

W e a t h e r :

Making it a National Priority in Surface Transportation



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Foreword

The American Meteorological Society in a partnership with the Intelligent Transportation Society of America has committed to increasing weather information awareness for transportation related issues. By participating in Annual Meetings, Exhibition programs, workshops and conferences, we hope to improve the dialog and coordination between the organizations and their members.

As a part of “Enabling Technologies,” Track 3, at the ITS America 11th Annual Meeting and Exposition in Miami Beach, Florida, two sessions about weather information and applications for surface transportation are planned. Session 37, the first session, will initiate an agenda for a “Transportation-Weather Applications for National Deployment (T-WAND)” program. Session 50, the second session, will explore specific case studies on the use of weather information in the ITS to serve surface transportation. This session will begin with a panel presentation, organized by the AMS, focusing on the 2002 Winter Olympics in Salt Lake City. Examination of the public/private/academic model of cooperation used to deliver winter weather information for road maintenance and transportation operations will be the main focus. Two paper presentations will follow. The first paper will examine use of weather information to improve winter road safety and maintenance. The second presentation will discuss a real-time state level road and weather information network.

At the conclusion of session 50, an informal wrap-up session will convene to discuss the results of these sessions and plan for future involvement for AMS with ITS. Expanding the session for the 2002 ITSA Annual Meeting will be a main topic.

AMS is also operating an exhibit booth in the Exhibition Hall. Information about the society and its services are available. Also, private sector meteorologists and certified consulting meteorologists who have chosen to participate have information about their services in this booth.

Please refer to the updated conference program for more details about this program and all other sessions.

Sincere gratitude goes out to the Planning Committee, without whose assistance none of this would have been possible. Thank you also to the panelists, presenters, moderators and authors that have contributed to this program helping to make it a success.

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A NATIONAL PROGRAM FOR SURFACE TRANSPORTATION WEATHER APPLICATIONS

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ABSTRACT

Surface transportation is the major carrier of people and commerce in the United States, and all of its performance goals—safety, mobility, productivity, environmental quality and national defense—are vulnerable to weather threats. Given how much is at risk, it is dismaying that, unlike for aviation, there is no dedicated program of research and deployment for surface transportation weather needs.

The Intelligent Transportation System (ITS), that includes environmental sensing, information dissemination and decision support, promotes the operational techniques and travel planning that need better weather information. The ITS also prepares surface transportation to be a full partner with the aviation, maritime and military interests that have worked so productively with the meteorological community in the past on research and deployment programs. What surface transportation still lacks is a nationally focused, surface transportation weather program with dedicated funding equal to the needs. It is recognized that surface transportation provides the challenges of decentralized operation, across modes, between levels of government, and between the public and private sectors. This should not prevent all the interested parties from participating in a coordinated program. It is necessary to focus federal resources. It is necessary to catalyze a national agenda for coordinated intermodal, public sector, and private sector efforts. It is necessary because thousands of lives and billions of dollars could be saved annually by such a focus and coordination. Making surface transportation a full partner with other weather interests has two-way benefits. The ITS creates important new dissemination channels for weather hazard information, as part of travel planning applications on the road or at home. Surface transportation can be an important contributor to environmental observations. Finally, surface transportation will be an important constituency for the land components of an integrated land-air-water environmental observation and prediction system. This paper describes these motivations and some of the issues that a dedicated national program should address.

A NATIONAL PROGRAM FOR SURFACE TRANSPORTATION WEATHER APPLICATIONS

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BACKGROUND

Surface transportation is the dominant carrier of people and commerce, and weather is a significant threat to the performance of all the surface modes, as shown in Figure 1. Weather—or more specifically the adverse environmental conditions near the ground of visibility, wet/slippery/flooded roadways, high winds, temperature extremes, damaging hail/lightning, pollutant/HAZMAT transport, etc.—dynamically affects the goals of safety, mobility, productivity, environmental quality and national security.

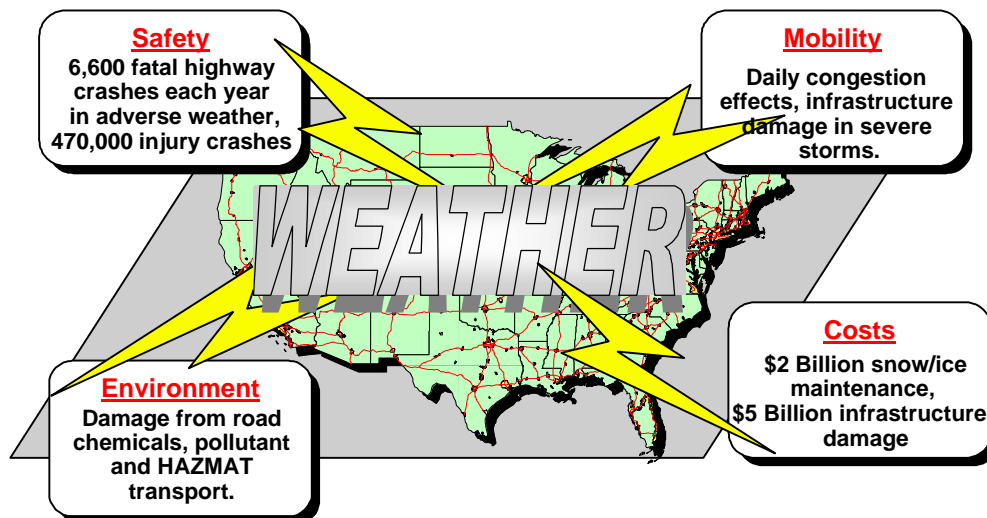


Figure 1: Weather Effects on Surface Transportation

Despite its immense national significance, surface transportation has not had the stature of the aviation or maritime modes when it comes to weather information and research. The original charter of the National Weather Service (NWS) includes service to commerce and navigation¹. Commerce meant surface transportation. Navigation has come to mean air and maritime transport. Today, our national meteorological services serve “navigation” well. There is a partnership in weather systems planning, research and deployment primarily between the NWS, the Federal Aviation Administration (FAA), and the Department of Defense (DOD). Each has dedicated funding and operations for weather purposes, and there is a mutually beneficial interchange of facilities, data and applications. For example, in addition to a \$427 million budget for weather operations, the FAA has an Aviation Weather Research budget of \$30 million in FY 2001². Surface transportation, even through its federal modal administrations, is not a significant player in these activities.

Comparison with the “big three” of the NWS, FAA, and DOD is not intended to take anything away from their efforts. There is an excellent national, and public, infrastructure of weather information and it is vitally applied to national security and transportation—in the air and on the sea. An unequal surface transportation presence in weather issues and systems at the national level is not consistent with the importance of surface transportation. It is important to have a comparable presence to assure that the infrastructure is properly leveraged in application to surface transportation. This presence requires a federal component and includes the proved federal role in catalyzing the public sector and private sector markets for modally-applied weather services.

THE CONSTRAINTS

There are two reasons for the present inequality of surface transportation with the other weather principals. The first is basically geophysical. Weather is in the atmosphere, which is important to aviation, and the important, large-scaled, air-ocean interfaces extend the interest to the maritime domain. There are land-weather interactions vital to surface transportation, but these are at fine scales. Road temperature is a good example. It determines the roadway condition in combination with weather, but it is quite variable at scales below kilometers. Getting to the surface/air environmental conditions of importance to surface transportation requires a finer scale of observations and prediction, consideration of land-air interactions in

¹ U.S. Code, Title 15, Section 313.

the atmospheric boundary layer, and the conversion of weather phenomena to sensible surface effects such as road friction, visibility, and vehicle stability.

The second set of constraints is institutional. In both weather and transportation, there is a mixed public/private, federal/state/local system. However, while the airspace system is federally operated, and the maritime system in international waters must have a strong federal representation, mostly there is no federal operation of the surface transportation system (although inland waterways under federal operation are included in the surface category). The state and local public sector dominates road and transit operations, and the private sector dominates rail operations. All the modes have private carriers of course, but they are much more decentralized, and the movements of most of the traffic, that is on public roads, is not positively controlled.

The result of the constraints is that the provision of environmental-condition information (referring to weather-related surface transportation conditions) is fragmented. There are no strong federal representatives for surface transportation matching the big three agencies. None of the surface modal administrations—the Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), the Federal Rail Administration (FRA), and the allied Research and Special Programs Administration (RSPA) or the National Highway Transportation Safety Administration (NHTSA)—have dedicated funds for weather programs nor any budgets with the ability to buy into the requirements for joint surface and remote sensing systems of the big three.

THE PUBLIC/PRIVATE PARTNERSHIP

The specialization required to get fine-scaled environmental conditions has created contention over the bounds of the NWS relative to private sector services. This issue has to be addressed head-on. The private sector has been filling the gap between weather and surface-environmental information, often ably but not always uniformly.

There is no question that applications that directly serve niches of end users, whatever their interest in weather, should be provided by the private sector. But this overlooks three facts:

1. The private sector products *depend on* the public, national, environmental infrastructure.

² Table 2.1, The Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 2001, Office of the Federal Coordinator for Meteorology, June, 2000, Washington, DC.

2. The state/local public sector operators of the surface transportation infrastructure, are both customers for services and providers to the information infrastructure through publicly operated environmental sensor stations (ESS).
3. A public sector, federal/state/local, activity is *necessary* to develop a strong and capable private sector market in environmental information services.

These points are all related to the evolution of the Intelligent Transportation System (ITS) in surface transportation and the consequent shift in focus from construction to operations of the transportation infrastructure.

The ITS begins to make surface transportation more like the aviation and maritime modes in terms of getting information on the relevant travel conditions, and making them available through communications to vehicles and the stationary sites that dispatch, produce or receive surface trips. Travelers, private and commercial, are already increasing the market for information that includes the road or rail-specific environmental conditions. Wireless data to vehicles and the Internet make better user-specific products possible. But the ITS involves an information infrastructure very analogous to the physical transportation infrastructure that logically requires a public sector, federal/state/local, role.

Most of the observational system for environmental conditions is bought and operated by the public sector. The fixed and potentially mobile ESS for road and surface-weather conditions are mostly a public-sector market for privately-supplied devices. A problem has been the fragmentation of the ESS data. There has not been an open information system for sharing the data, including with the national infrastructure of other environmental weather observations.

The ITS is founded on the National ITS Architecture that, with its dependent standards, creates an open system for the ITS. It has been the federal role to establish that open system, in order to facilitate the market for information services, just as a standardized highway system facilitates private highway traffic. The open system concept requires a new perspective on the old concept that “tailoring” of environmental information draws a clear line between the public and private sectors.

An open information system, like the highway system, connects sources and users of information, that may be public or private on either end. The connections are via many information processes. The processes will compete, among vendors and technologies, if they are in an open system rather than “stovepiped”, where an end service is necessarily tied to a string of processes that cannot be mixed and matched. An open system will stimulate the

private market for services, as better information becomes available, from the best provider, more cheaply. The national 511 number for travel information is an example of how the federal ITS leadership creates a new market for information services. There is also a federal/state/local role in advancing the public operator demand for services by establishing the benchmarks for operations by highway or transit operators.

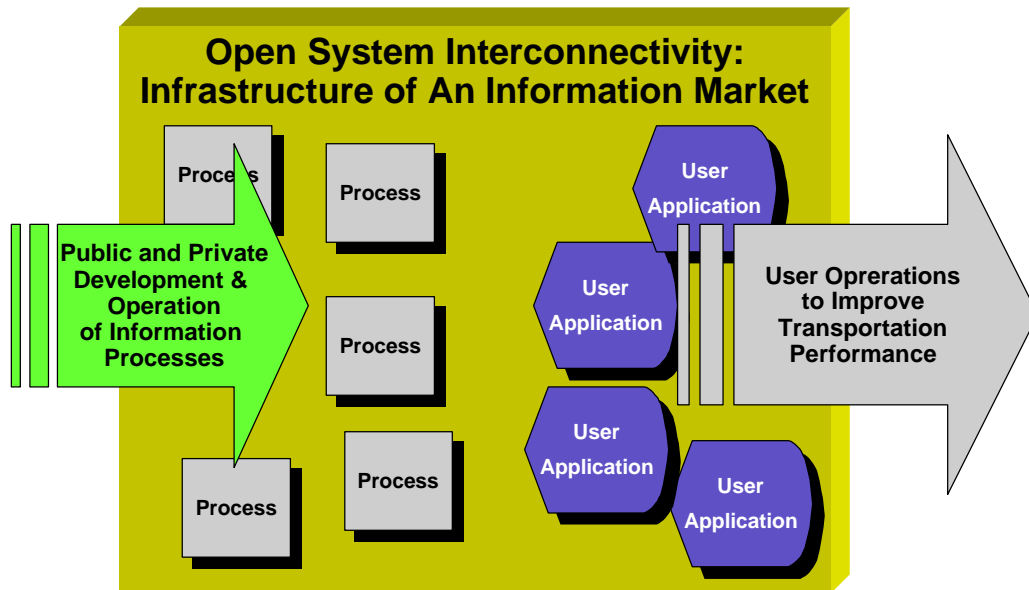


Figure 2: An Open System Supports and Open Market of Information Processes for Diverse User Applications.

