IDEA

Innovations Deserving
Exploratory Analysis Programs

Highway IDEA Program

Development of a Wide Area Optical Surface Contamination Detection System for Public Transportation Application

Final Report for Highway IDEA Project 83

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TRANSPORTATION RESEARCH BOARD
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INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS
MANAGED BY THE TRANSPORTATION RESEARCH BOARD (TRB)

This NCHRP-IDEA investigation was completed as part of the National Cooperative Highway Research Program (NCHRP). The NCHRP-IDEA program is one of the four IDEA programs managed by the Transportation Research Board (TRB) to foster innovations in highway and intermodal surface transportation systems. The other three IDEA program areas are Transit-IDEA, which focuses on products and results for transit practice, in support of the Transit Cooperative Research Program (TCRP), Safety-IDEA, which focuses on motor carrier safety practice, in support of the Federal Motor Carrier Safety Administration and Federal Railroad Administration, and High Speed Rail-IDEA (HSR), which focuses on products and results for high speed rail practice, in support of the Federal Railroad Administration. The four IDEA program areas are integrated to promote the development and testing of nontraditional and innovative concepts, methods, and technologies for surface transportation systems.

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Table Of Contents

Table Of Figures

1 EXECUTIVE SUMMARY

This is the final report for the NCHRP-83 program. This program consisted of a three phase approach and are described as follows.

Stage one consisted of initial testing and analysis of the IceHawk® wide area ice detection system for adaptation to roadway ice detection., Initial in service data gathering was conducted with several IceHawk® wide area ice detection systems being used to gather roadway data in Scandinavia, North America, and Asia. Analysis of the collected data indicates that the IceHawk® product technology can be adapted to detect ice and snow on roadway surfaces. Preliminary system requirements have also been established.

Stage two consisted both of defining performance specifications as well as designing and developing prototypes that can achieve the necessary specifications. As shown in this report (as well as in the stage two report), multiple prototypes were developed to achieve these specifications.

Stage three consisted of testing and evaluating the performance of these working prototypes. As this report shows, extensive progress has been made in improve overall range and capabilities of the prototypes over existing products currently available. Going forward, continual develop is underway to commercialize the Laser Road Surface Sensor (LRSS) and offer for use with DOTs and other consumers interested in increasing the safety of their roadways, walkways, etc.

2 MAIN

The purpose of this IDEA project is to analyze the viability of adapting ice detection technology currently available for use in ground-based public transportation. The IceHawk® wide area ice detection system developed by Goodrich Sensor Systems uses patented laser light polarization techniques to detect ice and other frozen contamination (snow, frost, rhime ice, etc.) on aircraft wing surfaces. The system is typically used by ground de-icing crews to quickly and positively analyze aircraft flight critical surfaces. By using the IceHawk® system, Goodrich Sensor Systems have shown several advantages in the following areas of ground based aircraft ice detection.

1. **Removal/ reduction of human error.**
   Aircraft de-icing is obviously only done on an as needed basis (when weather dictates) and as such is not typically encountered in normal airline operations. This leads to possible safety concerns, as the crews do not get significant hands-on experience detecting ice. Because aircraft icing weather is sporadic, airlines generally do not staff a fulltime de-icing crew. Instead these crews are selected and trained to fill in from a variety of other operations (baggage handlers, mechanics, etc.). When the weather dictates de-icing, crews are called upon to work long hours and as such human fatigue can play a dangerous role. The IceHawk® system eliminates possible errors resulting from in -experience and fatigue.

2. **Improve airline throughput.**
   By utilizing the IceHawk® system, crews can quickly identify if and aircraft is requiring de-icing or if so, where they need to concentrate their efforts. This can significantly reduce departure delays

3. **Reduce cost and environmental impacts.**
   To remove ice, de-icing crews typically utilize a glycol fluid. This fluid, similar to car antifreeze, is neither cheap nor friendly to the environment. Significant costs are incurred in dispersing and collecting these fluids and as such and reduction in the usage positively impacts airline's profits.

2.1 IDEA PRODUCT

Successful adaptation of the IceHawk® wide area ice detection system into a Laser Road Surface Sensor (LRSS), can result in a variety of new capabilities and positive impacts to the ground transportation market. Listed below are some identified potential end products and applications.

2.1.1 Stationary Mount Ice and Snow Detection System.

By positioning an LRSS as shown in the figure below, the LRSS can monitor selected sections of road with a high probability of developing black ice (i.e. bridges, roadways vulnerable to high straight-line winds, etc.). Multiple sensors could be installed throughout a roadway network and monitored remotely; allowing ice and snow removal equipment to be effectively dispatched at the first sight of ice.

