Synthesis of Vehicle-Based Winter Maintenance Technologies

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Agenda

- Background
- Methodology
- Research Findings
- Conclusions
- Acknowledgements

Project

- NCHRP Project 20-07/Task 200 (Nov. 2005-Sept. 2006)
- To synthesize the information on the state of the practice:
  - Automatic Vehicle Location (AVL)
  - Mobile RWIS Technologies
  - Millimeter Wave Radar Sensors (MWRS)
  - Visual and Multi-Spectral Sensors (VMSS)
  - Fixed Automated Spray Technology (FAST)
  - Other Vehicle-Based Winter Maintenance Technologies

Challenges for DOTs

- Maintain and operate the highway network during the winter season while dealing with increased traffic volumes, higher expectations from the public, and unprecedented budget and staffing constraints.

- Provide a high level-of-service and improve safety and mobility in a cost-effective manner while minimizing corrosion and other adverse effects to the environment.

Winter Maintenance Best Practices

- *Vision: to deliver the right type and amount of materials in the right place at the right time*
- A variety of vehicle-based winter maintenance technologies have been implemented by agencies to optimize material usage, reduce associated annual spending, and ensure the safety of the personnel responsible for maintaining winter roadways.

Advanced Technologies Identified for Winter Maintenance

Technology	Application					
	Detect Environmental/ Road Surface Conditions	Detect Obstacles	Detect Position on Roadway	Conduct Road Treatment	Improve Vehicle-to-Center Coordination	Track Vehicle Location and Activity
AVL	*		X		X	X
Surface Temperature Measuring Devices	X					
On-board Freezing Pt. Detection System	X					
Ice-presence Detection System	X					
Salinity Measuring Sensors	X					
Millimeter Wave Radar Sensor	X	X	X			X
Visual and Multi-Spectral Sensors	X	X	X			X
FAST Systems	X			X	X	

