PILOT TEST OF AUTOMATIC VEHICLE LOCATION ON SNOW PLOWS

Technical Memorandum 1: Recommendations for Pilot Test

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GLOSSARY OF ABBREVIATIONS

AVL	Automatic Vehicle Location
CDPD	Cellular Digital Packet Data
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
IVU	In-Vehicle Unit
MDT	Montana Department of Transportation
NOVA	Northern Virginia District of the Virginia Department of Transportation
SEMSIM	Southeastern Michigan Snow and Ice Management

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1. INTRODUCTION

In their efforts to preserve mobility for motorists, many transportation agencies spend a significant amount of resources on winter maintenance operations. These operations are critical for protecting traveler safety and ensuring efficient flow of people and goods in and through the state. As noted by one author, however, winter maintenance operations are continually being challenged toward "simultaneously increasing productivity, quality, and environmental sensitivity while maintaining a constant or improved level of service on roads." (1) In addition, improvements in traveler information through 511 and the Internet in recent years have enhanced public expectations on the quality, accuracy and timeliness of information.

Into this environment, automatic vehicle location (AVL) emerges as a technology with significant promise. In widespread use in the transit, trucking and emergency response communities, AVL has been recently used in winter maintenance applications as well, with goals such as improving agency efficiency and enhancing traveler information.

The Montana Department of Transportation's (MDT) Maintenance Division has expressed interest in adopting AVL on a statewide basis. Realizing that other states and agencies have used AVL for similar applications, they are interested in proceeding with implementation by learning from the experience of other agencies. They plan to conduct a pilot test to prove whether AVL will work satisfactorily on a small scale, and then to eventually expand statewide as funding and technology allows. The purpose of this technical memorandum is to provide recommendations to guide MDT in the implementation of the pilot test.

Chapter 2 will provide background on AVL as a technology, how it has been used in winter maintenance applications, and lessons learned regarding potential benefits and concerns. Chapter 3 reviews the MDT-specific context in which AVL would be adopted, reviewing project goals, the maintenance vehicle fleet, and communications availability. Chapter 4 summarizes the results of outreach to the vendor community. Finally, Chapter 5 presents recommendations for the pilot test.

2. BACKGROUND

This chapter provides background on automatic vehicle location (AVL) as a technology. It will describe how it is represented in the National ITS Architecture and some example applications. Case studies regarding transportation agency experience with using AVL in winter maintenance applications are reviewed. The chapter closes with a review of the potential benefits of implementing AVL for winter maintenance, as well as potential concerns.

2.1. Definition of AVL

Automatic vehicle location (AVL) is a computer-based system that collects and transmits information on a vehicle's actual location and other characteristics. The location may be determined through several means, but is generally determined through the use of global positioning systems (GPS), which can provide accuracy of ± 3-5 meters. GPS technology uses signals transmitted from a network of satellites orbiting the earth and received by a GPS antenna placed on the roof of each vehicle. A GPS receiver calculates the vehicle position by measuring the travel time of radio signals from at least three satellites (2). AVL uses location information, new communication technologies, new GIS technologies, route planning technologies, and the Internet to allow real-time tracking of vehicles from a computer with access to the World Wide Web. The process consists of a vehicle calculating its position from data transmitted by satellites. This data, along with other data from the vehicle, is transmitted to a computer via radio, cellular communications, or satellite uplink. The computer then takes the information to plot a symbol on a map which is made available on a web site.

2.1.1. System Architecture

In the National ITS Architecture, the basic AVL functionality is represented by the Vehicle Location Determination equipment package. Under this equipment package, technology inside the vehicle receives information regarding its absolute or relative location. This location information is then transmitted from the vehicle to a dispatch center. The basic data transmission consists of a timestamp, which is associated with a specific location as identified through GPS. This transmission may be supplemented with other data, depending upon the application.

Figure 2-1 shows how the National ITS Architecture represents an example AVL application, in this case tracking of emergency vehicle location. The Location Data Source would represent a determination of the vehicle's location (i.e. through GPS). The vehicle's location would be contained in a vehicle-based system. The vehicle would send this information to a dispatch center on a real-time basis; the dispatch center would respond with information on suggested routing. Communication between vehicles and dispatch centers has previously occurred without AVL technology through the use of voice (radio) communications. Once a channel has been opened for real-time data communications between the vehicle and the dispatch center, additional data may be added as well, within the limitations of communications bandwidth and coverage.

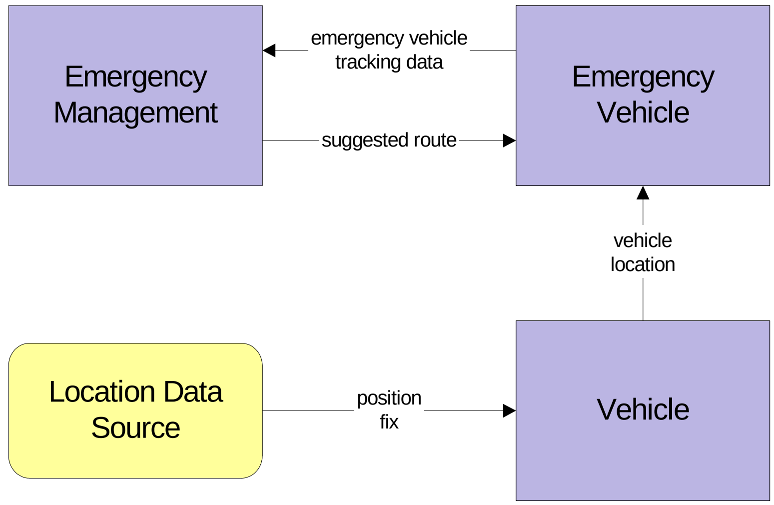


Figure 2-1: Example AVL Schematic from National ITS Architecture

Once the information is received at a dispatch center or central location, the information can be parsed and used in a variety of ways. For example, data may be passively displayed on a Web page to allow travelers to view the progress and activity of vehicles. Data may be archived and stored for monitoring and management purposes to assist in analysis of events.

Vehicle location capabilities are included in the National ITS Architecture for commercial vehicle, emergency response, transit and maintenance applications. The market packages and equipment packages in the National ITS Architecture that include AVL are shown in Table 2-1.

2.1.2. Example Applications

Public transit has been one major application area of AVL technology. AVL can be used for monitoring of location of transit vehicles to improve vehicle routing, assist in transit security, and provide real-time traveler information, even at transit stops. A review of national ITS deployment experience published in 2001 judged the use of AVL in public transit to be "successful" (2). According to recent statistics, 81 metropolitan area transit agencies have deployed AVL on their fixed-route buses, with over 23,000 vehicles using the technology(3). As an example of the types of benefits transit agencies may receive through AVL, the Denver Regional Transportation District (RTD) decreased the number of early-arriving vehicles by 12 percent over a five-year period, and decreased the number of passengers per vehicle who arrived at their stops late by 21 percent. The number of passenger assaults per 100,000 passengers decreased by 33 percent in the same period (4).

The emergency response community has found benefits in having AVL capabilities on their vehicles, as it can allow dispatchers to locate the closest available unit to respond to a call, evaluate the efficiency of various emergency routes, and adjust route decisions based on traffic (5). Recent national statistics show 72 agencies in 41 metropolitan areas having deployed AVL on over 2,800 fire and rescue vehicles, while 105 agencies in 59 metropolitan areas have deployed AVL on over 11,000 law enforcement vehicles (3).

Commercial vehicle fleets have also been major users of AVL, to provide real-time shipment tracking and routing for carriers operating over longer distances (6).

Table 2-1: Vehicle Location in National ITS Architecture

Application Area	Market Package	Equipment Package
Commercial Vehicles	• Fleet Administration • HAZMAT Management	• On-Board Cargo Monitoring • On-Board Trip Monitoring • Vehicle Location Determination
Emergency Response	• Autonomous Route Guidance • Emergency Routing • Roadway Service Patrols	• On-Board EV En Route Support • Vehicle Location Determination
Transit	• Autonomous Route Guidance • Transit Vehicle Tracking	• On-Board Transit Trip Monitoring • Vehicle Location Determination
Maintenance and Construction	• Maintenance and Construction Vehicle and Equipment Tracking • Roadway Maintenance and Construction • Winter Maintenance	• MCV Roadway Maintenance and Construction • MCV Vehicle Location Tracking • MCV Winter Maintenance • Vehicle Location Determination

2.2. Experience with AVL in Highway Maintenance

AVL has been used for winter maintenance applications in several areas. This section describes some systems which have been well-documented in the literature. Some installations have been considered successful, while others have experienced significant difficulties.

2.2.1. Southeastern Michigan Snow and Ice Management (SEMSIM)

AVL was implemented in Michigan to help a coalition of public maintenance organizations cooperatively work to clear snow and ice on the roadways. This coalition, called Southeastern Michigan Snow and Ice Management (SEMSIM), was formed in the spring of 1999 and consisted of the Detroit Department of Public Works, the Road Commission of Macomb County, the Road Commission of Oakland County, and the Wayne County Department of Public Services (7). The coalition, starting in 1999-2000, implemented AVL on the region's snow plows in a project which is still in operation today. The program's web site is located at http://www.rcocweb.org/home/semsim.asp.

The SEMSIM AVL system was developed by Orbital. Communications from the plow to the server is accomplished through a 900 MHz radio system. A server system at Orbital's headquarters in Maryland receives the data and makes the information available on the internet through a web application. This allows any computer connected to the Internet to use the system on their web browser.

About 300 vehicles were initially equipped with Orbital's Orbtrac120 (this has increased to 500 vehicles today). This system consists of four main components: a charge guard to provide power after the vehicle is shut off; a 900 MHz radio; an Orbital VLU, which provides processing of information; and a mobile data terminal to provide the plow operator a way to interact with the system.

Three types of sensors are used on the vehicle. Mercury switches were mounted on the plow structure to sense whether the plow is up or down. Road and air temperature readings are retrieved by a sensor manufactured by Commercial Vehicle Systems. Spreader rate information is gathered from interfacing the system to the automatic spreader controllers. Information gathered by these sensors is sent to the server along with the GPS coordinates.

SEMSIM partners expect the system will improve supervisor efficiency. They believe the system will allow the supervisor to see the whole picture of activities on their computer screen. After the activities are finished from a storm event, the system will allow them to analyze strategies used and adjust them for the next event. As the maintenance personnel begin to make full use of the information, they will be able to make better and quicker decisions, freeing them up for other duties.

It is expected that the system will improve the use of sand, chemicals, and fuel due to the fact that the use of these materials can be more closely monitored. Fuel could be saved by the ability of supervisors to determine and dispatch the closest trucks to a problem area.

Safety for travelers is also expected to be improved with this technology. The ability for the roadways to be monitored closely enables the plows to keep roadways cleared more efficiently. Roads that have been missed or that have not been cleared for a long time become apparent to supervisors on their computer screen. The end result is roadways may be in a potentially hazardous condition for a shorter amount of time.

A final evaluation report on SEMSIM AVL system was completed in 2004. The evaluator concluded that it was yet too early to observe the expected benefits; SEMSIM is still in the process of "tuning" the system. Also, evaluators believed more time is needed for the personnel to become comfortable trusting the information that was being collected.

One area of the technology that has been unsuccessful to date is the text messaging system. Up to a five-minute delay can occur until the message arrives. Another potential problem is that computer terminals used by SEMSIM to monitor activities are also used by other personnel and applications. Evaluators believed that this has caused the system to be less reliable and useful than it could be. These issues, along with the lack of sufficient training, have prevented the system from achieving its full potential.

Costs were not available in the literature for this system. From information provided by the ITS Joint Program Office of the U.S. Department of Transportation, total costs including installation and operations for the project from September 1998 through July 2004 were $8,187,829.

2.2.2. Virginia Department of Transportation

Starting in 1997-98, the Virginia Department of Transportation conducted a pilot test of AVL over three winters (8). Virginia implemented AVL in response to the growing need to hire contract equipment due to the expanding roadway system and higher traffic volumes. Managing a growing number of vehicles required a new way to keep track of operations. AVL was implemented in the Northern Virginia (NOVA) District, which includes large suburban areas adjacent to Washington D.C.

Eighty trucks were equipped with GPS units. Orbital Sciences Corporation was selected to provide the AVL system. Cellular digital packet data (CDPD) communication was used to relay the positional information back to the server, because NOVA could implement it quickly without adding additional communications infrastructure. Differential GPS correction was used to increase the accuracy to five meters, allowing lanes and subdivision streets to be separated. A portable box, called the in-vehicle unit (IVU), was installed in the cab that contained the GPS receiver and communications equipment. Plow up/down, chemical spreader on/off, and vehicle on/off data, along with the positional information, are sensed every two seconds then sent back to headquarters every ten seconds. This device also allowed text messaging between the truck and headquarters.

On the other end, three computers were used for tracking activities. One computer combined the information received from the plow and a database of maps and aerial photos to display the positions on the other two computers connected to a network. The current location and color-coded route traces were overlaid on the maps to show what activities the plow performed on roads covered by the plow. The data was archived on the server to allow it to be reviewed at a later time.

The system used by NOVA was plagued by many problems. The system was not able to distinguish specific lanes due to the lack of positional accuracy. On average, the system could only give 10 to 15 meter accuracy, as opposed to the 5 meter accuracy expected from the differentially corrected GPS signal. Lane separation was later abandoned. Another problem was that the system slowed down after about an hour of data collection. At this point the AVL system became unusable. This was caused by the volume of data that accumulated by plotting data at two second intervals. Due to these problems in the first two years, headquarters did not consider the system information reliable enough to be useful.

Inside the truck, the portability of the IVU caused the unit to be damaged easily. Broken wires and connector disconnections were common. Some of the units weren’t mounted securely in the truck, causing them to float around in the cab, further exposing them to damage. The end result was the collection of faulty data, preventing the use of the data for compensation and performance evaluation.

The text messaging feature was also unsuccessful. The main purpose of the messaging system was to allow contractors to communicate with headquarters without also installing radios. Many contractors disliked the complexity of the system. A high turnover of contractor drivers contributed to the complexity issue.

Additional problems arose between snow removal activities: vehicles were removed from the tracking list due to expiring IP addresses, network passwords expired, configuration changes weren't known until a snow event, and IVUs out for repair weren't available for operation.

In addition to these challenges, there were not enough storm events to adequately test the capabilities of the system. Consequently, the pilot test was terminated without further expansion of using the technology.

Cost data were not available in the literature found for this system; however, it was mentioned that the system was "expensive and is now outdated," and that it would cost "considerably" less to install a new system now.