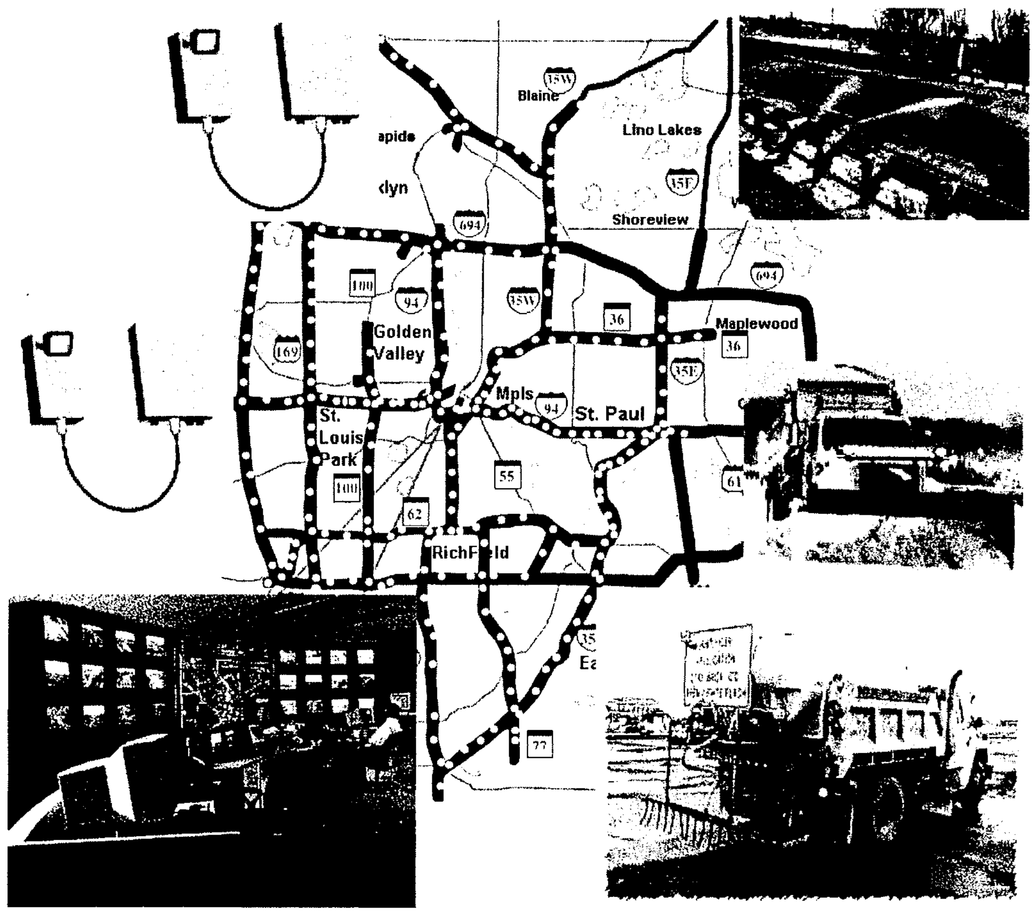

Figure 1 System for road condition monitoring

2.1.2 System for Automated Elimination of Ice for use on Salt Dispersion Vehicles

Another application of the LRSS could be used in conjunction with salt dispensing systems as shown in the figure below. Automation would allow for advance detection of black ice and dispersion of salt (or other ice removal chemicals) and thus eliminate human error and improve safety and the truck driver could concentrate solely on driving.

Figure 2 Automated ice detection and removal system

2.1.3 Smart Vehicle Traction Control

LRSS systems could be potentially incorporated into traction control systems on passenger vehicles to reduce accidents resulting in property damage and, more importantly, loss of life.

Figure 3 Ice detection for smart traction control systems

2.1.4 Mobile Mapping of Roadway Conditions

LRSS systems equipped with GPS and wireless communications could be mounted on various public and private transportation vehicles and continually report road conditions as the vehicle travels as shown in the figure below.