*Used for this application only when coupled with other sensor technologies

☐ Technologies often linked with AVL

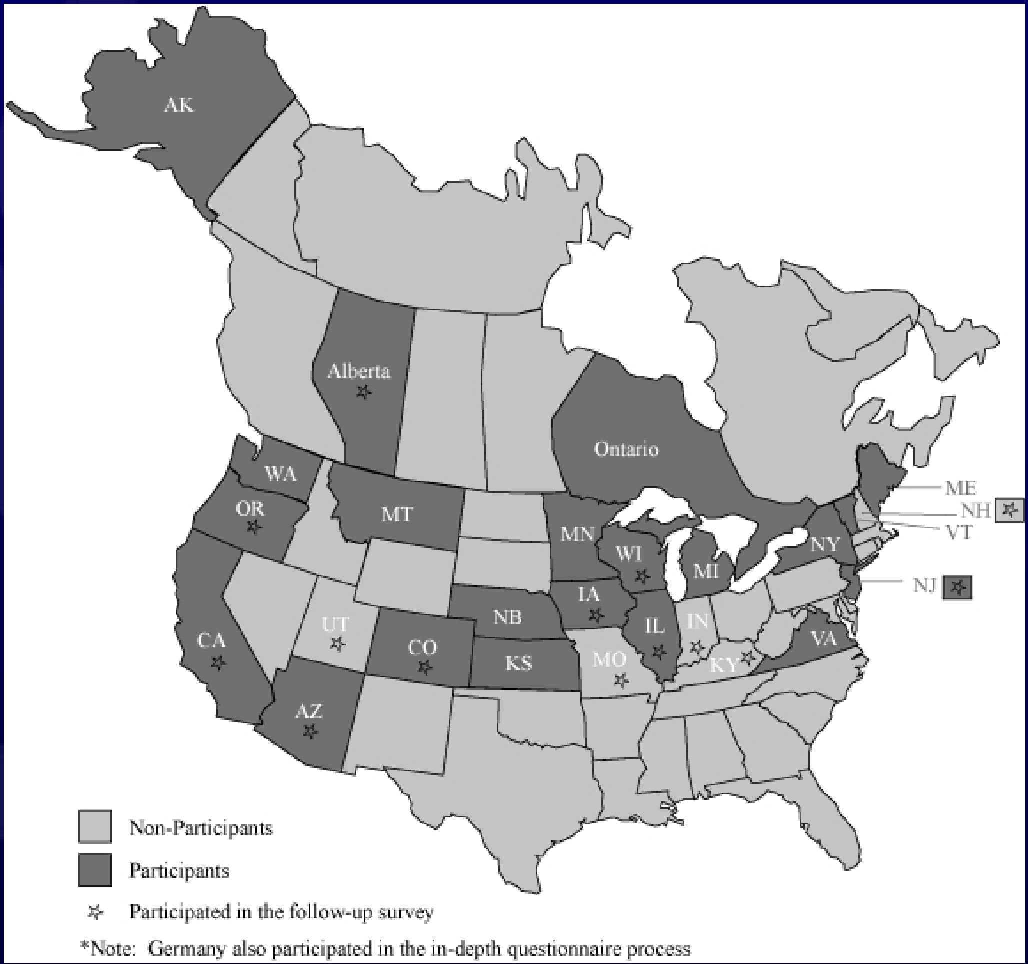
Methodology

- **Literature Review**
- **Agency Surveys**
  - Preliminary Survey on Snow and Ice List Serve
  - Technology Questionnaires (15-16 questions)

    Extent; Planning; Selection/Design; O&M; Evaluation; Future; Other
  - Follow-up Survey
- **Phone Interviews as Necessary**

Reporting Agency Statistics

- **152 individuals contacted**
  - 21% response rate (33)
  - 63%: state DOTs
  - Other: U.S. city and regional maintenance agencies, the Canadian Ministry of Transportation, Canadian city and regional maintenance agencies, and the German Federal Highway Institute



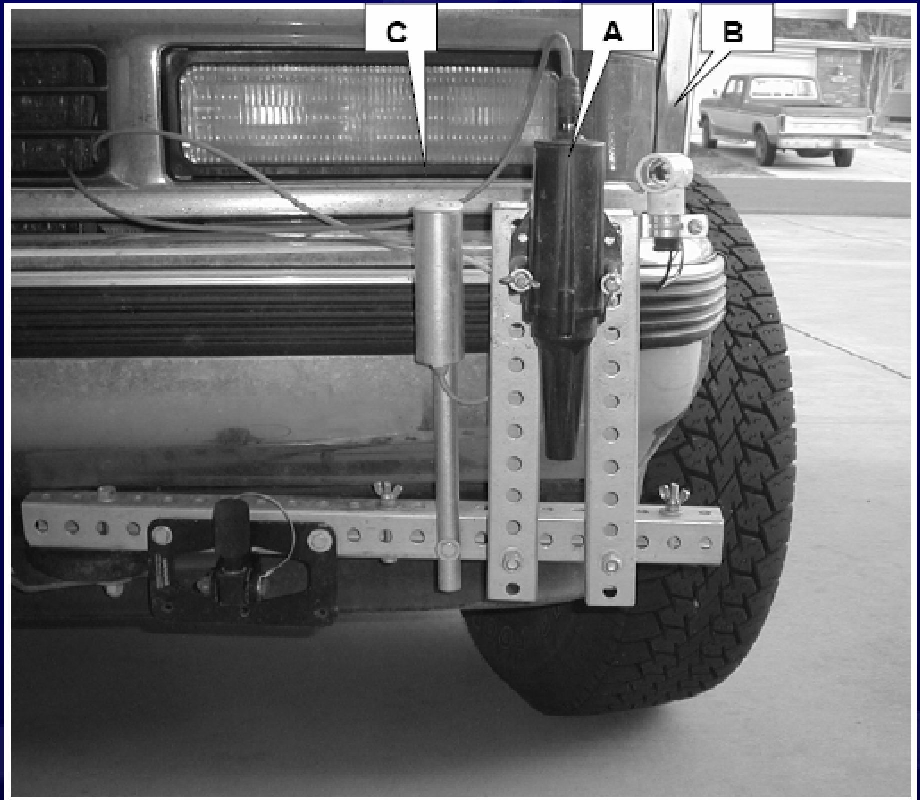
General Research Findings

- Technologies reviewed are in varying stages of development
- The advent of these technologies, however, has facilitated the management of operations and saved resources and time.
- Integrating some of these technologies together can be beneficial, though it may be challenging. Difficulties for integration included the interference between communication systems, incompatible hardware and software, and others.