2.2.3. Howard County, Maryland

In Howard County, Maryland, the Bureau of Highways implemented AVL on their snowplow fleet starting in 2000-01 to track and balance progress in three operational zones (9). The Bureau's goals included being able to send a replacement truck to a specific area when a truck breaks down. Another goal of the Bureau was to be able to manage the maintenance of the roadways based on the time since the road was last maintained. Finally, the Bureau hoped to increase public trust through improved service.

The total cost of this system in 1999 was just over $400,000 for installations on 83 snowplow trucks; it is now installed on 100 vehicles (10). Maintaining the system costs the Bureau about $10,000 per year. Howard County estimated they could recover the costs of the system in less than three years if it helped them reduce the number of trucks by one.

Howard County uses a system from Enterprise Information Solutions. The system consists of a Sierra Wireless Dart 300 modem and mobile data terminal installed in each snowplow truck. This modem connects to servers at headquarters using Verizon's wireless network. A GPS receiver connected to the mobile data terminal relays the location of the plow to the wireless modem, which sends the information to the servers. Three servers are used to process the data. One server receives the coordinates from the wireless network, performs Inverted Differential Correction, and then enters the location in a SQL database. Another server retrieves the information from the database and generates maps with the information. The third server makes the maps available on the Internet to allow tracking of the progress of the snowplows.

Software used to make the system work includes the software on the servers listed above. An administrative program that provides a user with administrative privileges to do map queries, look at history archives, and configure the overall system is also included on the servers. A Web application is also used to allow a user to view the current status of the maintenance operation. This program displays the map with the ability to zoom up on more detailed areas showing the location of the snowplows.

The Bureau of Highways considered the AVL system to be a success. They had several snow events over the winter that allowed them to track their snowplow operations. Managers were able to watch the location of plows and plowed routes from their office in real-time, allowing them to send plows to areas with greater snowfall and re-deploy snowplows if one becomes unusable.

Call volume was decreased to the Bureau concerning road conditions due to real-time information that was made available to the public through a Web site (http://snow2.co.ho.md.us/Index.asp). Another benefit was the ability of the 911 dispatchers to route emergency vehicles based on the information provided by the Web site. If there wasn't a cleared route to the location of the emergency, the dispatcher could request that the nearest plow on the map be sent to clear a path for the emergency vehicle.

It is not known whether the Bureau was able to recoup the costs as they had expected.

2.2.4. Vaughan, Ontario

The city of Vaughan, located about 15 miles northwest of Toronto, has a population of over 220,000 people. AVL was implemented in Vaughan's winter maintenance operations in 2001-02 due to population growth and increasing complaints from residents and council members regarding the level of service on their streets (11). These complaints included missed streets, missed sidewalks, and poor timing of driveway clearance operations. Winter maintenance operations involve over 600 miles of roads, about 450 miles of sidewalks, and clearing windrows from driveways of residents. To accomplish this, 110 pieces of equipment are used, 40 of which are owned by the city, with the rest contracted. Over $6.5 million is budgeted for winter maintenance annually.

Grey Island Systems, Inc. of Toronto was selected to provide AVL equipment for Vaughan. The information the system acquires is sent to Grey Island's server via wireless text messaging provided by Rogers AT&T and Tellus. The installation of the system involved two power wires, two quick connectors for GPS and communications, and a magnetic mount antenna on top of the vehicle.

Operations of the equipment can be monitored on any computer connected to the Internet. Equipment can be tracked in real-time or past activities replayed in order to determine the location at any point in time. Vehicle summaries are also provided, including information on the amount of salt used and the distance covered by the vehicle. Computerized salt spreaders were also connected to the system to relay the rate and location of salt application. The spreaders were DICKEY-John and Compu-Spread units.

There are many benefits of this system. The total cost of a storm event can be determined. Management can determine if minimum maintenance standards mandated by the province and council are met. Paper timesheets and progress reports in the field are eliminated or reduced; an electronic record of each vehicle's activity is kept by the system.

A public Web site allows residents to see where the driveway clearing units are in relation to their property. Previously during winter maintenance, about 400 calls per hour were received by the public works department, mainly regarding the location of the snow clearing equipment and when it would arrive at the caller's house. This information is now provided to the public at www.snow.city.vaughan.on.ca. Different types of users are authorized to receive different levels of information. This site consists of static maps with vehicle locations transposed over the map. A cookie trail is put on the map every 5 minutes or 100 meters. Residents can track both the locations of the plows and driveway clearing machines to see how close they are to reaching their home. A call center staffed by temporary personnel who monitor operations was also created to assist residents without access to the Internet.

The final result of the application of AVL in winter maintenance operations was a significant decrease in complaints, better coordination, better information for Council members and residents, and better management of in-house and contracted services.

2.2.5. Aurora, Colorado

Aurora, which borders Denver on the east, is the third largest city in Colorado. Since 1998, the city has used AVL on its fleet to improve winter maintenance operations (7, 12, 13). The city has over 60 maintenance vehicles, but the initial installation has focused on the winter maintenance vehicles, which comprise about half of the fleet.

The deployment has undergone several transitions. First, the original installation used a CDPD backbone, but then was transitioned to GPRS (General Packet Radio Service) GSM (Global System for Mobile Communications) when CDPD was transitioned out of existence. CDPD was favored for the initial installation because the city's radio system did not adequately cover their winter maintenance area. They use Sierra Wireless GSM/GPRS modems, which cost $1,000 apiece compared to the $3,500 CDPD modems. Communication costs have dropped from $65 per vehicle per month to approximately $40. Second, the in-vehicle equipment was originally supplied and installed by Orbital Sciences, but the city changed vendors to CompassCom, a Colorado company. Their reasons for this change included Orbital no longer supporting the in-vehicle unit, the CDPD phase-out, and improved reporting modules in CompassCom's product.

The basic system collects position information every two seconds and transmits information every 20 seconds. The Orbital equipment did not provide a way to detect the spreading rate for the Muncie and Component Tech spreaders they used.

The city found that they were able to cut the rate of application of road chemicals in half, saving over $200,000 in one winter out of an annual chemical budget of $1 million. They also documented a 15 percent increase in the productivity of their sweepers.

2.2.6. Survey of Other States

To gain further knowledge of AVL systems already in use, various agencies were contacted regarding their use of AVL for winter maintenance. Most of the information was gathered from responses to a list of questions sent via e-mail. Highway departments in rural, mountainous states with geography similar to Montana were originally targeted. Unfortunately, it was found that the use of AVL in this setting is extremely limited. Most work done with AVL in winter maintenance has been experimental, without widespread use. The search was expanded to include Canadian provinces and some urban areas where use of the technology has moved beyond experimental stages. The following is a synthesis of the responses received from Alberta, Colorado, Iowa, Utah and Washington.

- Geographic Coverage. All five agencies contacted use or have used AVL primarily in rural areas. Colorado did operate in some suburban environments and Utah tested in one urban setting. Alberta had the most widespread use, stating that they were using AVL throughout the entire Alberta province. Other agencies employed the technology in smaller, test situations. Colorado's use was limited to three 40-mile sections, two of them interstate, and another on a four-lane primary road. Iowa's use of AVL was tested at two maintenance garages while Utah tested at three garages. Washington was testing in two different areas: Snoqualmie Pass on I-90 and another around Wenatchee, covering 1,200 lane miles of highway.

- Fleet Size. Alberta had the largest number of trucks equipped with AVL, with 72. They are planning on having over 550 after 2007. Colorado tested 20 AVL snowplows, Iowa tested 18, and Washington equipped seven plows and seven supervisor pick-ups in the Wenatchee area.

- Communications. Alberta, Colorado, and Utah relayed data back to headquarters with cellular communications. Iowa and Washington tested systems that used digital radios to transmit data. Iowa had good luck with this method, but Washington had problems and switched to satellite communications. Washington has been pleased with satellite due to the fact that it has been very reliable even in mountainous terrain. On AVL systems using cellular or digital radio, data was stored locally in the truck electronics if the system was unable to communicate with headquarters. When communications were restored, the stored data was transmitted.

- Data Transmission. All agencies except Washington sent plow/wing up/down status, air/road temperatures, and spreader controller data. Colorado's system also allowed operators to enter information on a touch screen, such as current lane, type of chemicals, and road and weather conditions. Washington relayed only GPS data.

- Update Frequency. Alberta relayed GPS and current status of sensors every ten seconds or 100 meters, and every 2 minutes when stationary. Colorado also had ten-second updates on some trucks; others had 180-second updates. Iowa updated every ten minutes or if the status of selected sensors changed. Washington and Utah both had 15-minute update intervals.

- Vendors. Alberta's systems were supplied by Grey Island Systems. Colorado's were from IWAPI Inc. Iowa used equipment from Orbital Sciences. Utah's system was provided by GrayLink. Washington did not state which vendor supplied equipment.

- Cost. The cost per truck varied due to which sensors were installed on each truck and how the truck was equipped before the AVL was installed. Another variable in cost is when the systems were installed, as prices have dropped quite a bit over time. Alberta estimated the cost to be $2,000 per installation, which included one plow sensor. Colorado's installations were $1,250 per vehicle for the GPS and communications hardware. The optional touch screen displays in the trucks were $285 each. Iowa's installations cost around $3,500-4,000. Utah stated that their AVL cost around $3,000 per truck. Washington's cost was reported at about $1,250 per truck without sensors.

- Installation Issues. Very few problems were reported by the various agencies. Iowa had some problems early on with the installations standing up to the rough environment during plowing operations, but convinced manufacturers to remedy this.

- Driver Opinions. Operators of Iowa's AVL snowplows had a strong positive opinion. This was attributed to the high involvement of the drivers from the very beginning of the project. Washington's drivers liked the fact that they didn't have to call in as often, although some did have concerns about being watched by "Big Brother".

- Traveler Information. None of the agencies contacted provided the information on a public Web site.

- Future Plans. Alberta is planning on equipping their entire fleet with AVL. A billing system is also being implemented that uses the AVL data to determine payments to contractors. Before making any future plans for AVL, Colorado is waiting for some final results of their test. Iowa is still performing small tests, but hasn't developed a strategy for equipping its entire fleet due to lack of funds. Utah is planning on a large scale test this season. Washington is planning on equipping the rest of their plows in their North Central Region and adding precision application equipment.

2.2.7. Other Studies

Several other jurisdictions have been using or testing AVL. Massachusetts DOT has implemented AVL on its plows statewide, for tort protection, resource management, and monitoring employee efficiency (14). The City of Baltimore installed Orbital on 75 winter maintenance vehicles in 2001. The system has been fairly reliable, but there have been issues of incompatibility between the communication system and the software (7). Minnesota DOT is installing ThomTech AVL systems in 60 of its snow plows using IDEN (Nextel) high speed communication (7). Waukesha, Wisconsin did a test project using equipment furnished by Orbital. They stopped the test and removed the equipment after experiencing server problems and slow polling speeds (7).

A 2003 study for the Kansas Department of Transportation (KDOT) indicated there could be substantial economic benefits in implementing AVL (15). The study queried agencies currently using AVL about the estimated benefits in terms of reduced time in paperwork, reduced fleet maintenance costs due to improved fleet management, and reduced snow-related crashes due to reductions in snow removal times. Using conservative estimates from other AVL users, the study estimated that the benefit-cost ratio of implementing AVL on its maintenance vehicles on a statewide basis was between 2.4 and 24, depending upon the assumptions used. This assumed AVL would be able to use KDOT's existing 800 MHz radio system with no additional cost.

2.3. Benefits and Concerns

In reviewing the experience of other transportation agencies, there are a number of potential benefits that may be realized in using AVL for winter maintenance applications. There are also some concerns with the technology and/or its implementation that may affect the ultimate success of an AVL deployment. This section summarizes these benefits and concerns, with the goal of providing context for the Montana Department of Transportation's specific goals with the pilot test, along with trying to highlight potential concerns that should be considered in implementation. These benefits and concerns are summarized in Table 2-2 and Table 2-3 (see page 14), respectively.

2.3.1. Benefits

Many of the benefits associated with AVL on winter maintenance operations reflect that AVL had its origin in the trucking industry, where dispatching and vehicle tracking have significant economic impacts. Management of snow plows, to know where vehicles are at, to provide informed real-time routing and dispatch decisions, and to have a means of accelerating performance measurement of maintenance operations, are among the management-oriented benefits sought for AVL on snow plows.

Related to these management benefits are anticipated cost efficiencies and a potential reduced work load for dispatchers and drivers in documenting vehicle activity during maintenance events. With AVL, data entry by operators and section managers can be greatly simplified. This can help efficiency and allow for gathering of additional information (e.g. pavement temperature between RWIS sites, road condition information on a real-time basis) that could provide significant added value.

Traveler information is another popular benefit of the AVL systems. When data presented to maintenance managers is stripped of unique identifiers (for example, a vehicle name or identification code) and excessive detail (e.g. spread rate), similar information can be provided to travelers to help them make more informed decisions. This could include more accurate information on current pavement conditions, the amount of time since a road was last plowed, or similar information. Reducing tort and liability exposure is another potential benefit of AVL, as it can be used to verify vehicle location and either confirm or deny claims.

It is also anticipated that there would be secondary benefits from AVL, especially in the areas of safety and highway operations. If AVL helps to improve maintenance efficiency, it would make sense that winter maintenance operations would proceed more quickly and effectively, reducing the amount of time that the pavement is icy or snowy. This would reduce crash risk and improve highway capacity and speeds.

Table 2-2: Potential Benefits of AVL

Management

- Ability to map current location of AVL equipped snowplows by management on a computer
- Ability to map current status of roadways – plowed/unplowed/sanded/salted
- Ability to quickly determine the length of time since roads were last plowed or salted by looking at a colored coded map of roadways
- Ability to continuously map air and road temperature information to help with salt/sand application decisions
- Ability to plan redeployment based on mapped information of closest plows in case of mechanical failure of a plow truck
- Ability to determine if drivers have stopped working by lack of plow movement on map
- Ability to determine if drivers are off their assigned route from current mapped location
- History of plow operations kept electronically which can be replayed and reviewed at a later date to analyze and improve efficiency
- When mobile internet technologies become more widespread, supervisors will be able to monitor snowplow activities on a laptop computer in their vehicle
- Ability to add new sensor technology later on, such as road friction meters and road material freeze point detectors as they are perfected

Operator

- Less radio “chatter” from supervisors asking plow operators about their location
- Reduce or eliminate field progress reports and timesheets due to information being recorded electronically as activities are in progress

Cost

- More efficient use of de-icing chemicals due to records of application rates and locations being kept
- Improved fuel efficiency due to the ability to determine the closest plow to reassign to a problem area

Safety

- Accident reduction due to more efficient snow removal
- Accident reduction due to public being able to make informed travel decisions based on condition of roadways
- Ability of plow operators to report exact locations of accidents through a text message system that relays GPS coordinates
- Faster response to emergencies due to emergency vehicle route planning based on plowed status of roadways
- Easily determine closest plow to reassign in order to clear routes for emergency vehicles

Other

- Reduced volume of phone calls concerning road conditions and plowing status due to public’s ability to monitor operations on the internet
- Increased public opinion and trust of plowing operations
- Ability to have accurate records of the location of plows at points in time as evidence in tort claims

2.3.2. Concerns

There are a variety of concerns that may affect whether an AVL implementation will be practical or successful. First, there are concerns over the initial and ongoing costs to support AVL. Initially, vehicles will need to be outfitted with an in-vehicle unit, wiring to integrate sensors into the in-vehicle unit, an antenna, and a driver input device (such as a touch screen monitor). This equipment will need to be securely attached and environmentally hardened. There are costs associated with servers and "back office" equipment required to support the AVL. While the data needs for a small fleet may be relatively manageable with a regular desktop computer, the number of vehicles, the speed of updating, the requirements for instantaneous communication (e.g. text messaging), and the amount of data transmitted could require far greater complexity. There are also ongoing costs associated with maintaining the vehicle-based equipment, providing communications, hosting a Web application to display and process information, and similar costs. While AVL can offer significant benefits and these benefits may outweigh costs, the implementing agency should enumerate specific ongoing costs before implementation to ensure that the system can be sustained before the initial investment is made. Ongoing maintenance is a special concern, so designating personnel to handle maintenance or having contract support is vital to ensure that a consistent level of service may be preserved.