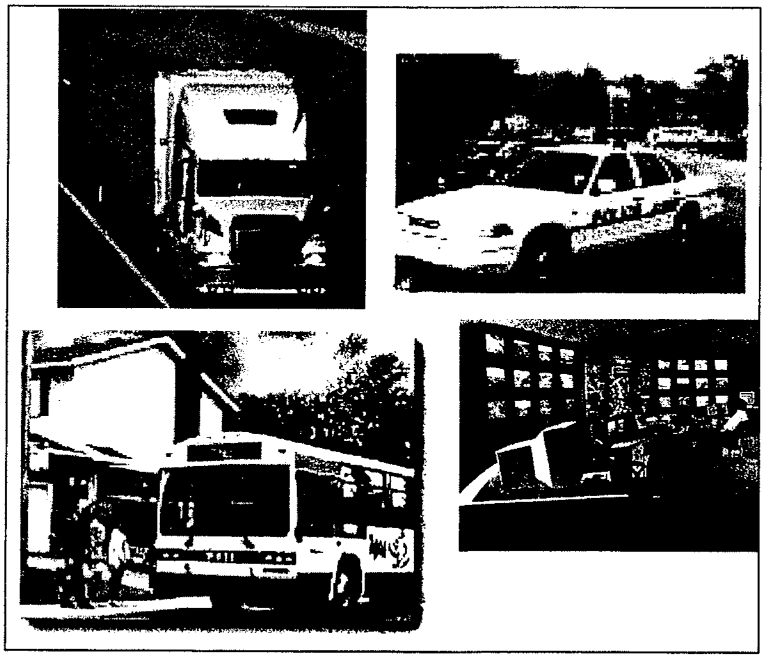

Figure 4 Mobile road condition mapping

2.2 CONCEPT AND INNOVATION

The principle concept of this IDEA project is successful adaptation of the IceHawk® wide area ice detection system for use as a Laser Road Surface Sensor (LRSS). The primary advantage of this system over others currently available is it's non-invasive method by which it can detect ice or snow. Costly road installation can be avoided as the LRSS could be mounted on light poles or overhead traffic signs (as envisioned in a stationary mount implementation).

2.3 INVESTIGATION

To determine the IceHawk® technology viability to roadway surfaces, preliminary testing and analysis was necessary. In this stage one, existing IceHawk® systems were modified minimally to allow for stationary mount and remote operation. Systems were deployed in Asia, Scandinavia, and North America for data gather and analysis. Target materials (i.e. concrete, asphalt, etc.) were analyzed for polarization reflection behavior.

As IDEA stage 1 report illustrates, the underlying technique by which the IceHawk® system detects ice on aircraft surfaces can be applied to detect ice and snow on roadway surfaces. Furthermore, the stage 1 report states preliminary system requirements.

2.4 PROTOTYPE IMPLEMENTATION

Illustrated below is the prototype LRSS. Prototype performances are stated as follows;

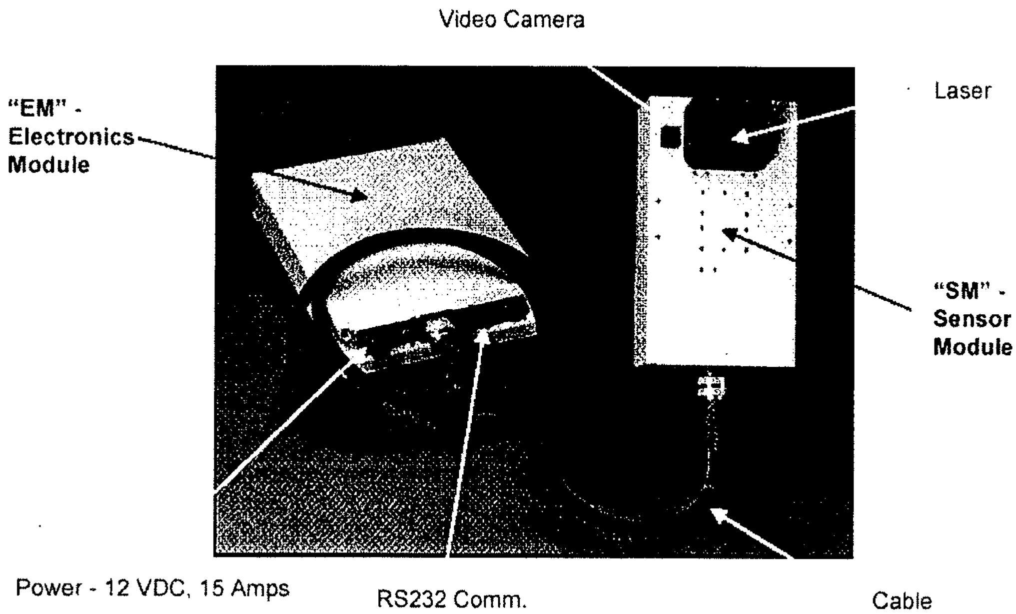

Figure 5 LRSS prototype

Figure 6 LRSS with pan tilt system implementation

2.4.1 Communication:

Remote operation can be accomplished through an external modem connected through the RS232 port. Final production versions would likely need to utilize a faster communication medium (i.e. Ethernet) as scan images are typically large.