Mobile RWIS Technologies

- Could be integrated with AVL to provide improved real-time knowledge of road and environmental conditions throughout a network, and not merely at points where in-pavement measurements are collected.
  - Surface temperature measurement devices
  - On-board freezing point and ice presence detection sensors
  - Salinity sensors

Surface Temperature Sensors

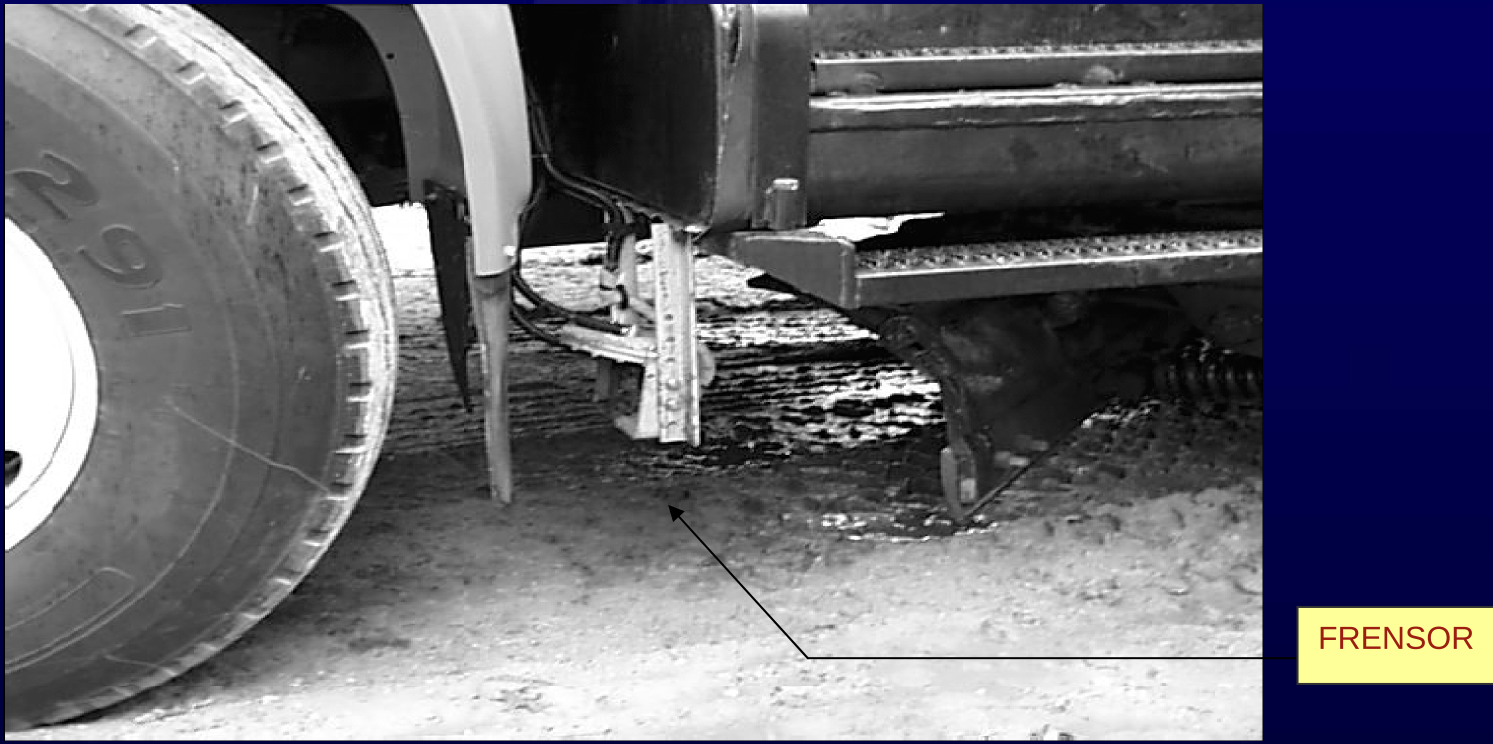


(A) Surface Patrol™ IR Sensor, (B) Air Temperature Sensors, and (C) Roadwatch™ IR Sensor (from Tabler, 2004)