Table 2-3: Potential Concerns of AVL

Hardware

- Cost of AVL hardware per vehicle
- Cost of servers and software to support AVL
- Ability of equipment and sensors to hold up in a rugged environment inherent in winter maintenance operations
- Strength and quality of installations for sensors and in-cab equipment
- Sharing of computer terminals with other users and applications
- Cost-effectiveness of different sensor equipment
- Compatibility of new AVL equipment with existing equipment on trucks

Communication

- Availability and cost of AVL communications
- Likelihood of communication system to become outdated
- Update speed of system
- Speed of messaging system
- Reliability of Internet hosting service

Personnel

- Training for efficient use of new technology
- Willingness to use new technology
- Concern over "Big Brother"-type monitoring
- Assignment of AVL maintenance duties

Other

- Accuracy and reliability of information from system
- Public awareness of web site tied to AVL system

Providing real-time communications, beyond simply the cost of communications, is also a concern. If the agency desires to have updated information on vehicles every 15 minutes, for example, this will require a significant amount of communication coverage and will likely not be fully realizable when the communications infrastructure is underdeveloped or there are significant topographic challenges. The benefits of providing full coverage with predictable updating frequencies need to be weighed against the costs of providing that. This is discussed further in section 3.3.

There are significant concerns from a personnel perspective as well. AVL may change a transportation agency's winter maintenance practices – for example, a plow driver may use a touch screen display to indicate road conditions as opposed to talking to a supervisor by radio (with the associated manual data entry) later. Some agencies have allowed for text messaging capabilities as a supplement to or replacement of radio communications to improve efficiency; agency case studies have indicated limited success with these. There could be concerns about intrusiveness of the technology – i.e. the "Big Brother" idea.

Finally, if the AVL is used in relation to traveler information or tort/liability, it is important for the system to have a high standard of reliability and accuracy. This may be especially affected by time delays in transmitting or receiving communications because of drops in coverage or connection speed. As travelers become aware of this information being available, there will also be increased expectations regarding data timeliness and accuracy; thus, the transportation agency needs to be prepared to manage or meet these expectations.

3. AGENCY NEEDS

Over the years, personnel at the Montana Department of Transportation (MDT)'s maintenance division have become acquainted with the potential applicability of AVL to winter maintenance operations in Montana. This chapter summarizes the goals that have been identified for AVL.

3.1. MDT Goals

There are several factors that are driving MDT's interest in automatic vehicle location; these are discussed in this section.

- Traveler Information. During the winter months, MDT sees value in having real-time information about the progress of snow plows in clearing and treating roads. A vehicle may be equipped with sensors that can automatically communicate information on the vehicle's status so that the public can see, for example, how recently a road was plowed. Sensors could include whether the plow is raised or lowered, whether chemicals are being used, pavement temperature and friction, and other data. This information can be updated in maps on the MDT traveler information Web page. For this information to be of value, real-time communications will be critical (see section 3.3).

  The in-vehicle unit may also allow for keypad entry by the driver to enter the road condition information (e.g. "bare and wet"), or perhaps a plug-in to support a PDA with various data. Any such features would need to be well tested to ensure that they don't interfere with the driver's work load.

- Tort Liability. MDT often faces liability challenges because of claims that MDT vehicles have kicked up rocks that have damaged other vehicles. Having an AVL system with archived data would enable the state to verify that an MDT vehicle was or was not present on a particular stretch of highway when the vehicle damage was said to have occurred.

- Review of Maintenance Activities. The AVL system may help in review of maintenance activities following winter events, to see whether plows are doing the jobs as expected.

- Safety. With real-time tracking information, MDT could receive earlier notification when an MDT vehicle is stopped where it normally wouldn't be, suggesting that it may have been hit, drifted off the road, or otherwise been involved in a safety-related incident.

MDT would like to implement the technology on a pilot test basis, to resolve technical problems, determine actual benefits, and develop an appropriate approach for statewide adoption. The initial focus will be on winter operations, but they may expand this to other maintenance operations (e.g. striping) in the future. During the pilot test, it is also likely that MDT personnel may find additional benefits to the technology that help to expand the goals of using this technology.

3.2. Vehicle Inventory

MDT eventually hopes to deploy AVL on all of its maintenance vehicles, provided that the pilot test is successful and that funding is available. For the pilot test, the chief of MDT's Equipment Program said that vehicles could be moved to facilitate an optimal test. For reference, Table 3-1 lists the number of vehicles based at each shop and section in MDT. These numbers may change slightly before the 2005-06 winter.

Table 3-1: Vehicle Inventory by Shop/Section

Missoula Shop	**51**	**Butte Shop**	**57**	**Great Falls Shop**	**39**	**Wolf Point Shop**	**28**
Missoula	4	Butte	6	Great Falls East	6	Wolf Point	6
Seeley Lake	5	Bernice	4	Fort Benton	4	Culbertson	5
Clinton	3	Boulder	5	Belt	3	Plentywood	4
Drummond	4	Helena	9	Neihart	1	Glasgow	4
Phillipsburg	3	Whitehall	5	Cascade	4	Malta	4
Lolo Pass	2	Twin Bridges	3	Wolf Creek	4	Opheim	2
Lolo South	3	Dillon	3	Rogers Pass	2	Scobey	3
Hamilton	4	Lima	3	Lincoln	3	**Miles City Shop**	**25**
Lost Trail	3	Divide	3	Sun River	3	Miles City	7
Evaro	2	Wisdom	3	Augusta	2	Fiddleback	1
Alberton	2	Anaconda	3	Choteau	2	Broadus	4
Superior	2	Deer Lodge	5	Dutton	5	Forsyth	5
Saltese	5	McDonald Pass	5	**Havre Shop**	**36**	Ashland	4
Ravalli	2	**Bozeman Shop**	**41**	Havre	7	Jordan	3
Ronan	2	Bozeman	9	Harlem	4	Colstrip	1
Plains	2	Livingston	5	Big Sandy	2	**Billings Shop**	**41**
Thompson Falls	2	Wht Slphr Sprngs	5	Chester	3	Lodge Grass	6
St. Regis	1	Wilsall	1	Shelby	5	Billings	5
Kalispell Shop	**43**	Carbella	2	Dupuyer	2	Billings Airport	3
Kalispell	6	Big Sky/Gateway	4	Conrad	4	Custer	4
Columbia Falls	3	Duck Creek	4	Cut Bank	3	Hardin	3
West Glacier	3	Ennis	2	Browning	3	Busby	2
East Glacier	3	Harrison	2	St Marys	1	Laurel	3
Bigfork	3	Three Forks	3	Sunburst	2	Bridger	2
Swan Lake	2	Townsend	3	**Glendive Shop**	**25**	Red Lodge	4
Polson	2	Deep Creek	1	Sidney	4	Columbus	3
Rollins	2			Circle	3	Big Timber	6
Hot Springs	2			Flowing Wells	2	**Lewistown Shop**	**21**
Marion	1			Richey (Crcl Sat.)	1	Lewistown	5
Crystal Creek	3			Wibaux	3	Roy	1
Noxon	2			Terry	3	Mobridge	2
Whitefish	3			Glendive	6	Grass Range	2
Eureka	2			Baker	3	Winnett	1
Libby	4					Roundup	3
Troy	2					Ryegate	1
						Harlowton	2
						Standford	4

MDT's current vehicle inventory includes a few newer trucks in each region that already contain road/air temperature sensors and computerized spreader controllers (Force America and Monroe) that are compatible with many of the AVL systems.

3.3. Communications

One critical element in supporting AVL is communications infrastructure. When AVL is used to provide traveler information or to assist with management of winter events, real-time communications is vital. This means that vehicles must be able to transmit information on a regular basis back to a central server where the data is processed. If AVL is used primarily toward monitoring and post-storm analysis activities, real-time information will be less critical. Under this type of model, information could be downloaded at maintenance sections at the end of a vehicle's patrol.

With MDT's interest in real-time applications, the focus of this section will be on comparing various data transmission methods that may be used to support AVL.

3.3.1. Radio

MDT's current radio communications systems aren't set up for data transmission. Piggybacking data on the current voice channel is an option that some agencies have used, but it has the potential for safety issues. The channel would become more and more congested as more trucks were added to the system, possibly interfering with voice traffic and blocking emergency calls.

Another option is to add a second radio to the truck that uses a different channel that is solely used for the AVL system. Montana's radio system depends on remote towers that use repeaters and other methods to get radio traffic back to base. Adding another channel would require a complicated process of adding more equipment at not only the base, but also at the tower sites. The cost and time required for adding the additional equipment would be prohibitive for a pilot test.

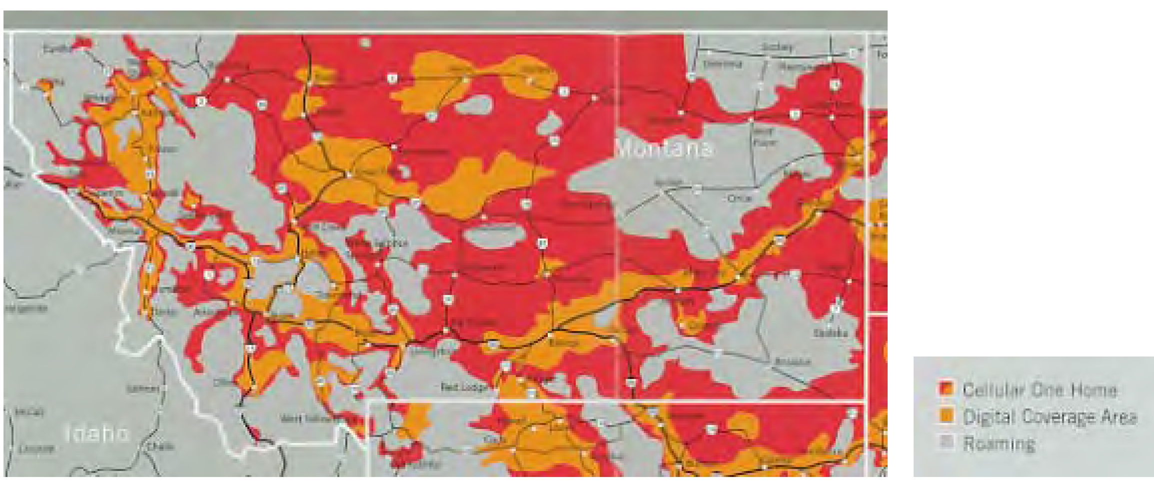
Montana Highway Patrol is currently working on a data transmission project using microwave communication that is still in its infancy at this time. This communication method could possibly be an option in a few years when the system is completed. Radio communications would be preferable in that the only costs involved would be the initial equipment, set-up, and maintenance costs. A monthly service subscription would not be needed.

3.3.2. Cellular

Cellular communications is an attractive communications alternative, because it is widely used and can take advantage of a variety of off-the-shelf technology and support options. Of special concern, however, is the extent of cellular coverage. Coverage maps for digital and analog coverage for Verizon and CellularOne, two major carriers in Montana, are shown in Figure 3-1 and Figure 3-2, respectively.

(Source: http://www.verizonwireless.com)

Figure 3-1: Map of Cellular Coverage (Verizon)



(Source: http://www.cellularonewest.com/)

Figure 3-2: Map of Cellular Coverage (Cellular One)

Montana's cellular coverage is less than ideal for AVL systems. The state has fair coverage for analog communications, but digital cellular coverage is spotty. The digital coverage is limited to the larger cities and major highway and interstate corridors. For AVL data communications, a digital cellular network is preferred as it provides a much better data rate. Unfortunately, the limited coverage of digital cellular signals may limit the effectiveness of an AVL system. Data would have to be stored until a digital signal was found. The delay might be too long to realize all the benefits of a real-time AVL system across the state.

It is possible to send data over analog cellular service using a modem. This is similar to a modem used by a home computer to connect to the Internet using a standard phone line. Because the analog cellular connection can have more noise than a wired phone line, the data will transfer at a much slower rate. AVL only needs to send small bursts of data (dependant on the amount of sensors installed), so an analog signal might be adequate.

3.3.3. Satellite

With satellite, lack of coverage wouldn't be a problem, even in the most remote areas of Montana. Anywhere there is an unobstructed view of the sky, a data link connection would be possible. There is only one factor in preventing this method from becoming the ideal solution to data communication across Montana: cost. Connection and airtime charges with a satellite link can be very high. Also, the hardware to connect to the satellites would cost considerably more than the hardware required for standard cellular data communications.

Two vendors offering satellite service are Globalstar (http://www.globalstarusa.com/en/data/) and Iridium (http://www.iridium.com/service/iri_service-detail.asp?serviceid=13). Globalstar is already used heavily for AVL in the commercial trucking industry. Iridium has started offering a new service called Short Burst Data (SBD). This service is designed to efficiently transfer small amounts of data, which is exactly what is required for AVL. Prices of satellite services are decreasing, so this might be a viable option sometime in the future.

4. VENDOR OUTREACH

The research team contacted several vendors of AVL technologies to get a better understanding of current products:

- CompassCom (http://www.compasscom.com/)
- Enterprise Information Solutions, Inc. (http://www.enterinfo.com/)
- Grey Island Systems International Inc. (http://www.interfleet.com/)
- IWAPI (http://www.iwapi.com/)
- Orbital TMS (http://www.tms-online.com/)
- ThomTech Design (http://70.58.239.33/thomtech/)

Some of these vendors provided brochures or marketing materials on their technologies; these are included as Appendix A. After initial contact was made, the vendors received a listing of the benefits and concerns identified in Chapter 3, and were asked to respond regarding their products' ability to meet those benefits or address those concerns. Enterprise Information Solutions (EnterInfo) and IWAPI responded to this inquiry; their detailed responses are included as Appendix B.

