Evaluating the Use of Inertial GPS While Collecting PMS Data

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Alaska 2002 Research

Purpose:

Evaluate the use of an inertial GPS (Global Positioning System) while collecting highway pavement condition data. This effort will compare spatial accuracy and consistency of data collected using a normal GPS (Global Positioning System) having sub meter accuracy to that collected using an inertia l GPS system. The inertial GPS system is comprised of tactical grade inertial sensors, GPS, and azimuth measuring equipment. Better spatial quality of data offers the benefit of cost savings currently incurred when post processing PMS (pavement management system) data and subsequent improved analysis and presentation of pavemen condition.

Executive Summary:

- The inertial GPS system performed very well both integrating with the existing pavement measuring equipment and collecting data where mapping grade GPS generated inconsistent spatial locations of data. The system performed well on very rough roads.
- The use of an inertial GPS system will allow the more rapid delivery of the yearly pavement condition report by reducing time spent manually editing the spatial data.
- Use of this Applanix system during the 2002 annual collection of pavement condition data will provide a complete and accurate map of the paved road system that currently does not exist. This mapped road system will not only benefit pavement management efforts, it will also be used by other DOT and non-DOT groups to integrate their data with that of the highway location e.g. traffic, accidents, storm water features of NPDES, as-built information, document management, asset management, etc.
- Statewide Mapping would have an annual check on the spatial definition of the paved road system to monitor their mapping effort; annual construction changes would be registered.
- This effort points out the need to use GIS technology to integrate the CDS route system with spatial coordinates due to the impact of frequent changes and to provide spatial linkage to all data used in the pavement management system.

Historically pavement management data was presented in a tabular form; however, now decision makers request graphical presentat ions of data, which allows for rapid, accurate decisions. GIS (Geographic Information System) technology allows the integration of much more information with pavement conditions such as programmed projects, traffic volumes, age of the pavement, and any other data collected that is spatially referenced as a GIS layer. The following GIS presentations (Figures 1 through 5) illustrate this.

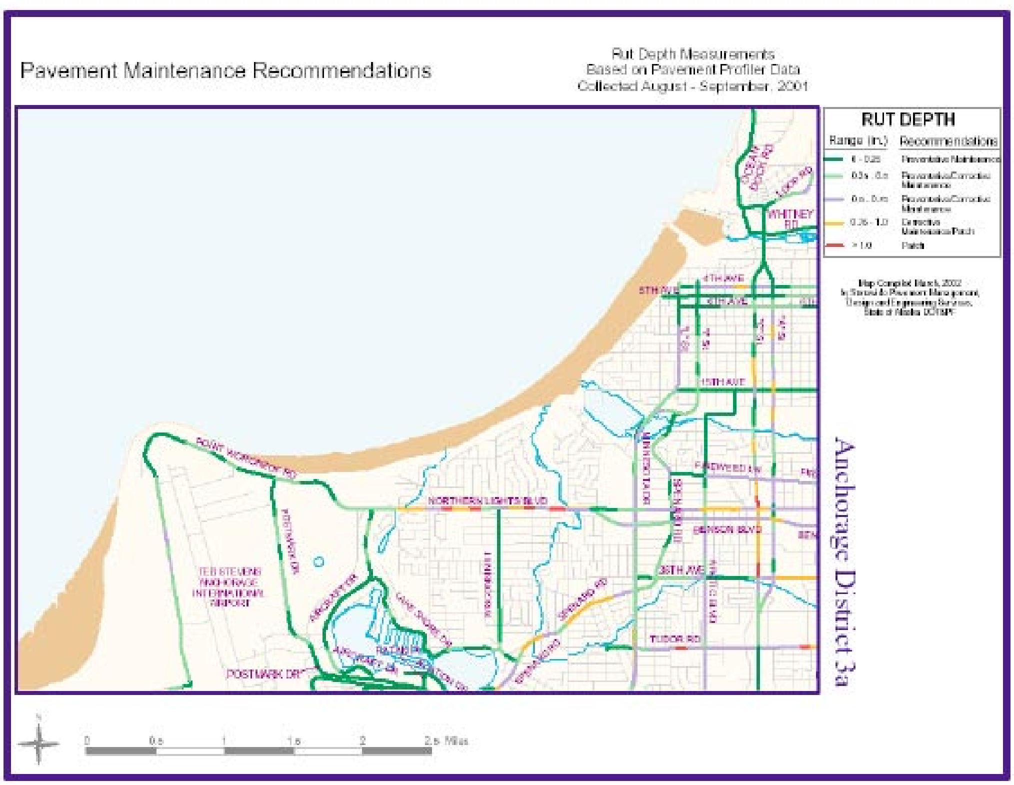

Figure 1: Anchorage District 3A

Figure 2

Figure 3

Figure 4

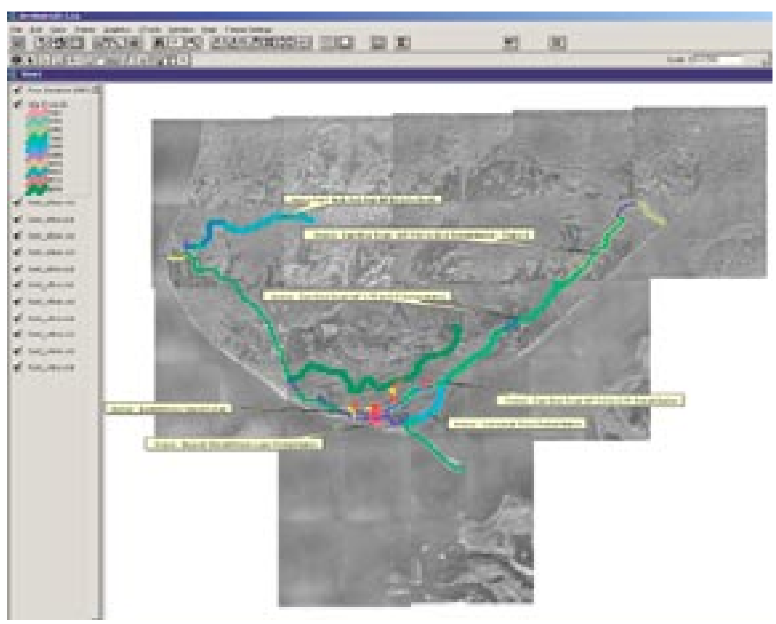

Figure 5

An accurate map of the road is necessary to display pavement condition information, especially when it interacts with other maps or photography. Statewide Mapping is currently producing a map of the roads; however, a complete statewide map of paved roads is not currently available. Statewide Mapping displays only a road centerline and the pavement condition data is displayed on lanes. Normally two lanes are associated with one centerline; therefore, an additional line must be created to display data. (Shown in Figures 6 and 7)

