Weather and Highways

Report of a Policy Forum

Developed by the

Atmospheric Policy Program
American Meteorological Society

Study Series Underwriters

ITT Industries
Engineered for life

Raytheon

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Study support provided by the

Federal Highway Administration
&
National Science Foundation

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Atmospheric Policy Program
1120 G Street, N.W. – Suite 800
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(202) 737-9006

PREFACE

This report of a policy forum on "Weather and Highways" presents recommendations that, if implemented, could offer considerable benefits to the safety of the nation's traveling public and the national economy by supporting the effective application of weather information services to the operation of our road systems.

The AMS Atmospheric Policy Program developed this forum to address the issues connected with effective use of road weather information. The participants included nearly 100 public, private, and academic representatives of weather information providers; transportation managers and users; and policy makers knowledgeable about the nation's highway system. We remain poised to assist in the further development and realization of the recommendations that have emerged from the forum.

The AMS Atmospheric Policy Program acknowledges, with thanks, the contributions of numerous individuals and organizations to the success of the forum. The fact that they were so numerous inhibits my ability to name them all. The planning committee (Gina Eosco, Genene Fisher, William Mahoney, and Leland Smithson) guided me throughout the forum development process from the initiation to the development of the final report. Of course, the forum could not have been undertaken without the generous labors of the moderators and panelists. The Federal Highway Administration and the National Science Foundation provided support for this forum and ITT Industries and Raytheon provide underwriting support to the AMS Policy Study Series, of which this forum is an undertaking.

Gina Eosco and Carolyn McMahon, AMS staff, very ably handled all of the logistical and administrative details involved in the forum. We are grateful for the efforts of Mark Fernau and R. Gary Rasmussen of the AMS who documented the main outcomes of the discussions. In the course of the review of the initial drafts, several forum participants, too numerous to mention, offered comments and suggestions that influenced the text in the final report. However, the services of William Mahoney, who contributed significantly to the final report, deserve special mention.

Finally, I want to especially acknowledge the outstanding efforts of Genene Fisher, Policy Fellow, AMS Atmospheric Policy Program who, not only was the primary planner of the forum, but was also the principal editor of the report.

Richard S. Greenfield
Senior Policy Fellow and Associate Director
Atmospheric Policy Program
American Meteorological Society

EXECUTIVE SUMMARY

The United States, and more specifically its economy, is highly dependent on the national highway system. More than 200 million cars and trucks use the national highway system and critical parts function at or near their maximum capacity much of the time (OFCM, 2002). About 77% (by weight) of domestic freight shipments are by truck (versus other modes of transportation). Adverse weather, including rain, snow, sleet, fog, etc., can easily reduce roadway capacity and significantly affect the efficiency of this system. Weather also plays a critical role in highway safety. In the United States each year, approximately 7,000 highway deaths and 800,000 injuries are associated with poor weather driving conditions. The estimated annual economic cost from these weather-related crashes (deaths, injuries, and property) amounts to nearly $42 billion (Lombardo, 2000). Weather is a factor in about 28% of the total crashes and 19% of the total fatalities. It is clear that the societal and economic impacts of adverse weather on the highway system are huge.

The traveling public is the ultimate user of the road transportation system. People rely on the system as commuters, tourists, and consumers. In addition, police, fire fighters, school transportation systems, and emergency medical service providers, along with many others, rely on the transportation system to meet the vital needs of the public. Travelers are quite aware of the impact of weather on the roadway system. A Gallup public opinion poll conducted in 2002 indicated that 40% of the potential users of the national "511" system identified weather and road condition as the most important information element (ITSA, 2002). The public clearly understands the relationship between weather and highway safety and congestion, and they seek solutions to enhance mobility.

Given the enormous impact weather has on the highway system and the potentially huge safety and economic benefits that could be realized if weather information was used more effectively by road operating agencies and the public, why has it not received the attention it deserves? What has or has not been done to promote road weather services, what opportunities are emerging, and what impediments are in place that have slowed progress to date? What policies, if any, are needed at the federal and/or state levels?

In an effort to discuss responses to these questions, the Atmospheric Policy Program of the American Meteorological Society (AMS) developed a forum to foster vigorous policy level dialogues. These dialogues led to recommendations on how to improve the safety and operations of the nation's highway system through better application of weather information. The forum brought together representatives of the weather information providers; transportation managers and users; and policy makers knowledgeable about the nation's highway system. The representatives were drawn from the public and private sectors at the national, state, and local levels.

The forum took place over a two-day period on 4-5 November 2003 in Washington, DC. It consisted of three panel discussions focused on 1) present and near-term potential in providing weather information to improve the highway system, 2) public and industrial development of strategies to effectively respond to weather information, and 3) policy issues in implementing effective application of weather services to the management of the nation's highway system. Each panel was followed by a period of discussion leading to recommendations. The panelists' position papers, along with a policy white paper prepared for the forum, are available on the AMS Website at http://www.ametsoc.org/atmospolicy.

The forum discussions led to the following six recommendations, of which two are overarching. All recommendations are directed at improving the safety and efficiency of the roads for the ultimate benefit of the traveling public.

OVERARCHING RECOMMENDATION: NATIONAL ROAD WEATHER RESEARCH, DEVELOPMENT, AND APPLICATIONS PROGRAM

1. Congress should authorize and provide long-term funding for the appropriate federal agencies to develop a *national road weather research, development, and applications program*, to improve the application of weather information for highway safety and operations.

The program should:

- be a multi-faceted interdisciplinary road weather research program focused on addressing the needs of road operating agencies and the traveling public;
- be designed to support the operational decision making process of the traveling public and operational personnel involved in traffic, incident and emergency management, construction, and maintenance activities;
- include technology transfer components that provide mechanisms for the resulting technologies to be applied nationally in a timely manner;
- result in technologies that are consistent with and complimentary to the Intelligent Transportation System (ITS) architecture and framework;
- be designed for drivers and transportation managers to take advantage of and augment current and emerging transportation technologies including intelligent vehicles, telematics, mobile sensing systems, 511 systems, dynamic navigation systems; and
- include mechanisms, such as rapid prototyping and model deployments, to assess user feedback and the potential benefits of the new technologies.

OVERARCHING RECOMMENDATION:
COORDINATION OF PUBLIC, PRIVATE, AND ACADEMIC SECTORS

2. The federal and state departments of transportation should closely coordinate with public, private, and academic sector road weather stakeholders to improve the safety and efficiency of the nation's highway system during adverse weather.

The coordinated activities should include:

- aggressively reviewing and quickly implementing, where appropriate, currently available weather and ITS technology to highway operations—in particular, technology that responds to weather conditions (e.g., variable message signs, dynamic speed limits, ramp metering, and road condition information kiosks);
- promoting the use and expansion of road weather and road condition measurement and information systems;
- developing and applying national standards for Road Weather Information Systems (RWIS) that include accuracy, data format, and siting requirements; and
- working with organizations (e.g. AAA and AMS) to implement programs of education and public awareness, including effective driver education programs that provide instruction on appropriate driving responses to hazardous weather and better utilization of advanced automotive capabilities.

