working to advance road weather information systems technology

Laser Road Surface Sensor Camera Evaluation Project

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Aurora Project 2004-02

Final Report
August 2008

About Aurora

Aurora is an international program of collaborative research, development and deployment in the field of road and weather information systems (RWIS), serving the interests and needs of public agencies. The Aurora vision is to deploy RWIS to integrate state-of-the-art road and weather forecasting technologies with coordinated, multi-agency weather monitoring infrastructures. It is hoped this will facilitate advanced road condition and weather monitoring and forecasting capabilities for efficient highway maintenance, and the provision of real-time information to travelers.

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16. Abstract

This project was conducted to determine whether the IceHawk® Laser Road Surface Sensor (LRSS) could be used in the winter road maintenance environment to detect road frost and pavement conditions. The device is a wide-area ice detection system that provides color-enhanced images of frozen contaminants such as snow, frost, slush or ice. Data were collected using one device installed at two different bridge locations. One set of data was collected between February and March 2004, and another set was collected during the winter of 2004–2005.

The LRSS was found to provide useful information about the condition of the road in its view, which winter maintenance supervisors and the public can use to monitor the spatial distribution and phases of water substance on the driving surface. The device can also collect useful data in dark areas where traditional cameras may not produce useable images. However, the software that processed the image data limited the operating system of the download computer to Windows 98; the device required manual, on-site downloads to access the data; and the cost of the device was found to be prohibitive for deployment by the Iowa Department of Transportation (DOT).

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LASER ROAD SURFACE SENSOR CAMERA EVALUATION PROJECT

Final Report
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1. PROJECT SCOPE

This project was conducted to determine whether the IceHawk® Laser Road Surface Sensor (LRSS) could be used in the winter road maintenance environment to detect road frost and pavement conditions. The results presented in this report were collected between February and March 2004 and during the winter of 2004–2005. It was originally intended that two versions of the IceHawk® camera would be tested. However, only one version of the camera was tested due to production problems. This project was funded by Aurora, an international partnership of public agencies who work together to perform joint research activities in the area of road weather information systems (RWIS).

2. PRODUCT DESCRIPTION

The Goodrich next generation IceHawk® wide-area ice detection system provides color-enhanced images of frozen contaminants such as snow, frost, slush or ice. According to the manufacturer, the IceHawk® system was the only on-ground, wide-area ice detection system approved by the Federal Aviation Administration to replace tactile ice inspection requirements on aircraft. The IceHawk® LRSS scans a surface by sending a beam of polarized infrared light and analyzing the returned signal strength and polarization to detect water and its phases on surfaces. The LRSS saves the information from each scan in its electronics module.

The scan information is downloaded onto a computer equipped with special software designed to interpret and display the information. This software produces two images using the scan information and image pixel summary information. One of the two images is a black and white image, similar to that taken by a standard infrared camera. The second image produced by the data is a color-enhanced image in which the pixels determined to be snow, water, or ice are highlighted. The image pixel data show the percentage of the image's pixels that represent ice, snow, and water.

3. RESEARCH LOCATIONS AND CAMERA POSITIONING

During the test period, one version of the LRSS was installed in two different locations (Figure 1). The red dot in Figure 1 identifies the first location, a rural bridge crossing US Highway 30. The blue dot in Figure 1 represents the second test location, a bridge on northbound Interstate 35.

For the first set of scan data, the LRSS was installed throughout February and March 2004 on a rural concrete bridge crossing US Highway 30. This location was chosen so that the camera's ability to detect frost could be tested. This bridge was being observed for frost formation by human observers as part of a different Aurora project (number 2004-05). The LRSS was mounted on a steel pole erected by the Iowa Department of Transportation (DOT). This pole was affixed to the bridge deck side rail. The Iowa DOT provided hardware and custom brackets used for mounting and installing the LRSS system and related components.

The camera was installed at the top of the pole to a slotted bracket that allowed adjustment of the sensor module (see Figure 2). The electronics module was attached to the side of the pole (Figure 3). The camera was positioned to view an area in the middle of the bridge.