Referencing data along a road is an issue. Data can either be referenced by distance along a CDS route using DMI (distance measuring instrument) or by spatial location as defined by GPS. One of the problems with a distance reference system is that a fixed point along the road, such as a milepost marker, can "move" due to changes in the defined beginning point of the route as well as due to roadway construction realignments. Another issue related to the route referencing system is that each distance measuring instrument (DMI) will measure differently, and even the same DMI will change with tire temperature, tire pressure, and vehicle speed, and ability to precisely start the measurement recording at a known real-world measurement point. These changes of spatial locations on a route make it difficult for the pavement management system to make annual comparisons of condition data in the same segment of road and then to make predictions of remaining pavement life.

This dilemma led to this research project. The current pavement data collection vehicle uses one of the most accurate DMI available, as well as mapping-grade GPS equipment. However, GPS does not always give accurate spatial locations, especially when GPS signal is lost due to poor satellite coverage, or is blocked or scattered by buildings, trees, and nearby steep slopes. Inertial GPS systems are now available to overcome these limitations and improve road-mapping efforts. The system manufactured by Applanix was selected to test as it is used by other state DOT's and integrates easily with the data collection system in the pavement profiling vehicle.

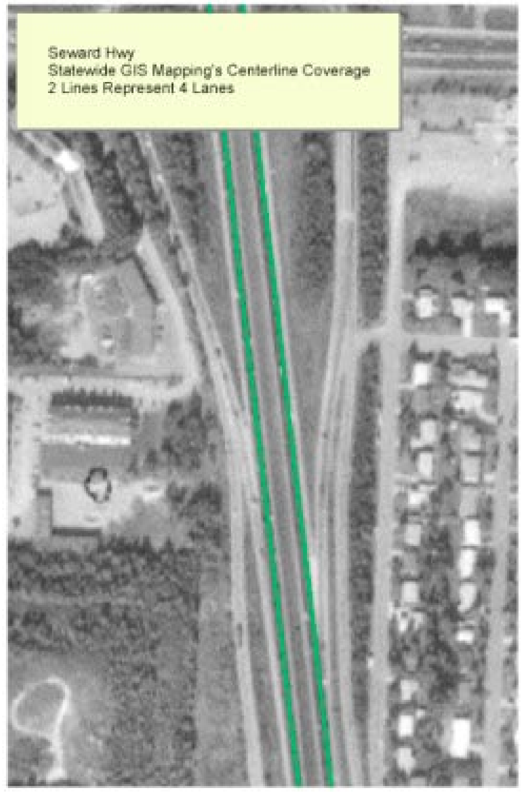

Figure 6

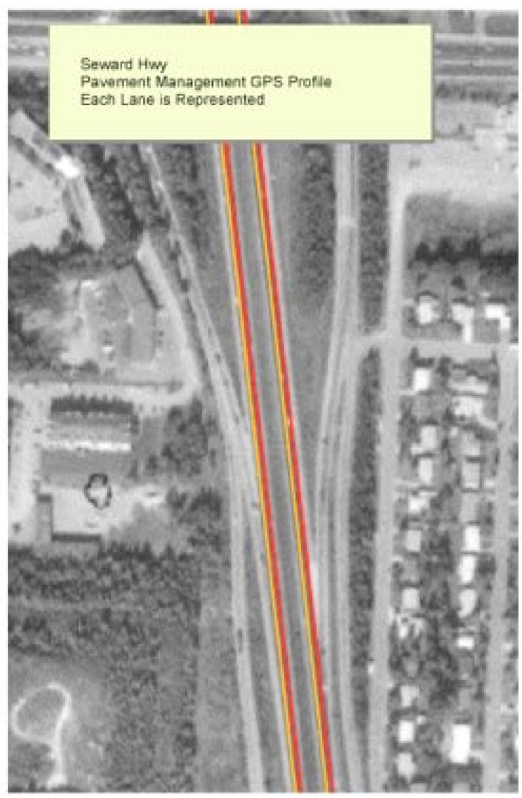

Figure 7

This research effort consisted of having Applanix (the manufacture of the inertial GPS system) and Dynatest (the manufacture of the data collection equipment) come to Alaska and make test runs with both systems working and collect pavement condition data where GPS problems occurred last year during data collection. Statewide Research sponsored this effort. Statewide Materials, Pavement Management directed this operation with Statewide Mapping evaluating the process. A special thanks to Angela Parsons and David Oliver. The following GIS maps illustrate the resulting improved spatial representation of roads. (See Figure 8)

Note that tall buildings exist between all of the streets in downtown Anchorage and caused the poor GPS signal (noted in red) during the 2001 PMS data collection. (See Figures 9 through 13)