DATA INFRASTRUCTURE

3. DOT/FHWA and NOAA, working with state DOTs, should establish a national road weather and road condition data collection, processing, and dissemination infrastructure to improve the safety and efficiency of the roadway system.

The infrastructure should be designed to ensure:

- the open two-way exchange of relevant transportation data and practices between weather and transportation industry stakeholders;
- that national standards are established and used for weather, traffic, and road condition measurement systems and that open system formats and protocols (e.g., NTCIP) are adhered to;
- that quality control methods and techniques are applied to the data;
- that it can take advantage of existing weather information and warning technologies (e.g., NOAA Weather Radio) and future communication networks (e.g., telematics); and
- that data are collated on a national level and made available centrally on a non-exclusive basis.

OBSERVATIONS, FORECASTS, AND DELIVERY OF ROAD WEATHER INFORMATION AND SERVICES

4. NOAA/NWS, commercial weather providers, and weather information users should work cooperatively to improve the observation system, develop and improve forecasts, and enhance the delivery of information and services on road weather.

Road weather observational and forecast improvements should focus on:

- boundary layer and near-surface meteorology (0-3 meters above ground level) where travelers generally experience road weather hazards (fog, ice, snow, hail, heavy precipitation, blowing snow, etc.);
- collecting and distributing observational data (e.g., ASOS, AWOS, RWIS) with sufficient temporal resolution (minutes) to support tactical decision making;
- distributing weather prediction datasets with sufficient time resolution (hourly), spatial resolution (1-10 km), and data elements needed to analyze and predict pavement conditions;
- road (and bridge) condition prediction models and characterization of the pavement surface;
- developing and implementing probabilistic weather products tailored for the road weather risk management decision process;
- developing new-generation weather and pavement condition sensors to improve the measurement of parameters critical to support roadway operations; and
- making output (data and products) understandable and relevant for highway decision makers and the traveling public.

USER TRAINING AND ROAD WEATHER EDUCATION

5. Federal and state DOTs should train the road management community to more effectively integrate weather into the decision process. In addition, the atmospheric science community, particularly academia, should develop course curricula focusing on road weather science and engineering.

Training and education programs should:

- be focused on educating transportation decision makers (traffic, incident, and emergency management, construction and maintenance personnel) and the automobile industry to improve their understanding of weather hazards and the impact of those hazards on the transportation system;
- be developed at universities to ensure that an adequate pool of qualified "road weather" meteorologists exists to service the surface transportation community; and
- train weather information providers on the needs/challenges of the surface transportation community.

IN-VEHICLE ROAD WEATHER INFORMATION

6. DOT/FHWA should provide incentives for vehicle manufacturers and highway engineers to raise public and private sector demand for in-vehicle road weather information.

Specifically, the incentive program should include:

- support for research and development, benefit analyses, and human factors studies of in-vehicle weather and road condition information systems;
- FHWA and state DOT participation in prototyping activities, field demonstrations and model deployments of new in-vehicle information systems; and
- support for the development of promotional campaigns describing the safety and mobility benefits of utilizing in-vehicle weather and road condition information technologies.

Meaningful actions in response to these recommendations will require cooperative efforts by federal, state, and local DOTs; transportation decision makers; academia and research centers; and weather information providers. Leadership by the U.S. DOT, in cooperation with NOAA and NSF, with support from Congress, is vital if these recommendations are to be successfully applied to improve the safety and efficiency of our nation’s roads.

I. INTRODUCTION

The United States, and more specifically its economy, is highly dependent on the national highway system. More than 200 million cars and trucks use the national highway system and critical parts function at or near their maximum capacity much of the time (OFCM, 2002). About 77% (by weight) of domestic freight shipments are by truck (versus other modes of transportation). Adverse weather can easily reduce roadway capacity and significantly affect the efficiency of this system. Weather also plays a critical role in highway safety. In the United States each year, approximately 7,000 highway deaths and 800,000 injuries are associated with poor weather driving conditions. The estimated annual economic cost from these weather-related crashes (deaths, injuries, and property) amounts to nearly $42 billion (Lombardo, 2000). Weather is a factor in about 28% of the total crashes and 19% of the total fatalities. It is clear that the societal and economic impacts of adverse weather on the highway system are huge.

The traveling public is the ultimate user of the road transportation system. People rely on the system as commuters, tourists, and consumers. In addition, police, fire fighters, school transportation systems, and emergency medical service providers, along with many others rely on the transportation system to meet the vital needs of the public. Many goods and services are based on just-in-time delivery, and so disruption in mobility brings considerable negative economic impact. Weather can no longer be considered an inevitable inconvenience. Fortunately, there are many commercial off-the-shelf technologies and service improvement techniques available now that, if implemented, could reduce the loss of lives and improve the operational efficiency and carrying capacity of our highways. A Gallup public opinion poll conducted in 2002 indicated that 40% of the potential users of the national “511” system identified weather and road condition as the most important information element (ITSA, 2002). The public clearly understands the relationship between weather and highway safety and congestion and wants solutions to enhance mobility.

The nation’s roads are operated and maintained by a variety of transportation managers, including traffic managers, maintenance managers, and emergency and public safety managers. These managers, along with the traveling public, receive weather information from the private sector (also known as commercial weather providers) and public sector sources.

Today, the nation’s highways and roads present many challenges. For example, the U.S. highway system is extremely decentralized. The system is owned and managed by the 50 states and tens of thousands of local governments. This decentralization creates obvious challenges with respect to maintaining consistency across the system and to transferring new technologies into nationwide use. Judiciously applied increased highway funding would allow states to keep pace with the growth in demands for increased capacity, better environmental mitigation, and improved system management. Without certain increases, highway agencies are unable to often compete with the long-standing desire to add lane miles even though technologies designed to improve system performance and management capabilities often cost far less.

Given the enormous impact weather has on the highway system and the potentially huge safety and economic benefits that could be realized if weather information was used more effectively by road operating agencies and the public, why has it not received the attention it deserves? What has or has not been done to promote road weather services, what opportunities are emerging, and what impediments are in place that have slowed progress to date? What policies, if any, are needed at the federal and/or state levels?

In an effort to discuss responses to these questions, the Atmospheric Policy Program of the American Meteorological Society (AMS) developed a forum to foster vigorous policy level dialogues. These dialogues led to recommendations on how to improve the safety and operations of the nation's highway system through better application of weather information. The forum brought together representatives of the weather information providers; transportation managers and users; and policy makers knowledgeable about the nation's highway system. The representatives were drawn from the public and private sectors at the national, state, and local levels.

The forum took place over a two-day period on 4-5 November 2003 in Washington, DC. It consisted of three panel discussions focused on 1) present and near-term potential in providing weather information to improve the highway system, 2) public and industrial development of strategies to effectively respond to weather information, and 3) policy issues in implementing effective application of weather services to the management of the nation's highway system. Each panel was followed by a period of discussion leading to recommendations. There was a final discussion among a subset of the panelists, moderators, and forum planners and staff on the day after the close of the forum. A draft report was circulated to the panelists, moderators, and all participants for comments.