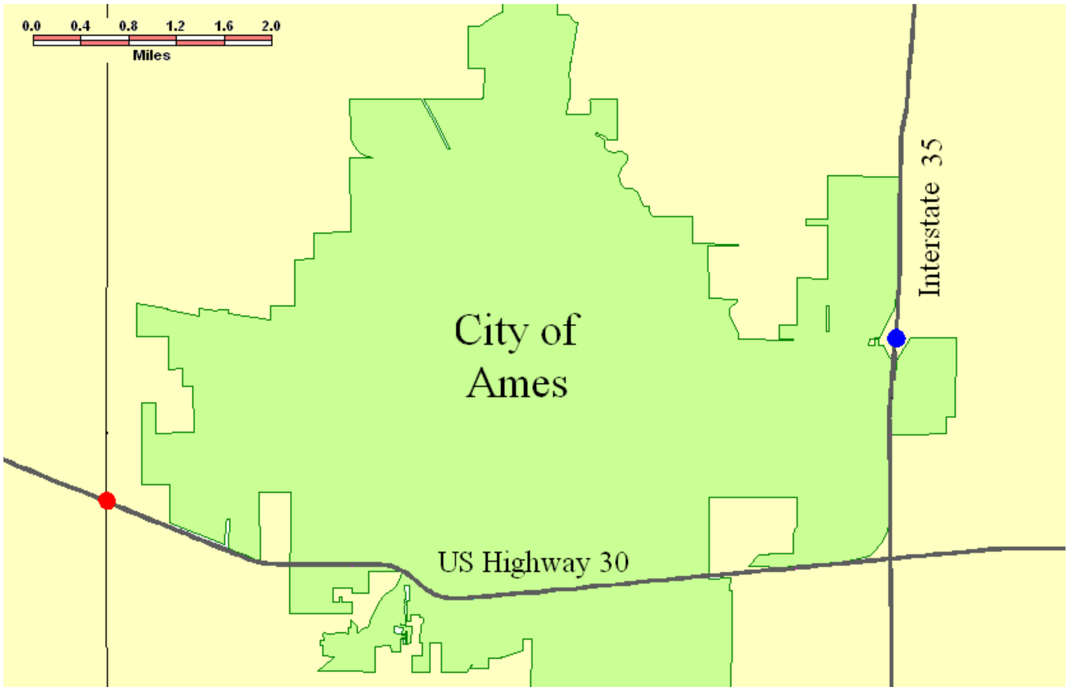

Figure 1. Map of LRSS test locations

Figure 2. LRSS sensor module and mounting bracket

Figure 3. Electronics module mounted to the side of the pole

For the second set of scan data, the camera was later installed on northbound Interstate 35 on a concrete bridge east of Ames, Iowa, from October 2004 through April 2005. The camera was aimed so that the image covered the outside wheel track of the driving lane and the apron area of the bridge deck (Figure 4). The LRSS was positioned in this way so the condition of the treated bridge deck could be compared to the condition of the untreated apron area. It was hoped that this comparison would allow the researchers to determine whether the camera could detect and differentiate frost formation on an untreated surface from chemically melted frost on a treated surface. The viewing area covered approximately 153 ft^2 of bridge pavement. A road weather station was located approximately 200 ft from the LRSS. This station provides pavement condition reports in the vicinity of the LRSS scanning area, precipitation identification, dew point readings, and other weather observations. Observations from this station were used for comparison with the LRSS images.

A lockable box supplied with 12 V DC power was installed on one of the bridge pillars below the bridge. The box was also provided with a 120 V AC receptacle, used to supply voltage to the power supply. Locks were installed on the pole mount and the cover of the power supply box. The download cables were secured to the side of the bridge and terminated in the power supply box below the bridge. This location provided a much safer place to complete downloads than the bridge above (Figure 5).

For both the US Highway 30 and Interstate 35 locations, personnel from the Iowa DOT periodically visited the sites to download the scan data to a laptop computer equipped with special software designed to interpret and display the information.