In the open system, some of the observational data will be public, some private. The environmental information processes to predict weather or road conditions will be public and private. The end users will be both public and private. The technology development for better processes, sensors, and in some cases the communications media, will be both public and private. As an example, the FHWA is sponsoring the Maintenance Decision Support System (MDSS) project, that involves State transportation staff for the operational requirements, a set of national research labs for technology insertion, and the private sector for system deployment. In addition, the FHWA and the NWS are examining weather infrastructure issues affecting the ITS. The open system concept infers a complete partnership of the public/private, federal/state/local parties. The Internet is a perfect example of how this has worked in the past, with strong initial federal leadership, to catalyze the private market for everyone's benefit. Environmental information applications in ITS can emulate that model.

WHAT IS NEEDED

There are still barriers to the envisaged partnership, which means there are still barriers to a fully articulated market for environmental information in the ITS. The barriers include:

1. There is still a long way to the maturity of the open-system ITS, and that requires continued work on the architecture, standards, and deployment—in terms of technical training of transportation experts and funding priority to operations.
2. There is still research to be done on the technologies and techniques for producing the environmental condition information that meets the prime requirements of *Relevance, Accuracy* and *Timeliness* for users.
3. There is still research and development to be done on the decision support applications, combined with the operational techniques, that put the environmental information to work for the transportation users—both operators and travelers.
4. The current level of effort among the federal modal agencies is inadequate to perform the coordination role, mobilize research assets (e.g., federal laboratories and academia), or leverage the efforts of the other federal weather programs.

Addressing these barriers is a matter both of funding and institutional leadership. There is a U.S. Weather Research Program, and there is an Aviation Weather Research Program. These programs address the cited barriers, in their own domains. Their existence is a statement of the importance of the issues, on the part of both the agencies and the Congress that authorizes those programs. It is time to have a similar recognition for surface transportation. There should be a Transportation-Weather Applications for National Deployment (T-WAND) program that parallels the other two and that brings together all the surface transportation stakeholders under federal auspices. The program does not duplicate the other two, but leverages them, pursues *applications-oriented* research, and bridges the gap from research to deployment among the local operators.

The practical barrier to such a program is funding. There has been a long FHWA interest in road weather. Only in 1999, with the creation of the Operations Core Business Unit, and under that the Road Weather Management Program, was there an institutional focus for the issue. About the same time, the Office of the Federal Coordinator for Meteorology (OFCM) also began to organize surface transportation constituencies. The Road Weather Management Program participation with the OFCM has only increased the recognition of how much

remains to be done to reach the status of the big three agencies that the OFCM was created to coordinate.

The Road Weather Management Program operates with less than a tenth of the staff and funding of the FAA programs for aviation weather. The other surface-modal agencies devote even less. Enough work has been done, on the MDSS for instance, to devise a list of future research topics and to indicate the success of federally-catalyzed stakeholder efforts. But the resources to sustain, even to continue, the effort are inadequate, are not dedicated, and cannot be increased with current authorization levels.

CONCLUSION

The FHWA has been instrumental in creating recognition of the importance of road weather information, within the ITS and to the goals of surface transportation. A case has been made that surface transportation deserves the federal coordination and stimulus in weather-related environmental information enjoyed by aviation. The multi-modal nature of the ITS and the diversity of stakeholders suggests that there are challenges to structuring a comparable program. But the next surface transportation legislation, due for 2004, offers the opportunity for stakeholders to introduce the idea of a dedicated program. It is hoped that ITS America and the American Meteorological Society, as representatives of many of the stakeholders will pursue the idea.

AN ADVANCED WINTER ROAD MAINTENANCE DECISION SUPPORT SYSTEM

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ABSTRACT

A challenge faced by winter maintenance decision makers is to properly identify, monitor and respond to weather conditions that lead to poor road conditions. A major objective of the Intelligent Transportation System (ITS) program is to improve the efficiency and capacity of the surface transportation system. Because weather is a major factor in transportation efficiency, its impact on surface transportation must be understood and addressed. In addition, investments must be made to improve road weather diagnoses and forecasts, and the dissemination of weather information to winter road maintenance practitioners and the traveling public. The ability to obtain accurate, high resolution, weather forecast information along road segments is difficult and time consuming. DOT (Department of Transportation) personnel are often required to consult numerous weather sources and interpret weather data in an attempt to determine the impact of the weather on their local maintenance operation. This process can often result in frustration, misinterpretation of environmental conditions, and poor decisions.

In fiscal year 2000, the U.S. Federal Highway Administration's (FHWA) Office of Transportation Operations (HOTO) Road Maintenance Management Program began an initiative to gather surface transportation weather decision support requirements from State DOT personnel. In addition, the Office of Federal Coordinator for Meteorology (OFCM) together with the FHWA co-sponsored symposiums on Weather Information for Surface Transportation (WIST). The primary objective of these activities was to increase the awareness of the impact of weather on surface transportation and to solicit feedback from the surface transportation community on potential solutions.

Utilizing information obtained from the above-mentioned outreach activities, the FHWA began a project in fiscal year 2001 to develop a prototype Maintenance Decision Support System (MDSS) tailored for winter road maintenance decision makers.

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BACKGROUND

One of the biggest challenges faced by winter maintenance decision makers is to properly identify, monitor, and respond to weather conditions that lead to poor road conditions. A major objective of the Intelligent Transportation System (ITS) program is to improve the efficiency and capacity of the surface transportation system. Because weather is a major factor in transportation efficiency, its impact on surface transportation must be understood and addressed. In addition, investments must be made to improve road weather diagnoses and forecasts, and the dissemination of weather information to winter road maintenance practitioners and the traveling public.



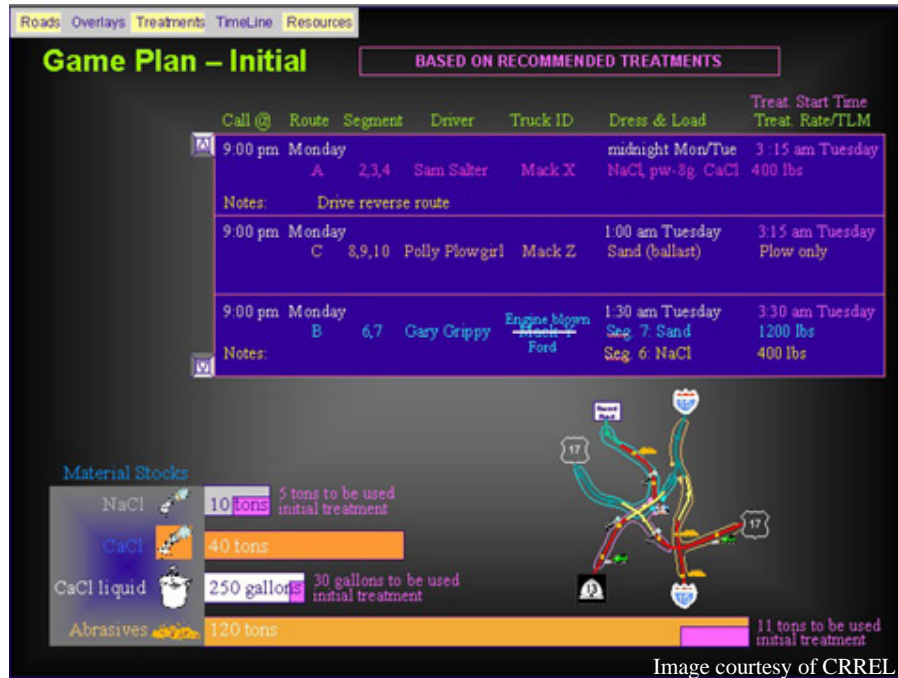
Winter road maintenance in action.

State Departments of Transportation (DOTs) use a variety of systems and consultants in an attempt to become knowledgeable about the current and forecasted weather conditions. The ability to obtain accurate, high resolution, weather forecast information along road segments is difficult and time consuming. DOT personnel are often required to consult numerous weather sources and, in many cases, interpret weather data in an attempt to determine the impact of the weather on their local maintenance operation. This inefficient process can often result in frustration, misinterpretation of environmental conditions, and poor decisions.

INTRODUCTION

In fiscal year 2000, the US Federal Highway Administration's (FHWA) Office of Transportation Operations (HOTO) Road Maintenance Management Program began an initiative to gather surface transportation weather decision support requirements from State DOT personnel. In addition, the Office of Federal Coordinator for Meteorology (OFCM) together with the FHWA co-sponsored symposiums on Weather Information for Surface Transportation (WIST). The primary objective of these activities was to increase the awareness of the impact of weather on surface transportation and to solicit feedback from the surface transportation community on potential solutions.

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Early prototype of MDSS Graphical User Interface (GUI).

While it is recognized that similar tools exist or are under development, there are two important features of MDSS that will make it unique. The MDSS will be: 1) based on leading diagnostic and prognostic research systems (high resolution numerical weather forecast models and state-of-the-art algorithms) of weather and road (surface and subsurface) behavior, that are being developed at national research centers; and 2) non-proprietary; that is, the use of intellectual content contained within the MDSS prototype will not be restricted and thus will be available for federal and private applications.

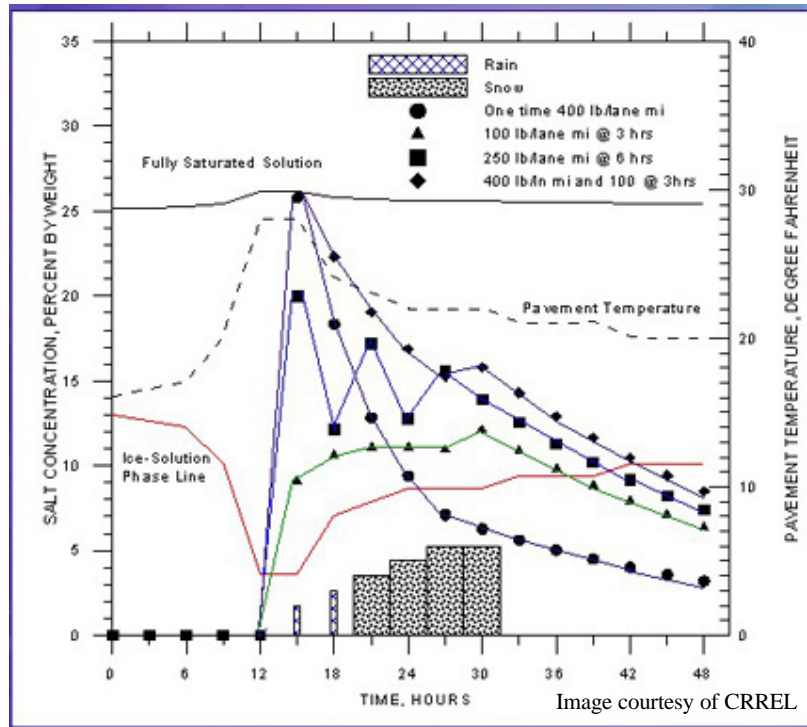
The FHWA selected six national research centers to participate in the development of the prototype MDSS. They were selected because of the applicability of their expertise to the MDSS task. The participating national labs include the Cold Regions Research and Engineering Laboratory (CRREL), National Center for Atmospheric Research (NCAR), Massachusetts Institute of Technology - Lincoln Laboratory (MIT/LL), National Severe

Storms Laboratory (NSSL), Environmental Technology Laboratory (ETL), and Forecast Systems Laboratory (FSL).