Each panel was composed of public and private sector experts in their respective topic areas. The forum program is provided in Appendix A. The names, affiliations, and addresses of the moderators and panelists are available in Appendix B. A list of the participants is provided in Appendix C.

The panelists' position papers, along with a policy white paper prepared for the forum, are available on the AMS Website at http://www.ametsoc.org/atmospolicy.

The forum discussions resulted in a set of recommendations that pertain to improvements in the provision of weather services for highway operations and the traveling public. These recommendations are presented in Section II.

Over the last several years, much progress has been made in bringing together the surface transportation and weather community. The Intelligent Transportation Society of America (ITSA) established a Weather Information and Applications Task Force in 1996. The FHWA, working with state DOTs and national laboratories developed Surface Transportation Weather Decision Support Requirements (STWDSR) in 2000. The Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) worked with transportation stakeholders and developed the *Weather Information for Surface Transportation National Needs Assessment Report*, which was published in December 2002. The AMS had an Ad Hoc Committee on Surface Transportation in the mid-1990s. The AMS more recently created a Standing Committee on ITS and Surface Transportation Weather in 2002. In January 2004, the National Research Council (NRC) completed a study and published a report titled *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services,* which describes a research agenda for improving road weather services. In parallel with these efforts, the FHWA Road Weather Management Program has been actively engaging the meteorological community through projects designed to address the needs of highway operations decision makers. All of this activity demonstrates a deep appreciation for the impact of weather on the roadway and the need to move ahead aggressively with a program plan designed to improve the performance of the transportation system during adverse weather.

There is an ongoing discussion in the road weather community about how a research, development, and applications program should be organized. Should it be organized around weather phenomena (winter storms, thunderstorms, surface winds, etc.) or decision categories (winter road maintenance, traffic management, emergency management, etc.)? Should regional transportation weather research centers be created around the country to perform the work or should technology development teams be established to focus on specific research topics? What organizations should be involved and who should take the lead? Before a national road weather research, development, and applications program is initiated, these questions must be answered.

II. RECOMMENDATIONS AND SUMMARY DISCUSSIONS

The forum discussions led to the following six recommendations, of which two are overarching. All recommendations are directed at improving the safety and efficiency of the roads for the ultimate benefit of the traveling public.

OVERARCHING RECOMMENDATION: NATIONAL ROAD WEATHER RESEARCH, DEVELOPMENT, AND APPLICATIONS PROGRAM

1. Congress should authorize and provide long-term funding for the appropriate federal agencies to develop a *national road weather research, development, and applications program*, to improve the application of weather information for highway safety and operations.

Specifically, the program should:

- be a multi-faceted interdisciplinary road weather research program focused on addressing the needs of road operating agencies and the traveling public;
- be designed to support the operational decision making process of the traveling public and operational personnel involved in traffic, incident and emergency management, construction, and maintenance activities;
- include technology transfer components that provide mechanisms for the resulting technologies to be applied nationally in a timely manner;
- result in technologies that are consistent with and complimentary to the Intelligent Transportation System (ITS) architecture and framework;
- be designed for drivers and transportation managers to take advantage of and augment current and emerging transportation technologies including intelligent vehicles, telematics, mobile sensing systems, 511 systems, dynamic navigation systems; and
- include mechanisms, such as rapid prototyping and model deployments, to assess user feedback and the potential benefits of the new technologies.

To successfully meet the needs of the surface transportation community (as reported in the OFCM *Weather Information for Surface Transportation--A National User Needs Assessment*), a coordinated road weather research and applications program needs to be established at the national level. The program must be adequately funded and must include research, development, implementation, verification, training, outreach, and education. It must cut across multiple transportation operations categories and involve stakeholders. The recent NRC report, *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services,* lays out many of the necessary components of a national road weather research program (NRC, 2004).

In implementing this recommendation, Congress should fund the FHWA to lead the development of this program. The FHWA should closely coordinate the program with the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the appropriate national laboratories, university transportation research centers, commercial weather service providers, and the atmospheric science and civil engineering communities. The primary objective of the research program must be to develop tools to improve both safety and the performance of the roadway system by effective application of weather information.

A road weather research and applications program could be organized in several ways. Regional centers could be established that focus on specific topics relevant to the local road weather challenges. Demonstration corridors could be used to develop, test, and demonstrate new capabilities. Technology Development Teams (TDTs) could also be formed to address specific topics when expertise and technologies require the formation of specialized research teams to address specific decisions. For example, the development of a winter road maintenance decision support system requires a different set of technologies than a traffic management decision support system. Development teams focused on ITS technologies will be different than those focused on high-resolution modeling. Methods used to organize the research program must be flexible so that it can adjust to changing requirements, be lean, and make the most efficient use of limited research funding.

An initiative to understand the societal impacts and economic benefits of improved highway weather information must be an element of the research plan. Data need to be gathered for several decision categories (e.g., incident management, traffic management, winter maintenance, emergency evacuation) to highlight the potential benefits of improved weather information for decision makers and the traveling public.

There was a general consensus at the forum that making research results publicly available will provide the best opportunity to get the results into the commercial marketplace in a timely manner. However, before the national transportation community will accept new technologies, their effectiveness must be successfully demonstrated in regional tests or test-bed setups. The establishment of national transportation corridors has been proposed as a means to test the feasibility of new road weather applications. This concept has merit and should be explored further as part of a national road weather research program.

The DOT Federal Aviation Administration (FAA) Aviation Weather Research Program (AWRP) provides a good leadership model for a national road weather research program. The AWRP has existed for 10 years and has significantly improved aviation weather hazard detection and prediction and product delivery to users. However, surface transportation weather issues differ significantly from those of aviation, which typically focus on upper-air hazards such as turbulence, in-flight icing and windshear. Road weather research needs to focus on the layer between the height of a truck cab (~3 meters) and the ground and also to focus on the interaction of the weather and the road surface. The framework for a road weather research program must be broader than for aviation, because of the greater number of contributing parties and the extensive mix of federal, state, local, and private sector responsibilities. Such a program must coordinate diverse stakeholders and must capitalize on the contributions of the National Weather Service (NWS) and private sector interest and the fact that the FHWA does not operate any roadways, with state and local organizations having that responsibility. A federal program is required since states focus on limited geography, are struggling with severely constrained budgets, and have difficulty coordinating major research activities across state boundaries.