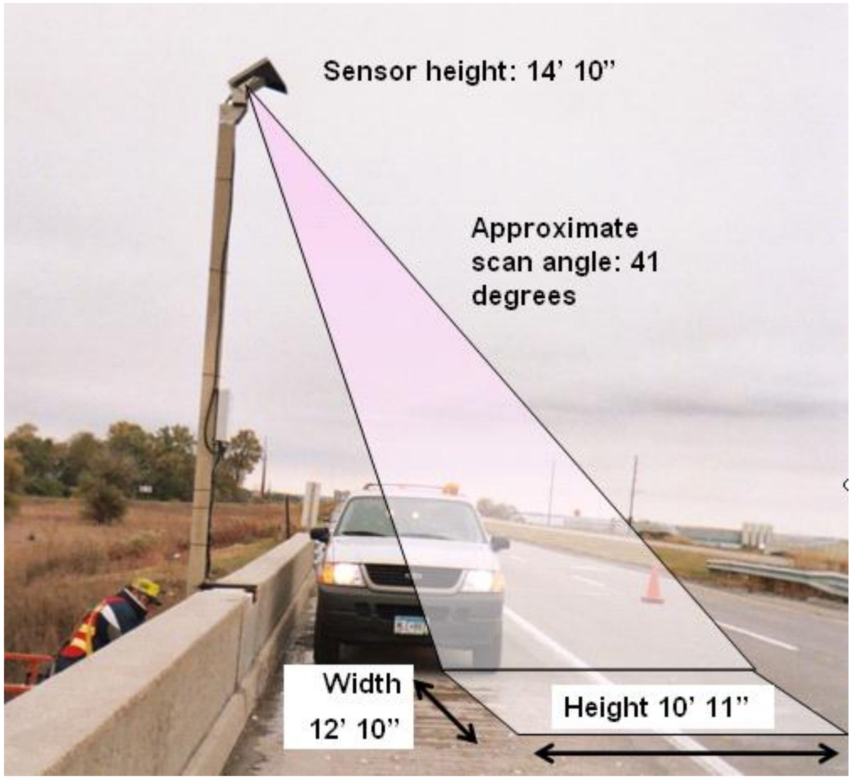

Figure 4. Viewing area and camera position on the I-35 overpass near Ames, Iowa

Figure 5. Lockable box with 12 V power supply located under the bridge

4. SYSTEM CONFIGURATION

The LRSS image software installed on the Iowa DOT laptop computer was calibrated after the camera was installed at the two test locations using a method suggested by the manufacturer. Calibration was accomplished by throwing water and ice onto the pavement viewing area and adjusting the LRSS scan information thresholds so that the images adequately differentiated the locations of the ice, water, and dry pavement. Figure 6 shows an LRSS image during calibration of the image software. Five piles of ice cubes were used to calibrate the ice table in the LRSS software. Calibration was necessary any time the camera was relocated.