Surface Temperature Sensors

- Matured: Non-contact infrared (IR) sensors are widely to indirectly measure surface T by quantifying the amount of thermal radiation emitted by the road surface.
- Support decisions regarding chemical application timing and rates.
- Advantages of using IR sensors:
  - ease of installation, operation and maintenance;
  - fast response time (1/10th of a second);
  - generally accurate and reliable measurement, as proven by laboratory and field evaluations; and
  - low cost relative to expected benefits.
- Numerous agencies are planning on incorporating this technology on their entire fleets. Future enhancements in the technology may improve how quickly it responds to changing conditions, as well as how it may successfully be integrated into an AVL platform.

On-board Freezing Point and Ice-Presence Detection Sensors



Frensor™ Device Mounted on the Highway Maintenance Concept Vehicle (from Andrle, 2002)

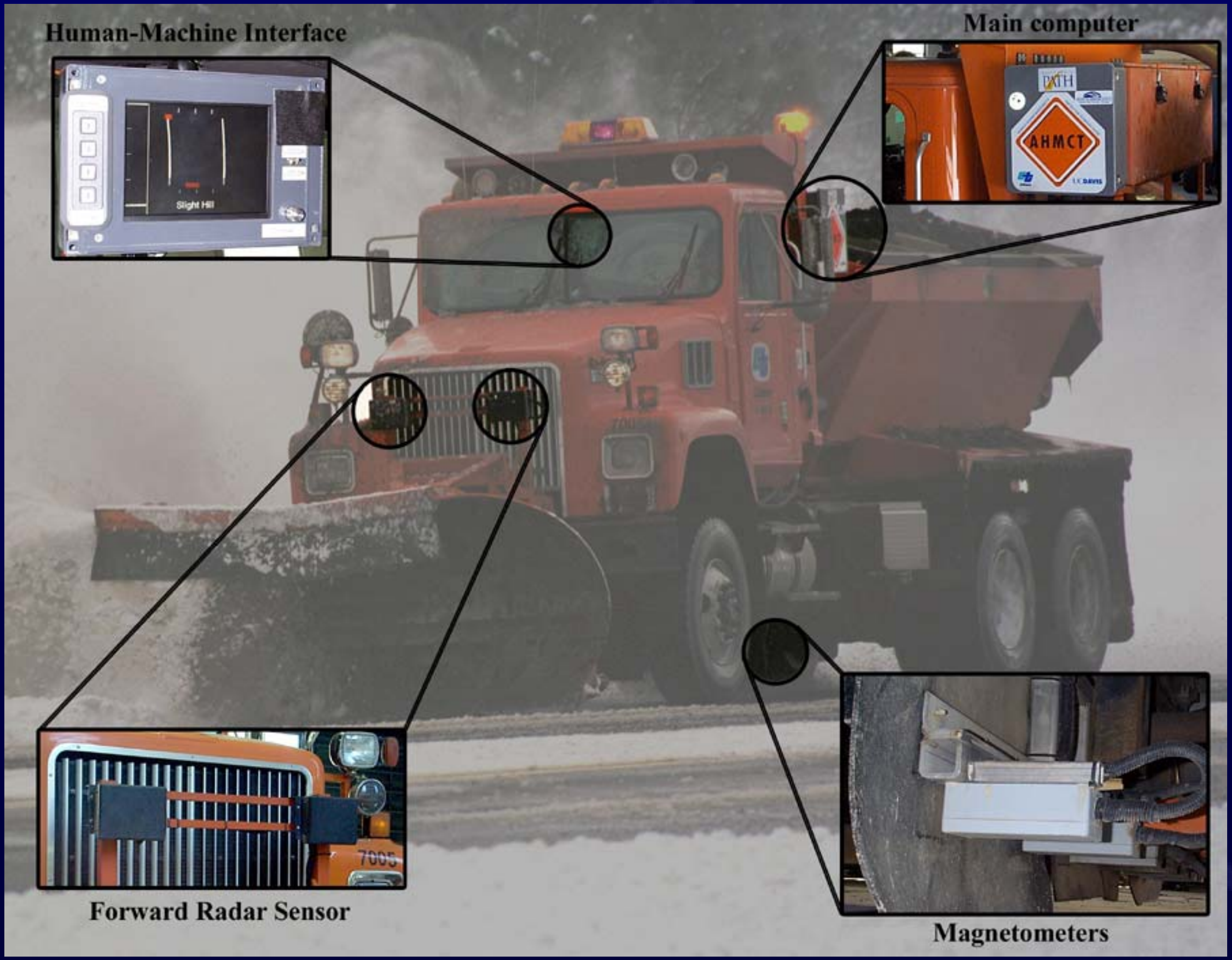
On-board Freezing Point and Ice-Presence Detection Sensors