The purpose of the vendor outreach was not to develop a short-list of candidate vendors. In fact, at first glance it appears that several vendors may offer solutions that could meet MDT's needs. Moreover, vendors show a willingness to work with another vendor's products. One company uses a card modem to work with different cell phone companies. Another company works with in-vehicle units produced by many manufacturers. There appears to be a significant amount of flexibility, which necessitates clear expectations on how the AVL system should function from the customer's perspective.

Some key considerations appear to be the following:

- Communications. There will be a tradeoff between the frequency at which data needs to be updated and the cost. Higher frequency updates mean transmissions will need to occur in some areas where digital cellular communications is not available and may not be available indefinitely. The ability of in-vehicle units to store data when communication cannot occur appears to be a relatively standard feature; therefore, it is not a concern about lost data but delayed data. Using satellite communication exclusively would avert this difficulty; some vendors offer the ability to switch between cellular and satellite based on coverage availability. There is concern about the cost of satellite communication, however, especially as the frequency of updates increases. It is hoped that the pilot test will establish at some level an optimal frequency of data transmission, which would allow the state to develop more accurate estimates of communications costs under different alternatives.

  With communications, there will also be concerns about the hardware required to support both cellular and satellite communications, and integrating these in a way to save costs.

- Flexibility. A variety of vendors could provide a solution for the pilot test, as well as for the statewide system. All else being equal, it would be easier from a training perspective to utilize the same vendor for both the pilot test and the statewide system. Since it is still unclear what a statewide system might eventually look like – what data may be collected, how the Web interface will integrate with MDT's traveler information Web page, etc. – it is important that the pilot test system include significant flexibility. This would include flexibility in the communications media, in the capacity to integrate with various sensors, in the programmability of an operator input device, and similar factors.

- Server-Side Integration. It will be helpful to develop a framework for how the AVL application should integrate with other databases, servers and applications that MDT already has, as this may affect which vendors would be able to provide a product responsive to MDT's needs. For example, some vendors have proprietary protocols that make it impossible to incorporate their output into a different format.

5. RECOMMENDATIONS FOR PILOT TEST

This technical memorandum has provided background on other transportation agencies' experience with AVL on winter maintenance vehicles, reviewed MDT's goals for an AVL system, briefly discussed vehicle fleet and communications considerations, and then reviewed feedback received from the vendor community.

This chapter concludes the technical memorandum by providing recommendations for the pilot test. The purpose of these recommendations is to help MDT in working with the vendor community to purchase a solution that will work for the pilot test and provide flexibility for future statewide implementation. After presenting a concept of operations that may be used to develop a bid, potential benefits to MDT and an evaluation plan are briefly presented.

5.1. Concept of Operations

As there are numerous vendor approaches which could address MDT's needs, this chapter focuses on defining functional requirements according to the systems engineering process. The systems engineering diagram is shown in Figure 5-1. The first step is to develop a concept of operations, which defines some parameters within which the system is supposed to operate. Upon consensus of a concept of operations, requirements are developed, which drive design. After the system is implemented, testing, verification and systems acceptance procedures are used before considering the system mainstreamed. For the purposes of the pilot test, MDT prefers to use off-the-shelf vendor solutions, and therefore will not be involved with system design. They will, however, be highly involved in developing requirements. These requirements necessitate a thorough understanding of how the AVL system should work.

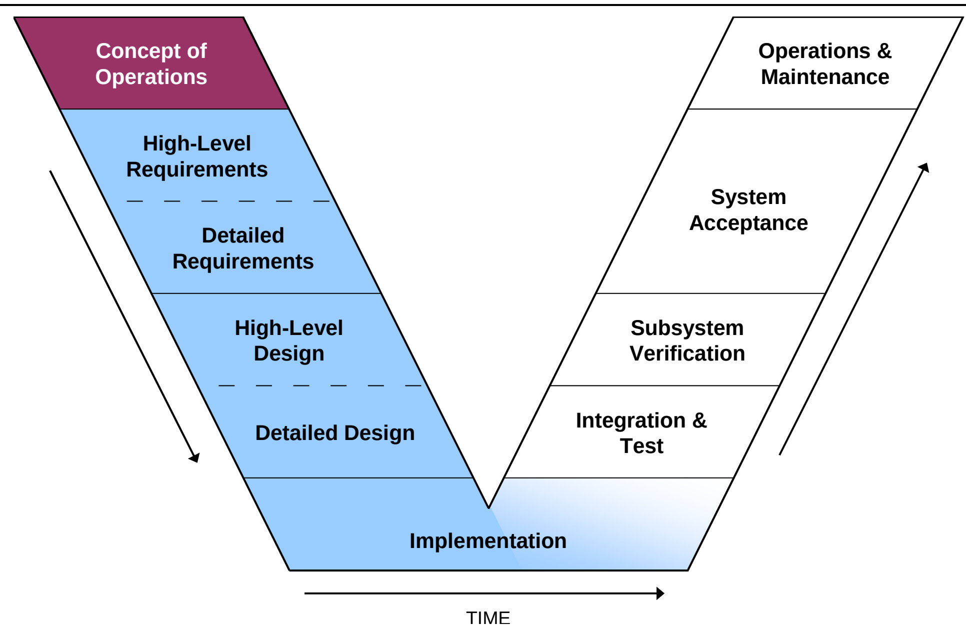


Figure 5-1: Systems Engineering Diagram for AVL Project

Therefore, this section presents a concept of operations. It will include the following considerations, following the outline of the National Highway Institute course on systems engineering (16): stakeholders, deployment, practices and procedures, performance, utilization, effectiveness, life cycle, and environment. Under each category, the concept related to the pilot test will be considered first, followed by the addition of any larger considerations with statewide implementation.

5.1.1. Stakeholders

Pilot Test

- MDT Maintenance Division Headquarters Staff. These staff are responsible for acquiring the equipment from the vendor, entering into contracts to support AVL implementation, and determining the department's future direction with respect to using AVL for maintenance activities.

- MDT Maintenance Division Supervisor / Section Managers / Vehicle Operators. Following Iowa DOT's recommendation, it is proposed that all winter maintenance vehicles in a given shop area and for all of its sections be equipped with AVL for the pilot test. These personnel will be the primary direct users of the technology. The vehicle operators will be exposed to this technology on a daily basis in their normal work activities. They would also be responsible for reporting problems with the AVL system to the section manager or division superintendent.

  The section managers and division superintendent would be able to receive information on vehicle location and other data as transmitted by the vehicles, and use this information at their discretion. Because a goal of the pilot test is that the usefulness of the technology be evaluated, it is important that the shop superintendent (and ideally most, if not all, section managers in the shop) would be receptive to the technology and interested in its potential benefits.

  The division superintendent is ultimately responsible for reporting maintenance problems and seeing that they get remedied during the period of the field test. Repair inquiries would need to be addressed directly to the vendor(s), with notification simultaneously provided to headquarters staff who are tracking this project.

- Vendor. For the pilot test especially, the vendor will be a key stakeholder. The vendor would be expected to ensure that the in-vehicle equipment and attached sensors are installed correctly (either through directly installing them, or training MDT personnel). The vendor would be responsible for ensuring that any software programs they plan to use would integrate easily with existing MDT systems.

  One special consideration on vendors is how they will package a particular service. For example, a communications vendor may provide a one-stop service, where the manufacturer of the in-vehicle units acts as a subcontractor to the communications vendor. As another option, a vendor of AVL equipment may sell that equipment with the promise that it could interface with a variety of communications systems, but require

MDT to arrange for communications services. Regardless of which vendor approach is selected, it is important to clearly delineate responsibilities between MDT and vendor(s), so that technical problems – likely at the outset of any pilot test – can be quickly addressed.

- MDT Personnel. Because of the eventual statewide roll-out of AVL for traveler information, it is important for MDT to get a sense of how the traveler information may be most effectively conveyed, while making sure that the general public does not get a bad impression about the information's quality and accuracy before it has been fully proven. To do this, MDT could establish an internal web site which could first be used by maintenance personnel to make sure the system is accurate and reliable, and then by MDT staff more broadly to see if it works from a traveler information perspective.

Statewide Deployment

In addition to the earlier identified stakeholders, the following stakeholders would be involved in a statewide deployment.

- All MDT Maintenance Field Personnel. Having a successful pilot test may help to alleviate some personnel concerns about the difficulty of using or maintaining the equipment, or about the "Big Brother" concern. Nevertheless, the value of AVL will need to be communicated to these personnel as statewide deployment begins.

  In addition, maintenance of the AVL equipment would be expected to evolve as statewide deployment occurs. Training of staff at a division or section level to do preventative and basic repair maintenance would be essential to ensure that vehicles are able to remain operational with full AVL capabilities.

- MDT. The quality, accuracy, reliability and timeliness of traveler information will affect MDT's reputation as an organization. Successful improvements in traveler information through AVL can have significant benefits for the agency. Conversely, a hastily-implemented feature of dubious accuracy could adversely affect the agency's reputation. In this light, the agency should be conservative in presenting information to the general public, holding back the introduction of new features of AVL-type information until they have been thoroughly tested internally.

- General Public. Traveler information is expected to be a major goal of the AVL system, as the public may use AVL-based data to help them make decisions on where to travel and when. There will be some information that MDT maintenance supervisors need that the public does not need and/or should not see (for example, the identity of specific vehicles as they are making their routes). Therefore, the statewide system will need to have some filtering/cleaning capability to allow certain information to be visible only by certain parties.

- Risk Management. Data regarding vehicle position and activity will need to be archived for some time in the event of tort actions. MDT staff involved in this type of litigation will need to be involved to help determine how much data should be stored for how long and in what format. When a litigation action occurs, they will need to be able to access this information easily. This will also require support from information technology personnel within MDT to identify appropriate server and archival resources.

5.1.2. Deployment

Pilot Test

It is recommended that all vehicles used for winter maintenance within one of MDT's maintenance divisions be instrumented with AVL for the duration of the pilot test. This will ensure that the benefits of fleet-wide coverage may be examined on a small-scale.

At this point, it does not appear that radio is a feasible option for supporting AVL. Therefore, after excluding radio, the pilot test location should include both "good" and "bad" cellular communications environments. Under "good" environments, vehicles would be expected to have digital communications coverage through the majority of a given patrol. Under "bad" environments, digital communications coverage would not be available for most of their route. Having areas with "good" communications allows MDT to see a best-case scenario regarding the potential utility of AVL, and to ensure that the AVL technology itself is functioning acceptably. Including areas with "bad" communications tests the capability of the AVL technology to store information and to switch between cellular and satellite communications if needed. It also can provide valuable information regarding how frequently information needs to be updated to support winter maintenance operations and traveler information purposes.

Statewide

For statewide deployment, it is recommended that the focus first be on winter maintenance applications. Then, as this proves successful, the AVL system should be adaptable toward information on other maintenance activities (e.g. striping).

5.1.3. Practices and Procedures

The general practices and procedures will be similar for the pilot test and statewide implementation.

System Processes

The in-vehicle unit will collect data from sensors on-board the vehicle. This requires seamless integration of the in-vehicle unit with sensors from a variety of manufacturers. This information will be combined with a timestamp generated by the in-vehicle unit and transmitted wirelessly to a remote server. The transmission of this timestamp will be used to fix the vehicle location through the use of GPS.

The in-vehicle unit will be integrated with a driver input device, such as a keypad or touch screen display, such that location information and other types of information are transmitted simultaneously. Any data entry tasks on the driver input device should be as simple as possible so as to protect operator safety. This may include the use of features such as large buttons or audio feedback.

The server will house and process the location and sensor information. The server may be located at MDT or could be provided through the vendor, as long as MDT may have unlimited and immediate access to all data at no additional charge.

The specific sensors to be used initially include sensors for the existing spreader controllers. The in-vehicle unit should be able to easily expand for additional sensors in the future from the perspectives of hardware (i.e. expansion ports), data transmission (i.e. formatting for data that receiver can recognize what data is), and software (i.e. adding new layers in a map based on additional data fields). Additional sensors or data fields that may be useful include a mercury switch for whether the plow is up/down, air temperature, pavement temperature, and salinity measurement.

<u>Human Processes</u>

Human interaction to support AVL functionality is to be minimized. As was mentioned, operator input should be simple. System maintenance requirements, described more in section 5.1.7, should be seasonal.

Users of the data, such as maintenance supervisors or the general public, will likely be accessing the AVL data as one of many simultaneous tasks. For example, the maintenance supervisor could be tracking vehicle activity through an AVL interface and entering maintenance activity through a spreadsheet or database at the same time. Someone planning a trip may be looking at weather forecasts on the Internet while seeing current pavement condition information. Therefore, the AVL interface should be able to seamlessly integrate into MDT's existing traveler information Web page. This could be facilitated through the use of non-proprietary data schemes.

5.1.4. Performance

The in-vehicle unit should transmit location and sensor information every 5 to 15 minutes. The in-vehicle unit should have short-term storage capabilities so that if transmission is not possible (due to a gap in coverage), the information can be transmitted once communication resumes. This next transmittal could occur either immediately when communication is available, or at the next scheduled transmission. The historic information will be invaluable from maintenance and risk management perspectives, so it is important that this information is not lost, and furthermore is transmitted in a fashion to ensure a continuity of data points.

The system should be able to transmit information in "real-time". Instantaneous or simultaneous communication is not necessary; however, it would be desirable for vehicle location and associated sensor information to be available on a Web page within 1 minute of the information leaving the vehicle. This should be sufficient for MDT operations.

The system should be able to identify vehicle location within 5 meters. This will not be sufficient to identify the specific lane of travel for a maintenance vehicle on a multi-lane facility, but would be sufficient to differentiate an interstate from an adjacent frontage road. (On two-lane facilities, tracing the vehicle back using historic data could be used to determine direction of travel.)

5.1.5. Utilization

The utilization environment would be similar for the pilot test and the statewide implementation.

Vehicle Level

At the vehicle level, the in-vehicle unit and any new sensors are being added to the normal task load of a vehicle operator. These tasks include those related to driving the vehicle such as steering, accelerating, braking and watching vehicle gauges; operating equipment, such as the plow and spreader; and communicating via radio to other drivers or agencies. In a winter weather event (when AVL would be most valuable), the driver will be engaged in all of these functions simultaneously, with the hope of seeking to clear the pavement as quickly as possible. In some extreme circumstances, drivers may have long working shifts which could impact their ability to process information quickly.