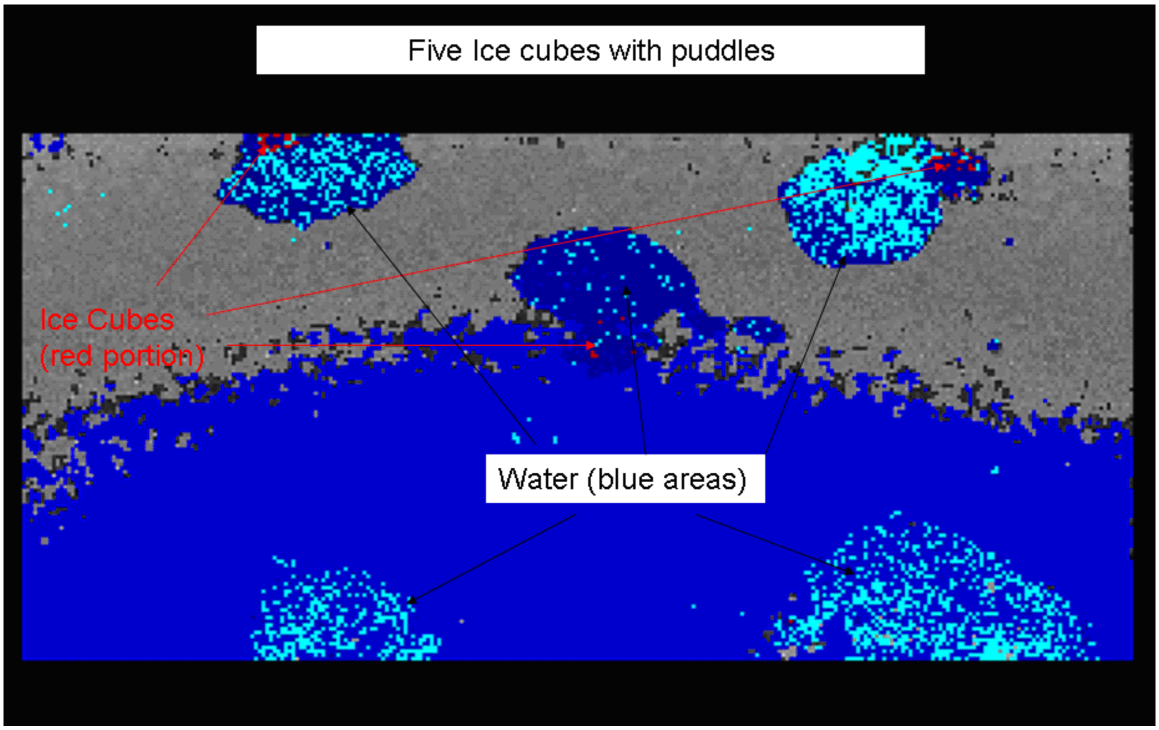

Figure 6. Color-enhanced picture from the LRSS during its calibration phase

Colored portions from the LRSS images represent different water phases. A properly configured, color-enhanced LRSS image would show ice in red, snow in dark blue, and water in light blue coloration. The LRSS was set in the automatic scanning mode so a scan was taken every 15 minutes. If a storm event was expected, Iowa DOT personnel would change the scan rate to every two minutes, thereby increasing the number of images that could be used to study how the snow and ice formed on the roadway. Unfortunately, setting the camera to two-minute intervals caused a malfunction, and the camera had to be taken down and returned to Goodrich for repair.

Data from the scans were stored in the LRSS electronics module and then downloaded by means of a laptop computer running Windows 98® and a DOS-based program. Images were then distributed to the appropriate personnel. Prior to installation of the LRSS system, the Iowa DOT's laptop computer was configured at Goodrich for downloading images and communicating with the LRSS. The Iowa DOT used a download (Ethernet) cable and an RS 232 cable to change settings in the calibration tables or clock settings.

5. RESULTS AND CONCLUSIONS

After the LRSS was properly mounted and configured, it was able to detect many different pavement conditions. The winter of 2004–2005 started late in the season, but produced many types of winter storms and created many different pavement conditions. When the camera was configured to scan in two-minute intervals, the evolution of the surface condition could be closely monitored. The data produced reasonably detailed images that could clearly show different pavement conditions.

Figures 7 through 9 show examples of some pavement conditions observed during the test period. In these figures, the upper portion of the image is the northbound driving lane of Interstate 35. The driving lane is separated from the bridge apron (bottom portion of the image) by a white line. Surface conditions in the color-enhanced images are differentiated by color. Red indicates ice, dark blue indicates snow, and light blue indicates water. Darker variations of those colors denote thicker accumulation.