2.4.2 Remote operation:

Remote operation is handled via a DOS program. While this program works fine, DOS operation is outdated and as such doesn't allow for multi-tasking. At this time, only one system can be connected to the remote software at one time. Production versions would likely need to control a multitude of sensors from one station.

2.4.3 System range:

The system is capable and is calibrated to detect ice and snow up to a range of 75 feet. Actual detectable distances vary as a function of reflected light. Surfaces that greatly diffuse light (scatters impacted light in all directions, i.e. snow, concrete) can be detected at longer ranges than those that diffuses light poorly (black asphalt, water, etc.). Initial laboratory testing indicates the system, when mounted at a height of approximately 23 feet, should detect snow and ice out to 75 feet, while water puddle surfaces may only be seen out to distances of approximately 45-50 feet. Field testing will need to be conducted to obtain a better feel to the systems overall usable range.

2.5 PROTOTYPE TESTING

Over the last year, extensive testing of the Laser Road Surface Sensor (LRSS) prototype was conducted, both in Asia and North America. Notable performance improvements were realized and continuing product performance enhancements were envisioned for full production scale systems. Some of the performance improvements over initial investigation systems are illustrated below

Improved Range- increased SNR allowed for improved signal integrity and evaluation of lower signals, allowing for an approximate 1.5 times improvement in useable range (useable range is loosely defined as the average distance at which Ice/ snow detection is possible given the underlying surfaces and angle at which the laser impacts the surface relative to normal).

Improved reliability- Improvement in the prototype design has allowed for increased temperature operation as well as overall MTBF.

Improved communications- while Ethernet as yet has not been implemented (although envisioned for final production quality systems), improvements in software automation has allowed for the system to automatically connect and disconnect between images. This improvement has allowed for feasible remote operations as expensive long distance phone connections are minimized.

2.5.1 System Test Images

The following images are only a sampling of data gathered and are included to illustrate the performance of the prototype LRSS system. The LRSS images (figures 9-14) are color coded to aid in characterization of surface contamination. Red indicates ice, dark blue indicates snow, and light blue indicates water. Greyscale (no color) indicates clean surfaces.