A significant goal of government-funded research is to ensure that the results of the research get implemented for the good of the public. The mechanisms used to transfer information and technologies vary greatly and range from publishing research to delivering turnkey solutions to user organizations. The FAA AWRP, for example, utilizes several technology transfer strategies including document publication, delivery of specifications and prototype software, technology commercialization through the private sector, and direct implementation of new technologies into FAA and NOAA facilities. The FHWA Road Weather Management Program uses a complementary approach. For example, it has structured its Maintenance Decision Support System (MDSS) project as a public-private partnership, whereby new technologies are prototyped and the resulting technologies (code, specifications, etc.) are openly distributed on request to any interested party on a non-exclusive basis. This structure is required because the highway systems are operated by the states, not the FHWA, and any new technologies must be implemented by the state DOTs.

OVERARCHING RECOMMENDATION: COORDINATION OF PUBLIC, PRIVATE, AND ACADEMIC SECTORS

2. The federal and state departments of transportation should closely coordinate with public, private, and academic sector road weather stakeholders to improve the safety and efficiency of the nation's highway system during adverse weather.

The coordinated activities should include:

- aggressively reviewing and quickly implementing, where appropriate, currently available weather and ITS technology to highway operations--particularly technology that responds to weather conditions (e.g., variable message signs, dynamic speed limits, ramp metering, and road condition information kiosks);

- promoting the use and expansion of road weather and road condition measurement and information systems;

- developing and applying national standards for Road Weather Information Systems (RWIS) that include accuracy, data format, and siting requirements; and

- working with organizations (e.g. AAA and AMS) to implement programs of education and public awareness, including effective driver education programs that provide instruction on appropriate driving responses to hazardous weather and better utilization of advanced automotive capabilities.

The amount and quality of off-the-shelf weather data and information have increased dramatically over the last decade. The NOAA National Weather Service (NWS) modernization program has resulted in improved detection and prediction capabilities across the nation, and private sector offerings have expanded as well. Emerging technologies now exist to provide the impact of weather on a specific road segment based on objective calculation of the weather impact. Dedicated communication systems are no longer the only option in providing data to transportation managers and vehicle operators, making the delivery of weather information less expensive and more accessible. It is time for road operating agencies to take advantage of these capabilities and to aggressively integrate weather into their operations and for automotive manufacturers to expand the weather information available to the drivers to improve safety.

It has been clearly demonstrated that RWIS (over 2000 sites in North America) does benefit highway maintenance operations, particularly winter maintenance. However, these systems do not have a national standard for location, equipment performance, and capabilities or data representations. As a consequence, the quality and accuracy of the meteorological equipment can vary from site to site. Pavement sensors, which have no standardization, can vary even more significantly from vendor to vendor and measured pavement temperatures can have significant differences between products and technologies. In addition, chemical measurements and freeze point calculations can also vary--some vendors report only chemical factors (a relative measurement) while others provide freeze-point based on the chemical used. In forecasting the pavement freeze point, there is an additional critical measurement, the sub-surface temperature. At present, the sub-temperature probe depths can vary from 8 to 24 inches based on procurement specifications or vendor standard practices. The development and enforcement of RWIS standards will make the data more attractive and usable by the broader road weather community.

Hazardous weather training is also an area that needs attention. In Japan, driver training includes demonstrated proficiency on snow-covered roadways. The Japanese also provide detailed road condition and visibility reports in their rest areas. Japanese traffic management centers set the speed limits on variable message signs based on road conditions and existing and forecasted weather. Northern Europe has also invested significant resources into road weather. Weather and road condition sensor networks are expanding and advanced snow and ice prediction systems based on these networks are being implemented. These and similar technologies have been slow to arrive in the United States because the investment in road weather systems has been lower than in Europe and Japan.

During the forum, a repeated message from state DOT representatives is that they do not really care about the technical aspects of forecasting—they do not want to become meteorologists. However, there are exceptions, such as the Utah DOT, which is beginning to integrate a group of consulting meteorologists into its traffic operations centers, as well as hire an operations forecaster to oversee the weather and RWIS operations for the state. Overall, there is a need for better communication among researchers, users, and state DOTs. States are not utilizing information they have now as well as they could because it is often disjointed, conflicting and provided in multiple formats. They need to be able to make decisions easily and are seeking decision support systems that focus on information rather than data. The meteorological community needs to respond to these requirements and to begin to focus on solutions that address the decision making process.

Significant progress has been made in the last 5 years to bring the atmospheric science and surface transportation community together to better understand each others' needs and capabilities. This dialogue must continue and be expanded to other stakeholder groups who are affected by inclement weather in their daily operations. The FHWA and NOAA, working together with the commercial weather providers, NSF, national laboratories, and stakeholder groups including AMS, ITSA, TRB, AASHTO and others, should proactively identify opportunities for collaboration and information exchange. A long-term relationship is needed between these organizations to influence change.

DATA INFRASTRUCTURE

3. DOT/FHWA and NOAA, working with state DOTs, should establish a national road weather and road condition data collection, processing, and dissemination infrastructure to improve the safety and efficiency of the roadway system.

The infrastructure should be designed to ensure:

- the open two-way exchange of relevant transportation data and practices between weather and transportation industry stakeholders;

- that national standards are established and used for weather, traffic, and road condition measurement systems and that open system formats and protocols (e.g., NTCIP) are adhered to;

- that quality control methods and techniques are applied to the data;

- that it can take advantage of existing weather information and warning technologies (e.g., NOAA Weather Radio) and future communication networks (e.g., telematics); and

- that data are collated on a national level and made available centrally on a non-exclusive basis in real-time.

For the traveling public and highway managers to make decisions during adverse weather, they must not only have good weather and road condition information, but they must also know the resulting traffic impacts on the roadways in near real-time. It is imperative that a national road weather data and information collection and dissemination infrastructure be established. Currently, a variety of weather and road condition information is available from multiple sources across the country. However, the information can be difficult to access and the format and quality vary greatly. The NOAA National Climatic Data Center archives data and maintains scientific data stewardship for much of NOAA's atmospheric data. However, much of the data and forecasts for road weather are non-NOAA data. It would be valuable to researchers and the private sector to have these non-NOAA road weather data and forecasts archived and accessible. Modernized NOAA/NWS offices in each state have technology available to process information from diverse sources and make those data and information available to external users as well as other weather offices. Weather, traffic, and road condition data collected by state DOTs and other organizations could and should be made available to NOAA and the public. Access to these data will provide opportunities for the NWS to provide improved highway weather warnings and for road operating agencies and commercial weather providers to create products and services that will benefit the operational efficiency of our highway system and the safety of the traveling public.

While advancements have been made within the highway system in the use of Road Weather Information Systems (RWIS), a robust deployment and utilization of RWIS has been limited by their cost and the strong competition for limited funds within state DOTs. Further, while the present environmental sensor station technology in use today is more sophisticated than it was just a decade ago, it could still be used more effectively to support the operational decision making process. No RWIS deployed today has the capability to measure some of the most basic hazards to winter mobility. For example, RWIS does not have heated precipitation gauges. Hence, they are not able to observe and report accumulations, freezing, or frozen precipitation. RWIS provides critical weather and road condition information to maintenance personnel, but the data are generally presented in simplistic meteorological form requiring interpretation by non-meteorologists. Use of sensor data in roadway weather analyses and forecasts could be enhanced if standards for field calibration, quality control, and siting were more readily available. Only in limited situations are statewide RWIS networks designed for joint purposes of supporting specific maintenance challenges and broader meteorological applications.