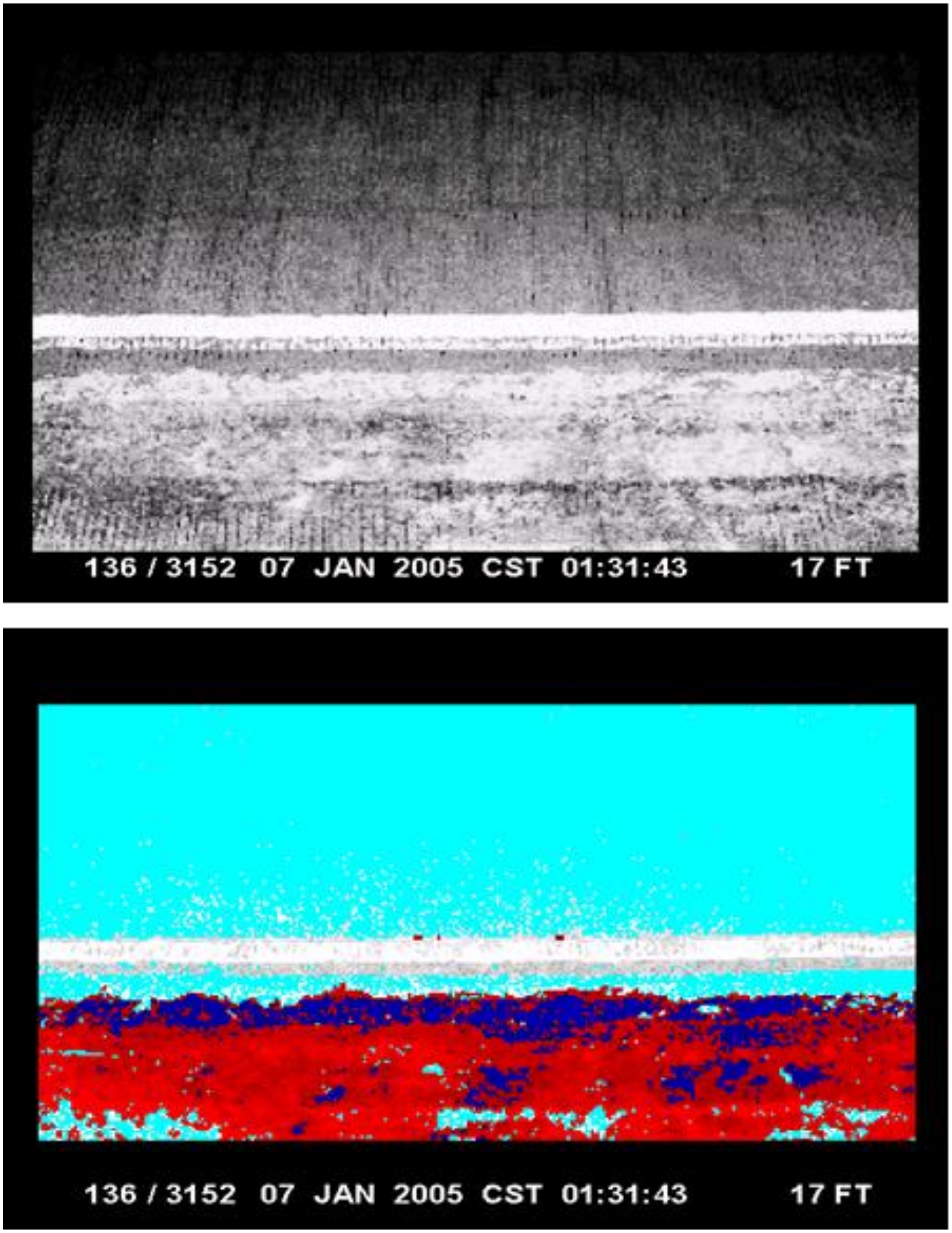

Figure 7. LRSS images of snow collecting on the apron of the bridge

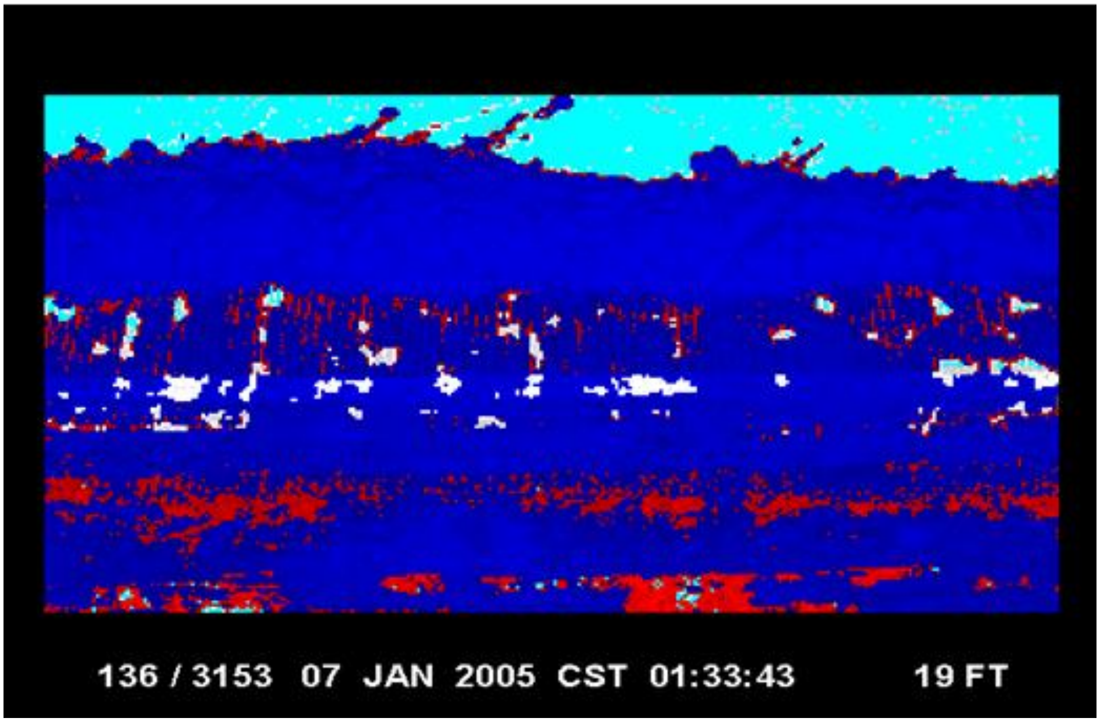

Figure 8. LRSS images showing snow being cleared from the apron of the bridge, leaving some snow on the roadway near the white line