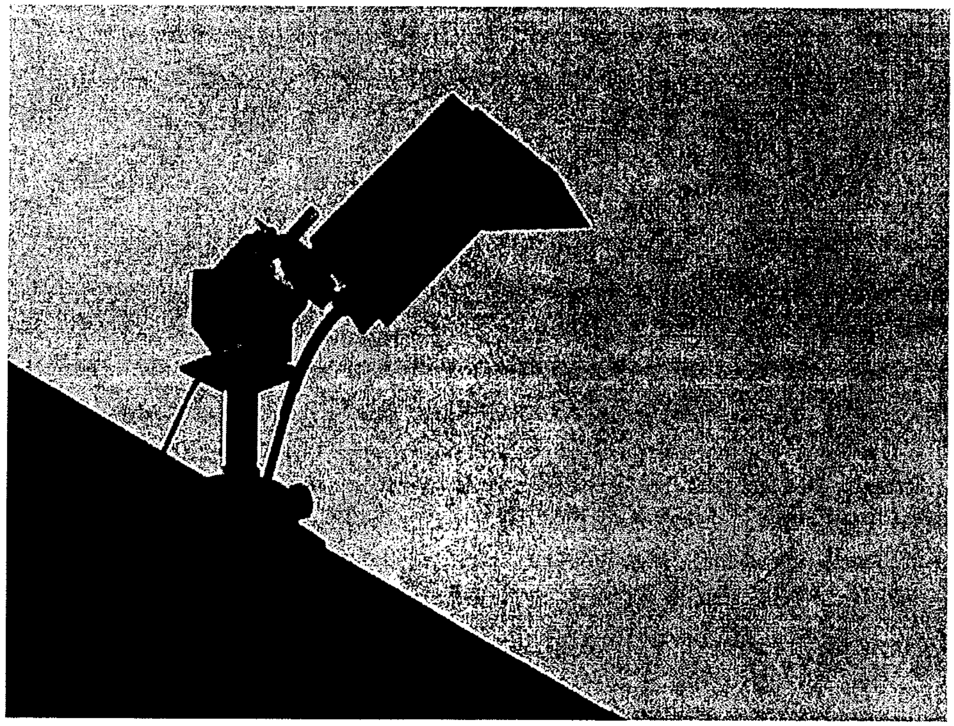

Figure 7 Prototype LRSS evaluation setup

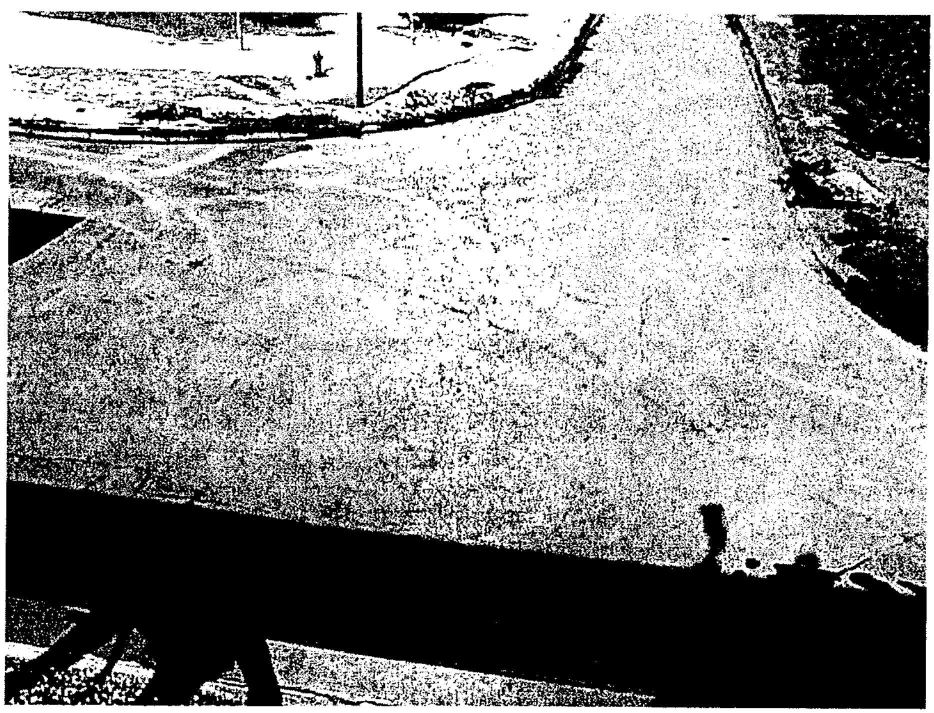

Figure 8 Prototype LRSS evaluation target

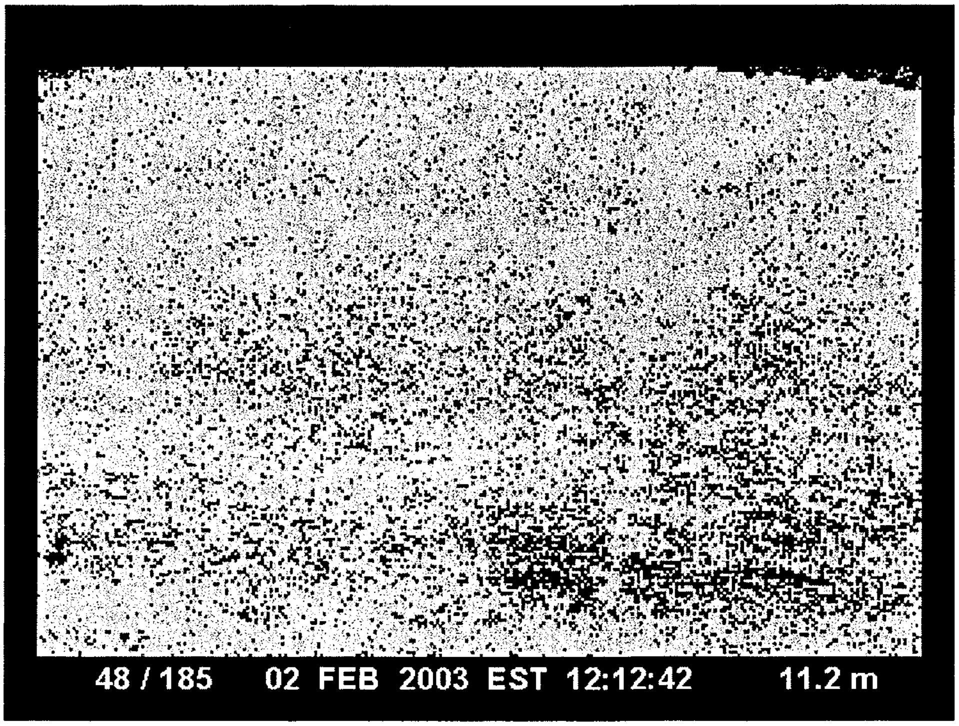

Figure 9 wet road surface image detection

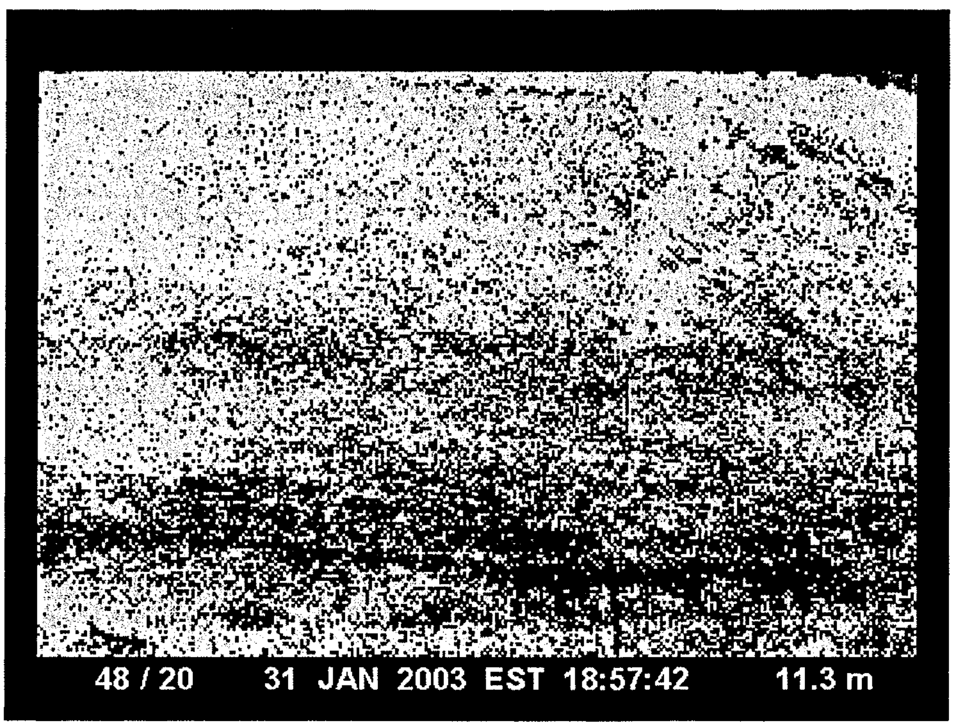

Figure 10 wet road surface image detection

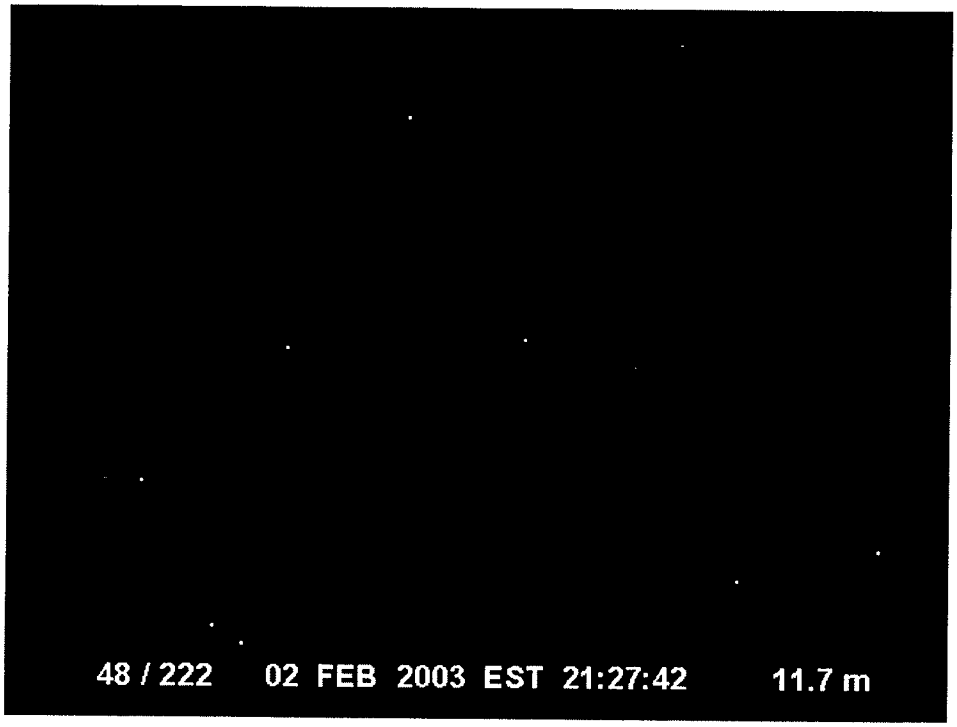

Figure 11 snow covered road surface detection

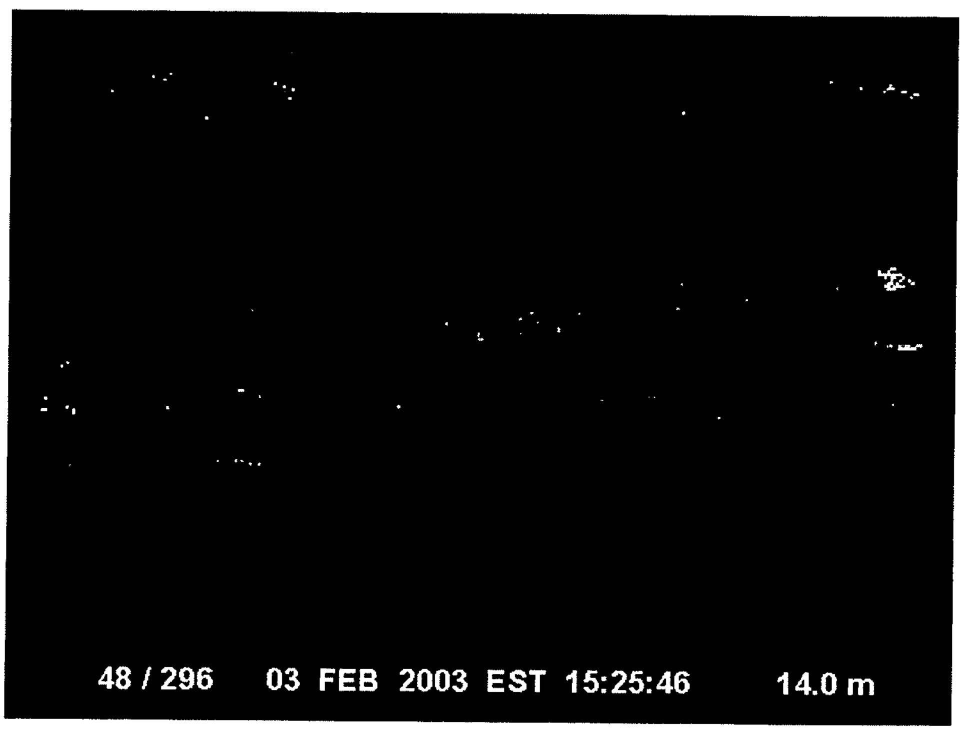

Figure 12 Snow and ice covered surface detection

Figure 13 primarly clean surface

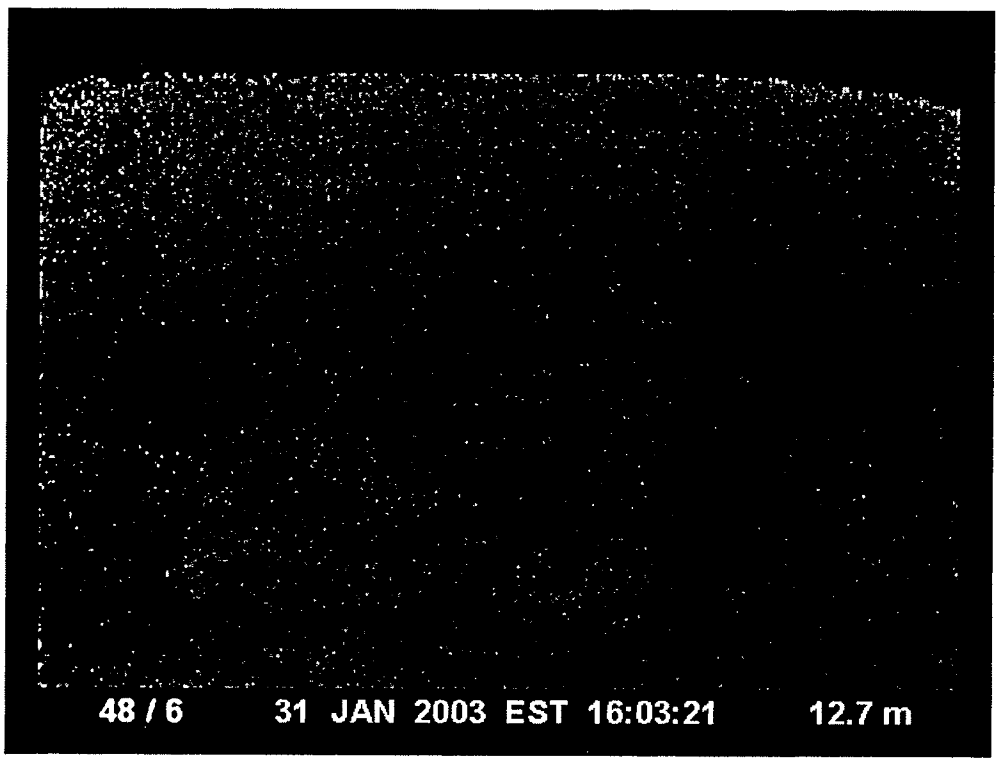

Figure 14 Primarily clean surface

3 CONCLUSION

Initial testing has proven the IceHawk® ice detection technology can be adapted for use in roadway applications. As a result of this initial testing, preliminary performance specifications were drafted to accommodate a station pole mounted system. Subsequent prototypes were developed for additional testing. As illustrated in this report, the prototype were assembled and tested for improvements and market viability.