Consequently, it is critical that the AVL system require minimal driver interaction. Once installed, the in-vehicle unit should be able to transmit vehicle location and sensor information without operator intervention. There may be advantages in transmitting other information that cannot be automatically measured while the vehicle is in motion, such as the current road condition or snow depth. For this type of information, the in-vehicle unit should have a simple, easy-to-read keypad or touch screen display that will allow the driver to quickly enter information without needing to divert attention from the roadway. The keypad or display unit should be durable and well-lit. To help the driver keep his/her eyes on the road, the in-vehicle unit could have an audio feedback mechanism indicating the information that was just entered (e.g. “The pavement is bare and dry”).

Text messaging capability would be a simple add-on to the system; however, with data transmissions every 5 to 15 minutes, most drivers would likely prefer to use their radios. This could be useful when there is non-time-sensitive information to be transmitted, such as seeing a section of guardrail needing to be replaced. Therefore, the AVL should be viewed as supplementing the existing radio system.

Remote Level (Management Information Display)

On a real-time basis, MDT personnel should be able to use a Web-based interface to see current vehicle location (with a pop-up window that could provide additional detail on the vehicle), and any sensor or input data as layers on a GIS map which can be selected or de-selected. For example, a map could display the current pavement condition, and then could be changed to display the duration of time since the road was last patrolled/plowed. The user should be able to zoom in to distinguish information by direction on the roadway. The map should be able to display information for the entire maintenance section during the pilot test, and the entire state during final implementation (i.e. seamless across section boundaries). Maps should be displayed in a conventional graphics format, such as .GIF or .JPG.

Remote Level (Public Information Display)

The general public should receive similar information as MDT maintenance management personnel, but the system should be able to sanitize the information to remove data which the public does not need to know (e.g. identification of specific vehicles, spreading rate). For consistency purposes, the information should be able to be displayed in the same district breakdown as other traveler information on MDT's traveler information Web site.

5.1.6. Effectiveness

In general, the AVL system will be effective if its overall benefits outweigh its costs. Effectiveness of the AVL deployment will depend on the impact on stakeholders. First, it is important that vehicle operators see no net additional burden with the equipment. Use of a touchscreen or keypad to provide information would create an additional workload at first, but over time this should become standard practice so as to not seem burdensome. For maintenance managers at the division or section level, AVL should be perceived as improving efficiency in several areas, such as data collection and processing, supporting real-time decision-making on winter maintenance, use of materials, and assisting in expediting maintenance activities. For risk management professionals, the AVL must have sufficient accuracy that its data are defensible in future litigation actions. For the general public, AVL will be effective if it provides new information that helps travelers make more informed travel decisions, improving safety, reducing delay, and enhancing comfort, convenience and customer satisfaction. Prior to the pilot test, however, it is unclear the level of any of these benefits which should be expected before the system is deemed to be effective.

5.1.7. Life Cycle

The in-vehicle units should last for a minimum of five years. Maintenance requirements for the AVL system should be designed to be minimal, so as to not divert resources from actual road maintenance activities. On-board sensors should be inspected and tested annually. All connections should be cleaned, inspected and tested annually. To be conservative, given the harsh environment in which the sensors will be used, it should be assumed that sensors will need to be replaced every other year.

If vendor-developed software is necessary in order to be able to access and process the vehicle data, the vendor should provide software upgrades and support through the life of the in-vehicle units.

There are several ways to simplify maintenance. In-vehicle units should use exchangeable components (for example, off-the-shelf flash memory) to facilitate repairs. It should be possible to exchange in-vehicle units with minimal testing and set-up, to allow for diagnostics and repair of a malfunctioning unit, without adversely affecting level of maintenance service. The use of moving parts in sensors should be minimized.

5.1.8. Environment

The environmental requirements should be similar for the pilot test and statewide implementation.

At the vehicle level, the in-vehicle unit will be contained within the cab of the maintenance vehicle, and should be relatively sheltered from extreme environmental conditions with the possible exception of vibration. The system will be used during winter maintenance operations, which may occur at any time of day or night, any day of the week. Any in-vehicle display, such as a touch screen display, will need to have dimming capabilities to ensure that the driver can view the display at all times.

The system will also involve components outside of the cab of the vehicle. Sensors collecting data will need to be appropriately environmentally hardened and tested. The antenna transmitting information will be exposed to the environment, including wind, moisture, road grime, and extreme temperatures. The antenna may be mounted on the roof of the cab, or perhaps mounted on a vehicle mirror. The sensors and antenna equipment should be able to withstand temperatures to -40° F, along with exposure to chemicals, water and road grime. The sensors and antenna should be able to remain on the vehicle when the vehicle is being normally washed and cleaned without the need for reinstallation or adjustment.

For the pilot test, effort should be made to minimize permanent modifications to the maintenance vehicles. This means that care should be exercised regarding drilling holes in the cab or dashboard area to mount the in-vehicle unit or install sensors. However, based on the experience of other transportation agencies, it needs to be recognized that the vehicles operate in a rugged environment with significant vibration; therefore, all installed equipment needs to be well-protected and well secured. For statewide implementation, vehicle modification is not as important, except as in-vehicle units or sensor technologies are upgraded.

The in-vehicle unit and all sensors should run off the vehicle’s power. Finally, vehicles will be operating in environments were communications availability will vary. In some cases, digital cellular coverage will be available; in others, there may be either analog or no coverage at all. Satellite coverage is assumed to be ubiquitous. The specific communication method will depend upon MDT’s specific goals. If flawless, regular communication is deemed essential, then either a satellite-only or hybrid digital cellular-satellite method is recommended. If drops in coverage are acceptable, digital cellular alone would likely be sufficient.

Usage of AVL at the remove level, for information or management purposes, has no special environmental considerations.

5.1.9. Summary

The ideas presented in the concept of operations were synthesized in the form of some draft requirements, as shown in Table 5-1. These requirements are not sufficient for technology procurement, but reflect the ideas contained in the concept of operations.

Table 5-1: Recommendations for AVL Deployment

1. Deployment	
1.1.	The vendor shall provide a minimum of one in-vehicle unit and operator input device per included MDT maintenance vehicle, along with an appropriate percentage of spares based on expected time to failure and the need to maintain a consistent level of service.
1.2.	The vehicles shall be able to use the AVL equipment anywhere on the state highway system within the state of Montana, although wireless communications may not always be available.
2. In-Vehicle Unit	
2.1.	The in-vehicle unit shall transmit a timestamp with which a location is uniquely specified.
2.2.	The in-vehicle unit shall send data at regular intervals, with a minimum frequency of once every 15 minutes when wireless communications are available. These intervals shall be specifiable by the user.
2.3.	The in-vehicle unit shall store observations for up to 8 hours when communications are not available. When wireless communications are restored, the in-vehicle unit shall transmit this data in such a fashion that it will be received accurately, with a clear indication of chronological order.
2.4.	The location determined by the in-vehicle unit shall have an accuracy of ± 15 feet (± 5 meters).
2.5.	The in-vehicle unit shall transmit information from the operator input device simultaneously with the timestamp.
2.6.	The in-vehicle unit shall transmit information from all integrated sensors simultaneously with transmission of the time stamp.
2.7.	The in-vehicle unit shall have external ports using plug-in or twist-in jacks for accepting data from sensors.
2.8.	The external ports shall be expandable to allow input from a minimum of eight different sensors.
2.9.	The in-vehicle unit shall transmit data using protocols which seek to minimize communications costs.
2.10.	The in-vehicle unit shall run without needing to be reset for a minimum of 24 hours.
2.11.	The in-vehicle unit shall be able to be reset without special training or equipment.
2.12.	In-vehicle units shall be exchangeable between vehicles with minimal re-programming and downtime.
2.13.	Spare parts to replace key components in the in-vehicle units shall be available from a minimum of two vendors.
2.14.	The in-vehicle unit shall be able to be firmly mounted within the vehicle cab, so as to not be susceptible to excessive vibration or harsh environmental conditions.
2.15.	The in-vehicle unit shall run off the vehicle's power system.
2.16.	The in-vehicle unit shall include documented procedures for preventative maintenance; these maintenance activities should be required to occur no more than once per year.
2.17.	Preventative maintenance activities shall require no specialized equipment and minimal training.
2.18.	The in-vehicle unit shall have self-diagnostic capabilities which will facilitate in troubleshooting maintenance needs.

Table 5-1: Recommendations for AVL Deployment (cont.)

3.	**Operator Input Device**
3.1.	The operator input device shall consist of a keypad with buttons or a touchscreen interface with its screen segmented into input zones similar to a keypad.
3.2.	Each button on the keypad or touchscreen shall have a surface area at least twice that of a key on a conventional computer keyboard.
3.3.	The operator input device shall be able to be located in the cab so that a vehicle operator will be able to input information from a normal driving position, and without compromising the visibility of the roadway or the visibility or utility of any other sensors or gauges in the cab.
3.4.	The operator input device shall have variable internal lighting so as to be easily visible during day and night driving conditions without distracting the vehicle operator.
3.5.	The operator input device shall provide clear feedback (audio or visual) to indicate to the vehicle operator the input most recently received and/or current settings that would be transmitted with the next timestamp (e.g. plow is lowered).
3.6.	The operator input device shall be programmable to include specific preset messages. These messages may include text messages, or codes related to pavement condition, snow depth, plow status, and similar factors.
3.7.	The operator input device shall include the ability for the operator to transmit communication instantaneously, as opposed to waiting until the next normal transmission time.
4.	**Communications**
4.1.	The in-vehicle unit shall transmit data wirelessly.
4.2.	The in-vehicle unit shall be able to send data at preset frequencies, with a minimum frequency of every 15 minutes.
4.3.	The in-vehicle unit shall be able to use radio, digital cellular or satellite communications.
4.4.	The in-vehicle unit shall permit MDT to select its own communications carrier – either private-sector or public-sector.
4.5.	The in-vehicle unit shall transmit data at such a speed that, for a simple data load (i.e. no customized text messages, no video or audio feed) the data will be successfully received by the server and posted on the Web interface (see Software section) within 1 minute.
5.	**Antenna**
5.1.	The antenna shall be able to be mounted firmly on the vehicle, on the roof of the cab, on the mirror, or similar parts.
5.2.	The antenna shall be able to withstand extreme cold temperatures (-40° F) and high wind speeds (up to 100 mph) with no loss of function.
5.3.	The antenna shall operate without failure for a minimum of five years.
6.	**Sensors**
6.1.	The vendor shall, at a minimum, provide one in-person training session on-site regarding how off-the-shelf sensors can be integrated with the system, and their operation can be verified.
6.2.	The AVL system shall be able to accept data from MDT's existing spreader controllers.
6.3.	The AVL system shall be programmable to accept input from sensors provided by the vendor.
6.4.	The AVL system shall be programmable or amendable to accept input from sensors provided by MDT or third parties.
6.5.	The sensors shall be connected to the in-vehicle unit through hard-wire connections.

Table 5-1: Recommendations for AVL Deployment (cont.)

7.	**Server**
	Note: The server refers to one or more computers which act together as a single system to support the AVL project. The server will not necessarily be dedicated to AVL applications.
7.1.	The server shall receive information from all MDT maintenance vehicles equipped with AVL.
7.2.	The server shall add a timestamp when it receives information from a vehicle.
7.3.	The server shall identify the vehicle from which every transmission was received.
7.4.	The server shall collect all information transmitted by each in-vehicle unit.
7.5.	The server shall be able to archive all AVL data for a duration to be determined by MDT risk management personnel.
7.6.	The server shall store information for real-time use for maintenance management and traveler information purposes, including ready access to data collected within the previous 24 hours (to allow for replaying of recent truck activity).
8.	**Data Format**
8.1.	All system data shall be made available in a non-proprietary format, such as XML.
9.	**Software (Data Collection)**
9.1.	The vendor shall provide software which interprets and translates data received from each in-vehicle unit.
9.2.	This software shall produce, as a minimum, a record for each vehicle-transmitted timestamp indicating vehicle identification, timestamp of transmission, timestamp of receipt, any other sensor inputs, and input from the operator input device.
9.3.	This software shall clean all data received so that a chronological progression of timestamps for each vehicle is clearly discernable.
10.	**Software (Mapping and Analysis)**
10.1.	The vendor shall provide software which maps data collected from the AVL system on a real-time basis.
10.2.	This software's maps shall use layers that allow the user to choose which information is displayed.
10.3.	This software shall use a Web interface.
10.4.	This software shall have security features that allow certain users to be restricted as to which information they may view.
10.5.	This software shall display current information on a specific vehicle, including vehicle identification, estimated speed, data from on-board sensors, and operator input when that vehicle is selected or highlighted by the user.
10.6.	This software shall be capable of displaying the current value of a specific attribute for all displayed highways simultaneously (for example, most recent pavement condition).
10.7.	This software shall be capable of calculating and displaying the time since a certain maintenance activity occurred (for example, time since road was last plowed).
10.8.	This software shall use the state of Montana as a base map, with smaller maps being available for each MDT District.
10.9.	This software shall allow users, with proper permission, to zoom in for a closer examination of specific highway segments.
10.10.	The software's maps shall be capable of showing all state-maintained highways. The maps shall be customizable to allow different highways to be visible on different views (for example, showing lower traffic secondary routes only on highest zoom settings).

Table 5-1: Recommendations for AVL Deployment (cont.)

10.11.	The software's maps shall be in a conventional computer graphics format, such as but not limited to GIF or JPG.
10.12.	The software shall be capable of determining vehicle direction and speed based on reviewing recent data.
10.13.	The vendor shall provide support for the software for up to five years after its purchase. If the vendor elects to not support that software during those five years, the vendor shall provide MDT with free software upgrades. If the upgraded software requires modifications to the AVL hardware, the vendor shall supply at no charge sufficient hardware upgrades to ensure that the system at least maintains the functionality it had before the upgrade.
11. Vendor Support	
11.1.	The vendor shall provide one on-site, in-person training session on preventative maintenance and basic repairs of the in-vehicle units, antennas, and any vendor-furnished sensors.
11.2.	The vendor shall provide one on-site, in-person training session on how to use all vendor-furnished software.
11.3.	The vendor shall provide manuals and documentation for all hardware and software. Two copies of paper documentation shall be provided to MDT's maintenance headquarters, two copies to each maintenance division office using AVL, and one copy to each maintenance section using AVL.
11.4.	The vendor shall provide support via telephone and e-mail for unusual maintenance problems with the AVL system hardware or software. The vendor shall respond to support requests within 24 hours.
11.5.	The vendor shall provide single point-of-contact technical support for the entire AVL system, with the exception of non-vendor-furnished sensors and communications (if MDT chooses its own communications provider).
11.6.	During the pilot test, from the installation of the equipment to the conclusion of using the AVL for winter maintenance after the winter season, the vendor shall call the MDT maintenance division field staff person responsible for administering the field test monthly to ensure that the system is working acceptably. The vendor shall respond to any maintenance requests, but is not required to respond to requests for additional functionality.
11.7.	The vendor shall have a track record of a minimum of one customer who has purchased AVL equipment for winter maintenance or highway maintenance activities through the vendor. The vendor shall provide the agency, a contact person, telephone number and e-mail address as a reference.