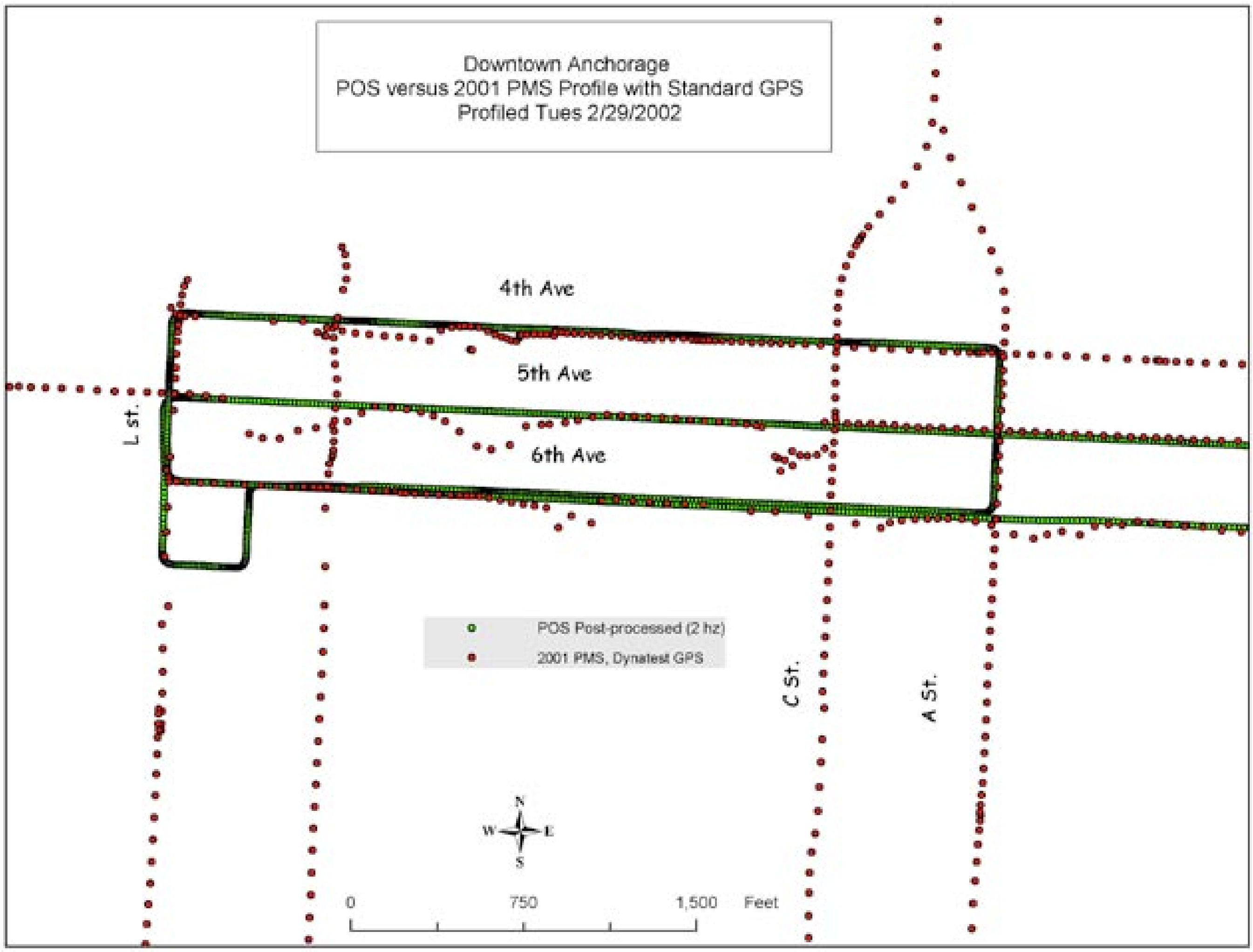

Figure 8

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Tel: 905-709-4600 **Fax:** 905-709-6027 **Web:** www.applanix.com

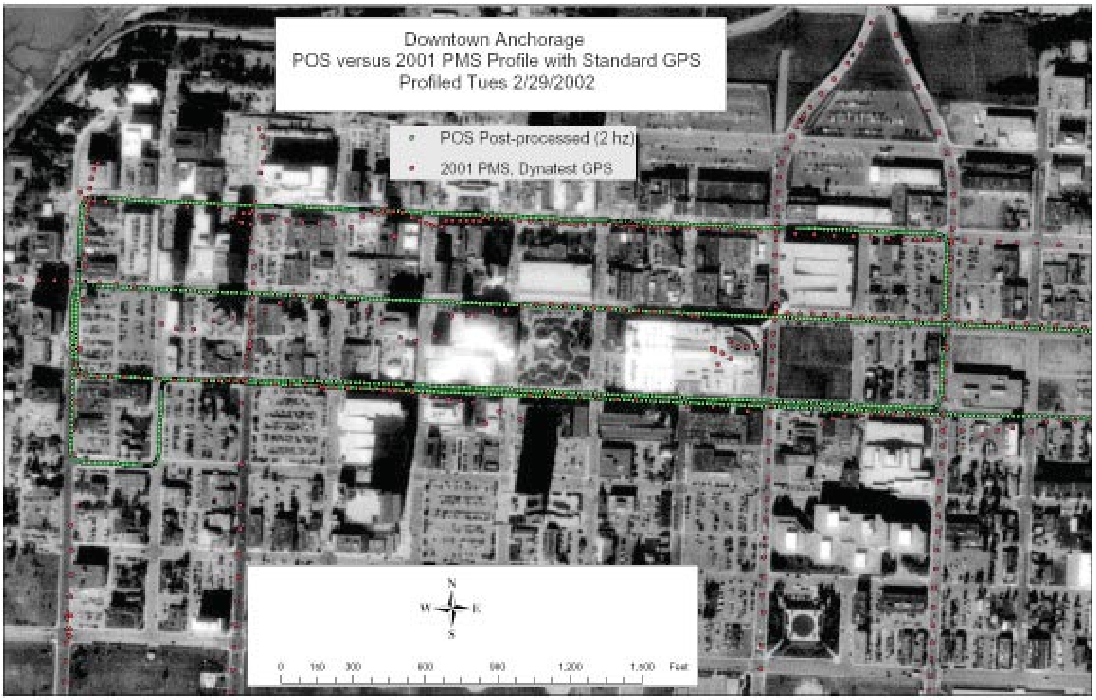

Figure 9

Figure 10 - Note the lane definition of the POS or inertial GPS system.