Activities to date have shown the viability of adapting the IceHawk® wide area ice detection system for usage in roadway safety. Continued development is currently underway at Goodrich Sensor Systems to produce production quality systems that will meet and exceed all the performance criteria defined in appendix A. Development is scheduled for initial system availability late 2003/ early 2004.

APPENDIX A: PRELIMINARY SYSTEM REQUIREMENTS DOCUMENT

TABLE OF CONTENTS

1. MECHANICAL REQUIREMENTS

The following sections dictate mechanical requirements necessary for the roadway ice detection system.

1.1. WEIGHT

The systems weight shall not exceed 30 kg.

1.2. COLOR

The exterior shall be colored primarliy of Munsell N7 gray.

2. INTERFACE REQUIREMENTS

The following sections dictate requirements necessary for the user to connect and control the roadway ice detection system.

2.1. PHYSICAL

The following sections describe the physical/electrical connections necessary for the roadway ice detection system.

2.1.1. Ethernet

The system shall allow for connection and control through an ethernet port.

2.1.2. Local operations connection

Connection ports shall be provided to allow for connection and control of the system locally.

2.2. USER OPERATION INTERFACE

The following sections describe the interface necessary for control/ operation of the roadway ice detection system.

2.2.1. Windows compatible GUI

The user interface shall be compromised of a user friendly windows compatible software program.

2.2.2. Local/ remote operational capability

The system shall allow for remote operation via ethernet connection and a windows compatible software program shall be provided for installation onto the remote operations computer.

3. ELECTRICAL REQUIREMENTS

The roadway ice detection system shall obtain CE mark applicable per this product type. Additional electrical requirements are as defined within the following subsections.

3.1. POWER INPUT

The system shall function properly when power by 12 volt, ±10%. Furthermore, current draw shall not exceed 15 amps.

3.2. POWER INTERRUPT

The system shall maintain operation without interruption when exposed to one 10 millisecond interruption in power.

3.3. SYSTEM RANGE

The system shall detect ice, and snow on a flat surface when mounted at a vertical distance of 7 meters and at a viewing distance of up to 18 meters.

3.4. SYSTEM RANGE RESOLUTION

The system shall have a maximum range resolution of 13cm.

4. ENVIRONMENTAL REQUIREMENTS

The roadway ice detection system shall obtain CE mark applicable per this product type. Additional environmental requirements are as defined within the following subsections.

4.1. OPERATING TEMPERATURE

The system shall power up, following sufficient time for warm-up, and guarantee operation over –30° to +20° C.

4.2. SYSTEM WARMING TIME

The system shall be operable within 20 minutes of power applied when exposed to cold temperatures.

4.3. HUMIDITY

The system shall function properly when exposed to humidity levels ranging from 20% to 95%.