5.2. Evaluation

As MDT implements a pilot test of AVL, evaluation is a critical component. Evaluation can give MDT methods for objectively assessing to what extent the technology has been beneficial or not, in what areas the technology has or has not met expectations, and what modifications would be necessary or desirable before statewide deployment. It is important to consider evaluation before the pilot test commences, to ensure that all necessary data can be collected.

This section proposes an evaluation plan for the AVL pilot test. The plan is presented from a top-down approach: identifying the system goals, developing objectives and measures of effectiveness associated with those goals, determining data sources required to quantify the measures of effectiveness, and then developing a brief data collection plan for collecting that data. This plan is presented as a proposal, and will need to be finalized in conjunction with MDT personnel who would be highly involved in ensuring its successful implementation.

5.2.1. Goals and Objectives

The primary goal of the AVL pilot project is to demonstrate that AVL is technically feasible in Montana and is beneficial for winter maintenance activities. Benefits that would be expected during the pilot test include the following:

- AVL should provide accurate and reliable data that can improve traveler information.
- AVL should archive data that could be used for risk management or tort liability.
- AVL should improve the efficiency of winter maintenance operations.
- The AVL vendor should provide a reasonable approach for statewide implementation.

Because AVL has not been used in winter maintenance in Montana previously, other benefits or concerns may be found in executing the pilot test; these should be noted in final documentation of the evaluation.

5.2.2. Measures of Effectiveness and Data Sources

Table 5-2 presents several measures of effectiveness and related data sources that may be used for evaluating the pilot test. In examining this table, it is clear that the vast majority of data is subjective, relying on the judgments of personnel at various levels within MDT. This is appropriate for a pilot test for a couple of reasons. First, a full benefit-cost scenario of AVL would be practical only when MDT personnel have developed an understanding of the potential benefits of AVL and have exhausted its capabilities; this would be unlikely in a short duration pilot test. Second, the department has expressed the belief that the benefits of AVL will outweigh its costs and are planning to proceed with statewide implementation provided the pilot test is successful and funding is available. The evaluation needs only to provide information that would help MDT to confirm that the technology is reasonably worthwhile, and to help “tweak” the system to make it better on a statewide implementation.

5.2.3. Evaluation Plan

As is shown in Table 5-2, most of the data required for the evaluation of the pilot test will be collected through interviews or surveys of MDT personnel at various levels. Vehicle operators can provide a ground-level assessment of whether the technology is easy-to-use or in any way interferes with maintenance operations. Section supervisors will have familiarity with maintenance challenges, as well as the potential utility of the data. Information technology (IT) staff can provide valuable insight regarding how well the technology could integrate into existing MDT processes and databases. Risk management personnel could provide some input regarding the value of the information for their purposes. Finally, it would be important to have a perspective on the value of the traveler information. This could be done through encouraging MDT employees in the pilot test area to look at an internal Web page where AVL data is displayed, and then provide their feedback through a Web survey.

Table 5-2: Proposed Measures of Effectiveness and Data Sources for AVL Evaluation

Objective	Measure of Effectiveness	Data Source
Provide accurate and reliable data that can improve traveler information	The data regarding pavement conditions is accurate, timely and reliable	Interviews of MDT staff in pilot test area
	The interface for traveler information integrates with MDT's existing web page	Interviews of MDT staff in pilot test area
	The interface for traveler information is easy-to-use	Interviews of MDT staff in pilot test area
	The data regarding maintenance vehicle activity is accurate, timely and reliable	Interviews of MDT section supervisors
	Data is timestamped and stored according to MDT requirements	Interview with MDT information technology (IT) personnel
Archive data that could be used for risk management or tort liability	Data is stored in an easy-to-access format	Interview with MDT IT and/or risk management personnel
	Data has sufficient accuracy and reliability to be defensible in tort claims	Interview with MDT risk management personnel
Improve the efficiency of winter maintenance operations	The AVL system does not create a significant additional workload on vehicle operators	Surveys of vehicle operators
	Section supervisors find value in the new information available through AVL	Interviews of MDT section supervisors
	The AVL system offers opportunities to streamline data collection (e.g. pavement conditions)	Interviews of MDT section supervisors
	The AVL system offers valuable opportunities to expand data collection capabilities	Surveys of vehicle operators and interviews of MDT section supervisors
	The AVL technology is reliable and relatively maintenance-free	Surveys of vehicle operators and interviews of MDT section supervisors
	The sensors are reliable and relatively maintenance-free	Surveys of vehicle operators and interviews of MDT section supervisors
Provide a reasonable approach for statewide implementation	Communication speed is acceptable in "good" and "bad" wireless environments	Comparison of transmission and receipt timestamps Interviews of MDT section supervisors
	Vendor technical support has been acceptable.	Interviews of MDT section supervisors
	Software and database formats are compatible with other MDT applications	Interview with MDT IT personnel

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APPENDIX A: VENDOR LITERATURE

The following vendors are included in this appendix:

- CompassCom
- EnterInfo
- IWAPA
- ThomTech

CompassLDE™

Products for Automatic Vehicle Location and Mobile Asset Tracking

Location Data Engine - Universal AVL & Mobile Asset Tracking Server Software

CompassLDE is an universal AVL and Mobile Asset Tracking Server software that simultaneously receives vehicle location and status data for multiple fleets over different wireless communication networks. CompassLDE can communicate with a variety of standard in-vehicle AVL equipment, CompassCom software clients, 3rd party software applications, and computer aided dispatch systems. Data is archived and served in real-time to clients via the Internet or intranet using standard TCP/IP, UDP and XML protocols.

FEATURES

- Supports most standard GPS devices, sensors, RFID, and wireless communication devices
- Provides position, status and event data (discrete inputs, such as: lights on/off, siren on/off, plow up/down, airbag release, etc.)
- Allows grouping of vehicles and mobile assets by department, agency, etc.
- Allows user to set up vehicle colors based on status and/or discrete inputs, select vehicle icons and customize vehicle titles for display
- Archives all data to a database for replay of mobile asset data and activity report generation
- Contains built-in security to control user access. Built for redundant and self-healing server operations
- Supports mobile and static sensor data transport
- Serves as the data source for CompassCom's suite of client software
- Open architecture and standard API for third-party client and browser-based development
- Supports two-way messaging and statusing
- Scalable to any size
- Integrated message switch
- Scalable by adding hardware and communication bandwidth
- Supports thousands of vehicles

BENEFITS

- Enhances integration of AVL data into third-party Fleet Management Software, Computer Aided Dispatch (CAD), and Enterprise Software Systems
- Enables data sharing and interoperability through a published API among different AVL systems and entities such as Public Works, Public Safety, Law Enforcement, and Emergency Management
- Allows extended geographic coverage without depending on a single communication network
- Flexible architecture provides migration path for future development of in-vehicle hardware and communication protocols
- Enables users to manage and control their own data
- Requires minimal system administration
- Supports multiple communication networks and protocols simultaneously with optimized wireless connection management

MINIMUM SYSTEM REQUIREMENTS

- Microsoft Windows 2000 or 2003 Server
- Microsoft Internet Explorer 6.0
- Pentium 4 1 GHz
- 512+MB of RAM
- 40+ GB Hard Disk Drive (depending on fleet size)
- CD-RW or Tape Drive (recommended for backup)
- License for database software required (Access*, SQL Server**,Oracle*** supported)

INDUSTRIES SERVED

- Law Enforcement
- Fire
- EMS
- Public Works
- Commercial Fleets
- Government Agencies
- Utility Service Fleets
- Emergency Management
- Traffic Operation Centers
- Enterprise Software Solutions
- Mobile Asset Tracking and Location Based Services

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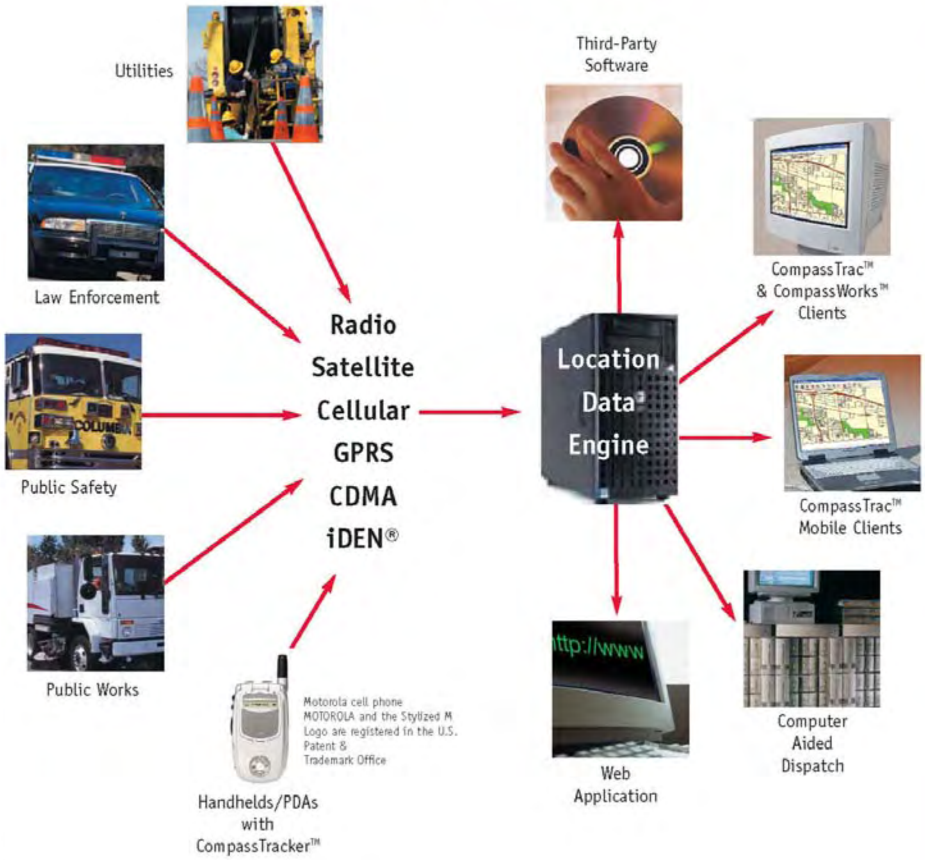
http://www.compasscom.com Latitude 39° 35' 40.1921" N Longitude 104° 48' 58.8105" W

CompassLDE™ Architecture



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***Oracle is a registered trademark of the Oracle Corp.

COMPASSCOM

SOLUTIONS FOR AUTOMATIC VEHICLE LOCATION AND MOBILE ASSET TRACKING

NEXTEL compatible product

The Nextel Compatible Product Logo refers to CompassLDE which has passed the Nextel Compatible Product Program Tests

COMPASSCOM

CompassTrac™ Mobile

Products for Automatic Vehicle Location and Mobile Asset Tracking

Client Software for Mobile Computers

CompassTrac™ Mobile is an in-vehicle software application that tracks and displays vehicle and mobile asset location and status on a mobile computer. The software is ideal for public safety commanders and field managers who need to track their fleet or mobile assets on laptop computers in their vehicles or in the field. As with other CompassCom mobile asset tracking products, CompassTrac Mobile is capable of tracking multiple fleets simultaneously by displaying the information on a mobile device.

FEATURES

- Works on standard laptops or portable computers
- Supports full touch-screen capability
- Communicates via wireless technology
- Tracks vehicles on a digital map
- Displays vehicle position, speed, heading and status
- Locates addresses
- Places map pins at user-definable locations (911 callers, job sites, incidents, etc.)
- Changes map pin title and symbol
- Provides map zoom and pan capabilities
- Provides visible or audible alerts based on discrete inputs
- Uses ESRI® shapefiles for map display
- Connects to multiple CompassLDE servers simultaneously
- Night-view for reduced eye strain
- Displays satellite and aerial imagery in compressed & uncompressed formats
- Offers optional capabilities:
  -Incident location/work order display
  -Two-way text messaging
  -Vehicle route to call location/in-vehicle navigation

BENEFITS

- Commanders can monitor and manage events from their vehicle
- Commander knows precise location and status of vehicles in real-time
- Increases command and control; Commander no longer relies on second-hand information from dispatcher
- Allows dispatching of vehicles to jobs and/or incidents based on their true location and status
- Increases driver safety
- Reduces response times
- Utilizes current investment in GIS data
- Map refreshes faster than web-based applications

MINIMUM SYSTEM REQUIREMENTS

- Microsoft Windows 2000 or XP
- Microsoft Internet Explorer 6.0
- Pentium III 450+ MHz
- 256 MB of RAM (512 MB recommended)
- 20+ GB Hard Drive (depending on map data)

Patent pending

INDUSTRIES SERVED

- Law Enforcement
- Fire
- EMS
- Public Works
- Commercial Fleets
- Government Agencies
- Utility Service Fleets
- Emergency Management
- Mobile Asset Tracking and Location Based Services
- Energy
- Telecom

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COMPASSCOM

CompassWorks™

Products for Automatic Vehicle Location and Mobile Asset Tracking

Client Software for Vehicle Location and Mobile Asset Tracking

CompassWorks is client software for the CompassLDE™ server, optimized for public works, DOTs, municipalities and utility organizations. As the mobile asset tracking component of the AVL system, CompassWorks displays the location and status of mobile assets on a digital map in real-time. CompassWorks has the added ability to create fleet management reports, trace vehicle routes and connect with in-vehicle devices, such as text messaging devices, laptops, and vehicle sensors. CompassWorks can be configured with any ESRI® formatted map data.