The FHWA collected and refined the needs of the winter road maintenance community and identified new technologies that could reasonably be expected to address and improve the performance of the road maintenance practitioner. The MDSS project goal is to develop a prototype capability that:

1. Capitalizes on existing road and weather data sources,
2. Augments data sources where they are weak or where improved accuracy could significantly improve the decision-making task,
3. Fuses data to make an open, integrated and understandable presentation of current environmental and road conditions,
4. Processes data to generate diagnostic and prognostic maps of road conditions along road corridors, with emphasis on the 1- to 48-hour horizon,
5. Provides a display capability on the state of the roadway,
6. Provides a decision support tool, which provides recommendations on road maintenance courses of action, and
7. Provides all of the above on a single platform, and does so in a readily comprehensible display of results and recommended courses of action, together with anticipated consequences of action or inaction.

During a FHWA review of candidate technologies that could address road weather problems, it became clear that many candidate technologies currently exist at national laboratories, but the new technologies needed to be integrated, refined, and tailored to address road maintenance weather issues. It also became clear that new and focused research must be conducted to address specific winter maintenance decision support needs that are not addressed by current technologies.



Output of the chemical concentration algorithm.

NEEDS ASSESSMENT

Based on an extensive user needs assessment performed by the FHWA in 2000, it is clear that substantial benefits can be realized if weather forecasts are improved, more specific, more timely, and tailored for surface transportation decision makers. New data sets (e.g., road weather sensors, wind profiler, GPS, thermal maps, etc.), advanced forecast models, data integration techniques, and research results must be utilized to realize the potential for improved weather information for surface transportation. The most important environmental factors that have been identified to date and will be necessary for supporting maintenance decisions include the following:

- “Event” definition with respect to start and stop times
- Precipitation characteristics (type, amount, rate)
-

- Road condition (temperature, chemical concentration, coverage by liquid phases)
- Snow status (depth on road and drift patterns)
- Risk (confidence and/or probabilities associated with data elements)

The DSS components of the prototype MDSS will be designed to address decisions frequently made by users prior to, during, and after events occur. User decisions are generally based on having answers to the following questions:

- When will the event (storm) start and stop?
- When will the roads freeze?
- What type of precipitation will fall?
- How much precipitation will fall?
- What type of mitigation should be performed (salt, sand, anti-icing chemicals)
- Will there be low visibilities and fog (ice fog)?
- Where should I send my crews?

SCHEDULE

The FHWA has assigned a 3-year timeframe for the MDSS project. The first year will be dedicated to working with the state DOTs on the development of a prototype MDSS, which will demonstrate the scope and capabilities of components that address user needs and that can reach initial operating capability in one or more operational tests by the end of the second year. The second and third years (2002-2003) will demonstrate and evaluate operation of selected components from the prototype in one or more operational system(s) that provide decision support capabilities for winter road maintenance operations.

This is just one development track under the FHWA Road Weather Management Program. The MDSS Prototype products will be available for deployment on a non-exclusive basis. The FHWA will proceed to develop additional requirements beyond winter road maintenance. Priorities for requirements work in FY2001 include traffic/emergency management and traveler information. An objective of the MDSS development has been to create a surface transportation capability in the national labs and with surface transportation stakeholders. The stakeholders, who are public-sector transportation operators and private-sector information service vendors, will be the beneficiaries of applying that capability.

SYSTEM DESIGN

A conceptual system diagram for the MDSS prototype is shown in Figure 1. The system will utilize standard US National Weather Service data as well as specialized data including mesoscale and ensemble forecasts, video cameras, and road weather sensors. These data will be ingested into NCAR's dynamic, intelligent, forecast system (DICAST), which will generate point and time specific forecasts valid along road segments. The output will include probability (confidence) information for each parameter. The diagnosed and forecasted weather data will be integrated with DOT operational data and passed to a road condition module, which will generate information related to snow drifting, road temperature, and friction coefficient. These data will then be processed by a decision support system utilizing rules of practice logic and presented to decision makers on a geographic information system.

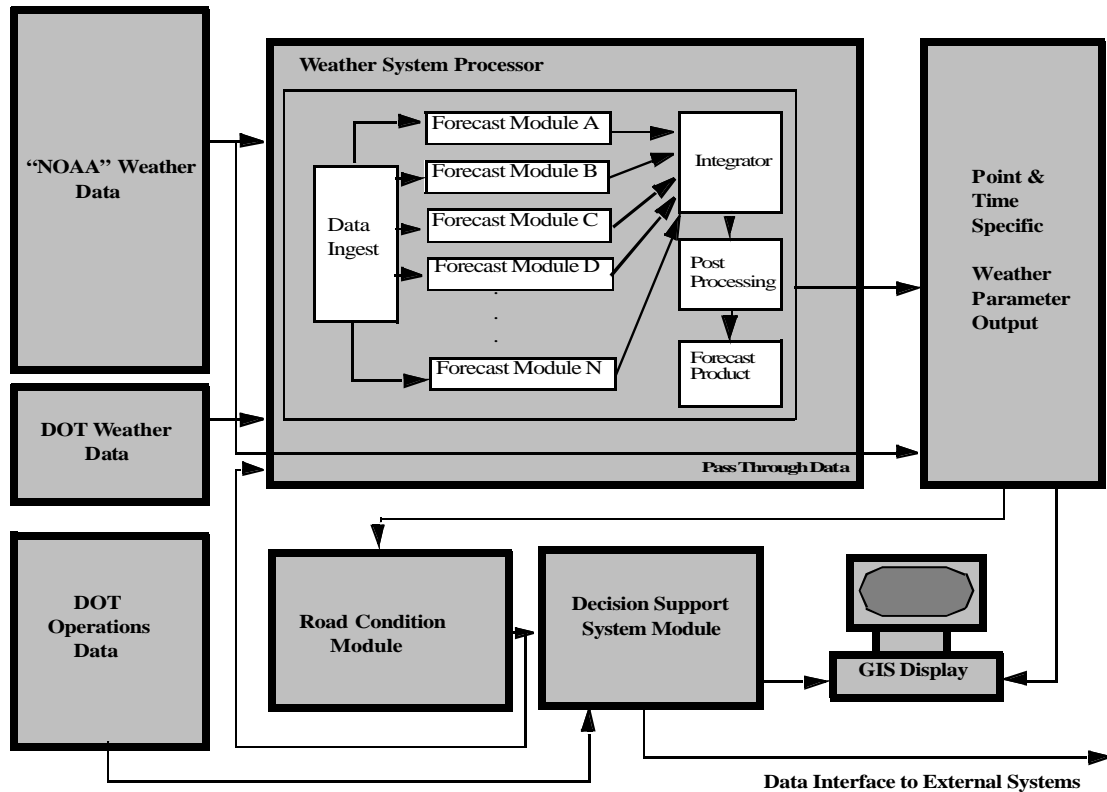


Figure 1. Conceptual system diagram for the prototype Maintenance Decision Support System (MDSS)

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**RESEARCH NEEDS IN WEATHER INFORMATION
FOR SURFACE TRANSPORTATION – THE
PERSPECTIVE OF THE USER COMMUNITY**

by

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ABSTRACT

An efficient transportation system is critical to the economic well being of the United States. Severe weather has the potential to severely downgrade the efficiency of any transportation system. However, if adequate precautions and measures are taken, the impact of severe weather on transportation efficiency can be minimized.

A critical component of such precautions and measures is timely and accurate information that is specific to the needs of those who must maintain the transportation system. At present, such information is not adequately available. Sometimes the information is not being collected at all. In other cases, the information may be available but has never been supplied to those who need it. On occasion, critical information may be buried in a flood of data that overwhelms the abilities of individuals to process and integrate in a meaningful manner.

There is a critical need to develop a far-reaching and innovative research program in the area of weather information for surface transportation. Components of this research program include determining what sorts of information are most critically needed, how to obtain and develop such information, and how to deliver such information in such a way as to enhance rather than degrade the performance of those seeking the information.

This paper will review these components and present scope and justification for the various aspects of the proposed research program.

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INTRODUCTION

The agencies that provide winter maintenance within the United States face a dilemma that is unlikely to become any more tractable over time. Road users are demanding ever-higher levels of service, while government funding is either stagnant or decreasing. To make matters worse, the drive for higher levels of service is not based upon whimsy, but rather reflects the increasingly important role played by the transportation system of the United States in the economic well-being of the country.

A study conducted by Standard and Poor's DRI in 1998 examined economic losses that might arise from the road system in a given state or contiguous collection of States being closed by winter weather. The results are sobering. The States considered in the survey stood to lose between \$30 and \$300 million a day as a result of a severe winter storm.

Even less severe winter weather may have significant economic impact. This arises from the widespread use of just-in-time delivery systems. Many manufacturing companies now use such systems to control inventory costs. For these companies, the mean travel time between two plants is less critical than the variation of travel time. That winter storms have

little effect on mean travel times is thus not relevant. The fact that travel time may double during a winter storm has significant impact on such operations, with the potential to completely idle a plant for several days because of travel delays due to winter weather.

Because of these increased expectations, winter maintenance agencies are facing increasing pressure to keep ahead of storms, to be pro-active in winter maintenance activities so that, in the ideal, there is no time during a storm when travel is unduly delayed. Meeting such high expectations will require that every person within the maintenance agency has the right information at the right time, and further, knows how to best make use of it. A major component of this information need is weather information. Achieving such an information utopia will be a substantial challenge.

DEFINING INFORMATION AND RESEARCH NEEDS

The information needed in a severe weather situation is highly dependent upon the individual who will receive the information. Obviously, individual needs can be infinitely variable, but three specific examples may help to illustrate the varying requirements. The vehicle operator (in a winter storm, the snow plow driver) has need of information that allows her or him to apply the correct amount of chemicals to the road segment for which they have responsibility. The road system manager (the supervisor at a DOT garage or equivalent) needs to know the status of the whole road system for which she or he is responsible, so that assets can be deployed in real time to address problem areas. The road user has different needs depending on the nature of their road use. A trucker might need to know of delays ahead due to inclement weather. Someone considering a family trip needs to know whether conditions are sufficiently severe to warrant delaying or canceling the trip. Each of these user needs is considered in some detail below.

Needs for Maintenance Vehicle Operators

The maintenance truck operator primarily needs to know that they are doing what needs to be done while they traverse their maintenance route. Much of this information is not weather related. For example, they need to know that their chemical application unit is delivering chemicals at the specified rate to the road surface. But overlying all their actions is a need for a clear but limited picture of the current and future weather situation.

Chemicals need to be delivered to the road surface when there is a likelihood of precipitation freezing to the road surface. This likelihood is a function both of current conditions (especially, of road surface temperature) and of how those conditions will develop over the next three to four hours (a typical cycle time for a maintenance vehicle route). The import of road surface temperature is very apparent from the popularity among vehicle operators of vehicle mounted infra-red thermometers. These devices, which provide a not very accurate (generally they are good to within a couple of degrees at best) measure of the road surface temperature appear to be popular because they provide operators with a sense of the temperature trends. A rising surface temperature may indicate that, given the chemical already on the road, no further application is required. Conversely, a forecast drop in temperature in a few hours may indicate a need for additional chemicals now (because the truck may not revisit that spot until after the drop has occurred).

The research need for the truck operator is to develop a system that indicates the road surface condition (temperature, precipitation and chemical levels) over a four to six hour window with sufficient accuracy to guide the operator as to whether and how much chemical to apply. A non-trivial component of this research is determining how much accuracy is “sufficient.”

Needs for Road System Managers

The knowledge needs for the road system manager are somewhat broader and less location specific. The manager needs to know (among other things) when a storm will start, how severe it will be what sort of precipitation it will involve and what will happen immediately afterwards. Such things are routine parts of forecasts today, but the degree of accuracy that a road manager would like is far from routine.

For purposes of assigning shifts for snow plow operators, a road system manager would ideally like to know (at least twelve hours ahead of a storm) when that storm would begin to an accuracy of ± 15 minutes. This allows the manager to get plow operators to the right place at the right time. A typical manager may have responsibility for an area of 400 square miles or more. Clearly, a storm is not going to start at the same time across that whole area, so there is a significant need to know how a storm will move through the area of interest.

In this regard, certain information is especially important. If a storm has areas of freezing rain and areas of snow, it is very important to the manager to know where the boundaries between the two types of precipitation will lie. Treatment regimes for freezing rain are substantially different than for snow, with the former requiring solid chemical, while the latter (in anti-icing mode) being best handled by liquids. Such degrees of temporal and spatial distinction are not typical in forecasts and will require significant research to achieve.

