmospheric conditions and GPS signals from a fixed point of reference. The GPS error is calculated and corrected. A correction signal is then broadcast to the test vehicles, permitting a degree of precision that can only be achieved using DPGS.

The Vehicle-Mounted System is comprised of five components:
TRIMBLE MS-750 GPS receiver with 13” Ground Plane Machine Antenna
Simrex Corp. GLB SNRDS Netlink Radio Data System – VHF Receiver 158.775
Eaton EVT-300 forward looking radar possessor
L3 Communications Mobile Projector and Heads-Up Display
On-board computers

The vehicle borne system shows the operator the relative computer generated location of the fog line, centerline, guardrails, and snow poles. The forward looking radar is integrated in the computer generated image of the virtual roadway and depicts other vehicle traffic relative to the test vehicle’s position. A personal digital assistant (First a COMPAQ iPAC Pocket PC® which suffered from battery issues) was subsequently replaced with a Palm Pilot Lifedrive® system, which worked quite well to monitor system performance and allow the operator to select vehicle offsets to align the vehicle on the virtual roadway.

Base Station Installation: The Base Station is installed temporarily at the Thompson Pass maintenance station. Installation of the Base Station required 24 man-hours to install the required antennas and cabling by both M&O (8 hours) and Radio Maintenance (16 Hours). Accupoint's Mike Gray, the Alaska TRIMBLE representative, worked an additional 8 man-hours performing the final calibration and commissioning the station. A preliminary radio propagation analysis performed by Accupoint indicated good satellite coverage and correction signal reception from approximately Richardson Milepost 19 to Milepost 39.

The Vehicle-Mounted Systems were installed in the two test vehicles:

- 94 Oshkosh Snow Blower
- 98 Freightliner 6x6 Snowplow

The goal is to test the effectiveness in two vehicles with different functionality, but similar purpose.

Vehicle Installation: Installation specialist Bryan Newstrom of the University of Minnesota arrived in Valdez, AK, January 4th, 2004. He spent the next three weeks installing the equipment in the vehicles and generating the highway model.

Installation in the Freightliner 6x6 Snowplow went smoothly since this system is installed in similar trucks at the Minnesota DOT. Despite the similarities, it still required 18 man-hours by State of Alaska Equipment Maintenance staff to install the system. Much of this time was devoted to fabrication of brackets for ZEPHYR Geodetic Antenna and the collision avoidance radar transmitters. Additional precautions taken to properly seal all wiring harnesses will help prevent connections to avoid possible infiltration of magnesium chloride salts used as an anti-icing agent. The chemical can easily corrode electrical connectors.

The Oshkosh Snow blower provided a unique challenge for installation since the vehicle's cab is small in comparison to the plow truck. A custom box now houses the electrical components in the cab. Additional time and consultation with the operators insured configuration of the display and projector worked operationally and ergonomically. It was determined that mounting it over the left shoulder of the operator worked best and the HUD screen placed approximately 12" in front of the operators face. Total State of Alaska Equipment Maintenance time for fabrication and installation of equipment in the snow blower was 12.5 man-hours.

Highway Modeling: Bryan Newstrom required three days to complete the initial base map from Milepost 20 to 38 of the Richardson Highway. Creating the highway model is a relatively simple process once the base station is installed. The modeler simply drives the test section of highway and records the location of the centerline and fog lines using the correction signal from the base station and the data from a standard GPS receiver. Special infrastructures, such as guardrails, when entered into the modeling program identify their location and have a special graphical identifier.

4. Project Challenges

There were several challenges to providing PGPS coverage to Thompson Pass. The topography of the terrain required the PGPS Station location on the highest terrain possible. The first installation, at the Maintenance Camp, provided coverage to about 12 miles of road. The PGPS station was relocated and integrated into the LMRS Repeater site as planned in late 2004. The PGPS Station at its new location provided coverage to about 16 miles of highway but required a high floatation tracked vehicle or helicopter to perform routine maintenance. In February 2006, a linear amplifier added to the site improved coverage to 20 miles of highway.