- Not well-established, not widely deployed for field use
- Advantages:
  - Ability to map the road surface conditions along an entire roadway network and detect localized ice patches
  - Obtain knowledge of the effectiveness of deicing/anti-icing chemicals
- The tire spray is collected and then isolated by closing the system using a pneumatic bladder. The measurement is made through a series of cyclic warming and cooling cycles of the sample.
- Frensor: generally reliable, but need to manually clean the sensor heads during field use. An automatic cleaning device, which can also alert the operator of a dirty sensor, was needed.
- Other conceptual designs: proposed, but still under development.

Salinity Measurement Sensors

- Advantages:
  - Allows for more accurate chemical application rates
  - Integrate measurements from salinity sensors to automatic spreader controls to apply the right amount of chemicals in the right place
- University of Connecticut sensor: heat the tire splash before measuring its conductivity. Field results indicated feasibility, but there was a delay in readings.
- Japan Highway Public Corporation sensor: measure the refractive index of an aqueous solution atop of the road surface. Field results indicated that the sensor was accurate and suitable for widespread deployment, but need improvement for dry surfaces.
- Both sensors have shown some promise in continuously measuring the salinity of the road surface. However, neither has been used over extended field tests.

Millimeter Wave Radar Sensors



RoadView^{TM} Technologies (Photo courtesy of Ravani et al., 2002)