But while specific sorts of information are very important for road system managers, equally important is presenting weather information in an appropriate manner. Road system managers are not meteorologists, and do not have the expertise to interpret much of the weather data that are supplied to them. There is substantial need for systems that tailor the information in levels, providing the most critical information at the upper level, with easy

methods of “digging below” to find additional information if the manager feels it is needed. Too much, unfiltered information can be as disabling as too little.

The research needs, then, for road system managers include improved forecasts on both spatial and temporal scales, with a clear focus on the road surface (rather than atmospheric conditions). They also include the need for an appropriate filtering of information so that the most critical information is presented first (while additional information is available if needed).

Needs for Road Users

The road user is primarily concerned with reaching their destination in a safe and timely manner. For some road users, trips may be optional (a family visit, for example) but for most the trip is driven by necessity. Road users need to know when their trip will be delayed by weather, how serious that delay will be, and how hazardous driving might be as a result of the weather.

Some of this information is already available on the web, and more may become available through, for example, the 511 system. However, in developing and presenting this information, considerable care is needed. For example, current winter storm information is often provided by Highway Patrols, who may warn of roads being 25%, 50% or 100% snow and ice covered. Unfortunately, there is some evidence that road users feel these warnings are unduly conservative. If overly conservative information is provided, road users may ignore it. Conversely, if information is provided that does not adequately warn of hazardous conditions, a law suit may follow. It is perhaps impossible to satisfy all users, but ways must be found of presenting the relevant information in easily accessible form, so that road users can factor it into their decision making.

The nature of the information to be provided also presents a challenge. If I plan to drive from Chicago to Omaha, I do not need to know road conditions in Omaha now, but in

seven or eight hours time. Tailoring information to road users along specific routes with specific travel times included will be an interesting challenge.

The research needs from a road user perspective focus more on presentation of information than on developing new forecast techniques or improving accuracies. Systems that can “integrate” forecasts along a travel route so as to provide location and time appropriate information for the road user will be a major future need.

CONCLUSIONS

Excellent weather information is a critical part of improving winter maintenance activities. However, the needed improvements in weather information must be specifically tailored to the end needs of the maintenance community. The first step toward ensuring such tailoring is an ongoing and extensive dialog between the meteorological community and the road maintenance community. This dialog has been started, but must continue and broaden because as winter maintenance practice changes and develops, the types of weather information required will also change.

A second major issue for the maintenance community is forecasts that are focused on surface rather than atmospheric conditions. Such information is critical to effective winter maintenance operations, and will require new modeling approaches.

A third area of research is in information packaging and preparation. Too much information can be as useless as too little, and determining what information is critical at what time for different end users will be a major challenge. Presenting the information in suitable ways will also be an issue.

There are of course many other areas of research that need to be addressed. Some are very specific (such as improving vehicle mounted pavement thermometers) and others will develop as winter maintenance practice evolves. If these are to be addressed, then the dialog

between maintenance personnel and the meteorological community must be sustained. The good news is that the dialog has begun.

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**UTILIZING FAA-DEVELOPED AUTOMATED
WEATHER ALGORITHMS FOR IMPROVING
SURFACE TRANSPORTATION OPERATIONS IN
ADVERSE WEATHER**

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ABSTRACT

Surface transportation is similar to air transportation in that adverse weather severely impacts the safety and speed of operations. A wide range of users from transit operators to golf course managers need timely and highly accurate weather information tailored to their specific needs. However, manpower restrictions make it impossible for forecasters to provide high resolution, tailored products over extended geographical regions. The use of automated detection and forecasting systems can provide high temporal and spatial resolution products for direct delivery to operational decision makers. A tremendous opportunity now exists to dramatically improve the safety and efficiency of surface transportation by capitalizing on advanced weather products developed for the aviation system.

Over the past decade, the FAA has deployed advanced sensors for weather detection (e.g. Terminal Doppler Weather Radar) and developed software to create high resolution weather products in and around major metropolitan areas. Up to this point in time, the FAA sensor data and aviation weather products have not been used by the NWS forecasters or been readily available to roadway users. However, the rapid implementation of robust communications to surface vehicles (e.g. cellular), accurate knowledge of vehicle location (via GPS) and the introduction of in-dash graphical displays, makes it possible to provide individual vehicles with very precise information about weather hazards they may encounter and how to avoid them. Similarly, by accessing this data, local and state highway departments and fleet operations control centers will be able to anticipate major weather impacts on their operations and then adjust surface operations quickly. In this paper, we describe contemporary weather decision support products being provided by FAA weather systems (e.g. The Integrated Terminal Weather System (ITWS)) and how they can help to achieve a dramatic improvement in surface transportation weather monitoring, storm management and automated traffic alerts during adverse weather.

UTILIZING FAA-DEVELOPED AUTOMATED WEATHER ALGORITHMS FOR IMPROVING SURFACE TRANSPORTATION OPERATIONS IN ADVERSE WEATHER*

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INTRODUCTION

As we look back on the 20th century, we see great advances in the availability and volume of high quality weather data. New radar systems, satellites and advanced numerical models have made the raw data used by meteorologists vastly superior to data used just a decade ago. However, greater amounts of raw data do not necessarily yield better practical applications of this new information. As we look forward to the 21st century, we must find ways to automate the conversion of weather data (observations and general forecasts) into decision support tools tailored to meet the needs of all types of users.

One success story in the area of automated weather tools has been the air traffic control system. The Federal Aviation Administration has funded many years of research to understand how weather impacts aviation operations. The result has been a host of automated systems that have made air travel safer and the aviation system more efficient. MIT Lincoln

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Laboratory (MIT/LL) has been a leader in developing and installing major weather decision support systems for the FAA for over twenty years. This paper discusses the FAA developed sensors and systems that are being used today by aviation to tactically and strategically manage aviation operations in adverse weather. We will also present a vision of how the surface transportation system can benefit not only from the technology developed for the aviation system but from targeted research into weather products specifically designed for roadway users.

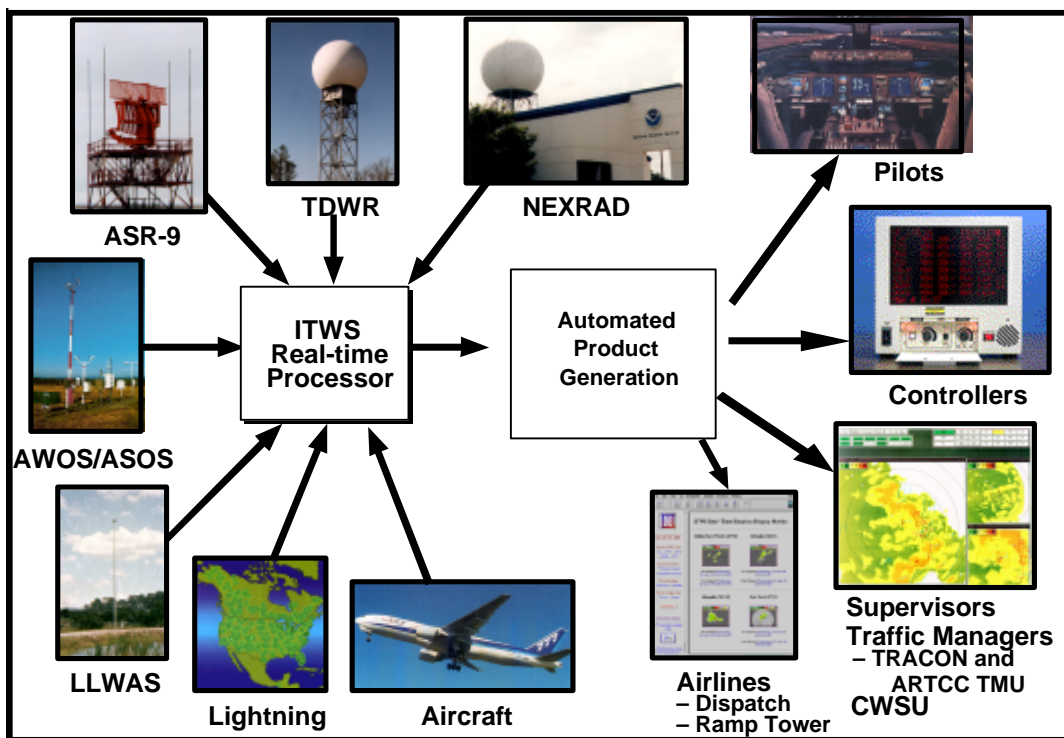
FAA FUNDED AVIATION WEATHER RESEARCH

Since the days of the Wright Brothers at Kitty Hawk, weather has always been an important factor for aircraft operations. A rash of serious airline crashes related to wind shear in the late 1970's spawned heavy research into microbursts and other thunderstorm related hazards. The result was the Terminal Doppler Weather Radar (TDWR) which was designed to alert air traffic controllers of strong wind shears and impending heavy weather. As a result of the TDWR, intensive training of pilots, and increased overall awareness of thunderstorm hazards, aviation safety related to thunderstorms has been drastically improved. MIT Lincoln Laboratory and the National Center for Atmospheric Research (NCAR) were the leaders in automated detection of wind shear hazards. MIT/LL built prototypes of the TDWR radar and processing algorithms and transferred the technology to Raytheon for delivery of a production system(1).

As a follow-on to TDWR's primarily safety benefit based system, MIT/LL began investigating the cost and benefits of mitigating weather delays to improve aviation efficiency and capacity. The Integrated Terminal Weather System (ITWS) is designed to not only improve the safety benefits of TDWR but also to give air traffic controllers, traffic managers, airline dispatchers and pilots common situational awareness of weather threats and impacts(2). The ITWS system integrates all of the available weather sensors in the terminal

area to provide the most complete weather picture available. Figure 1 shows the multitude of sensors utilized, products produced and users serviced by ITWS. Estimated savings in fuel costs, passenger and crew time from reduced delays due to the ITWS system are expected to exceed 235 million dollars annually. There are several key elements of ITWS, described in the following sections, that make ITWS unique in its generation and delivery of weather products.

Figure 1. Flow of data through the Integrated Terminal Weather System.



Advantages Over Current Surface Transportation Weather

Many planning operations for surface transportation focus on 2-5 day forecasts (hurricane evacuations, flood planning, and to some extent snow removal), where the National Weather Service (NWS) provides forecast models and generalized forecasts. However, there is a need for shorter-term forecasts for tactical responses to weather situations, for example:

- Alerting commuters and truckers of unexpected delays or road closures (as little as 30 minutes warning is potentially useful)
- Identifying localized impacts of weather (lightning strikes, strong wind gusts, street-level flooding, snow drifts, etc.)
- Assessing the accuracy of the longer-term forecast used for planning. For example, detecting that the onset of a snow event will occur 2-3 hours in advance of NWS model forecasts.

These short-term forecasts require high-resolution data both in time and space. In addition, the products must be delivered within minutes of detection for emergency services or commuters to respond quickly. By combining high-update rate radars (down to 30 seconds) with automated data-to-user product processing, FAA developed sensors and technology are uniquely suited for these requirements

Advanced Radars

Two of the radar systems shown, TDWR and ASR-9, were developed specifically for the aviation system. The Terminal Doppler Weather Radar (TDWR) is similar to the NEXRAD in that it provides multiple layers of precipitation and wind information. Most of the 47 TDWR radars have been installed and are providing protection at every major airport that has a significant threat of wind shear activity. The Airport Surveillance Radar (ASR-9), conversely, was primarily designed as an aircraft tracking radar. MIT/LL helped develop a secondary weather channel that allows a vertically integrated view of precipitation and winds. These enhanced tracking radars with their wind shear processors (WSP) are being installed in 35 medium sized airports across the country. Figure 2 shows the location of the two types of radar systems and Table 1 shows a comparison of the TDWR, ASR-9 and NEXRAD radar technologies.