A centralized national distribution of RWIS data would contribute greatly to the use of road weather data. Efforts to standardize the data are improving with the release of data standards (i.e., NTCIP-ESS) that will allow consistency in data formats and promote the transfer and exchange of data without proprietary software. The framework for a national clearinghouse of RWIS data has been established through the NOAA Forecast Systems Laboratory's Meteorological Assimilation Data Ingest System (MADIS) project (http://www-sdd.fsl.noaa.gov/MADIS). Already a number of state DOTs provide their RWIS data for distribution using MADIS; however, depending upon constraints imposed by individual state DOTs, this information does not necessarily provide the full dataset, which includes both meteorological and road condition information. Many of these constraints are either from liability concerns (such as the general public misunderstanding and misusing RWIS data), from proprietary contracts, or from a lack of technical ability to make the information available.

A national database will promote consistency between states and allow persons traveling across several states to have seamless data pertinent to their entire route. The data flowing though a national data collection and dissemination infrastructure would also be used as input to national and local-scale weather and road condition prediction systems. ITS technologies including in-vehicle traveler information systems, "511" services, and roadside kiosks would utilize the data flowing through the weather and road condition infrastructure, which would allow them to provide more timely and accurate information and alerts during poor weather conditions. The weather and road condition infrastructure should be designed to provide two-way communication. Users should not only be able to download data from the network, but upload data as well. For example, the existing roadside observing systems deployed by many states could serve an additional function. With modest investments of existing technologies, Data and Information for Driving Safety and Security (DIDSS) kiosks could be established. These kiosks could serve the function of collecting supplementary weather and roadway information and sending DIDSS information to passing vehicles. Selected long-haul carriers could provide invaluable information to verify weather and roadway conditions as they move about the country. The operators of these vehicles could set indicators of certain road conditions such as obstructions to visibility, ice and snow, and accidents that, along with GPS positional information, can be telemetered to roadside kiosks for relay to DOT management control centers and weather information providers. Transportable Information Pods (TIPs) could be utilized for temporary site-specific roadway situations such as bridge or road segment repair, flood damage, and so on and would transmit limited information to passing vehicles. This information would also be useful for alternate route planning by the vehicle operators.

Another idea worth considering is the NOAA Weather Radio (NWR) selective encoding capability. Each county and eventually sub parts of a county are identified with a unique number identifier. Products sent out via NWR are tagged with the specific identifier number of the county for which they are intended. Radio receivers can be programmed to accept products designated for any one, multiple, or all counties. It is technologically possible for digital warning information to be appended to NWR messages, making this existing system worthy of consideration for deployment of DIDSS and telematics systems at low incremental costs. Therefore, the NWR should be available in all vehicles so that the traveling public will have access to vital warning information.

OBSERVATIONS, FORECASTS, AND DELIVERY OF ROAD WEATHER INFORMATION AND SERVICES

4. NOAA/NWS, commercial weather providers, and weather information users should work cooperatively to improve the observation system, develop and improve forecasts, and enhance the delivery of information and services on road weather.

Specifically, road weather observational and forecast improvements should focus on:

- boundary layer and near-surface meteorology (0-3 meters above ground level) where travelers generally experience road weather hazards (fog, ice, snow, hail, heavy precipitation, blowing snow, etc.);

- collecting and distributing observational data (e.g., ASOS, AWOS, RWIS) with sufficient temporal resolution (minutes) to support tactical decision making;

- distributing weather prediction datasets with sufficient time (hourly), spatial (1-10 km) resolution, and data elements needed to analyze and predict pavement conditions;

- road (and bridge) condition prediction models and characterizing the pavement surface;

- developing and implementing probabilistic weather products tailored for the road weather risk management decision process;

- developing of new-generation weather and pavement condition sensors to improve the measurement of parameters critical to support roadway operations; and

- making output (data and products) understandable and relevant for highway decision makers and the traveling public.

There are barriers to progress in the use of weather information for highway operations. Some highway managers have described one barrier as “information overload.” Too often, highway managers are inundated with weather products and jargon that have no direct bearing on their mission. These managers must sift through products to find pertinent details. Often, managers give up and move on with their operations without the benefit of the latest weather information. Others find important weather information but do not have it presented in a way that is useable to them or in a format that can be handled by their systems. A nationwide road weather observing system that promotes open data sharing, analysis, and integration will be critical to support transportation operations during adverse weather.

Systems such as "511" and the Federal Maintenance Decision Support System (MDSS) Functional Prototype and the multi-state pooled fund research MDSS initiatives are beginning to address ways to enhance the quality and context of information provided to users of the highway system. However progressive these systems are, at present they still require final interpretation of weather information by the user. Some state DOTs' Requests for Proposals (RFP) on the 511 systems include emerging requirements such as that rather than receiving weather information, DOTs want information about the effect weather has on the roadway by way of alerts and incidents. Therefore, the goal of weather information providers should be to provide the greatest level of decision support without the need for extended analysis and interpretation by the user. This challenge is daunting, because it requires the weather information providers to integrate more effectively the user's needs into the information service provided. The shift from providing "weather content" to providing "potential results from weather" promotes allowing decision makers to focus on their area of expertise, which is not meteorology.

Of all the weather parameters that affect the surface transportation sector, precipitation has the largest impact. Without a doubt, an improvement in the detection and prediction of precipitation (snow, rain, sleet, etc.) is the most important item. However, many Automated Surface Observations Systems (ASOS) can no longer record or relay the nature of frozen precipitation. Improved observations of clouds and fog are required as well as new data-fusion technologies to better diagnose the occurrence of fog and low-visibility regions. Knowledge of road temperature is critical for anti- and deicing operations. Road temperature prediction models rely on weather model output of cloud height, density, and, where explicitly available, insolation. Road temperatures are also highly dependent on whether the surface is wet, dry, chemically wet, or snow covered. Better measurements of these parameters are required along the entire roadway.

Overall, an improved road weather observational system should include:

- precipitation data (type, rate, liquid equivalent, start and end times);
- data accessibility and sharing;
- radar data quality;
- visibility detection;
- insolation measurements; and
- road surface condition.

For more information of user needs, refer to the OFCM report, *Weather Information for Surface Transportation – A National User Needs Assessment* (2002).

With respect to forecasting, current atmospheric modeling efforts underway in both the research and operational realms will likely continue to improve both in spatial and temporal resolution. The need for specific weather forecasts that reflect the weather conditions found from truck cab height (~3 meters) down to the pavement surface (and below) is an area needing attention. Present atmospheric models do well in the free atmosphere, but begin to suffer the farther they move downward into the planetary boundary layer. Forecasting elements associated with pavement conditions such as roadway frost, snow drifting, and snow accumulation, requires more detail of the land-surfaces (natural and manmade) adjacent to the roadway and miso-scale topographical variations than are possible in current atmospheric models and those planned in the near future.