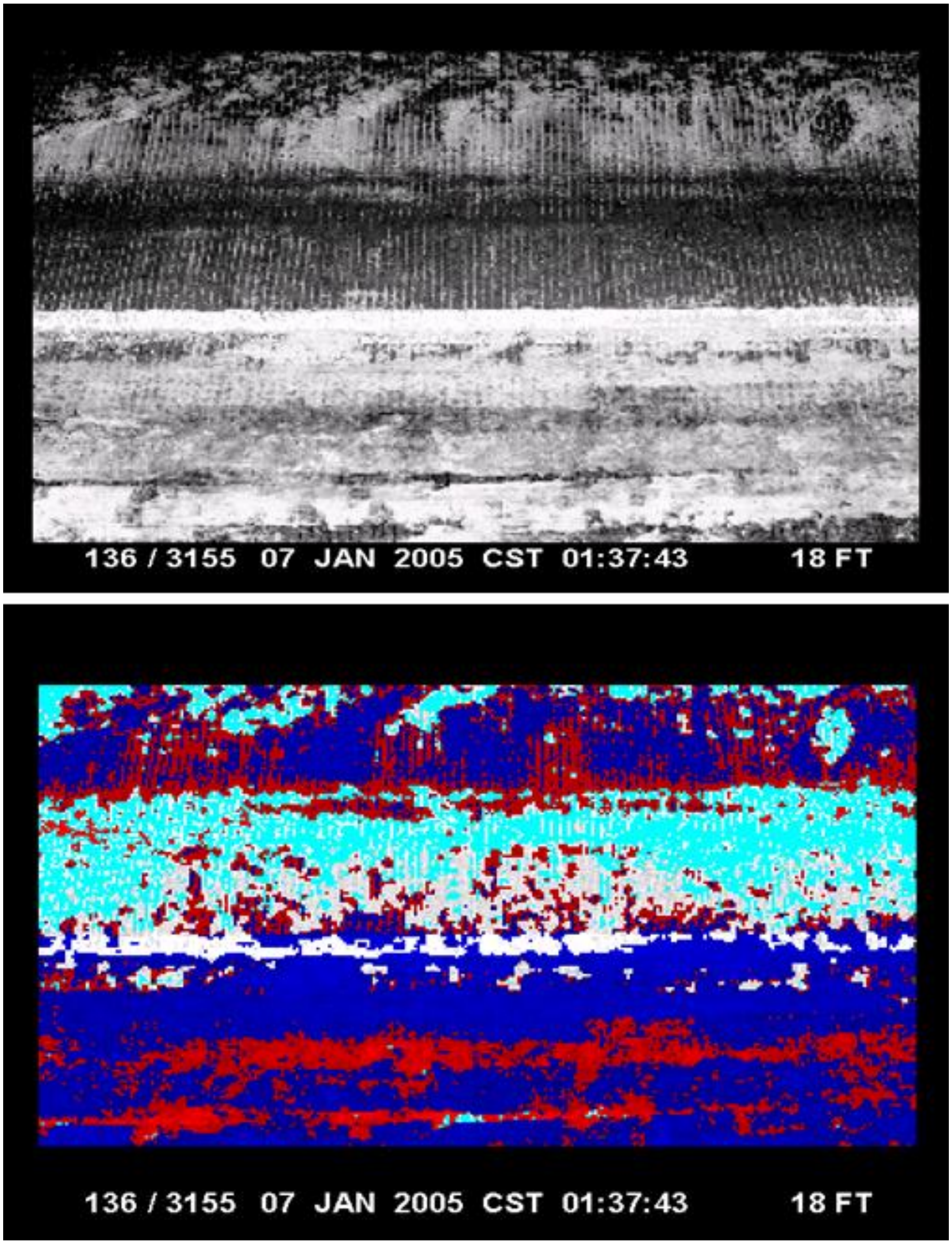

Figure 9. LRSS images showing a mixture of pavement conditions

In Figure 9, the shoulder and middle of the driving lane appear to have a thin layer of snow, while the wheel track seems mostly wet or icy.

Five weather events were used to examine whether the LRSS was capable of detecting the onset of surface wetness before such conditions were recorded by the nearby road weather sensor station. A summary of the results is found in Table 1.

Table 1. Summary of event onset times (local time) as indicated by the nearby road surface sensor, precipitation identifier, and the LRSS

Event date	Type of event	First surface sensor wetness	First recorded precipitation	First LRSS image wetness
11-3-2004	Condensation pavement wetting	05:35	None	05:22
11-25-2004	Condensation pavement wetting	20:40	None	20:24
11-26-2004	Rain showers	17:59	17:30	17:56
11-28-2004	Rain/snow showers	16:52	21:33	21:31
12-20-2004	Snow	15:38	15:35	15:31

Frost was detected by the LRSS on one occasion when frost was positively identified by human observers. The frost was observed forming in patches on the deck. Some patches were unusually symmetrical, a pattern seemingly determined by the internal structure of the bridge. These patches seen by the observers are similar to the patches found in the LRSS images. Figure 10 shows a color-enhanced image of observed bridge frost, with uneven patches and multiple water phases. In the center of the image, the faint diagonal impression in dark blue was visually observed as a stripe of heavier frost crossing the width of the bridge. Given there is no specific category for frost (only ice, snow, water, and dry), frost appeared as a variety of water substance types.