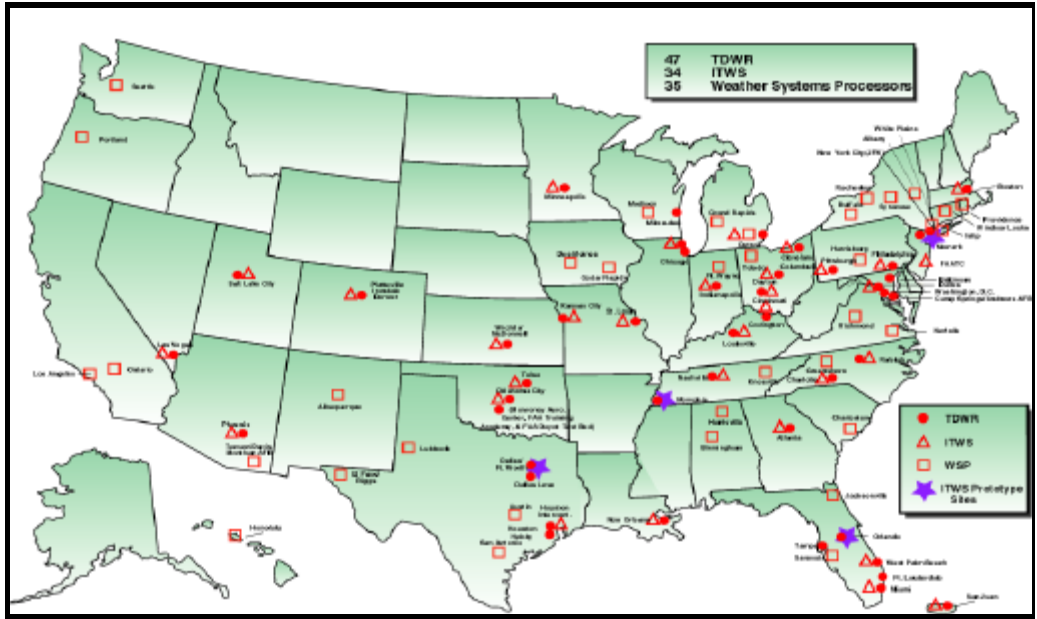


Figure 2. Location of FAA Weather Radars and proposed ITWS sites (installation beginning in 2002).

Table 1. Comparison of operating characteristics of NWS and FAA weather radars.

	NEXRAD	ASR-9	TDWR
Update Rate (min)	6	0.5	5
Horizontal Resolution	0.250 km X 1.0 deg	4 degrees	0.120 km X 0.5 deg
Range (km)	460	100	200
Number Installed	138(continental US)	35	47
Scanning	360 degree multiple-tilt volume	360 degree single-tilt integrated volume	Sector multiple-tilt volume centered over airport. Full 360 degree operations are technically feasible.

Integrated Approach and Advanced Algorithms

All of the input systems acting individually could not provide air traffic with a comprehensive view of impending weather impacts. By integrating all the available sensor in the airport area we are able to generate high quality, reliable products for aviation users. Figure 3 shows the ITWS situational display that allows users to view alerts and precipitation images at different ranges and locations. Some of the highlights of the system are:

- Enhance the quality of all weather images by verifying signals returned by one radar with an overlapping radar.
- Alert air traffic to hazardous wind shear, and warn air traffic planners of impending wind shifts that will require the airport landing operations to be reconfigured.
- Generate a single view of precipitation and safety alerts for all users to share
- Provide 3-dimensional gridded winds by combining multiple radar radial winds to estimate the true 2-dimensional wind.
- Combine radar sensed precipitation with forecast models and land and aircraft based temperature sensors to produce predictions of thunderstorm induced winds, and
- Produce a short-term (0-1 hour) forecast showing storm movement.

Integrating multiple sources of input data requires advanced processing to develop reliable products in all operating environments. Therefore, many of the products are based on a sophisticated fuzzy logic based image processing technique developed at MIT/LL called functional template correlation. This advanced technique allows various forms of data to be combined intelligently and product thresholds to be flexible in combining product components(3).

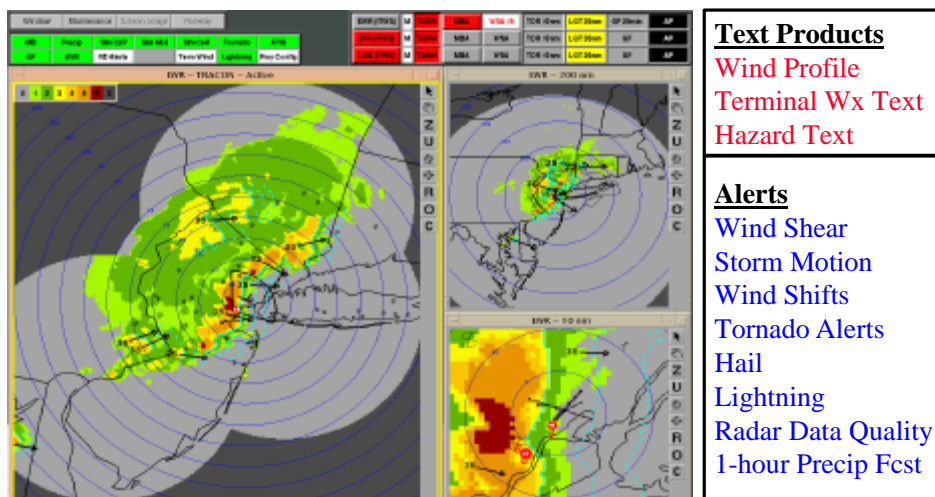


Figure 3. ITWS situation display provided to air traffic controllers and airline dispatchers. System provides a number of graphical, text and alert based messages (listed in the boxes to the right).

Tailored Products

Another key success in ITWS is that the decision support products are provided to air traffic in a form understandable to the end-user. No interpretation of the meteorological data is required. For example, microbursts (severe wind shifts hazardous during landing/take-off) are presented to the user as red-filled circles with an accompanying text alert indicating the runway area (if any) being impacted. Controllers base all their warning decisions on these two products, there is no need for the controller to understand (or for a human to interpret for him) the precipitation loading or thermodynamic support present for the microburst to occur.

Understanding what the users needs is a difficult but necessary process. The ITWS development process included requirements definitions by the FAA, user groups of air traffic controllers, and lengthy discussions with airline dispatchers and pilots. The FHWA administration has begun to define the basic weather requirements for surface transportation operations (4). The Maintenance Decision Support System (MDSS) is a first step in addressing the specific needs of winter road maintenance(5).

PARALLELS TO SURFACE TRANSPORTATION

The weather problems faced by the surface transportation system are similar in many ways to the problems faced by aviation: safety, planning and maintenance. Safety is a primary concern of any transportation operation. Aviation accidents and deaths caused by weather have been thoroughly researched and documented and the result has been systems like LLWAS (Low-Level Windshear Alert System), WSDM (Weather Support to Deicing Decision Making)(6), and TDWR(1). Conversely, while 10-13% of the fatal US highway traffic deaths occur during adverse weather(7), research has been limited in investigating the link between highway traffic fatalities and specific weather hazards(8). Accidents involving large numbers of vehicles typically do involve weather. This past winter's 100 vehicle pile-up

on I-95 in DC was caused by a strong line of snow squalls that rapidly reduced visibility(9). The line developed and impacted the roadway in an extremely short time span (<1hour); drivers were aware that a snowstorm was imminent from the NWS forecasts, but unaware of the rapidly approaching smaller scale event. A rapidly updating precipitation forecast, such as the one in ITWS, combined with variable message signs (VMS) may have alerted travelers ahead of the approaching event and slowed overall traffic. Other major multiple vehicle pile-ups over the years have been triggered by ice, snow, blowing snow and fog.

Advanced planning of impacted routes, whether it be by air traffic control or commuters, is the key to reducing traffic congestion and delay in adverse weather. Like the air traffic system, surface transportation must use specific routes and in urban areas these routes are filled to capacity during commuting hours. A single event (breakdowns, accidents, snow storms or even a passing shower) can cause the system to grid-lock causing hazardous travel conditions and long delays. In the aviation system, roughly 75% of all delays are caused by weather (fog, thunderstorms, snow, heavy rain, etc.)(2). National statistics for the causes of highway delays are not easily attainable, however, common observation suggests that while the vast majority of delay on the roads is caused by volume, weather (particularly snow, fog and heavy rain) can induce large delays.

Roadway maintenance is of higher interest to surface transportation because of the sheer volume of the job. Snow, sleet and freezing rain are the primary concerns of roadway maintenance crews, although heavy rain, strong winds and lightning may also result in flooding or debris on the roadway. MIT/LL is part of a consortium of national laboratories developing a prototype system called the Maintenance Decision Support System (MDSS) to assist DOT operators in the execution of roadway maintenance during winter storms(5).

Applying Existing FAA Technology to Surface Transportation

The ability of the ITWS system to generate user specific alerts for wind and precipitation hazards could be of benefit to roadway applications. Studies have shown that static signs indicating the potential for a hazard are routinely disregarded by motorists (e.g. “fog area”, “flash flood”, “high winds”)(10). Providing weather alerts to users as the hazard is happening (through VMS, cell phones, or in-dash monitors) would heighten the attention of drivers. For example, ITWS data could be used to automatically generate high wind or blowing snow warnings from its dual-Doppler winds processing or flash flood alerts by examining the 1-hour forecast of precipitation. Fueling operations at truck stops could be alerted when lightning is within a few miles of the operation allowing them to suspend or curtail operations. Building on a prototype system being developed for San Francisco airport, fog onset and dissipation could be delivered directly to commuters or strategically placed variable message signs. Combining these algorithms into an overall system such as the MDSS may allow the development and delivery of other alerts such as icy bridges and roads, hail and tornado warnings.

The Terminal Convective Weather Forecast ITWS product is a short term (0-1 hour) forecast of precipitation extent and movement. Advanced tracking techniques are used to generate forecasts superior to those created in the past(11). This product is used by air traffic controllers to strategically plan route and runway closures and openings. Similarly, commuters or truckers could use such a tool to plan alternate routes around weather impacted roadways. An automated tool could be developed to constantly compare the weather impacts of all potential travel routes and alert the user when alternate routes may be advisable. Again, integrating such an algorithm with systems like MDSS would add additional utility.

SUMMARY AND CONCLUSIONS

Weather impacts on aviation and surface transportation systems are similar, especially in the areas of safety and efficiency. While some research has been done to quantify the impact of weather on road and rail systems, further research is needed to develop specific product requirements. The FAA has funded many years of research and development that may form the basis for tailored surface transportation weather products. Advanced weather radars and processing techniques will enhance existing raw data, and an infrastructure of fuzzy-logic based algorithms will produce tailored and automated decision support products directly to users. The huge investment in research funded by the FAA allows other government agencies (FHWA, FEMA, etc) to leverage the national laboratory work already developed and beginning to be deployed. The MDSS system is a small example of the potential of such R&D efforts for a safer and more efficient surface transportation system.

Further information on ITWS and other MIT Lincoln Laboratory aviation weather programs can be found on the web at: <http://www.ll.mit.edu/AviationWeather> or by contacting the author.

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FORETELL - SOME FINDINGS, AND THEIR RESEARCH IMPLICATIONS

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ABSTRACT

FORETELL is a multi-state, public-private partnership which has sought to integrate Intelligent Transportation Systems (ITS) with advanced weather systems prediction. FORETELL has envisioned the creation of operational highway maintenance management and traveler information weather systems throughout North America. Now that FORETELL is operational within the Upper Mississippi Valley region, some initial user reactions can be reported and their research implications discussed.

FORETELL participants proposed a self-sustaining road and weather information system, fully integrated within a wider basket of ITS services, enhancing safety and facilitating travel throughout North America. The integration goal was pursued through the development of a parallel roadway event reporting system, CARS, that is also being deployed in several U.S. states. The paper discusses this original vision, and the extent of its practical realization to date.

Another key goal envisioned expansion to a continent-wide system within 5 years. Significant progress is being made in this direction through on-going developments in Arizona and the Pacific Northwest, and through the adoption of a FORETELL system in New England. However a critical mass threshold has to date inhibited the growth of a national dissemination system, a continuing issue that has significant policy implications.

FORETELL's aim is to deliver the benefits of advanced weather systems and Intelligent Transportation Systems (ITS) to travelers, shippers and transportation system operators across North America. It envisioned a widely accessible, real-time road and weather information system supporting seamless information sharing for travelers and highway maintenance managers. Additional, decision support work funded by FHWA has helped achieve these aims. Overall, progress has been encouraging, though perhaps inevitably slower than was originally hoped. Institutional and technical barriers have each influenced progress toward the FORETELL goals, as reviewed in the summary paper.

