Chapter 5
WIST Strategic Thrust Areas

5.0 Introduction

This chapter defines six strategic thrust areas for next steps in addressing validated user needs for weather information for surface transportation (WIST):

1. Identifying and specifying the gaps in coverage of WIST user needs
2. Expanding coordination among research and development (R&D) programs and providers of WIST products and services
3. Clarifying and defining roles and responsibilities in the information provider and disseminator communities that acquire, interpret, and tailor WIST to meet user needs.
4. Translating research results and new technologies into WIST applications
5. Supporting research to expand and fill gaps in the fundamental knowledge that enables and supports future technology development and application
6. Expanding outreach and education to both current and potential WIST users.

The purpose of this chapter is to characterize each of these strategic thrust areas well enough to specify one or more broad goals in each area, plus suggested next steps toward these goals. To this end, the discussion addresses courses of action to overcome barriers and meet the challenges in each strategic thrust area. The chapter closes with a vision of how future surface transportation systems in the United States could be improved by a concerted effort to meet the user needs documented by the WIST needs study.

5.1 Strategic Thrust Area 1: Identifying and Specifying the Gaps in Coverage of WIST User Needs

This report culminates the initial phase of needs identification and verification in a coordinated effort to understand and address WIST user needs. The needs compiled in the WIST templates include many that can be met with data already available to users, plus others that could be met with information derivable from available data. For the remainder, however, the data generally available are not at the levels of reliability, timeliness, or spatial and temporal specificity required for WIST users in making operational decisions. An important thrust area for continuing the WIST effort is to conduct a detailed analysis of the gaps in coverage, the nature of the gap (why is current data not adequate?), and how a diverse provider community of both public and private sector providers can best cover these gaps.

5.1.1 Barriers and Challenges in Identifying Unmet WIST User Needs

Meteorological support and services from the public sector have traditionally focused on the needs of the general public (for information to protect life and property) and on aviation weather support. Weather information providers have not met the needs of the surface transportation communities for accurate information at high spatial and temporal resolutions. This information also must be provided with sufficient lead-time (for forecasts) or currency (for observations) to guide operational decisions. With the rapid increase of applications for weather information in surface transportation activities and the increasing importance of WIST, information providers in both the public and private sectors need to pay more attention, in the form of resource investment and priority, to WIST users' needs. As noted in Section 1.3.3, specialized weather information services and products evolved over time, and sometimes belatedly, to meet the needs of diverse users within the aviation community. Thus, the history of aviation weather provides a precedent—with both positive and negative lessons—from which the WIST provider community can learn.

From the perspective of WIST users, limitations in the available weather data and forecasts have restricted their utility for surface transportation operations, even though the right kinds of information, if received with adequate lead time, could improve many types of surface transportation decisions. As noted in Chapter 4, many of the WIST needs identified by this study require very high resolution weather information to meet the need fully. This information is not generally available, from either observations or predictions based on numerical modeling, with the reliability and access times needed to influence decisions. There are also a large number of nontraditional or sector-unique weather (and environmental) elements that are important to WIST user communities.

Private-sector participants in providing (including producing, adding value to, or disseminating) WIST services and products will set their own criteria for defining their potential roles and responsibilities. However, a mechanism is needed to coordinate federal roles and responsibilities that cut across the transportation information infrastructure. For example, if a roadway weather capability for highway users is being developed or demonstrated operationally, some mechanism

Railroad cars are stranded on a stretch of flooded track after Tropical Storm Alberto doubled back over the area. Good advance warning as Alberto came off the Gulf of Mexico in July 1994 led to very little damage. The lack of warning when the storm came back caused considerable damage to rail operations.

is needed to recognize and push for the opportunities to leverage the technology in other sectors, such as the U.S. Marine Transportation System (MTS) or railways.

Participants in the WIST user meetings conducted for this survey supported a proposal to establish a nationwide baseline of weather information needs for surface transportation and endorsed the pursuit of solutions that would meet these needs. This report provides a first attempt at such a baseline of WIST needs. Next, a joint effort is needed to determine which needs are not fully met and how these gaps should be addressed. Finally, this initial baseline of WIST needs will require extension to other sectors and activities, as well as continued monitoring, advocacy, and validation, to ensure it continues to comprehend and represent the needs of surface transportation communities.