Overall, improvements in forecasts should include:

- very high resolution information (misoscale=40 m to 4 km);
- rapid updates (minutes to hours);
- current information for tactical operations (0-12 h), planning horizon (12-48 h), and seasonal planning (weeks to months); and
- information presentation including the use of probabilistic products for risk management.

Transportation decision makers, like most decision makers, are generally in the risk management business. Decisions are made to reduce costs, increase safety, and improve efficiency. In the transportation sector, weather plays a critical role in this decision process. One of the reasons the decision makers seek multiple sources for weather information is to get an indication of confidence in the forecast. If all the sources agree, there is a perception that the event will occur as predicted. Because weather will never be predicted perfectly at road scales, probabilistic products should be developed, implemented, and promoted. Transportation managers would like the weather community to do a better job conveying certainty or the lack thereof. This approach requires atmospheric, statistical, and human factors research to ensure the user receives consistent information and understands its content.

USER TRAINING AND ROAD WEATHER EDUCATION

5. Federal and state DOTs should train the road management community to more effectively integrate weather into the decision process. In addition, the atmospheric science community, particularly academia, should develop course curricula focusing on road weather science and engineering.

Training and education programs should:

- be focused on educating transportation decision makers (traffic, incident, and emergency management; construction and maintenance personnel) and the automobile industry to improve their understanding of weather hazards and the impact of those hazards on the transportation system;

- be developed at universities to ensure that an adequate pool of qualified “road weather” meteorologists exists to service the road transportation community; and

- train weather information providers on the needs/challenges of the road transportation community.

Transportation managers generally do not have technical training or education in weather data content and interpretation. Hence, when these personnel are supplied with weather data and forecast information that is inconsistent or improperly prepared for the intended application, they are still left with the challenge of making decisions; that frequently requires them to analyze and assess the meteorological content of available information. Recent changes in maintenance weather forecasting product delivery through the use of probabilities and finer spatial and temporal scales have worked to minimize the maintenance user’s analysis and interpretation, but have not eliminated the process. Further, the use of local observations, including weather satellite and radar imagery, still supplants short-range forecasts with the interpretation being almost entirely made by maintenance personnel. Some state DOTs have responded to this situation by employing professional meteorologists on staff to assist with the processing and filtering of this information to assist maintenance decision making.

The American Association of State Highway and Transportation Officials' (AASHTO) computer-based learning program for effective snow and ice control is an excellent example of a training program focused on helping the decision makers to make better use of weather information in their decision process. Both onsite and remote training programs (first time and recurrent) should be established for a broad range of road weather topics.

IN-VEHICLE ROAD WEATHER INFORMATION

6. DOT/FHWA should provide incentives for vehicle manufacturers and highway engineers to raise public and private sector demand for in-vehicle road weather information.

The incentive program should include:

- support for research and development, benefit analyses, and human factors studies of in-vehicle weather and road condition information systems;
- FHWA and state DOT participation in prototyping activities, field demonstrations, and model deployments of new in-vehicle information systems; and
- support for the development of promotional campaigns describing the safety and mobility benefits of utilizing in-vehicle weather and road condition information technologies.

Safety on our highways is a combination of informed drivers, effective maintenance measures, and improved forecasts and equipment. The most important factor, however, is proper driving behavior and equipment. Highway drivers, on average, have little awareness of traffic management or operations affecting the roads they travel until they are encountered. An informed driver must be made aware of life-threatening road conditions in sufficient time to allow the appropriate responses under the circumstances. Automotive safety features inside vehicles should be operated in concert with the desired action of the driver.

Changes introduced in automobile design are mostly implemented by the platform manufacturer for safety, performance, or financial reasons. Rarely is the broader public aware of new capabilities until they are introduced by the manufacturer. In recent years, the traveling public has had in-vehicle access to such advanced features as telephone/telecommunication capabilities (though most phones are carry-on types and few are integrated into master control consoles), laptop computers, GPS navigational aids, SOS safety features, night vision assistance devices, vehicle spacing radars, vehicle assisted emergency braking, and electronic stability control programs. The driver controls over some of these safety-oriented capabilities are limited, and the operation has usually been engineered to be almost completely unassisted. Platform manufacturers have a long and highly competitive process for introducing changes in the operation of convenience or safety features.

Great care is given to the operability, performance, and maintenance of the new feature. Concept cars, test/demonstration vehicles, and limited fleets of equipped vehicles are employed to test and evaluate the concept, manufacturing process, cost/benefit, and marketability of the enhancements.

The national ITS architecture provides the opportunity and framework for integrating road weather services into centers, vehicles, roadside, and traveler's operations. New technology industries such as intelligent vehicle initiatives by the major automobile manufacturers need to recognize the opportunity to include route-specific information that describes road and weather conditions in their value-added options. Auto industry/road owner partnerships may bring together roadway condition information gathered by vehicle probes that can be merged with other weather information sources to enable better winter road management.

The NWS, for decades, has issued weather warnings and traveler hazard advisories such as dangerous precipitation (snow, rain, and hail), icing potential, obstruction to visibility (fog and blizzards), and high wind conditions. NOAA Weather Radio (NWR) has also been available for decades, but is unavailable in most vehicles. When traveling along our highway system it is virtually impossible for the public to get pertinent and timely weather and highway safety information. A national policy requiring the in-vehicle capability to receive NWR information should be considered. This would provide the most basic level of weather information to the public. Currently VHF frequencies are utilized in NWR, but selected channels of the AM broadcast band (e.g. 550 MHz or 1550 MHz) could be set aside for national highway safety and security information. This would have the added advantage of making NWR information available to all AM radios in homes as well as vehicles and extending the effective range of the transmissions.

In-vehicle weather information, when coupled with navigation and traffic information technology, could provide a powerful combination of information that will not only help drivers to avoid or respond better to hazardous driving weather, but could offer alternative routes that would improve mobility. Trucking firms, motor coach carriers, and fleet operators could be some of the biggest beneficiaries of this type of technology. Dashboard-mounted electronics of the future should integrate radio (AM, FM, and XM), cell phone, telematics, data collection, and navigation systems. To maximize safety, user configurable voice alerts for traffic, weather, and incidents should be provided in a manner that would not require drivers to remove their hands from the steering wheel.

III. CONCLUDING REMARKS

Weather has a major impact on our nation's road system. Thousands of deaths and hundreds of thousand of injuries occur each year on the highways during poor weather conditions. In addition, the national economy is highly dependent on a safe and efficient transportation system, which is becoming more congested every year. A proactive approach for addressing how weather affects the transportation system must be taken to reduce casualties and improve system efficiency.

There is a need for both basic and applied research into specific weather problems such as boundary layer meteorology, small-scale forecasting, and hazard detection—not just an extension of today's aviation-based methodologies. This research could lead to better detection and prediction of fog, frost, ice, snow, flooding, and their relationship with road conditions. A significant effort is needed to apply meteorological knowledge to state and local DOT operations. There must be a transformation of the complex meteorological fields into elements that are of importance to the entire road transportation community (including state/local agencies and all users of the highway system).