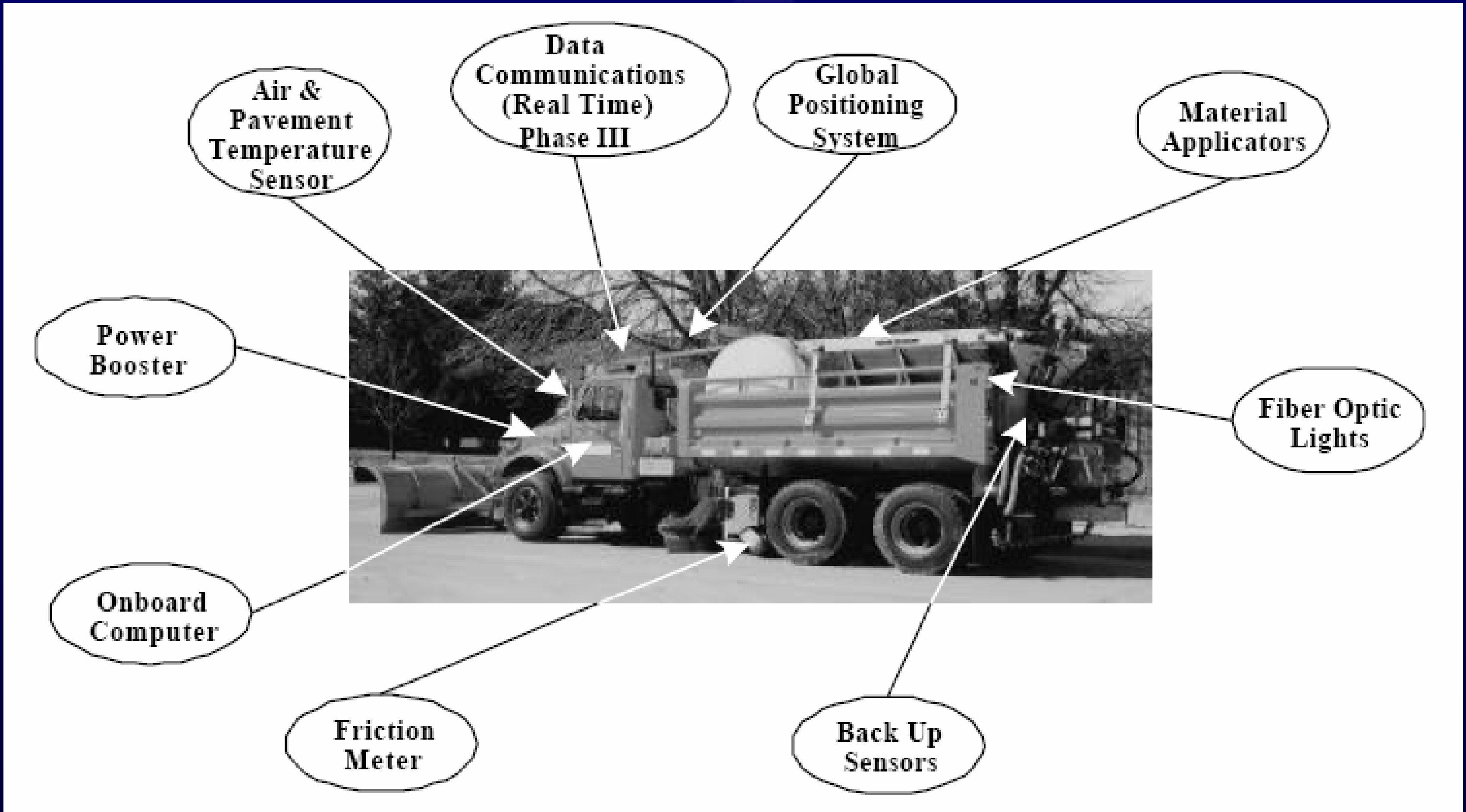
Millimeter Wave Radar Sensors

- For collision warning systems: work by sending out signals that reflect off objects in their path, and the radar system detects the echoes of signals that return.
- Two notable field tests in U.S.: RoadView™ in California, and Guidestar™ in Minnesota. Roadview was found to be most cost-effective in areas with high traffic and inclement weather conditions.
- Advantages:
  - Ability to detect obstacles in front of, behind, and to the side of vehicles
  - Over long ranges (up to 300 ft) and in extreme conditions such as heavy rain and snowstorms.