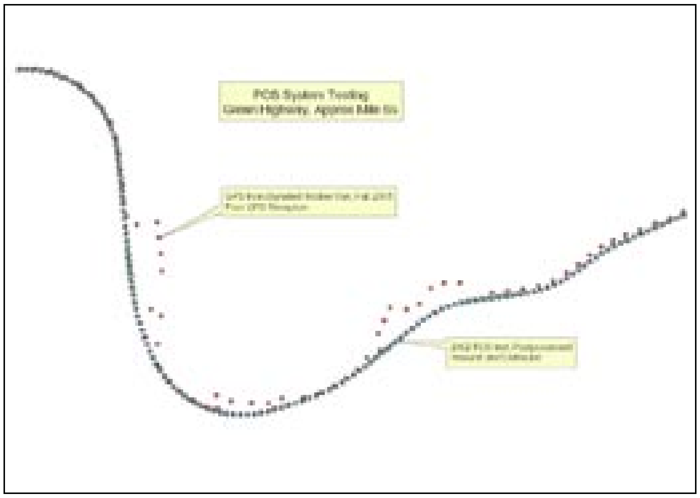

Figure 11

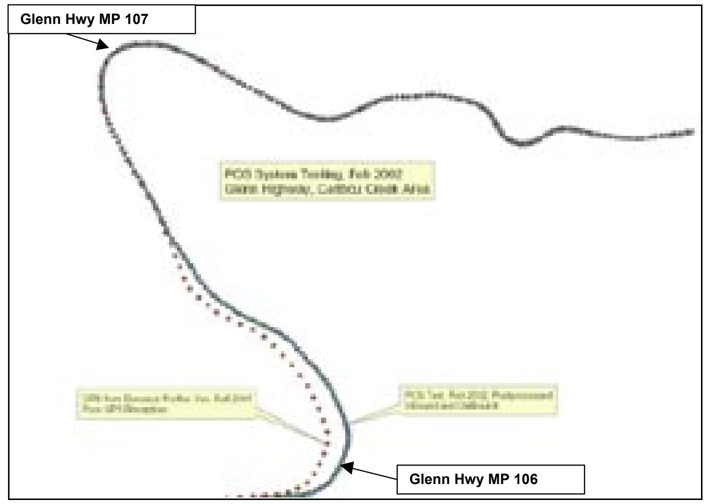

Figure 12

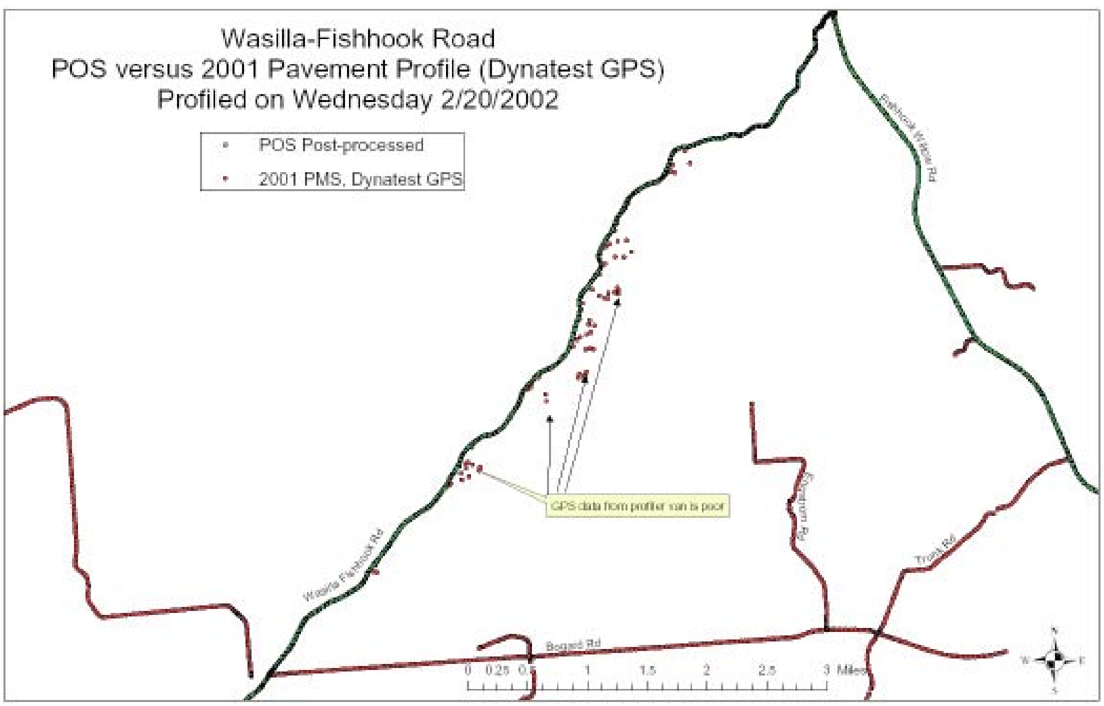

Figure 13

Figure 14

While doing this research, it was noted that this system could be used to update the mapped road system to account for the season's construction and realignment projects. An example of this is shown for the Glenn Highway exit south to Boniface Parkway where the ramp was realigned in Fall 2001 (as show by the inertial GPS points in Figure 14), which is not reflected in the photograph taken prior to this project.

Maps produced by Statewide Mapping are vital to data presentation and used when they are available for the presentation of pavement condition data.

A comparison of Statewide Mapping's conventional GPS data collection to the inertial GPS system was performed for a subdivision near Anchorage. The following maps illustrate this comparison. The inertial GPS equipment produced a more accurate map than that generated by conventional GPS. Note that Statewide Mapping has not published these maps as they are currently being edited to correct the intersection details and road alignment issues. The comparison is given only to illustrate the benefit potential to both Statewide Mapping and pavement data collection and the difference that the inertial spatial equipment can make. Also note that the Applanix system did not provide the field collection interface required by Statewide Mapping to fully function as a centerline roadway mapping and attributing system. (See Figures 15 through 21)