New weather and road condition measuring technologies are coming to fruition that, given time and appropriate resources, are likely to produce significant benefits to the transportation community and the ultimate user, the traveling public. A long-term, multifaceted road weather research program utilizing a public-private-academic partnership approach should be established to properly address user needs and to extract the scientific and technical capabilities that reside in organizations (government and private) across the country.

It is critical that the state and local DOTs be involved from the beginning in any federally sponsored road weather research program. State DOT personnel must be involved in the requirements, analysis, design, and testing processes. In addition, since state and local DOTs often purchase weather information from commercial weather providers, it is imperative that these providers be involved in any federally sponsored road weather research program. Commercial weather services should be provided in a cost-effective manner, because success will ultimately be determined by whether the states implement the new capabilities. This means that every effort should be made to design solutions with standardized interfaces that utilize readily available components or data sets and allow for maximum flexibility for adding or interchanging technologies.

This forum report presents two overarching recommendations: 1) development of a national road weather research, development, and applications program and 2) the need for close coordination of public, private, and academic stakeholders to develop strategies for improving the safety and efficiency of the nation's road system. The other four recommendations address data infrastructure; observations, forecasts, and delivery of information; user training and education; and in-vehicle road weather information. Meaningful actions in response to all of the forum recommendations will require cooperative efforts by all organizations and individuals involved in providing road weather information and those involved in developing responses to that information at the federal, state, and local levels and within the public, academic, and private sectors. Leadership by the U.S. DOT, in cooperation with NOAA and NSF, under the oversight and support of Congress, is vital if these recommendations are to be successfully applied to improve the safety and efficiency of our nation's roads.

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APPENDIX A - PROGRAM

A POLICY FORUM: WEATHER AND HIGHWAYS

Developed by the Atmospheric Policy Program,
American Meteorological Society

The Army and Navy Club
901 17th Street NW
Washington, DC

Tuesday – November 4, 2003

0830 Opening Remarks/Welcome: E. Friday, President, AMS; Regina McElroy, Director, Office of Transportation Operations, FHWA

0840 Federal Coordination Perspective – Samuel P. Williamson, Federal Coordinator for Meteorological Services and Supporting Research

0850 Forum Overview: Richard Greenfield, Associate Director and Senior Policy Fellow, Atmospheric Policy Program, AMS

0900 Keynote Address: Scott Rayder, Chief of Staff, NOAA

0930 Panel 1: Present and near-term potential in providing weather information to improve the highway system. *The panelists will provide their perspective on present and potential capabilities to provide useful weather information for effective, safe highway operations taking into account recent findings and recommendation of national organizations (OFCM, NRC, FHWA).*

Moderator: Ray Ban, Executive Vice President of Meteorology, Science and Strategy, The Weather Channel, Inc.

Bill Mahoney, Program Development Manager, Research Applications Program, National Center for Atmospheric Research

Greg Mandt, Director, Office of Climate, Water and Weather Services, National Weather Service, NOAA

Leon Osborne, President and Cofounder, Meridian Environmental Technology, Inc.

Lester Yoshida, Vice President, Intelligent Transportation Systems, Quixote Corporation

1030 Break

1100 General Discussion – preliminary findings and recommendations focused on the questions considered by the panel:

1. What improvements are needed in observational, technological, and modeling capabilities to significantly increase the nation's safety on the highway system during adverse weather?

2. How is weather information communicated to highway system decision makers and what improvements should be made?

3. What are the opportunities for and barriers to effective application of weather information to highway safety and operations?

1230 Lunch

1400 Panel 2: Public (federal, state, local) and industrial development of strategies and plans to effectively respond to weather and climate information. *The panelists will consider technological, economic, legal, and administrative issues.*

Moderator: Shelley Row, Chief Technical Officer and Council Secretary, Institute of Transportation Engineers

Lon Anderson, Director of Public Affairs, Mid-Atlantic Region, AAA
Lisa Ballard, Research Engineer, Western Transportation Institute, Montana State University
Rick Nelson, Assistant Director of Operations, Nevada Department of Transportation
Jeff Paniati, Associate Administrator for Operations, Acting Director of ITS Joint Program Office, Federal Highway Administration

1500 Break

1530 General Discussion – preliminary findings and recommendations focused on the questions considered by the panel:

1. How do highway system managers and users apply weather information?
2. How is the nation's highway system changing, and how will this affect the development of applications?
3. What are the opportunities for and barriers to effective application of weather information to highway safety and operations? What improvements in weather information and applications could enhance the safety and operations of the nation's highway system?

1700 First day wrap-up

1730 Reception and Dinner

***Speaker* –** Jeffrey N. Shane, Under Secretary for Policy, U.S. Department of Transportation

Wednesday – November 5, 2003

0815 Preliminary Remarks Richard Greenfield, Atmospheric Policy Program, AMS

0830 Panel 3: Policy issues in implementing effective application of weather services to the management of the nation's highway system. *The panelists will discuss policy needs to clarify roles, responsibilities, and funding (i.e., federal, state, local coordination; public-private sector cooperation; political considerations; and regulatory and equity issues).*

Moderator: Jonathan Gifford, Assoc. Professor of Public Management and Policy, George Mason University

Tony Kane, Director of Engineering & Technical Services, AASHTO
Eric Webster, Staff Director, Environment, Technology, and Standards Subcommittee, Science Committee, U.S. House of Representatives
Robert Skinner, Executive Director, Transportation Research Board, NRC
Louis Boezi, Former Deputy Director, National Weather Service, NOAA

The panelists will each make a 20 minute presentation followed by a 10 minute intra-panel discussion of policy issues, options, and opportunities related to the application of weather information to the highway management and policy system.

1000 Break

1030 General Discussion – preliminary findings and recommendations focused on the questions considered by the panel:

1. What are the key institutional and financial policy issues in promoting effective application of highway weather information?

2. What opportunities are emerging and what impediments are in place that have impacted progress to date?

3. What public policies are needed to foster effective application of weather services to the management of the nation's highway system?

1200 Lunch

1300 Discussion of the overarching findings and recommendations of the Forum.

Moderator: Richard Greenfield, Atmospheric Policy Program, AMS
Focus on identifying recommendations and policy implementation options necessary to effectively apply weather information to our nation's highway systems.