FEATURES

- Tracks vehicles, mobile assets and sensor data (SCADA, weather, etc.) on a digital map
- Displays vehicle position, speed, heading and status
- Locates addresses for service calls and incidents
- Places map pins at user-defined locations (call incidents, job sites, service requests, etc.)
- Provides visible or audible alerts based on sensor inputs
- Replays vehicle activity from user-defined date and time
- Comes with an integrated reporting module
- Uses ESRI shapefiles for map display
- Connects to multiple CompassLDE servers simultaneously
- CompassLDE can feed real-time data to third party workflow management software
- Supports two-way text messaging and statusing
- Displays satellite and aerial imagery in compressed & uncompressed formats
- Offers optional capabilities:
  - Custom reports
  - Incident location and computer aided dispatch display interface
  - Vehicle sensor interfaces, including data loggers and spreader/sprayer controllers

BENEFITS

- Displays precise location and status of vehicles and mobile assets in real-time
- Increases command and control
- Monitors employee and contractor performance
- Increases fleet efficiency and reduces costs
- Allows for more efficient dispatch of vehicles and crews to jobs or incidents based on their true location and status
- Increases driver safety
- Reduces response times
- Utilizes current investment in GIS data
- Map display refreshes faster than web-based applications
- Archive records of fleet performance
- Improves customer satisfaction

MINIMUM SYSTEM REQUIREMENTS

- Microsoft Windows 2000 or XP
- Microsoft Internet Explorer 6.0
- Pentium 4.1 GHz
- 256+ MB of RAM (512 MB recommended)
- 20+ GB Hard Disk Drive (depending on map data)
- 17-inch or greater VGA Monitor

INDUSTRIES SERVED

- Public Works
- Commercial Fleets
- Government Agencies
- Utility Service Fleets
- Emergency Management
- DOTs
- Traffic Operations Centers
- Mobile Asset Tracking and Location Based Services
- Energy
- Telecom

Patent pending

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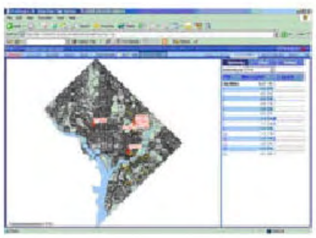
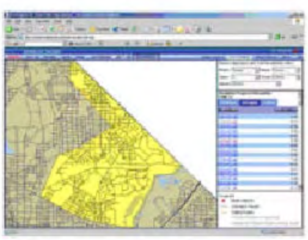
http://www.compasscom.com Latitude 39° 35' 40.1921" N Longitude 104° 48' 58.8105" W

Internet Open to Public



Intranet for Snowplow Management



Vehicle and Snowplow Progress Management

Enterprise Information Solutions, Inc. (EnterInfo) provides real-time snowplow tracking systems for snowplow management operations. The system integrates GIS technology with GPS and wireless communication to create maps and reports that benefit the management, resource assignment, and estimation of the plow and salting operations.

The system works by providing the snow operations management team with truck locations, road treatment activities (i.e. plow, salting, or both), as well as the progress statistics in real-time. The location data and the plow/salting sensor data are wirelessly transmitted from the vehicles automatically with no intervention from the snowplow truck driver. Once the data is transmitted to the database, the Snowplow Tracking Application uses ESRI GIS technology to process the data and produce needed reports and maps.

A tentative list of the system functions include:

Search and Query - Users can search and query by vehicles, plow routes, plow zones, and street names for the location and plow status.

Status Reports – The system provides an overview of plow status and statistics by vehicle plow routes, zones, street names, or times.

Playback and Simulation - Users can playback the archive data to see the progress of the road treatment during specific time periods.

Performance Tracking - Users can track performance on any vehicle in terms of percentage of plow completion and overall percentage completion by route, plow zone, or citywide area.

Role based Application Access - Multiple user classifications can be defined within the system to improve productivity and security. For example users could be setup so that: Only the Administrator can edit the User Account Table to add/remove/edit users. Only the Command Control and Field Commander can reset the citywide street treatment conditions. Only the Field Commander and the Dispatcher can assign vehicles to a Zone.

Snow Event Definition - The system allows the assignment of a snow event category for each street segment. For each snowstorm, a user has the ability to specify the current snow event category. After the type is specified, the street treatment progress percentage will be calculated based on the street category assignment.

Assignment of Vehicle to Zone - The system provides a user interface for dispatchers to assign vehicles to a zone. After the assignment, a user has the option to show only vehicles assigned to a particular zone in the zone information display.

Track Road Segment Treatment History - The system has the ability to display truck ID, treatment type, and time of the last treatment when the user clicks on a road segment.

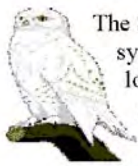
Enterprise Information Solutions, Inc.
9891 Broken Land Parkway, Suite 300 Columbia, MD 21046 (410) 381-7898 www.enterinfo.com

Picture from inside plow

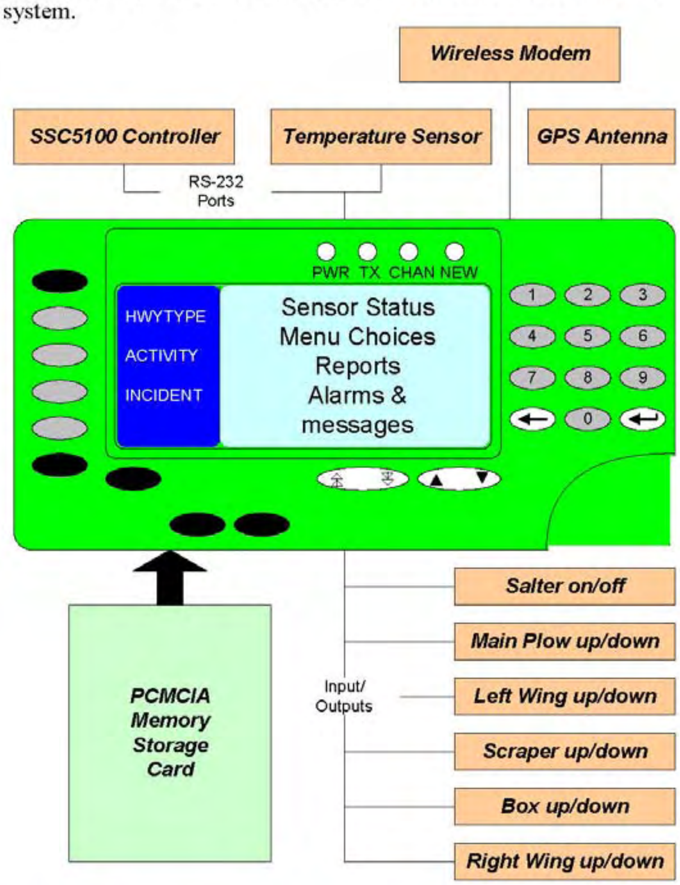
Intelligent Transportation System (ITS) Integration Specialist.

ThomTechDesign™

Snow Owl Passive Data Collection System



The Snow Owl Passive Data Collection System is an event logging and storage system for recording snowplow actions and tagging them with date, time, and location information. The events are stored as data records (each event is one record) on a memory storage card. The card is removed at the end of the day and the data is downloaded into a database application on a Windows based desktop computer. Because data is not actively transmitted using a wireless modem (such as cellular or radio), this system is considered a passive system. ThomTech also provides active systems using a variety of wireless modems for real-time applications and mapping display requirements. The diagram below illustrates our mobile data computer (MDC) and examples of the external sensors that can interface with our system.



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www.thomtechdesign.com

Sensor Interface

The SSC5100 controller provides a series of data fields each time an event occurs, such as turn spreader on/off, change spread rate, hit blast button, etc. The temperature sensor tags events with air and pavement temperature. The input/outputs (I/O) are standard two state voltage threshold devices that indicate movement (up/down) of the active plow devices, such main plow, wings, and scraper. These data fields are also added to the event record. The GPS antenna receives the location signals from the global positioning system (GPS) and sends them to the embedded GPS receiver. This signal provides the date, time, latitude, and longitude data fields for each record. The PCMCIA card is inserted into the card slot on the bottom of the MDC. The PCMCIA card records the events as records composed of several data fields. The data record fields are explained later in this document.

Event Logging:

Events are generated by several methods. The MDC seeks to record changes in snowplow activity and mark these changes (or tag them) with GPS information. An event is generated each time one of the following occurs:

1. An input/output (I/O) changes state (for example the main plow is changed from up to down, underbody blade up/down, salter on/off, etc.).
2. The SSC5100 provides a data set, this occurs if the rate changes, spreader turned on/off, blast button on/off, warning/error message, change for granular to liquid, or prewet on/off.
3. The unit travels 1000 feet or operates for 10 seconds.
4. Manual event is inputted by the operator, change highway type, record an activity, or mark an incident (such as downed light pole, drainage problem, pot hole, etc.).

Technical Specifications:

Supply voltage:	9 - 18 volts
Current consumption:	
• Typical (LCD heater off, medium backlight):	0.22 amps
• Maximum (LCD heater on, full backlight):	1.29 amps
Temperature range:	
• Operating:	-22 to +149 °F
• Storage:	-22 to +176 °F
Approximate Size (W x D x H):	8.5 x 2 x 3.5 in.
Weight:	1 pound
Interfaces:	2 RS-232, 6 I/Os wireless modem

SnowOwl™ Active Vehicle Tracking

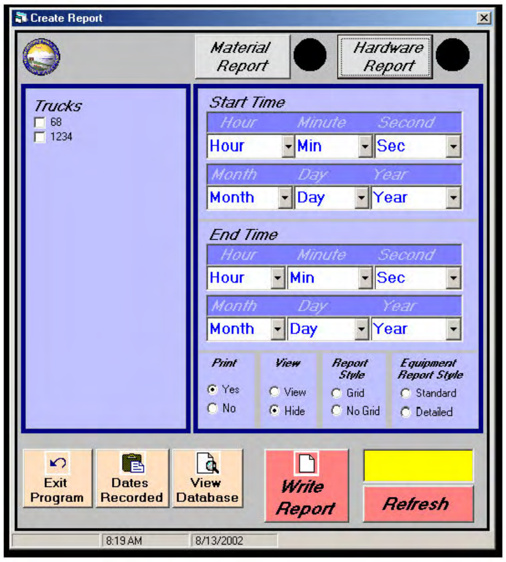
SnowOwl™ Active Vehicle Tracking

The SnowOwl™ active data collection system is an event logging and storage system for recording vehicle actions and tagging them with date, time, and location information. Events are transmitted in real-time using a wireless network to a host-end mapping & reporting application & database.

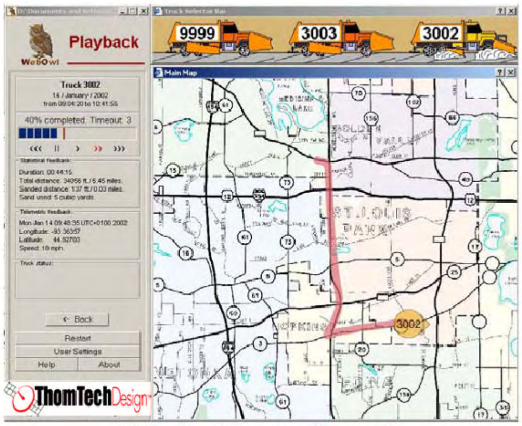
⇒ The concept of knowing "What is going on?" becomes increasingly important as service providers compete for resources, increase service areas, expand customer options, and solve budgetary constraints.

⇒ The requirement to create a virtual picture of system status at a given point in time from remotely collected real time data is crucial.

⇒ These systems provide valuable data points to aid managers, supervisors, and foremen; as well as provide high level data for executive staff to review when making policy, procedure, strategic, and budgetary decisions. The remote collection of data, the transmission of real-time data, and the presentation of gathered data provides the staff with a "situational awareness" of fleet location, driver and vehicle status, and mission progress.



Reporting Software Example



Web Site Mapping Example

We have the best mapping products both client/server based and web enabled designs.

Includes integration of mapping products from Microsoft MapPoint, ESRI ArcView, and Rastrac, & SnowOwl™.

Our sophisticated report generating system prepares standard and customized reports from the automatic vehicle location SnowOwl database (MS Access, SQL Server, Oracle, Foxpro, etc.

We specialize in integrating with your existing network.

ThomTechDesign™ *SnowOwl™ Active Vehicle Tracking*

Event Logging:

Events are generated by several methods. The SnowOwl hardware (consists of wireless modem, GPS receiver, and mobile data terminal) seeks to record changes in vehicle activity and mark these changes (or tag them) with GPS information. An event is generated each time one of the following occurs:

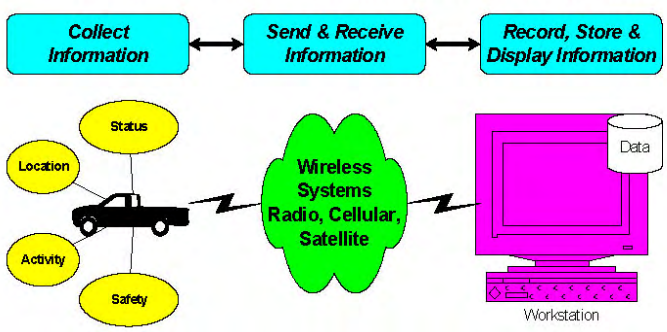
1. Salter/spreader/controller has an event, such as , blast, change rate, add prewet, etc.
2. An Input/Output changes state (e.g. engine temperature, oil pressure, door open, etc.).
3. An external data device reaches a threshold, such as temperature setting.
4. The unit travels 1000 feet or operates for 10 seconds or time and distance set by user.
5. Manual event is inputted by the operator, such as emergency button, lights on/off, etc.

Benefits:

- Optimize Fleet Operations Functions
- Customer Focused & Real-time Situational Awareness for Supervisors
- "Hands Free" data collection feeds existing management and maintenance applications
- Identify Areas where Real-time Remote Data Collection Assists Decision Making
- Employ the Routing & Database Features of GIS, Digital Mapping, Differential GPS
- Shared Dispatching Resources

Features:

- Real-time information for improved decision making
- Recorded information for after action playback and analysis
- Reduce paperwork, one write
- Allow operators to respond/send messages when it is safe or appropriate to do so
- Provides information for verification of route completion



An organized remotely collected data set reflecting:

- preventive maintenance
- operational schedule
- customer support

Is now becoming vital to providing:

- superior levels of service
- protecting operators & motorists
- achieving customer satisfaction

Three Distinct Subsystems Work Together Seamlessly

Not only do we have our own product line, but we also are resellers and offer vehicle tracking products from ***Trimble, Kenwood, Manning Navcomp, Mentor Engineering, Panasonic, and Technocom***. Contact us for more information or a demonstration. Tel: (651) 482-9680.

Email: thomtech@thomtechdesign.com
Address: 3830 Rustic Place, Saint Paul, MN 55126
Web Site: www.thomtechdesign.com

ThomTechDesign™

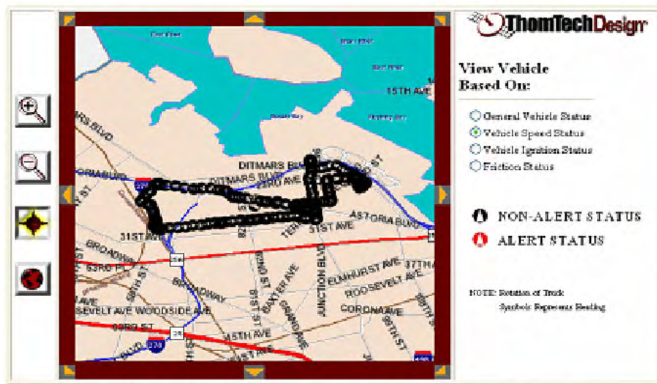
Leader in Mobile Data Collection - GPS/GIS/Sensors
Wireless, Photo, Video- for Public Works & DOTs

WEBOWL – Mapping & Reporting

Display – View – Mobile Data Using your Browser!