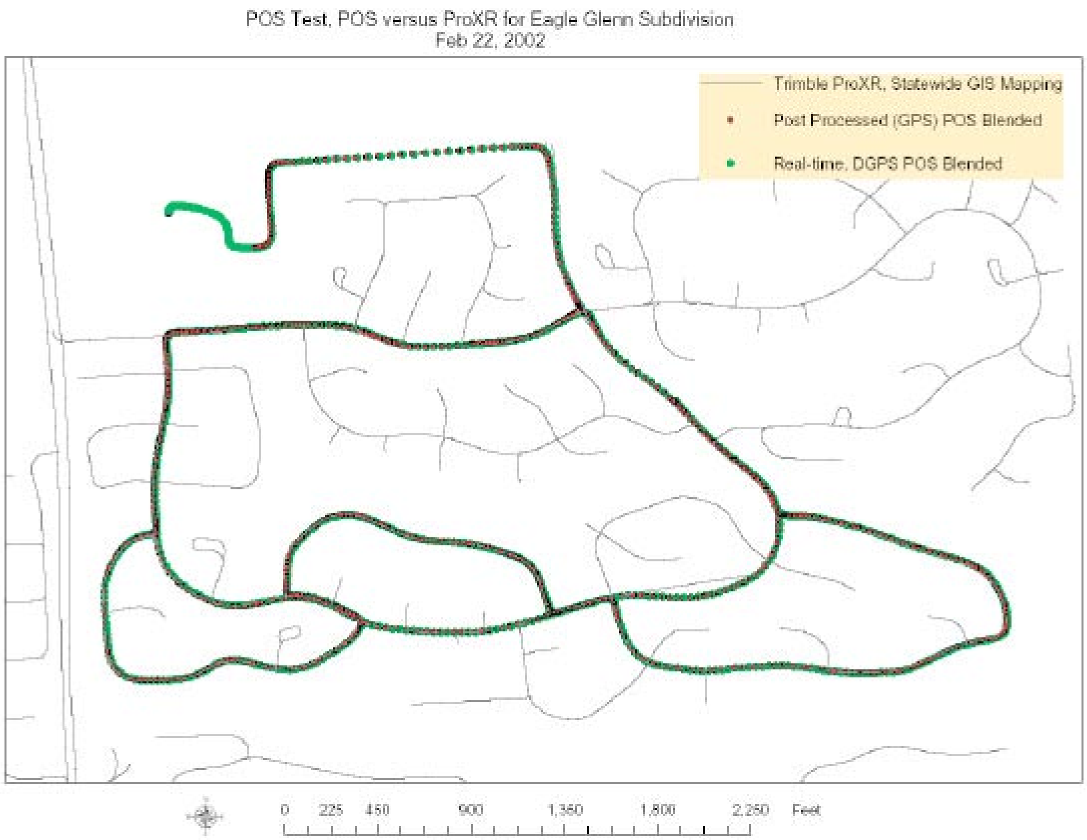

Figure 15

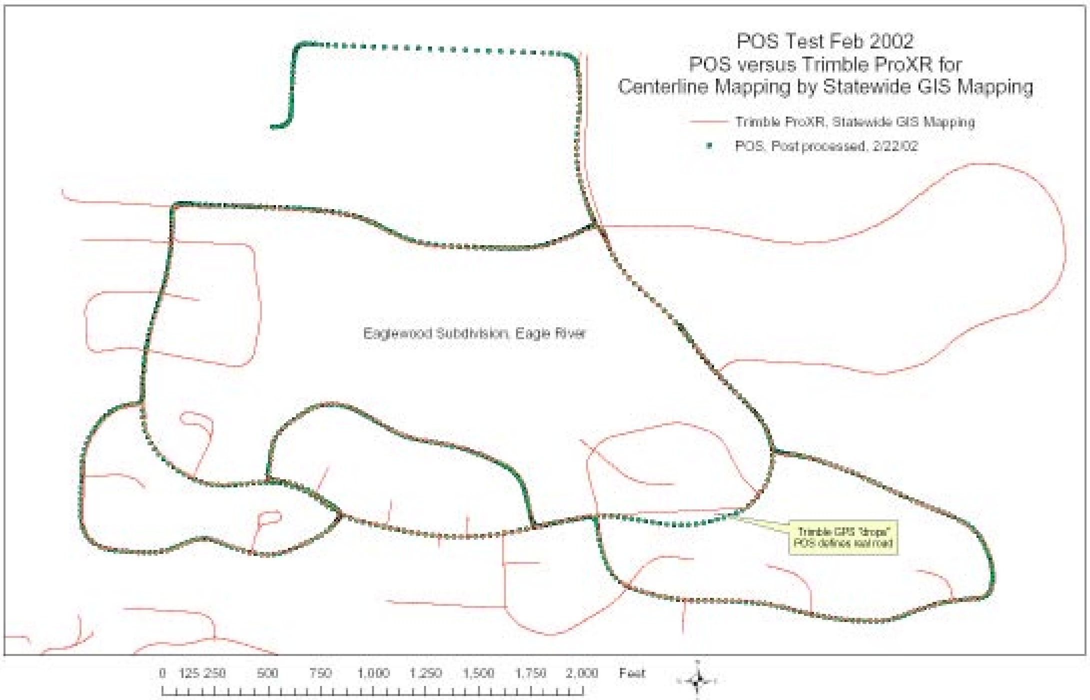

Figure 16

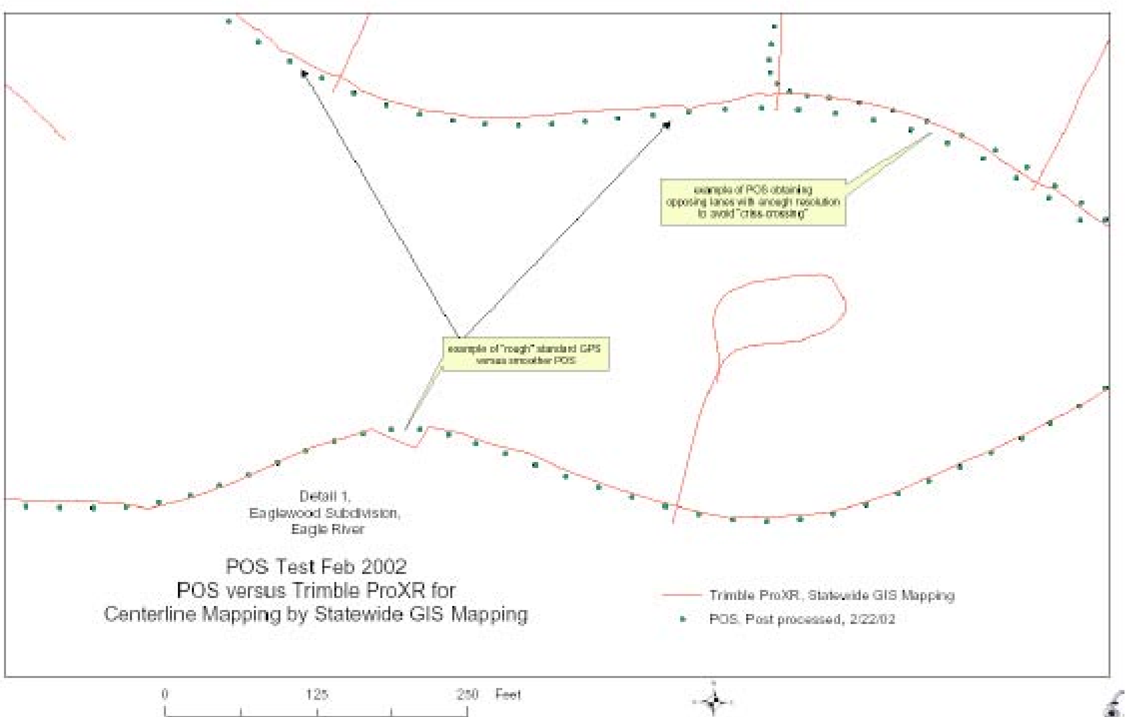

Figure 17

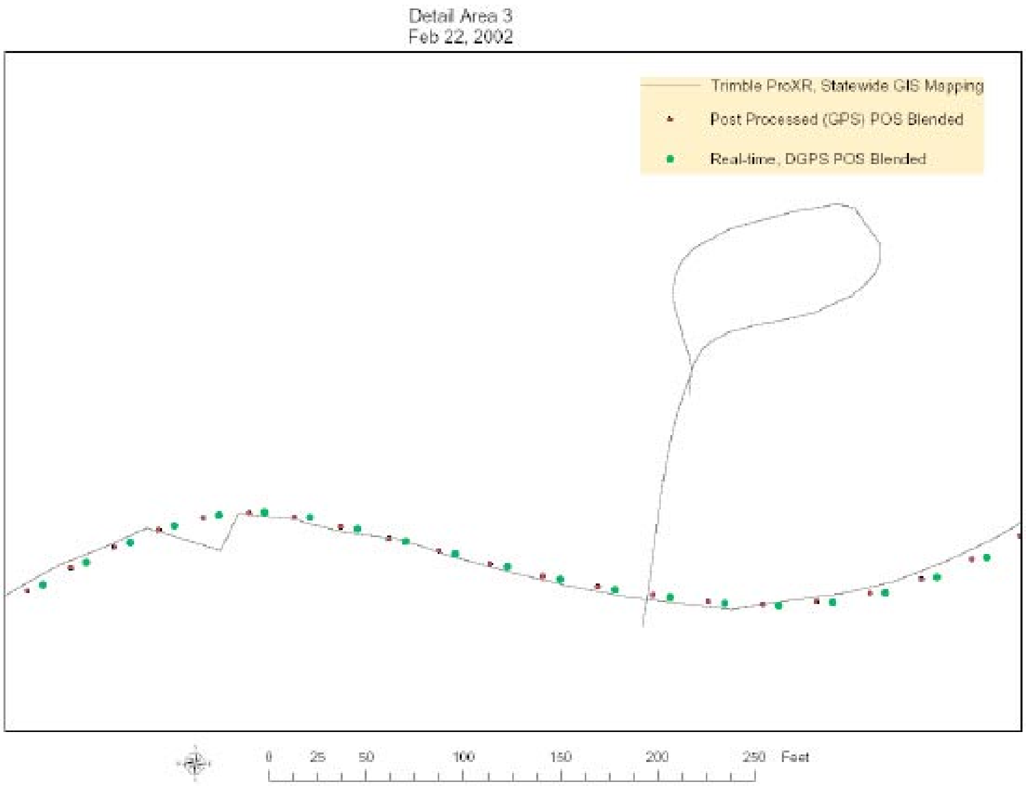

Figure 18

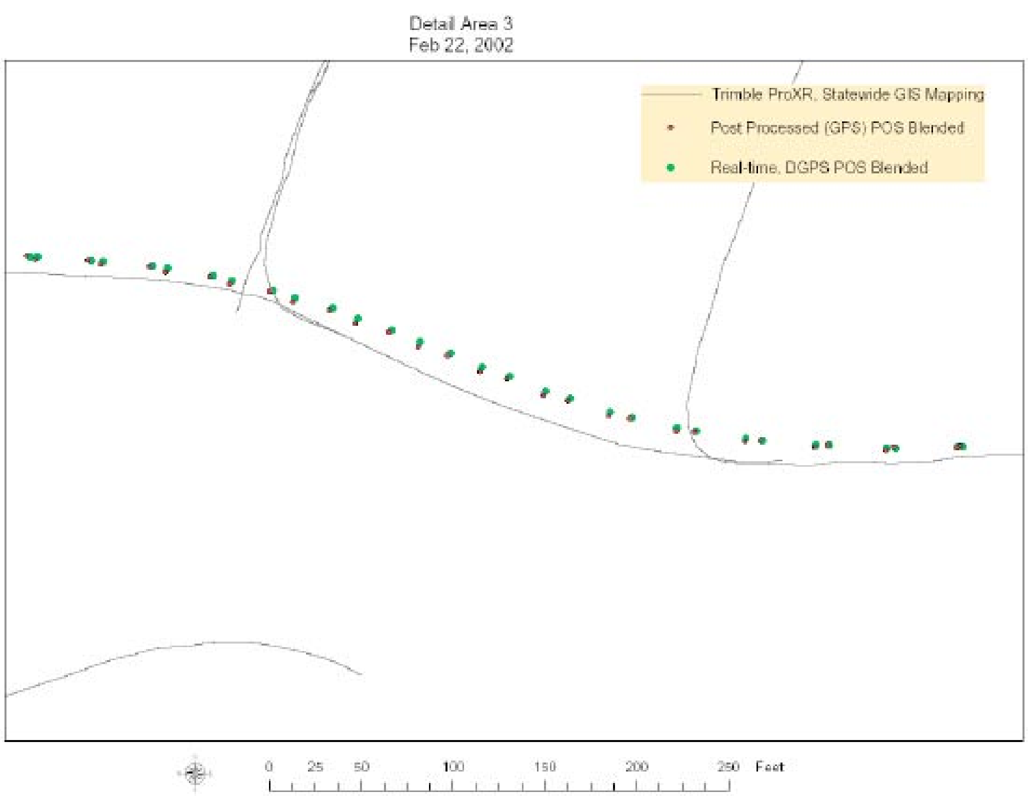

Figure 19

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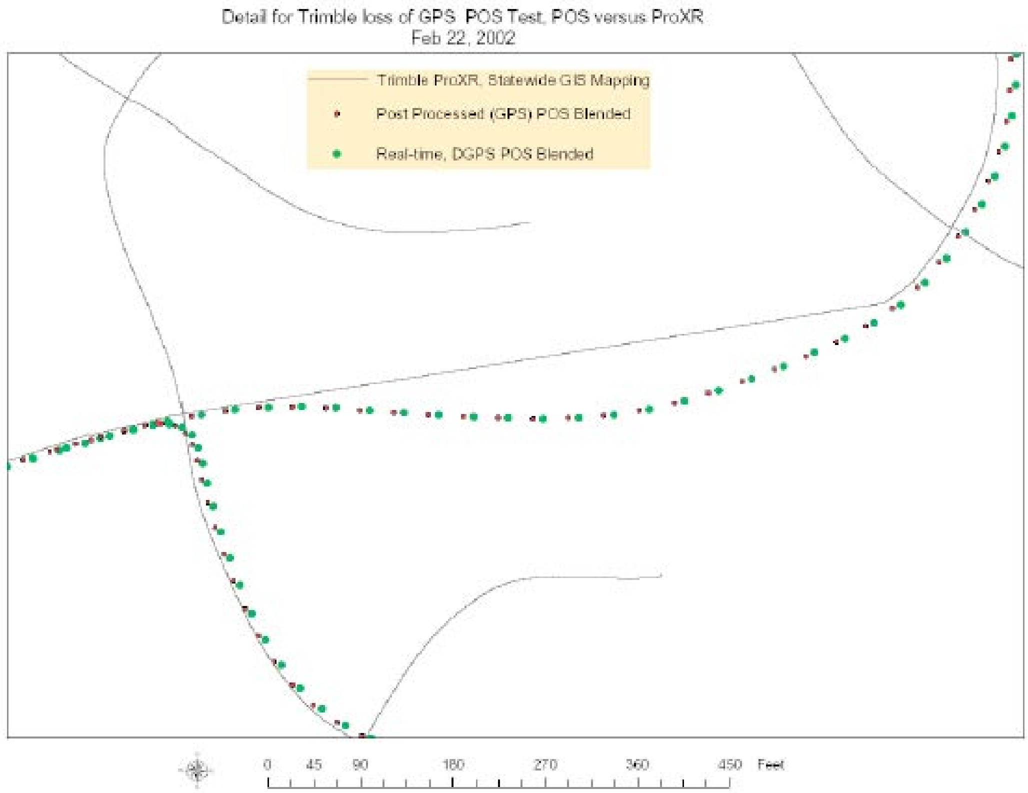

Figure 20

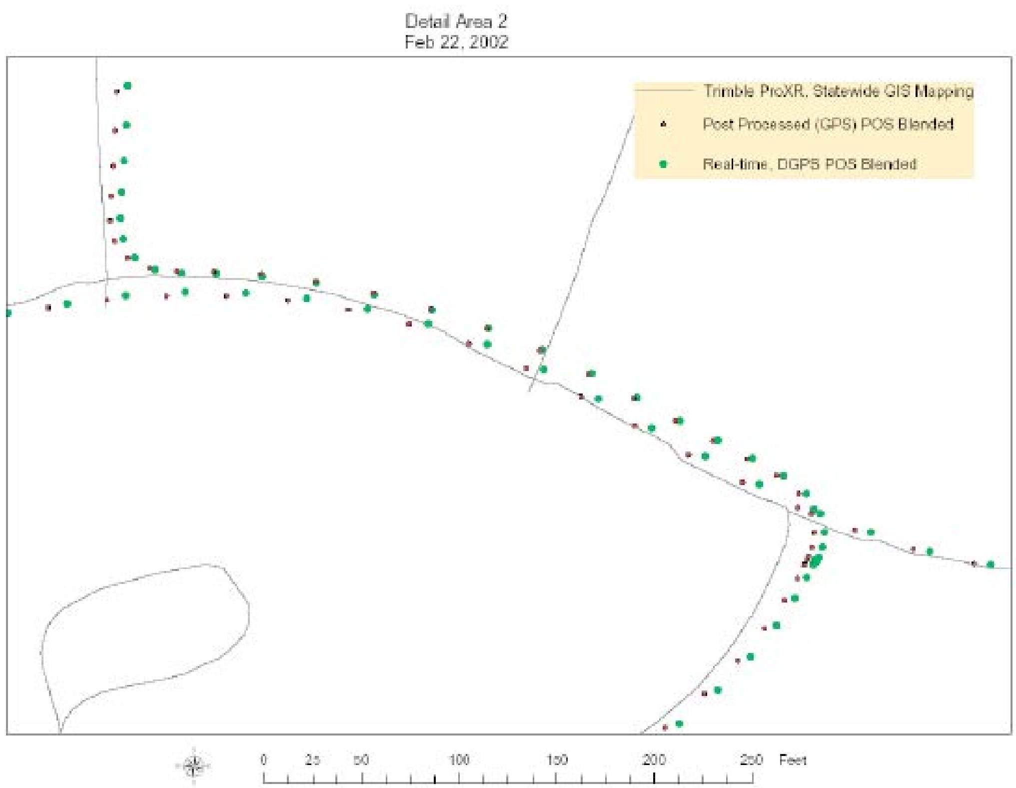

Figure 21

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Conclusion:

• The use of an inertial GPS system will allow the more rapid delivery of the yearly pavement condition report by reducing time spent manually editing the spatial data. PMS data is used to prepare annual work plans, budgets, and the STIP. Since the most current pavement data is desired for these preparations, the pavement condition data is collected in August and September following completion of the summer construction season. It is critical that the pavement reports be quickly prepared as the planning and budgeting efforts occur shortly after October.