1430 Actions and Next Steps

1500 Status of actions from prior fora in the AMS Atmospheric Policy Program Forum Series and summary of future plans (William Hooke, Atmospheric Policy Program, AMS)

1530 Adjourn

APPENDIX B - PANELISTS

Panel 1

Mr. Raymond J. Ban (moderator)
Executive Vice President, Meteorology, Science, and Strategy
The Weather Channel
300 Interstate North Parkway
Atlanta, GA 30339

Mr. Bill Mahoney
Program Development Manager
NCAR/RAP
PO Box 3000
Boulder, CO 80307

Mr. Greg Mandt
Director, Office of Climate, Water and Weather Services, NOAA
1325 East West Highway
SSMC2 Room 14348
Silver Spring, MD 20707

Mr. Leon Osborne
Director, Regional Weather Information Center
Center for Aerospace Sciences
University of North Dakota
Grand Forks, ND 58202

Mr. Lester Yoshida
Vice President, Intelligent Transportation Systems
Quixote Corporation
One East Wacker Drive
Chicago, IL 60126

Panel 2

Ms. Shelley J. Row (moderator)
Chief Technical Officer and Council Secretary
Institute of Transportation Engineers
1099 14th Street, NW, Suite 300 W
Washington, DC 20005

Mr. Lon Anderson
Director of Public and Government Affairs
AAA Mid-Atlantic
701 15th Street NW
Washington, DC 20005

Ms. Lisa Ballard
Montana State University
Western Transportation Institute
PO Box 173910
Bozeman, MT 59717

Mr. Rick Nelson
Assistant Director of Operations
Nevada DOT
1263 South Stewart Street
Carson City, NV 89712

Mr. Jeff Paniati
Associate Administrator for Operations
Acting Director, ITS Joint Program Office
Federal Highway Administration
HOP-1
400 7th St. SW
Washington, DC 20590

Panel 3

Mr. Jonathan Gifford (moderator)
Professor of Transportation and Planning
George Mason University
School of Public Policy
3401 North Fairfax Drive MS 3B1
Arlington, VA 22201

Mr. Louis J. Boezi
President
Atmospheric Science Advisors, LLC
909 McCeney Ave.
Silver Spring, MD 20901

Dr. Tony Kane
Director of Engineering and Technical Services
AASHTO
444 N. Capitol St, NW #249
Washington, DC 20866

Mr. Eric Webster
Staff Director, Majority
House Science Committee, Subcommittee on Environment, Technology and Standards
U.S. House of Representatives
2320 Rayburn House Office Bldg.
Washington, DC 20515

Mr. Robert E. Skinner
Executive Director
NRC, Transportation Research Board
500 5th St, NW
Washington, DC 20001

APPENDIX C - PARTICIPANTS

Mr. Elliot Abrams
Accuweather, Inc

Mr. Michael Adams
Weather Management Solutions, LLC

Mr. Dennis Anderson
Campbell Scientific

Mr. Robert K. Benedict
Unisys Corporation

Mr. Dan Berler
Cambridge Systematics

Mr. James H. Block
Meteorlogix

Mr. Ed Boselly
Washington State DOT

Mr. Lee Bowman
Scripps Howard News Service

Mr. Bill Callahan
WSI Corporation

Mr. Ray Cathcart
Surface Systems, Inc

Mr. CharlesW. Challstrom
NOAA National Geodetic Survey

Mr. James N. Cooper
Earth Satellite Corp

Mr. Paul Delannoy
Meteorological Service of Canada

Ms. Lisa Dumke
ADDCO

Ms. Gina Eosco
AMS

Mr. Frank Estis
NOAA/OFCM

Dr. Mark Fernau
AMS

Dr. Genene Fisher
AMS

Dr. Elbert (Joe) Friday
AMS

Mr. John Gaynor
NOAA

Dr. Richard Greenfield
AMS

Dr. Richard Hallgren
AMS

Mr. Bob Hallowell
MIT/LL

Mr. Art Handman
ITSA, Weather Information and Applications Special Interest Group

Dr. Bryan Hannegan
White House Council on Environmental Quality

Dr. William Hooke
AMS

Mr. Andy Horwitz
NOAA/NWS

Mr. Michael Jamilkowski
Raytheon

Dr. Edward Johnson
NOAA /NWS PPI

Ms. Sue Joy
High Sierra Electronics

Mr. Paul Kocin
The Weather Channel

Col. John A. Lasley

Mr. Michael Ledford
UCAR

Dr. Sharon LeDuc
NOAA/NCDC

Mr. Stephen J. Lord
NOAA/NCEP

Mr. John T. Manfredi

Mr. Robert Marsili, Jr.
DC DOT

Mr. Steve Matula
NOAA/NOS/NGS/RSD

Ms. Regina McElroy
Federal Highway Administration

Mrs. Carolyn McMahon
AMS

Dr. Ronald D. McPherson
American Meteorological Society

Mr. Brian Mills
University of Waterloo

Mr. David Montroy
Weathernews America

Mr. Barry Myers
Accuweather, Inc

Dr. Stephan Nelson
National Science Foundation

Mr. Curt V. Pape
MN DOT

Mr. Ralph Patterson
Utah DOT

Mr. Brooke Pearson
Vaisala, Inc

Ms. Maria Pirone
AER, Inc.

Mr. Paul Pisano
FHWA

Ms. Joanne Potter
Cambridge Systematics

Dr. Gary Rasmussen
AMS

Mr. Scott Rayder
NOAA

Mr. Kenneth Reeves
Accuweather, Inc

Mr. Robert Reining
The MITRE Corporation

Mr. David Rogers
SAIC

Mr. Daniel Roosevelt
VA DOT - VTRC

Mr. Jeff Rosenfeld
AMS

Mr. Tim Ross
NOAA

Mr. Paul Schultz
NOAA Forecast Systems Laboratory

Mr. Jeffrey Shane
U.S. DOT

Mr. Leon Shneider
Vaisala, Inc

Mr. Steven Smith
Accuweather, Inc

Mr. Leland Smithson
IA DOT

Mr. Rick Steed
University of Washington

Mr. Andy Stern
Mitretek

Mr. Nicholas Stoer
Transportation and Management Consulting

Mr. Doug Stone
AMS

Mr. Ronald J. Sznaider
Meteorlogix

Mr. Rich Taylor
ITS America

Ms. Deborah Underwood
Transportation Institute

Mr. Keith Vickers
Enterprise Electronics Corp

Mr. George Wilcox
NOAA

Mr. Sam Williamson
OFCM

Mr. Timothy M. Wolfe
AZ DOT

Ms. Joyce M. Wood
NOAA/PPI

APPENDIX D - ACRONYMS

AAA	American Automobile Association
AASHTO	American Association of Highway and Transportation Officials
AMS	American Meteorological Society
ASOS	Automated Surface Observation System
AWOS	Automated Weather Observation System
AWRP	Aviation Weather Research Program
DOT	Department of Transportation (Federal)
ESS	Environmental Sensor Station
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
ITS	Intelligent Transportation System
ITSA	Intelligent Transportation Society of America
MADIS	Meteorological Assimilation Data Ingest System
MDSS	Maintenance Decision Support System
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
NTCIP	National Transportation Communications for Intelligent Transportation Protocol
NWR	NOAA Weather Radio
NWS	National Weather Service
OFCM	Office of Federal Coordinator for Meteorological Services and Supporting Research
RWIS	Road Weather Information Systems
TRB	NRC Transportation Research Board