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FORETELL is a multi-state, public-private partnership which has sought to integrate Intelligent Transportation Systems (ITS) with advanced weather systems prediction. FORETELL envisions the creation of operational highway maintenance management and traveler information weather systems throughout North America. Now that FORETELL is operational within the Upper Mississippi Valley region, some initial user reactions can be reported and their research implications discussed.

FORETELL represents an investment of federal, state and private sector dollars already approaching \$5M. Within the next five years, that figure will have grown significantly larger. As with any program of this magnitude, there have been both successes and failures. This paper sets out to report on both. By learning from what did not work, as well as from successes, we can best secure the future of research in this key transportation sector.

Awareness

Nearly 6600 fatal crashes occur each year in the U.S. during inclement weather. In addition, 402,000 injury crashes occur nationwide, with one-third happening in rural areas.

Staggeringly, this annual death toll is equivalent to three, fully loaded 737 jets crashing each week of the winter season, with no survivors. *Fifty times* that number of jet equivalents can also be said to crash each week causing injuries to all on board ranging from minor to life threatening. FORETELL has played its part within the wider FHWA Weather Information for Surface Transportation (WIST) initiative to increase discussion and awareness of this hidden, national tragedy.

To combat unsafe road conditions, state highway maintenance agencies in the United States and Canada spend over \$1.5 billion to control snow and ice each year. Cities and counties in the U.S. spend an additional \$700 million for similar operations. The expenditure by these agencies accounts for a significant portion of their annual maintenance budgets. However, neither maintenance nor winter weather information were featured prominently in the original National ITS Architecture. Again, FORETELL has played a part in helping to change this over the past three/four years, in partnership with wider state and federal government initiatives. Weather monitoring and prediction, and maintenance activities in general, are now recognized as important subsystems within the Intelligent Transportation Infrastructure.

Design concept

The *FORETELL* design concept is to bring together all available weather data sources, including satellites, radars, and surface sites including those of NWS, DOD, aviation and conventional R/WIS stations throughout the *FORETELL* states. State-of-the-art mesoscale models are then applied to support fine resolution nowcasts and forecasts. This new

approach to highway weather forecasting truly represents a paradigm shift in relation to earlier road weather prediction approaches. This integrated design concept has now been largely realized in FORETELL's operational deployment.

Road weather monitoring began in Europe in the 1970's. In the U.S., simple point predictions were gradually added at the small numbers of RWIS sites then deployed. This changed in the late 1990's when two new ITS road weather systems were deployed, first ATWIS centered in North Dakota, and then FORETELL centered in Iowa. Both programs build on mesoscale modeling techniques developed at NOAA research laboratories such as the Forecast Systems Laboratory (FSL) in Boulder. The enormous advantage of these four-dimensional models is that they take account of total weather systems evolution in time and throughout space, not just temperature trends at a comparatively small number of points.

Deployment delays

In FORETELL, the road to full data integration was not always an easy one. At first, institutional barriers including senior staff changes at NWS prevented FSL from concluding a timely, technology support agreement with the State of Iowa, despite the best efforts of its always enthusiastic staff. After a year's uncertainty and delay, the integrated weather prediction module was shifted to a private sector substitute, Colorado Research Associates (CoRA), and the core weather models based on FSL's Local Analysis and Prediction System (LAPS) were quickly deployed in less than two months.

A related decision of the reshaped NWS quickly placed a second, major obstacle in FORETELL's path. NWS offices such as Chanhassen, Mn, and Pleasant Hill, Mo, were directed to focus on completion of the NWS modernization program. Planned cooperation

with FORETELL was an immediate casualty, including proposed siting of the FORETELL mesoscale model prediction equipment in regional NWS offices. Again, private sector partners responded by assuming former public sector tasks, reshaping FORETELL's architecture at short notice. Through an intensive, three-month effort, FORETELL operations were relocated from Eagan, Mn, to Boulder, Co.; a major, new NOAAPORT satellite data subsystem was procured and commissioned; and the whole, integrated monitoring and prediction system was made live.

What can we learn from these experiences? The need for flexibility and a willingness to make difficult, mid-course corrections is paramount, both in terms of partnerships and system architecture. Federal laboratories are excellent generators of core technologies, but can be subject to political priority changes beyond the control of any individual technology transfer. And NWS forms the cornerstone of weather forecasting in the U.S., but was eventually unable to step outside its well-defined, core mandate, even within the framework of a public-private partnership. Credit for turning these problems into opportunities and solutions is due mainly to the Iowa DOT, which led this challenging change process to an efficient and successful conclusion, and to FHWA for continued backing and support throughout. And on this occasion, private sector partners were able to step forward and fill unexpected gaps at short notice, using the flexibility often available only to small businesses.

Decision support

In the original FORETELL concept, it was proposed that "NOAA's proven decision support systems would allow complex data outputs to be understood and acted upon by highway maintenance staff, CVO dispatchers and individual travelers." In the event, the complex Java code routines being developed for NOAA's Advanced Weather Information and Prediction

System (AWIPS) decision support were not ready in time, and FORETELL partners decided to create their own. At first this proved as challenging as it had for AWIPS, the first generation FORETELL Java routines being too slow and cumbersome for practical application. Cost overruns by software subcontractor IMSC also took their toll, due in part to extended time lines resulting from earlier delays.

Further funding was obtained for additional decision support work from FHWA and Iowa. Funding priority was given to web browser-based decision support displays over voice, pager and fax dissemination. A new software contractor was hired and FORETELL's own, powerful Java routines were created for decision support. Most observers would agree that these striking and effective displays are the most significant achievement of the FORETELL program to date. FORETELL's decision support tools offer a firm foundation for introducing both established techniques and new, ground breaking technologies to an ever-widening group of committed users.

Additional components

Not all the pieces of the overall FORETELL design concept were fully integrated in the first generation deployment. Although a sophisticated, multi-channel NOAAPORT system had been procured, not all the data feeds it offered were being fully utilized in the first winter of full operations (2000 - 2001). Satellite cloud images, for example, were fully integrated with FORETELL nowcasts and model forecasts for the first time in Spring 2001.

Another key decision variable, Nexrad radar data, could not be included in FORETELL before January 2001 as it was not available in the public domain. These data, that would have originally been available to FORETELL through its partnership with NWS, only

became publicly available from January 2001. Work is currently in progress to decode this massive data stream and integrate it fully with FORETELL decision support, a task due to be completed in time for Winter 2001. User feedback shows very clearly that users expect to have all these tools available in a one-stop shopping, integrated decision environment. By this coming winter we expect that many more of these operational user demands will have been fully satisfied by FORETELL.

CARS, and Mobile Platforms

FORETELL went beyond the earlier ATWIS concept by recognizing that pavement temperature data from relatively few, fixed locations could be improved upon using widespread, manual data inputs on roadway conditions and maintenance activities, coupled with automated inputs from an increasing number of instrumented snow plows known as mobile platforms. FORETELL user needs studies also demonstrated that the traveling public locals and visitors, including freight, transit, school and social transit services - wants traffic event information fully integrated with road and weather data.

FORETELL's proposal envisioned "new ITS Service Centers, as the core of a much broader 'basket' of commercially-viable ITS services." FORETELL, and ITS as a whole for that matter, still has some way to go in realizing this vision. However, important progress has been made through the successful development and deployment of the 'CARS' Condition Acquisition and Reporting System, a sister web-browser development to FORETELL. This state pool-funded initiative has now grown from four to eight partner state DOTs, and continues to embark on major additional steps, such as wireless data input from the field, support for statewide, real-time 511 service, and integration with new Low Power FM technologies.

Progress with mobile platforms has been steady, as expected. It may be many years before all vehicles in a DOT fleet are equipped with automated telemetry equipment, and wireless data transmission in real time. The main difficulty in this area is the limited coverage of data services in rural areas. When FORETELL was planned, ITS was promised Low Earth Orbit (LEO) satellite service by 2001. Now this may not happen for many years, if at all.

Fortunately, CARS can cover these gaps in automated data collection for as long as is necessary, so long as essential commitments are obtained from operating staff at participating agencies. Motivation, acceptance of change, and re-training are key challenges for the coming winter seasons for both CARS and FORETELL deployments.

Regional and national extensions

FORETELL envisioned a self-sustaining road and weather information system, fully integrated within a wider basket of ITS services, enhancing safety and facilitating travel throughout North America. Phase 1 focused in the mid-west, Phase 2 would add on other, discrete regions, and Phase 3 would achieve national coverage. Currently FORETELL is shifting from Phase 1 to Phase 2, with the addition of four states in the north east - Maine, New Hampshire, Vermont, and Massachusetts. In each case, these states are deploying FORETELL not in isolation, but as part of a wider basket of rural ITS services known as Ratis - Rural Advanced Traveler Information System. CARS is an important co-technology that will accompany FORETELL in this new regional deployment.

Will Phase 3 - seamless, national coverage - ever be achieved? Only if state and federal agencies will take the initiative, and exercise the leadership required to make this happen. Currently, fragmented service providers in ATWIS, in Washington State, in FORETELL, in Ratis and Arizona act more like competitors than allies in the struggle to win acceptance

from reluctant institutions resisting the pains of change. Further fragmentation could still occur as the new Advanced Winter Road Maintenance Decision Support System federal laboratory systems deployments start to come on stream. Is it not time to start to ask for - or demand - an outbreak of cooperation in place of earlier rivalries?

The multi-state CARS initiative demonstrates what can be done using pool funding, and by applying national ITS standards. It may be time to see the same way forward in road weather prediction systems, if critical mass is to be achieved that will allow a seamless, coast to coast deployment and dissemination. Systems can be run locally and regionally, of course; but to the end user, they need to look like a single, national deployment, rather like AT&T One Rate cellular service. After five years of road weather prediction systems deployment, is this seamless vision still as far away as ever? Perhaps this, above all, should be our shared vision for the next five years, and the primary finding of FORETELL.

**FUTURE GROWTH OF SURFACE
TRANSPORTATION WEATHER: AN ACADEMIC
QUESTION**

by

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ABSTRACT

After years of struggling for recognition in the past, the surface transportation weather industry is gaining support within mainstream elements of the atmospheric sciences community. This support is highlighted by the involvement of the Office of the Federal Coordinator for Meteorology in convening two symposia over the past two years on weather information involving state, federal and private sector stakeholders of the surface transportation community. With a push at the federal level to establish a coordinated movement to enhance public safety through better planning based upon appropriate application of surface weather information, the potential for dramatic growth in the surface transportation weather industry is large. Unfortunately, the academic community has yet to embrace this potential to any widespread degree. Much of this can be traced to a historical lack of demand for trained personnel by the surface transportation weather community and to the lack of a well-defined set of research goals.

This presentation looks at the impact the academic community will have on regulating the growth of the surface transportation weather movement including the role that research and training will have on sustaining the present expansion. The role of public-private partnerships between academic, government and industry partners in building for the future will be addressed.

Future Growth of Surface Transportation Weather: An Academic Question

by

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INTRODUCTION

Surface transportation weather has been a niche industry for the past thirty years that has received little attention from the meteorological community. Recent federal interest in surface transportation weather has the potential to pull surface transportation weather from the meteorological shadows. The resulting research and operational enhancements should lead to improved surface transportation safety and efficiency. A critical element to this transformation will be the extent to which academia participates in surface transportation research and education and whether industry and government-industry-university partnerships can be developed. Further, the growth of surface transportation weather as an industry will depend upon a clear understanding between the meteorological and surface transportation communities of their respective functions and responsibilities to each other. This communication begins with a better understanding of each other's capabilities and limitations. While meetings and workshops can alleviate some of these issues, only through education and training programs that commit to cross-discipline instruction will an inherent long-term level of communication be established between the two cultures. In turn a more

responsive research program can be achieved where specific needs of surface transportation weather can be addressed

BACKGROUND

Interest in surface transportation weather has been slow to evolve over the past quarter century. Until recently, with the exception of improvements in environmental sensor technology, there have not been any notable technological breakthroughs in how the surface transportation industry has been served by the meteorological community. Surface transportation weather has evolved primarily through efforts to better estimate localized weather conditions at discrete points along the roadway, where maintenance actions are required due to winter weather conditions, using simple forecasting methods. Although limited meteorology private sector efforts have existed, only until recently have the affordable technologies required to provide wide-area support beyond individual RWIS locations been available. Further, the surface transportation community's lack of understanding of the capabilities and limitations of the meteorological community has created misconceptions and misunderstandings between meteorologists and maintenance personnel as to services that should be provided.