• More accurate spatially located data serves as a quality control check of the pavement condition data collected.

• Use of this Applanix system during the 2002 annual collection of pavement condition data will provide a complete and accurate map of the paved road system that currently does not exist. This mapped road system will not only benefit pavement management efforts, it will also be used by other DOT and non-DOT groups to integrate their data with that of the highway location e.g. traffic, accidents, storm water features of NPDES, as-built information, document management, asset management, etc.

• Statewide Mapping would have an improved spatial definition of the paved road system to facilitate their mapping effort.

• The equipment performed extremely well and integrated easily with pavement data collection equipment

Equipment Specifications:

Position and Orientation System Specifications

• Applanix POS LV 220RT Position and Orientation System for Land Vehicle applications

• The Position and Orientation System should be a proven and completely offthe- shelf system

• The system shall have high precision capability for measurement of roll, pitch, true heading, velocity, acceleration, latitude, longitude and elevation

• Performance characteristics under post-processed conditions must be able to meet the following: 0.02 m horizontal/0.03 m vertical with no GPS outages; 0.15 m horizontal/0.20 m vertical with 1 minute GPS outage; 1.0 m horizontal/1.2 m vertical with 3 minute GPS outage. (Positional accuracies are RMS at approximately 60 km/h)

• Performance characteristics under Real-time conditions must be able to meet the following: 1.0 m horizontal/1.5 m vertical with no GPS outages; 1.5 m horizontal/2.0 m vertical with 1 minute GPS outage; 2.0 m horizontal/2.0 m vertical with a 3 minute GPS outage. (Positional accuracies are RMS at approximately 60 km/h)

• Post-processing software must be able to compute optimal blended position solution and orientation solution from inertial, GPS and other data sources (DMI)

• Post-processed software must employ forwards and reverse processing, enhanced error modeling, multiple GPS base-station processing and enhanced gravity modeling.