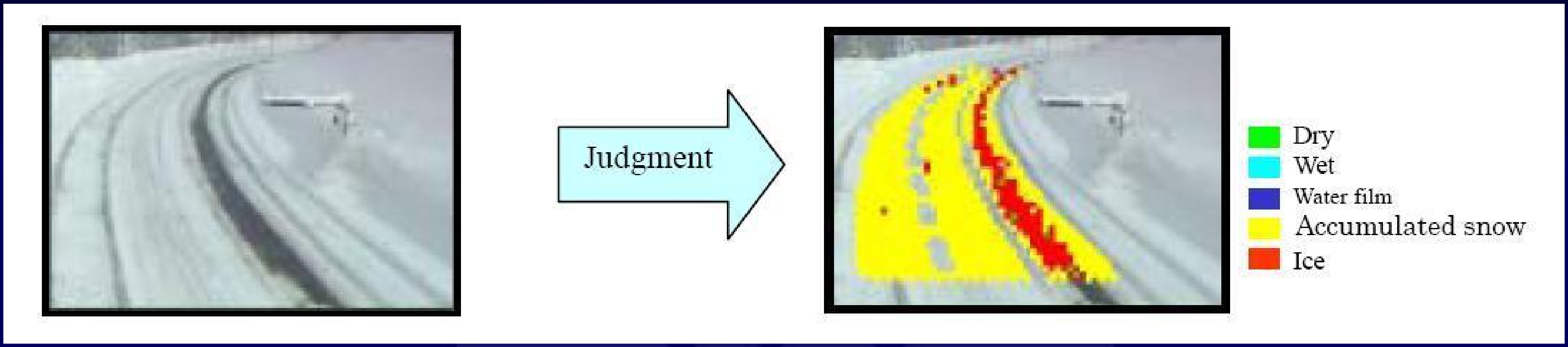
Millimeter Wave Radar Sensors

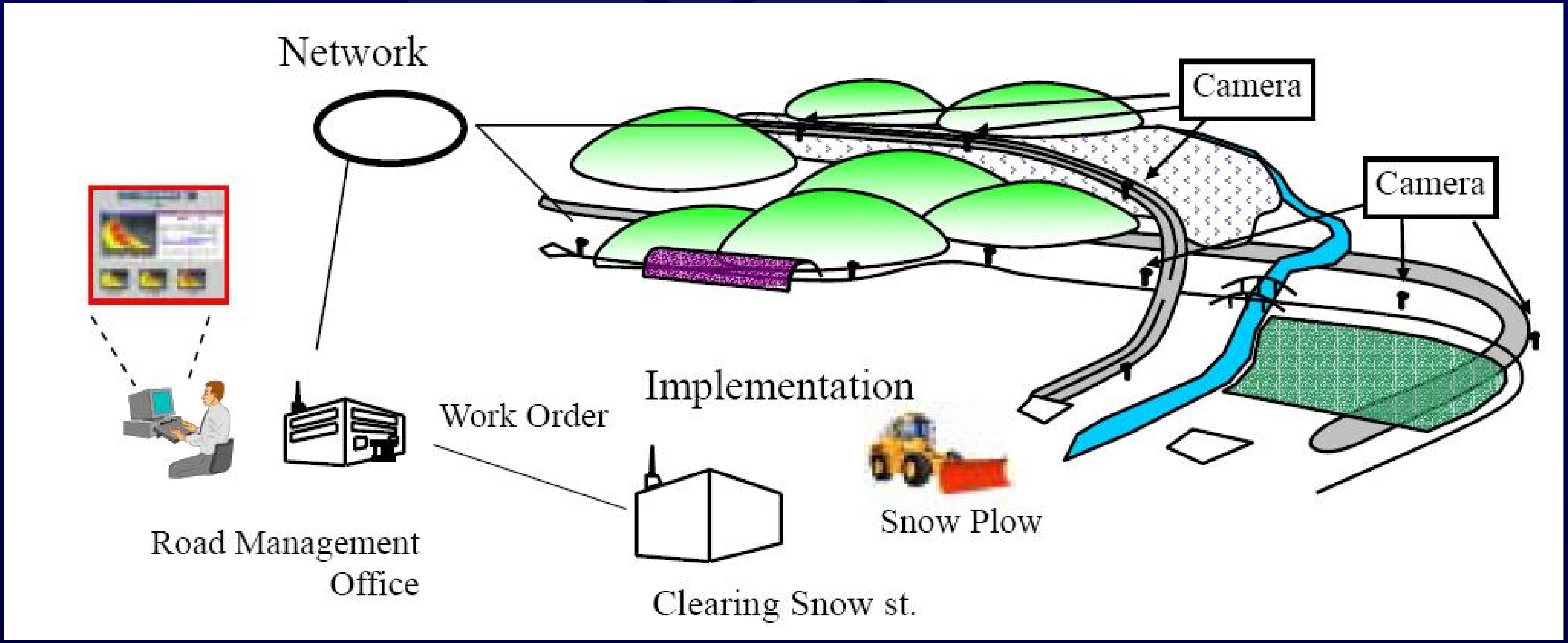
- MRWS continue to be refined, reducing the weight, size and cost of the product so that it may be more cost-effective for use in overland trucking, transit, and automobiles.
- This technology is not mature enough to be used as a “black box” solution as it is still in the development stage (addressing false alarms).
- Some agencies have installed simpler MWRS systems with a limited user interface that only warns of obstacles while backing up. Operator acceptance of these systems has been positive so far.
- Survey results show that rear MWRS are viewed as more beneficial than front and side MWRS.