Early attempts to bridge the gap between the two communities were made beginning in the late 1980s. Much of this effort focused on identification of surface transportation weather issues and information requirements within the maintenance sector. This effort was associated with the Strategic Highway Research Program, a program administered by the Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board. These studies developed an important base of knowledge that continues to provide guidance today, but did little to engage the broader meteorological community. Noting the potential importance of

weather-related issues within the federal government's Intelligent Transportation System (ITS), the American Meteorological Society formed an Ad Hoc Committee on Intelligent Transportation Systems in 1994. This committee, comprised of government and industry representatives, has the mission to describe the benefits of using weather information by travelers as well as by other decision makers who have responsibilities that are impacted by weather. It also has as a task the responsibility to educate the traveling and transportation community about the capabilities within meteorology and to suggest ideas for incorporating weather information into ITS. Unfortunately, after meeting sporadically for several years this effort has ceased to be productive.

One significant result of the AMS Ad Hoc Committee on ITS was to stimulate the ITS America Coordinating Council to form the Weather Information Applications Task Force (WIATF). The purpose of the WIATF is to promote dialogue and coordination between organizations and agencies involved in ITS and weather. The WIATF works to ensure that ITS America and the U.S. DOT consider the perspectives of weather information providers in the development and implementation of ITS programs. However, with a focus to facilitate dialog between the private sector and the federal government, the WIATF generally falls short in drawing either the State DOTs or academia into its discussions. As a result, the gap between the meteorological and surface transportation communities continues to exist.

TECHNOLOGY DRIVER

In recent years, drawn by improved telecommunications capabilities and a desire to improve maintenance and safety for rural highways, most states have deployed increasing numbers of environmental sensor stations referred to as Road Weather Information Systems (RWIS). Largely used as in-situ observations for rapid response to changing road and weather conditions, these sensors remain the focus for short-range weather forecasting by the

meteorology private sector. New technologies recently deployed, such as the Advanced Transportation Weather Information System (ATWIS) developed at the University of North Dakota, have expanded the application of the RWIS network to support Advanced Traveler Information Systems (ATIS) in addition to providing finer spatial depiction of road and weather conditions across a broader area than before. These technologies and similar programs that have followed ATWIS constitute the most significant forecasting advancement to surface transportation weather in decades and are providing maintenance personnel with a better perspective of how weather can be utilized to address surface transportation issues. In many cases the communications between meteorologists and maintenance personnel during the technology development have aided in defining the scope of problems that can be addressed by enhanced surface weather information. The iterative process resulting from this dialog between research and practitioners has driven the technology forward and heightened an awareness of capability in the surface transportation community.

Capitalizing on this greater awareness of meteorological capabilities, maintenance personnel are now better prepared to formulate their needs in the context of a demonstrated technology. Assisting this effort has been strong support from the Office of the Federal Coordinator for Meteorology (OFCM) and the American Meteorological Society. Both organizations continue to conduct workshops and symposia to discuss issues related to improving support for surface transportation. Gleaning information from maintenance personnel stimulated by this broader meteorological exposure, the FHWA has quantified the needs of the maintenance community in a comprehensive study i.e., the Surface Transportation Weather Decision Support Requirements (STWDSR). Molded into a working prototype for a Maintenance Decision Support System (MDSS), the STWDSR and MDSS will serve as the major technology driver for surface transportation weather applications for the next decade.

ACADEMIA'S INVOLVEMENT

While growth of surface transportation weather within the meteorology and surface transportation community appears promising, it is not a foregone conclusion. Of importance to academia is the question of whether surface transportation weather is to be an application of existing technologies found elsewhere in meteorology or should it be considered a sub-discipline within the meteorological profession. The answer to this question will largely determine the future focus that surface transportation weather will receive in university education and research. If deemed to be a specialized application, then likely little emphasis will be placed upon committing either educational or research resources to expand specialized technologies or solving current problems. Rather, this responsibility will be deferred to either the private sector or the federal government. Unfortunately, the private sector will likely remain motivated by profit and will not be willing to commit the extra resources unless so motivated by the availability of public funds. Similarly, federal agencies and laboratories will choose to focus on adapting existing technologies developed for other programs rather than committing to a focused surface transportation weather initiative. The result of this path will be more of the present situation that draws little attention from the broader meteorological scientific and academic community.

However, should surface transportation weather evolve into a sub-discipline within the meteorological profession, a more aggressive future lies ahead. As a sub-discipline surface transportation weather will develop similarly to the field of aviation meteorology. The field of aviation meteorology attracts strong participation from the private and government sectors and it is a significant part of research and education at numerous universities across the United States. Aviation meteorology curricula have been developed supporting degree programs for meteorologists and practitioners e.g. pilots, airport managers, dispatchers, etc. Aviation weather conferences are well attended and represent a broad cross-

section of meteorology and the aviation community. Further, a national commitment has been established to sustain the aviation meteorology industry through government-industry-academic partnerships that include major federal funding for ongoing research, education and training.

The field of surface transportation weather will have many of the same features as aviation meteorology. Meteorology degree programs will include coursework specifically designed to address challenges faced by the surface transportation meteorologist including issues related to road surface condition forecasting and developing an understanding of issues addressed by traffic managers and maintenance personnel. In addition to attracting meteorology students to the curriculum, service courses could provide support to civil engineering degree programs preparing students for the surface transportation profession. Such interdisciplinary education by meteorologists and engineers could alleviate the lack of understanding each profession has for the other and foster more rapid adoption and diffusion of new technologies.

Although the present technology will be driven to new heights by the deployment of the MDSS in coming years, much will remain to be done to further advance the technology. Just as aviation meteorology continues to search for answers to complex problems related to aviation safety and efficiency, a similar ongoing effort will result within surface transportation weather. The development of federal and private funding to support a broader university involvement in surface transportation weather will promote the field of surface transportation weather and provide an effective method of addressing fundamental and applied problems associated with surface transportation. Such federal research funding is presently in place for engineering related issues at 33 universities. The FHWA provides funding for surface transportation through a consortium of University Transportation Centers (UTC). However, only one report of approximately 350 research publications generated by

the UTCs in the past year involved weather as a major element in the research. This is not surprising as the total FHWA funding for weather research in FY 2000 was \$3 million. In comparison the FAA funding for weather research exceeded \$22 million. In order to advance the efforts of surface transportation weather, a commitment to sustained research across the government, industry and university sectors must be established through greater levels of federal support.

SUSTAINABLE GROWTH

As technological advancements continue to improve safety and efficiency of the surface transportation system, surface transportation and meteorological professionals, both present and future, must remain aware of research and operational innovations that have the greatest potential to promote safety and efficiency. Only open and frequent communication between researchers and practitioners in both surface transportation and meteorology will promote relevant research and speed the implementation of new technologies.

Sustainable growth of surface transportation weather applications is based not only on research and technology efforts, but also on ensuring an adequate supply of capable professionals. Commitment to professional development will improve present capabilities and provide the basis for future innovation. The diversity in backgrounds of professionals who require a fundamental background in surface transportation weather suggests an integrated approach to education. Innovative education concepts including distance education and web-based training offer flexibility and effectiveness, and promote a culture of lifelong learning.

The following recommendations are provided to encourage the development of the field of surface transportation weather and its related support within the surface transportation system:

1. Develop and promote university meteorology curriculum in surface transportation weather that includes aspects of operational and research meteorology as well as addressing surface transportation issues,
2. Promote the addition of weather elements to engineering academic programs emphasizing surface transportation,
3. Establish lifelong learning surface transportation weather through recurrent training and distance education programs for professionals in the meteorology and maintenance operations,
4. Establish federally-supported university research programs in surface transportation weather
5. Promote innovative government-industry-academic partnerships designed to address advanced technology development
6. Recommend the formation of an American Meteorological Society Committee on Surface Transportation Weather with a membership that equally spans sectors of government, industry and university.

There is excitement building within the meteorology and surface transportation communities that a new age of information and technology is near. To sustain the demands of this growth will require a unique labor force dedicated to understanding the challenges. The solidification of surface transportation weather as a legitimate field in meteorology will require vision, leadership and commitment, not least being a strong dedication from and to the academic sector. The implementation of the above recommendations will require broad institutional support from the FHWA, OFCM, AASHTO, AMS, State DOTs, academia and the U.S. Congress.

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PRIVATE SECTOR METEOROLOGY AND ITS

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ABSTRACT

Weather presents significant challenges to transportation, especially since it tends to have adverse impacts on many aspects of the various transportation modes, including surface transportation. The private sector weather industry has developed numerous products and services to address these challenges and the various impacts presented by weather. The variety of products and services ranges from sensors that monitor ambient weather and road conditions to specialized forecasts of these same weather and road conditions. Private sector companies involved in weather include large corporations as well as smaller entities that often consist of a single consultant. Weather information, in concert with associated products and services generally provided by the private sector, is truly an important ingredient for the development and deployment of intelligent transportation systems in the United States.

PRIVATE SECTOR METEOROLOGY AND ITS

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INTRODUCTION

Weather information plays a major role in surface transportation. In fact, weather has probably been one of the major decision inputs since people first began to travel. The public has always used weather information to assist in making decisions about travel. Most likely, the condition of the surface of a road was important even before motorized travel. As the modes of surface travel evolved and became more sophisticated, the requirement for weather information increased. In addition to knowing the weather and its impact on travel conditions, weather information became an important input in the process of managing transportation systems. Organizations, both public and private, responsible for managing surface transportation systems (cars, buses, trucks, trains, etc.) and for maintaining the surface transportation infrastructure of highways, streets, and bridges recognized the usefulness of incorporating weather information in their decision making processes. Surface transportation decisions affect safety, efficiency, user satisfaction, and cost for the traveling public and affect the activities and budgets of the organizations that are responsible for operating and maintaining all aspects of the various transportation systems.

Intelligent Transportation Systems (ITS) are considered to be the “next generation” of capabilities to be used for decision-making and for managing surface transportation activities.

ITS incorporates advances in information and communication technologies to better manage and improve surface transportation. Since weather has always been a major factor in the management of transportation systems and in the decision making process of the traveling public, it is only natural to consider the importance of weather information and its role in the evolving structure and deployment of ITS.

INTELLIGENT TRANSPORTATION SYSTEMS

Subpart B of title VI (secs. 6051-6059) of the Intermodal Surface Transportation Efficiency Act (ISTEA) provides for the Intelligent Transportation Systems Act of 1991 which authorizes the Secretary of Transportation to establish a program to research, develop, and operationally test "intelligent transportation systems". The U.S. Department of Transportation's Federal Highway Administration formed a Weather Team in 1997 as part of the Intelligent Transportation System (ITS) program of the Department of Transportation.

In a 1998 white paper (Weather Information for Surface Transportation, draft, May 15, 1998, The Weather Team, FHWA, U.S. Department of Transportation) on needs, issues and actions associated with weather information for surface transportation, the Weather Team stated that the goals of the ITS program and of the FHWA's National Strategic Plan are "to be met by a conceptual Weather Information for Surface Transportation (WIST) System that will be part of the ITS for use by surface transportation operators and travelers. They further stated that "The primary vision for the WIST System is: Transportation system operators and users have readily-available weather information that is accurate, reliable, appropriate and sufficient for their needs. The resulting decisions effectively improve the safety, efficiency and customer-satisfaction of the transportation system." So, it is obvious that the principal agency responsible for surface transportation on the roadways of the United States recognizes

the importance of weather information and the need to ensure that it is included in the evolving ITS infrastructure.

The surface transportation community consists of the users of surface transportation, the operators of surface transportation systems, and the managers and maintainers of the surface transportation infrastructure. They have, in some cases, similar requirements for weather information, but often have differing needs for their decision-making. Generally, their decisions involve space and time. For example, a trip route and schedule for a vacationer; or for a transportation supervisor, the time and location to plow a highway during a severe winter storm.

In general, weather information is probably not being fully utilized by the surface transportation community even though its use has tremendous potential to improve the decision-making processes of all of the parties within the community. It is important that weather information be considered in the planning and development of ITS in the United States in order for the transportation community to realize the maximum potential benefit of weather information.