• Data output rates user selectable at up to 200Hz

• Ethernet Input/Output for operation and data recording

• Logging output to removable PC Card

• NMEA output interface

Technologies Used in POS LV Systems

• Tactical-grade Inertial Sensors – self-contained sensor provides precise vehicle orientation data, and low-drift vehicle position through GPS outages.

• Global Positioning Systems (GPS) – provides precise positioning

• GPS Azimuth Measurement System(GAMS) – two GPS antenna solution for high accuracy heading, independent of latitude and dynamics

• Distance Measuring Indicator (DMI) – senses distance traveled to provide aiding data when GPS is not available

• Strapdown Inertial Navigation Software – provides precise, high-rate measurements of vehicle dynamics by integrating and processing sensor data using a proprietary tightly-coupled Kalman filtering technique

Travel Report for Applanix/Dynatest Data Collection Demonstration

Travel dates – February 21 and 22, 2002

Demonstration location –

Alaska Department of Transportation
Materials Lab
5705 East Tudor Road
Anchorage, Alaska

AK DOT&PF Participants –

Newt Bingham, Statewide Pavement Manager
Billy Connor, Statewide Research Manager
Angela Parsons
David Oliver

Participating vendors –

Robert Briggs, Dynatest Consulting, Incorporated
www.dynatest.com

Dan McQuarrie, Regional Sales Manager, Applanix Corporation
Thalanka Galappaththi, Customer/Technical Support, Applanix Corporation
www.applanix.com

Maps from the demonstration -

Maps comparing the Applanix derived data with previously collected pavement condition data and unedited road centerline data are available for viewing in a .PDF format on the Snap server (Planning 1 on Hqnts2) under the Applanix subdirectory.

Purpose of the demonstration –
The Statewide Materials Section, in conjunction with the Research and Technology Transfer Section, arranged the Applanix product demonstration. The purpose of the demonstration was to evaluate the potential for improving the annual pavement condition data collection process by replacing the Trimble agricultural grade Global Positioning System (GPS) with an Applanix integrated inertial navigation based sensor.

POS LV system –
Applanix Corporation, a producer of position and orientation solution equipment, was contracted to install their Position and Orientation System for Land Vehicles (POS LV) in the AK DOT pavement data collection vehicle. Dynatest Consulting, the 2001 AK DOT pavement condition data collection contractor, volunteered to help integrate the POS LV system with the existing pavement data collection system.

The POS LV system is composed of a Distance Measurement Indicator (DMI), two GPS receivers, and an Inertial Measurement Unit (IMU) that contains three fiber optic gyros and three accelerometers. Applanix merges data from the various sensors to produce a composite solution (a position in our case). The composite solution method allows the Applanix system to overcome GPS signal blockage, GPS signal multi-pathing errors, and poor GPS satellite geometry problems that would create errors or data gaps in a stand alone GPS systems. The Applanix composite solution data was fed to the pavement condition software via a GPS industry standard interface.

Sample data collection –
Following successful installation of the POS LV system, the AK DOT pavement data collection vehicle was made available for sample data collection and product evaluation for the remainder of the week. Sample pavement data was collected on major state roads such as the Glenn Highway and the Richardson Highway, as well as smaller state roads in downtown Anchorage and the Matsu Valley. Sample data was collected in the Eagle River area for centerline mapping evaluation purposes.

Data evaluation –
The pavement condition and road centerline/POS LV sample data was transferred from the collection van to an office computer for comparison with data collected along the same roadways in previous years. ArcView 8.1 was used to perform a visual comparison of the spatial quality of the data sets. The data collected with the POS LV system formed a smooth, continuous road track free of gaps and erroneous point locations that were typical in the older, stand alone GPS/pavement condition/road centerline data. The POS LV system eliminates the need for all data editing associated with gaps or errors in the road track. Editing to remove obvious errors and gaps in the road track is subjective and, typically, the most time consuming portion of the data editing process.

Conclusions –
The POS LV system could improve the pavement condition data collection effort by increasing the accuracy of the derived positions and by drastically reducing the need for manual editing. The improved accuracy and quality of the road track could allow the pavement condition data to be more easily integrated with GIS/Mapping Section road centerline data and allow the pavement condition data to be displayed without the need for background centerlines. Additionally, the POS LV pavement condition data could be used to supplement the GIS/Mapping Section centerline data collection effort by capturing missed or suspect roads.

Applanix Corporation produces position and orientation solution equipment; they do not produce data collection systems. As a result, their POS LV system is easily integrated into the existing pavement condition data collection effort. But, POS LV is not a data collection system tailored to address the diverse needs of the GIS/Mapping Section centerline data collection effort.

A functional centerline data collection system would include the following primary components:

- Software that would unify the process of road centerline collection with highway inventory feature collection (eliminating the need for manual calibration between the road centerlines and Roadlog that is required under our current process)
- Inertial navigation based sensors to overcome many of the problems associated with a stand alone GPS system (and thus reduce the need for manual editing techniques to improve the road track)
- Software that would automate road centerline intersection editing to produce topologically correct (GIS ready) data
- Software that would compute three-dimensional lengths for the road centerlines based upon the various sensors within the system

The POS LV, without custom data collection front-end and processing software, would only be capable of addressing the inertial navigation based sensor component. Applanix does not provide data collection software and their representative was not aware of any state that used the POS LV for road centerline or highway inventory feature data collection.

Further discussion –
In a perfect world, the Statewide Materials Section could collect their pavement condition data with a DMI and hang the resulting information (using GIS) on road centerlines created and maintained by the GIS/Mapping Section. The problem is that the GIS/Mapping Section and Highway Data Section are still years away from being able to reliably provide such a centerline product.

The GIS/Mapping Section is in the early stages of pursuing a centerline data collection system. Assuming funds are available and the RFP process goes according to plan, the earliest a system could be purchased and ready for use would be the fall of 2002. Anchorage and Fairbanks represent the biggest holes in the current centerline collection project. These areas could possibly be collected and processed in the summer and fall of 2003 if collection focused on the roads for pavement condition reporting. This optimistic schedule would have a basic pavement condition data set available in the winter of 2003, most likely after the mandated reporting date. The result would be that the first year the requisite centerline data would be available for pavement condition use would the 2004- collection season.