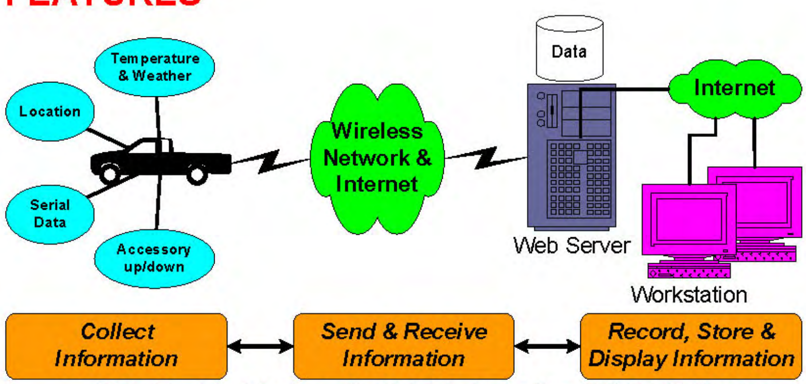
ThomTech offers real solutions for Automatic Vehicle Location & Mobile Data Collection for Public Works, Code Inspectors, and Airports

- "What is going on?" becomes increasingly important as service providers compete for resources, increase service areas, expand customer options, solve budgetary constraints, & **IMPROVE SAFETY**.
- The requirement to create a virtual picture of system status **ON THE WEB** at a given point in time from remotely collected real time data is crucial.
- The need to create or **GENERATE REPORTS** for equipment, material, personnel costs, performance, and usage.



Map Display Provides Real-time Status

FEATURES



Web Enabled Automatic Vehicle Location (WEAVL) System

ThomTech's WEAVL System =
1. Integration with existing computer network software applications.
2. Standardized sensor protocols and polling techniques.
3. Wireless data integration, seamless transition between communications subsystems, GPRS, iDEN, CDMA, WIFI

ADDITIONAL FEATURES

- Add your vehicle fleet to your Wi-Fi network, eliminating costly cellular real-time charges
- Central to the application – DATABASE – records location, sensor status, transmits wirelessly
- Mapping Software, Tracking Tools, & Playback Options - Standalone, Network, or Web Server
- Report generation, data manipulation, archiving, and statistics to make better decisions

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Leader in Mobile Data Collection - GPS/GIS/Sensors
Wireless, Photo, Video- for Public Works & DOTs

WEBOWL – Mapping & Reporting

Display – View – Mobile Data Using your Browser!

WHY THOMTECH DESIGN INC?

- Tracking vehicles since August 1995
- Focus on public works vehicles for state DOTS, cities, and counties.
- Web based and client server host end products.
- In-vehicle options for wireless connectivity, sensors, operator interfaces.
- Located in Saint Paul, MN.
- Concentrate on service oriented, customized, and tailored systems.

Example Photo tagged with Location & Weather

AVAILABLE SENSORS

SALTERS
PLOW ACTIVITY
LOCATION
FRICTION
VISIBILITY
PHOTOS
SURFACE TEMPERATURE
AIR TEMPERATURE
HUMIDITY
BAROMETRIC PRESSURE
& MORE

View all data, mapping, and reports using your web browser - Internet Explorer. Export data to existing legacy systems.

Display real-time location, playback past history, view one, two, a group, or all of your vehicles.

- These systems provide valuable data points to aid managers, supervisors, and foremen; as well as provide high level data for executive staff to review when making policy, procedure, strategic, and budgetary decisions.
- The remote collection of data, the transmission of real-time data, and the presentation of gathered data provides the staff with a “situational awareness” of fleet location, driver and vehicle status, and mission progress.
- Tracking, location, mobile data collection, digital sensors, these types of technology are only valuable if:
  - people understand their use
  - people trust the accuracy
  - people use it

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APPENDIX B: VENDOR RESPONSES TO QUESTIONNAIRE

Benefits	**EnterInfo**	**IWAPI**
Management Benefits		
Ability to map current location of AVL equipped snowplows by management on a computer	Yes	Yes
Ability to map current status of roadways – Plowed/Unplowed/Sanded/Salted	Yes	Yes
Ability to quickly determine the length of time since roads were last plowed or salted by looking at a colored coded map of roadways	Somehow	Yes
Ability to continuously map air and road temperature information to help with salt/sand application decisions	Optional equipment on selected units	Temperature information to be tied together with plowing activities.
Ability to plan redeployment based on mapped information of closest plows in case of mechanical failure of a plow truck	Plow visible on screen; manual dispatch needed	Yes
Ability to determine if drivers have stopped working by lack of plow movement on map	Reports idle plows	Yes
Ability to determine if drivers are off their assigned route from current mapped location	Vehicle track viewable	Yes
History of plow operations kept electronically which can be replayed and reviewed at a later date to analyze and improve efficiency	Yes	Yes
As communication technology progresses, supervisors will be able to monitor snowplow activities on a laptop computer in their vehicle	Yes	Yes
Ability to add new sensor technology later on such as road friction meters and road material freeze point detectors as they are perfected	Yes	Yes
Operator Benefits		
Less radio "chatter" from supervisors asking plow operators about their location	Yes	Yes
Reduce or eliminate field progress reports and timesheets due to information being recorded electronically as activities are in progress	Yes	Absolutely as data is placed into an open format Oracle or SQL format. Driver can enter personnel I.D. on Touch Screen.

Benefits	**EnterInfo**	**IWAPI**
Cost Benefits		
More efficient use of de-icing chemicals due to records of application rates and locations being kept	Management decision	Yes
Improved fuel efficiency due to the ability to determine the closest plow to reassign to a problem area	Yes	Yes
Safety Benefits		
Accident reduction due to more efficient snow removal	Well…	Yes
Accident reduction due to public being able to make informed travel decisions based on condition of roadways	Yes	Yes
Ability of plow operators to report exact locations of accidents through a text message system that relays GPS coordinates	Optional equipment	Yes
Faster response to emergencies due to emergency vehicle route planning based on plowed status of roadways	Yes	Yes
Easily determine closest plow to reassign in order to clear routes for emergency vehicles – YES	Yes	Yes
Other Benefits		
Reduced volume of phone calls concerning road conditions and plowing status due to public's ability to monitor operations on the internet	Yes	Yes
Increased public opinion and trust of plowing operations	Yes	Yes
Ability to have accurate records of the location of plows at points in time as evidence in tort claims	Yes	Yes

Concerns	**EnterInfo**	**IWAPI**
Hardware Concerns		
Cost of AVL hardware	$1K per vehicle including installation	Parts costs - per truck: - IVU (SMD) $1,250 - Monitor 450 - Cables and antennas included in IVU - MDT can do the install under supervision Cost of software: - One time, per truck charge included in IVU above - No middle ware required - No work station charges – end user determines who, and how many, have access. - No additional base software fees for adding more trucks or work stations to the network. Air Card: - Responsibility of end user. Using our carrier contacts, we will work with you to get the best price and ensure compatibility.
Can AVL equipment hold up to vibrations and harsh conditions during plow operations?	Yes	All equipment and sensors have been field tested under actual conditions. Depending upon the application, we hope to recommend sensors that have no moving parts and that can be equipped with TPE Wiring. TPE wiring meets NEMA 6 and IP 68 standards. We will work with you to source the best sensor for the desired information. Sensors are chosen with a background of 30 years experience with the conditions encountered in the Snow & Ice field. We prefer, where possible, to supply sensors with no moving parts.
Will the mounting plates for equipment be strong enough?	Yes	Yes. If appropriate, due to the gauge of sheet metal on new truck cabs, we might recommend backing plates. Individually decided in conjunction with MDT mechanics, once they have the ability to look at the two in-cab components.
Will installations detrimentally modify trucks?	No	No
Will wire connections on plow fail easily due to harsh conditions?	No	External wire and connections will be TPE where possible. TPE wiring meets NEMA 6 and IP 68 standards and will have the appropriate strain relief(s).
Will there be a computer terminal that is used solely for tracking plow operations by supervisors?	As many units on Internet as desired	If you want, there can be a dedicated terminal. However, there are no restrictions on number or location of access points/terminals. You determine where access can occur. There are no additional fees on the number or location of access points/terminals.

Concerns	**EnterInfo**	**IWAPI**
Hardware Concerns (cont.)		
Will the sensors provide useful information? Will the extra sensors on the truck break often?	Optional equipment	We will work with you to source the best sensor for the desired information. Sensors are chosen based on 30 years experience in the Snow & Ice field. Most have no moving parts.
Will the new AVL equipment interface with current temperature sensors and computerized spreaders already on trucks in inventory?	Need more info	Yes. It is our understanding that MDT currently is using both Force America and Monroe spreader controllers. We are familiar with the manufacturers and have interfaced with both those families of controllers as well as Raven liquid controllers. We would need Model numbers to make sure that we have interfaced with the exact Model numbers that you are using. With Controller manufacturer's cooperation (which we have enjoyed in the past), interfacing with a different model from the same supplier should not be an issue. Importantly, if necessary in the interim, the in-cab, touch screen monitor was originally programmed for MDSS use by Colorado DOT and has the ability for the operator to enter application rates, snow conditions, weather, Operator ID, etc…
Communication Concerns		
Cost of AVL communications	$40-60 per month per vehicle during winter season	Our experience indicates that the following rates are good ballparks: - Unlimited monthly $60 - 20 Meg monthly $20 - 2 Meg (not recommended) $10 Repeating, we are more than willing to use our contacts and work with MDT to source the most appropriate plan. However, the state might already have a contract in the desired test area with a wireless provider? Specific to the communication standard to be used, we prefer using TCP/IP which is consistent with the CLARUS NTCIP standard. TCP/IP allows for data receipt and integrity confirmation. We place the data to be transferred in an XML format for transmission. Again, ".xml" is compatible with the CLARUS standard. Please see the attached picture that illustrates our SMD "slot". The slot allows us to mix and match air cards for the proper wireless provider based on geographic coverage in your various areas. Also, the SMD will not be outdated if your carrier(s) abandon a current protocol – CDPD for example. All that is required is to install the proper, new card in the slot and load the supplied connection management software.

Concerns	**EnterInfo**	**IWAPI**
Communication Concerns (cont.)		
AVL communications reliability	Varies by location and provider	This is mainly a question for your local carrier. Please note the following steps that we have already implemented to compensate for the local carrier's inefficiencies: - TCP/IP allows us to verify transmission and receipt of a non-corrupted data stream. If we can't verify, we force a resend until we can verify. We verify each message sent. - "Out of coverage" situations are handled by our SMD being able to "store and forward" approximately 1g of data until a reliable signal is received. Again, the integrity of the data must be verified before the transmission is considered successful.
Likelihood of communication system to become outdated	Supports CDMA 1XRTT and RadioIP	See second response above. The presence of the PCMCIA card slot in our SMD ensures that the hardware will not become unusable. As carriers migrate to new technologies, you will be able to merely replace the air card and install the supplied connection management software.
Update speed of system	???	Determining factor is wireless availability, not the processing power of our 1 gigahertz on-board processor.
Speed of messaging system	Optional equipment near real-time	Same speed as messaging between laptops.
Reliability of internet hosting service	Depends on hosting site or ISP	We recommend not making the data available to the public this year for the following reasons: (1) Driver acceptability (See "Personnel" section following): With only a limited number of trucks, you will be pointing a finger at those drivers which could be detrimental to system acceptance; (2) Expensive public notification process for limited number of vehicles. NOTE: We do suggest & encourage MDT to experiment internally with modifying the database for publication to a select number of MDT employees, thus testing a future public access website. We are not an Internet-based solution. MDT will have the base software physically installed at their site. If you want us to temporarily host the system, we would do so at our site where we have multiple, redundant servers with load balancing and firewall protection built into the system. We encourage installation on MDT server, at which point this question becomes moot.

Concerns	**EnterInfo**	**IWAPI**
Personnel Concerns		
		We are willing to train the appropriate users and trainers. The first three items below are interrelated and are all tied into training and the approach that training takes. IWAPI and Jack Doherty have over 30 years experience in introducing new, useful concepts, strategies and equipment to the Snow & Ice field
“Big Brother” feel to snowplow operators	Yes at first. Okay later after realize the productivity gain.	SEE ABOVE. It will certainly be an issue if the proper training is not carried out. It could possibly be an issue if the drivers are going to be monitored internally IN CONJUCTION WITH having their activities available on the internet – prior to their acceptance of the new system.
Training for efficient use of new technology	Minimal training needed	SEE ABOVE. Definitely. We will work with your personnel to ensure that both the initial training is successful and on-going, follow-up questions and concerns are answered and addressed.
Acceptance of new technology	Yes if it is user-friendly and productive	SEE ABOVE. Supervisor training will be conducted and on-going support is available. Plow Operators will not be called upon to change their existing operations. AVL is automatic with the ignition key. There will always be questions and concerns. Experience tells us that the proper training, coupled with management involvement and explanations, are the best approaches to mitigate isolated objections and concerns.
Assignment of AVL maintenance duties	Yes	If IWAPI hosts the system, we will be performing maintenance of the software. If MDT hosts the system, MDT will, with the cooperation and involvement of IWAPI, perform maintenance. In that case, IWAPI personnel are available for consultation. Sensors and wire connectors (TPE) are chosen for their reliability – References available. Should an issue arise, MDT mechanics would be very capable of resolving. However, as previously stated… “We will work with you to source the best sensor for the desired information. Sensors are chosen with a background of 30 years experience with the conditions encountered in the Snow & Ice field. We prefer, where possible, to supply sensors with no moving parts.”
Other Concerns		
Reliability of information from system	Yes	We utilize TCP/IP and do not recommend UDP for communications from the truck to the base. UDP is unverifiable and, while duplicate messages can be run through a filter, non-sent or missing data cannot be regenerated. TCP/IP enables us to verify coherent receipt of each message. Therefore, the information will be highly accurate and useful.

Concerns	**EnterInfo**	**IWAPI**
Personnel Concerns (cont.)		
Public awareness of web site tied to AVL system	Agency decision	Please recall that we don't recommend publicizing a web site the first year. However, we do recommend laying the internal groundwork for future deployment of this portion of the system – and would be happy to supply IWAPI's "511" experience to assist MDT in developing this feature of the system.