A number of problems cropped up during both installation and operational testing. The Oshkosh Snow Blower has only limited locations for mounting the radar sending units. The blower head, which occupies the entire front of the vehicle, is unsuitable for mounting the radar sending units since it would interfere with the snow blower function. A compromise mount solution was to place the sending unit on the front side of the cab. This is less than ideal since the snow chute, which directs the jettisoned snow will occasional obstruct its field of view. This also required the radar system's alarm threshold limits be set to ignore anything within ten feet of the radar transmitter to prevent false alarms.

The COMPAQ iPAC Pocket PC rapidly lost charge with little use. A non-standard open source Operating System (OS) did not handle power management as well as the original Operating System. The Department returned the COMPAQ iPAC Pocket for replacement with a Palm Pilot Lifedrive PDA, thereby correcting the problem.

Once the vehicle systems installed, a more serious intermittent problem became apparent. The TRIMBLE MS-750 receivers loose the GPS signal for no apparent reason. The Accupoint representative visited Thompson Pass to troubleshoot the systems and made the necessary antenna coax repairs due to damaged by our staff.

5. Lessons Learned

5.1. Institutional:

The corporation received for the University of Minnesota (UoM) staff, Mike Gray, of Accupoint the Alaska Trimble representative, the State of Alaska Information Technology Services staff and Al Fletcher, FHWA, proved invaluable. Without the team efforts during project design, implementation and maintenance this project would have failed. The ADOT&PF is extremely appreciative of the support received and that this team worked well together form the beginning. Early and frequent communication by all parties resulted in everyone having a stake in the final product and its success.

5.2. Technical

Moving the PGPS station to a mountain top repeater site improved service to some sections of road while decreasing the signal to others. A linier amplifier added to the site in February 2006 boosted the VHF Radio Modem signal from 25 watts to 102 watts forward. The increased signal strength provided good PGPS coverage to about 20 miles of highway and eliminated short sections of the highway near the PGPS station where the signal was intermittent.

We also learned that the prefabricated buildings used for the Alaska Land Mobile Radio System repeaters will fly. During the process of moving the PGPS Station to the repeater site and replacing the old building things went wrong. The weather forced the heavy lift helicopter to set the new building, with the new repeaters and PGPS Station installed, near the site. The build was secured to the mountain top with drilled anchors. Heavy snow collected on the upwind side of the building. When the wind speed passing over the top of the building reached an estimated 150 + mph, enough lift was generated to rip the anchor bolts out of the metal frame and fly the building off the back side of the mountain. Only small pieces of the building were found and the radios and the PGPS Station were scattered over about a mile area of the back side of the mountain. The Trimble GPS unit was located about a week later and returned to the manufacture for inspection and testing. The unit was found to be operational and is in service at Thompson Pass today.

The staff at the UoM Intelligent Transportation Systems Institute has a solid program and is self motivated to excellence. They have mastered design, ordering and assembling the various components to create an ISVS. They were able to integrate our legacy 3M Magnet Sensor System into the ISVS through a vibrating seat to simulate rumble strips.

The ADOT&PF learned early in the evaluation process that the ISVS Heads-up-display was more natural and prevented the operator fatigue from trying to keep the vehicle in the desired lane. The ADOT&PF tested the 3M Magnet Sensor System before learning about the UoM ISVS and found it nearly impossible to keep the vehicle in the desired lane during whiteout conditions. The fatigue level was high with the 3M System alone.

The initial wiring to the power source supplied by our staff was not through the ignition switch and provided the opportunity to leave the ISVS system on. This happened on the snow blower at the end of the first winter and over time killed the batteries and damaged the VHF receiver radio. All components are now wired through the ignition switch.

Other equipment already mounted in the truck can change the mounting bracket design requirements. Planning for local fabrication is an essential part of a successful design and deployment plan. The UoM staff identified this early in the planning phase.

6. Driver Assistive System Block Diagram