SURFACE TRANSPORTATION REQUIREMENTS

The types of weather information that are important to surface transportation include much of the standard weather information that is needed by other user communities, but they also include several unique kinds of data, forecasts, and value-added products. In many cases, the conventional weather information products and services must be specifically adapted to meet unique requirements of the surface transportation community. For example, in addition to the standard meteorological parameters, such as ambient air temperature, dew point, and wind speed/direction, road maintenance personnel need to know whether a winter

storm event is predicted to be snow or ice, the rate, the amount, the start time, and the end time. In addition, they also need to know the pavement surface condition – dry, wet, freezing, frozen, etc. – as well as the pavement surface temperature over a specific time period. This type of specialized information requires specialized observing equipment, localized analysis of the data, and unique forecasts for very localized areas over time periods involving short intervals. In order to be of maximum benefit to the decision makers, the predictions often need to be generated well in advance of the actual start of the storm. Once a prediction has been issued, it must be updated frequently as new information is obtained and as the weather conditions change. And, as important as the information is the manner in which it is disseminated and presented to the decision makers.

This scenario is similar for many situations involving surface transportation and the use of weather information by operators and users of surface transportation systems. Thus it is obvious that even though ITS can and will use the conventional weather information products and services; it has unique requirements that must be met if it is to be of maximum benefit to the surface transportation community.

The general categories of weather information that should be considered for the implementation of ITS programs and projects in the United States include the following:

- Environmental observations: Includes data and information collected to determine the current state of the meteorological and hydrological environment. A special subcategory includes data collected to determine the condition of road surfaces.
- Analysis: Process of determining the current state of the meteorological and hydrological environment based on the collected data and information.

- **Forecasting:** Process of converting the analyzed meteorological and hydrological data and information into predictions of these same data and other derived parameters.
- **Value-added Products:** Various products that are generated from the meteorological and hydrological data and information that is collected and analyzed as well as from the subsequent predictions. These value-added products include weather satellite and radar images, graphical displays of current and predicted parameters such as temperature, wind velocity, precipitation, and road surface conditions (dry, wet, icing, etc.), severe weather, etc.

The typical flow of weather information through the current infrastructure that provides weather products and services in the United States is illustrated in Figure 1.

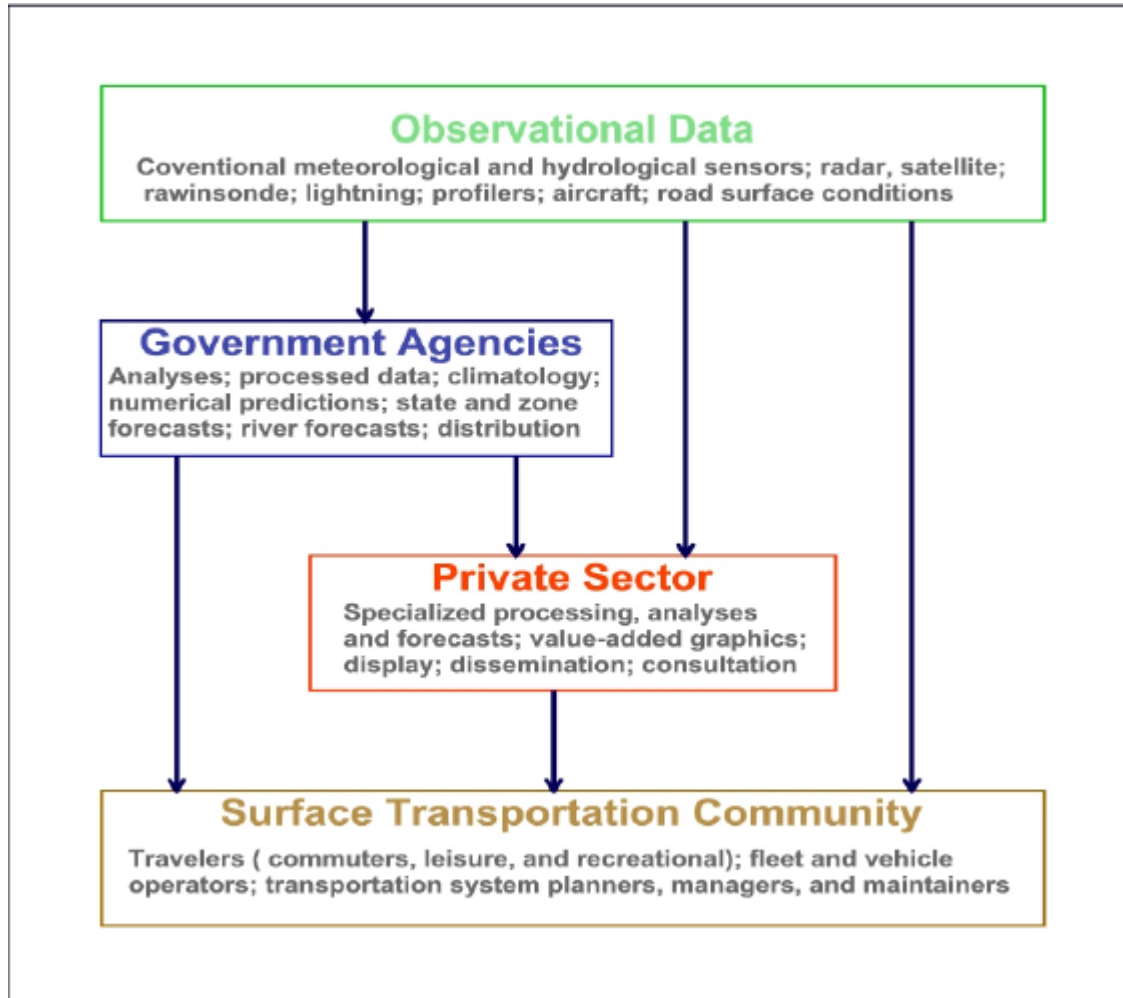


Figure 1. Generalized Weather Support Structure

WEATHER INFORMATION PROVIDERS

The provision of weather information in the United States is essentially a partnership between the public sector and the private sector. In the public sector, the National Weather Service, part of the National Oceanic and Atmospheric Administration (NOAA), has the principal responsibility for providing weather information. In addition to the NWS, other NOAA agencies as well as a number of other Federal agencies, such as the Federal Aviation Administration (FAA), the Department of Defense (DOD), the Environmental Protection Agency (EPA), the National Aeronautics and Space Administration (NASA), the Bureau of Land Management, and others are also involved in weather activities. Many state agencies

are also involved in operating meteorological and hydrological observing networks and in disseminating weather information.

The private sector weather information industry consists of many companies that provide a variety of products and services. These companies range from individuals that often function as consultants, to small firms consisting of only one or two people, and even to large, Fortune 500 companies. In addition to the development and manufacture of products and services that are required for the observation, communication, analysis, and display of weather information, many of these companies are involved in providing very specialized services that the NWS or other public sector entities are either unable or unwilling to provide.

ROLE OF THE PUBLIC SECTOR

In the public sector, the National Weather Service (NWS) has the principal responsibility for providing weather information. The mission statement of the NWS states:

“ The National Weather Service TM (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. “ (National Weather Service Web Site, May 9, 2001)

In an official NWS policy statement regarding the roles of the NWS and the private sector issued in 1991, the role of the NWS is further defined:

“..... the basic functions of NWS are the provision of forecasts and warnings of severe weather, flooding, hurricanes, and tsunami events; the collection, exchange, and distribution of meteorological, hydrologic, climatic,

*and oceanographic data and information; and the preparation of hydrometeorological guidance and core forecast information.” (From the **Federal Register**, Vol. 56, No. 13, Pg. 1984, Friday, January 18, 1991 / Notices, Docket No. 91045-1009)*

In general, the NWS and other Federal and state agencies do not provide the specialized types of weather information products and services required by the surface transportation community, but they do provide the basic observational data and information as well as generalized analyses and numerical predictions that are then used by the private sector to generate the unique information products needed by the end users.

In this same policy statement, the NWS stated the following regarding the role of the public sector relative to the role of the private sector:

*“The NWS will not compete with the private sector when a service is currently provided or can be provided by commercial enterprises, unless otherwise directed by applicable law.” .” (From the **Federal Register**, Vol. 56, No. 13, Pg. 1984, Friday, January 18, 1991 / Notices, Docket No. 91045-1009)*

This “public–private partnership” is the current mechanism that provides weather information support to the surface transportation industry and is the mechanism that will probably be the most productive arrangement for ITS programs and projects in the future.

ROLE OF THE PRIVATE SECTOR

Generally, the NWS does not provide specialized services such as weather forecasts tailored specifically for such activities as managing surface transportation systems.

Historically, these types of specialized services and products have been the role of the private sector weather information industry. In fact, in the NWS official policy statement issued in 1991, the role of the private sector is also defined:

*“The private weather industry is ideally suited to put the basic data and common hydrometeorological information base from the NWS into a form and detail that can be utilized by specific weather and water resources sensitive users. The private weather industry provides general and tailored hydrometeorological forecasts and value-added products, and services to segments of the population with specialized needs.” (From the **Federal Register**, Vol. 56, No. 13, Pg. 1984, Friday, January 18, 1991 / Notices, Docket No. 91045-1009)*

The private weather industry has, for many years, provided tailored weather, river, and water resources forecasts and detailed meteorological and hydrological information, consultation, and data for industries and federal and state government agencies that are sensitive to the meteorological and hydrological environment. The weather industry also provides products such as meteorological, hydrological and other environmental sensors and observing equipment and computer hardware and software for analysis, imaging, and display systems.

The private sector weather information industry in the United States consists of many companies providing a variety of meteorological and hydrological products and services. These companies, numbering in the hundreds and ranging in size from small, one-person consulting firms to large, Fortune 500 companies that have sections or divisions involved in

weather, have historically provided the specialized products and services needed by the surface transportation community. Weather equipment manufacturers develop and produce specialized sensors for observing specific meteorological and hydrological parameters and for observing pavement conditions as well as the standard weather observing instruments and sensors. There are a number of companies that manufacture or distribute sensors specifically designed for measuring pavement conditions as well as the temperature of the soil below the pavement. Many of these companies provide special monitoring stations that combine the conventional meteorological sensors with the pavement sensors and relay the combined information content to the centralized processing facilities where it is processed and disseminated to the decision makers. These special observations are also used in specialized forecast models, developed by the private sector companies that predict changes in the snow and ice condition of the pavement over time.

Weather information companies collect, analyze, and format conventional weather data and products from the NWS and other state and federal agencies as well as the observations from specialized sensors and recording stations and provide the information to decision makers at various levels. The decision makers generally require that the information be tailored for their specific geographic area and their individual surface transportation network. They also require the information in a very timely manner with reports often being updated every few minutes in some circumstances. The weather information companies also provide “quality control” functions by monitoring the various data sources and reports and by eliminating any data that does not appear to be in concert with the prevailing weather situation.

Weather forecasting firms provide specialized analyzes and predictions for the use of decision makers that are generally involved in managing some aspect of a surface transportation system. These decision makers require predictions that are tailored for their

specific geographic area and their individual surface transportation activity. And, they require the forecasts in a timely manner and generally require frequent updates, especially as the weather situation is changing. The weather company provides a “met watch” function by monitoring the weather situation in relation to the prediction and makes the end user aware of updates to the prediction when necessary.

The private sector weather information industry is also the principal provider of weather information that is provided directly to the public by the various media outlets. As such, it is, therefore, the group that essentially provides the current generation of “traveler information” services. The private sector companies that are involved with media have developed unique capabilities to develop and generate information and displays that are acceptable to the public and that are easily understood by the public. As advanced traveler information systems are developed, the private sector companies will be important participants due to their ability to develop, generate, and disseminate these types of information displays for the public.

The private sector, because of its role as the principal supplier of meteorological and hydrological products and service to industry, commerce, and education as well as to the government, continually incorporates technological advances into these products and services. Companies involved in weather information make significant investments in developing new sensors and data collection systems, new analysis and display equipment and software, new value-added products including forecasts, and new communications capabilities. This is true in the products and services supplied to the surface transportation community as well.

CONCLUSION

The private sector weather industry is currently a major participant in the surface transportation community and should be a major participant as the surface transportation

community takes action to realize the tremendous benefits that we be realized through ITS. As the ITS infrastructure evolves and is implemented and as specific needs and requirements are identified, the private sector weather information community will be able to provide the weather products and services needed by the surface transportation community. This will be done by working in concert with the National Weather Service and other Federal and state agencies and with other members of the surface transportation community in a true partnership.

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