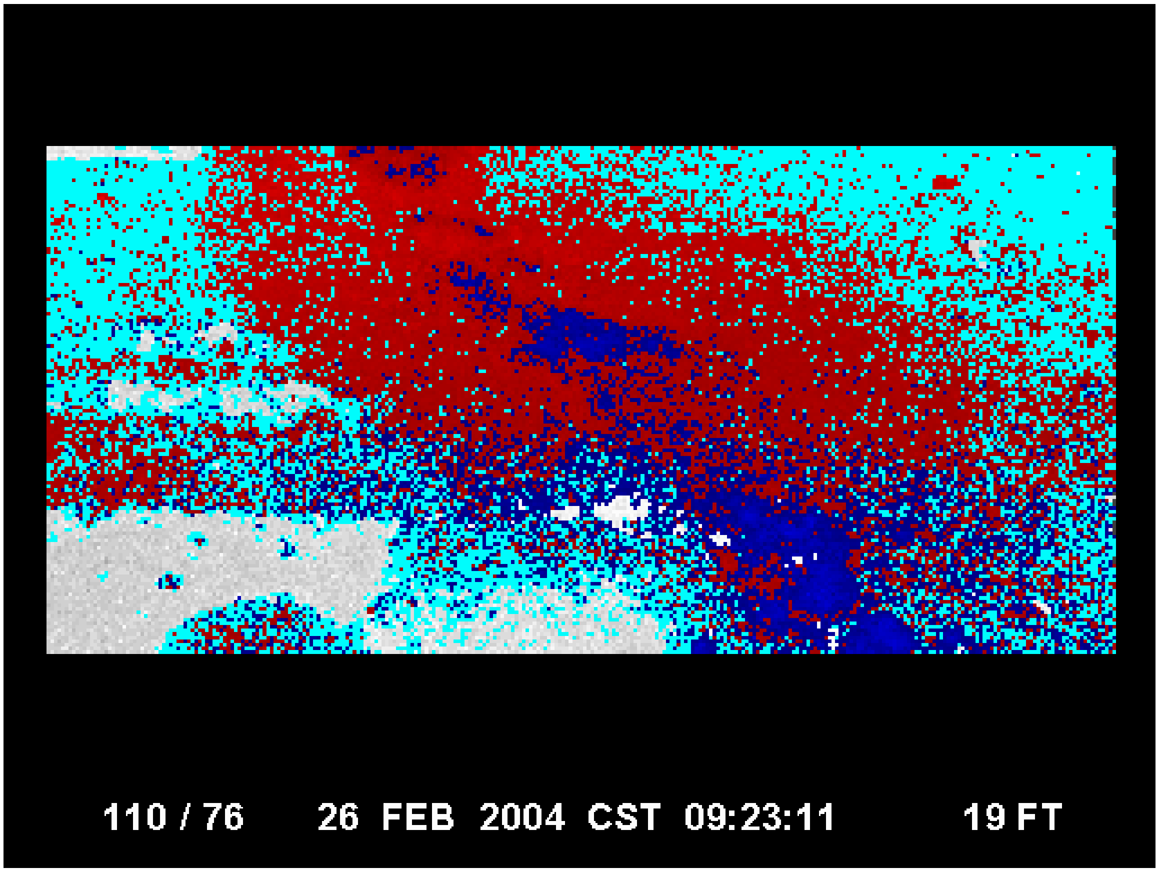

Figure 10. LRSS color-enhanced image of a human-observed frost event

The LRSS camera was found to provide useful information about the condition of the road in its view. Unlike in-pavement sensors that deduce the surface condition in a very small (approximately 25 in^2) portion of pavement, the LRSS can provide information regarding a lane-width of pavement. A larger area of information is preferable to smaller areas, especially when the condition of the road is not spatially uniform. These images can be used by winter maintenance supervisors as well as the public to monitor the spatial distribution and phases of water substance on the driving surface.

The LRSS provides images as well as the percent of ice, snow, and water included in the images. Another benefit of the LRSS is that it can collect useful data in dark areas where traditional cameras may not produce useable images. Since the LRSS uses an infrared beam to illuminate the surfaces in the viewing area, it is not necessary to illuminate the test site or rely on ambient lighting during the evening hours. Neither test location had any street lighting.

Although the camera performed very well, the Iowa DOT notes some significant shortcomings of the LRSS system for widespread RWIS deployment. The scan information was processed into images using the manufacturer's image software installed on the Iowa DOT's laptop computer. This method of image creation was helpful because the raw scan information was preserved and images could be recreated in the event that the initial image calibration was found to be inadequate.

Unfortunately, the image software requirements also limited the operating system of the download computer to Windows 98®. Furthermore, this camera is extremely difficult to access remotely and required manual downloads of the scan information. This would prohibit the use of the LRSS in real-time pavement monitoring. The LRSS system's method of image creation and scan information retrieval was found to be more applicable to research or data archival purposes. However, future versions of the LRSS ice camera do allow remote access.

The cost of the LRSS was also found to be prohibitive for deployment by the Iowa DOT, limiting any installation to the most vital or troublesome roadway segments. The camera was purchased for a price of $25,500. This price is many times the cost of an individual Iowa RWIS pavement sensor. Widespread deployment may become more appealing in the event that the unit price declines or if future versions of the LRSS offer additional capabilities beneficial to the Iowa DOT.