Visual and Multi-Spectral Sensors



Phase II Prototype Highway Maintenance Concept Vehicle using Backup Sensors (from Andrle, 2002)





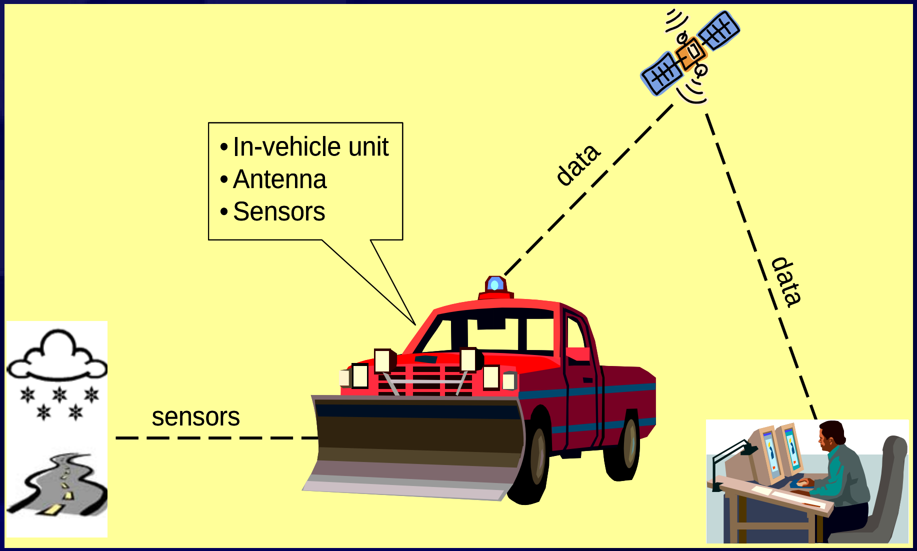
Winter Road Surface Management using Visible Image Road Surface Sensors (from Kawana et al., 2005)

Visual and Multi-Spectral Sensors

- Sensors that utilize electromagnetic energy at various wavelengths, especially in the infrared and visible wavelength spectrum, are common in advanced transportation applications.
- Multi-modal sensing, or the use of multiple wavelengths or even multiple technologies (e.g., video with acoustic sensing) in a single sensing system, has some attractive attributes for solving a wide range of problems.
- There is little information in the published literature about their specific application to winter maintenance vehicles.
- Two major applications for snowplows:
  – Collision warning systems (CWS): MWRS, LIDAR (LIght Detection And Ranging), Optical (including infrared) systems, Vision enhancement systems, LASERs (Light Amplification by Stimulated Emission of Radiation)
  – Road condition sensors: Visible image sensors, LIDAR, Radiometer sensors, Laser road surface sensors

Looking to the Future: *Integration*

- Projects: RoadView, Mn/DOT Advanced Snow Plow, and the Highway Maintenance Concept Vehicle.
- AVL is a platform that can integrate the on-board sensor technologies and connect the maintenance vehicle with the maintenance center.
- Integration is also a key consideration with MDSS. The mobile data collection platform is expected to provide more timely and comprehensive data for decision-makers.



Looking to the Future: *Automation*

- Currently, there is a trend toward increased automation of snowplow operations. This trend recognizes the complexity associated with executing winter maintenance tasks during storm events, when such tasks are most critical.

- With many technologies not at a market-ready level, the path to automation will be slow. However, there is belief that increased automation can provide benefits to transportation agencies, their employees, and the traveling public. Therefore, research will continue into the further integration and automation of the technologies.

Looking to the Future: *Barriers to Implementation*

- These barriers are primarily, though not exclusively, technological.
- Additional research and development should help address these technological barriers.
- There are a number of technologies early in the development phase or existing only as patents that may have the potential to address some of these barriers.

Conclusions

- This project provided a summary of various vehicle-based technologies that will enable maintenance agencies to easily find and evaluate tools that may be applicable to their particular location, available staff and vehicle inventory. These technologies are vital to addressing the challenges faced by DOTs.
- One critical challenge to be addressed is the communication between vehicles and maintenance center, especially in rural areas.
- Maintenance needs, costs, user acceptance, and training issues should be considered early on when planning for advanced technologies.
- Integration of various technologies is important yet challenging, particularly in the areas of communications, user interface, and software expandability and compatibility.

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Questions

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