5.1.2 Next Steps for Strategic Thrust Area 1

Goal for Identifying Gaps in Coverage of WIST Needs. Identify validated user needs for surface transportation weather information that cannot be met with existing information resources of the public–private provider community. Determine whether technology development in progress will meet the need or if additional technical development and/or research is needed.

Next Step 1A. The federal partners in the WIST effort should charter an appropriate entity (e.g., a task force or program council) to:

- Ascertain (1) which WIST user needs in the initial baseline compilation are fully met now, (2) which could be met more fully through improved presentation and interpretation of current observational and forecast data, and (3) which require data that are not yet available or that have attributes (e.g., accuracy, spatial and temporal scale, timeliness) beyond what is now available
- Review and sustain or adjust priorities for research programs and for transitioning promising tools and other technologies into operations
- Support agency processes to validate and update user needs and provider community programs and approaches for addressing them.

Next Step 1B. Sustain and expand the dialogue between the meteorological community as information providers and surface transportation communities as information users.

Next Step 1C. Use the baseline of WIST needs represented by the templates developed during this study as a work in progress, to be refined, extended, updated, and validated by the participants in a continuing assessment of where capabilities can be delivered that fill an identified gap or enhance value.

5.2 Strategic Thrust Area 2: Expanding Coordination Among WIST R&D Programs and WIST Providers

5.2.1 Barriers and Challenges to Expanded Coordination of WIST Efforts

Funds for improvements in weather information for surface transportation systems do not enjoy a high priority in state or federal agencies. As a result, programs and projects to increase the application of science and technology innovations are sponsored and funded haphazardly across the nation. This uncoordinated approach leads to duplication of effort and to lost opportunities for leveraging programs that could be applied in other states or nationwide. To accelerate the application and use of new or emerging technologies and capabilities for WIST support, technology transfer processes (concepts, capabilities, practices, and tools) linking the government and private sectors need to be enhanced.

Work to be done in this area includes more, and better, coordination and agreement among federal, state, and local governments and the private sector on the provision of data and services. The National Oceanic and Atmospheric Administration (NOAA) and commercial value-added vendors of weather information have been making progress on this "division of labor" in disseminating general meteorological information. Successful examples of coordination and active partnering can also be seen in the maturation of R&D projects that began under the Road Weather Management Program of the Federal Highway Administration (FHWA) and are now moving toward commercial operation (see Section 1.3.1). The FHWA and the Intelligent Transportation Society of America (ITSA) have worked out many areas of coordination and partnering for technology transfer related to intelligent highway systems, as represented in the *National Intelligent Transportation Systems Program Plan: A Ten-Year Vision* (ITSA 2002a). The Transportation Research Board of the National Academies has long served as an important coordinating and technology transfer agent for federal, state, academic, and private-sector entities concerned with transportation-related research and technology. However, the opportunities to meet ***weather-related information needs of surface transportation decision makers***, made possible by the advances in science and technology described in Chapter 1, open up new domains for coordination and partnering.

The guiding principle for expanded coordination and partnering must be to transfer the results of R&D programs, typically funded with federal support, to whichever entities are most capable of implementing effective and efficient delivery of WIST services and products to the users.

- Partnering is needed to guide and support the R&D agenda and to secure and maintain advocacy and funding for infusing technology (through technology transfer and implementation) into operations. New relationships among public and private sector groups will require changes in how federal agencies support, coordinate, and participate in the rapidly expanding WIST provider community.
- These evolving relationships may require changes in the roles and responsibilities of the federal partners in the Federal Committee for Meteorological Services and Supporting Research (FCMSSR), both as sponsors of R&D and as partners in WIST technology transfer and information dissemination.

- Designation of the Federal Aviation Administration as lead agency was critical for progress in coordinating the federal effort on aviation weather (see Section 1.3.3). Similarly, designation of a lead agency for WIST may be critical for coordinating WIST programs and related activities. As Figure 5-1 indicates, a number of Department of Transportation administrations, as well as other departments and agencies, have significant responsibilities and interests in surface transportation sectors.

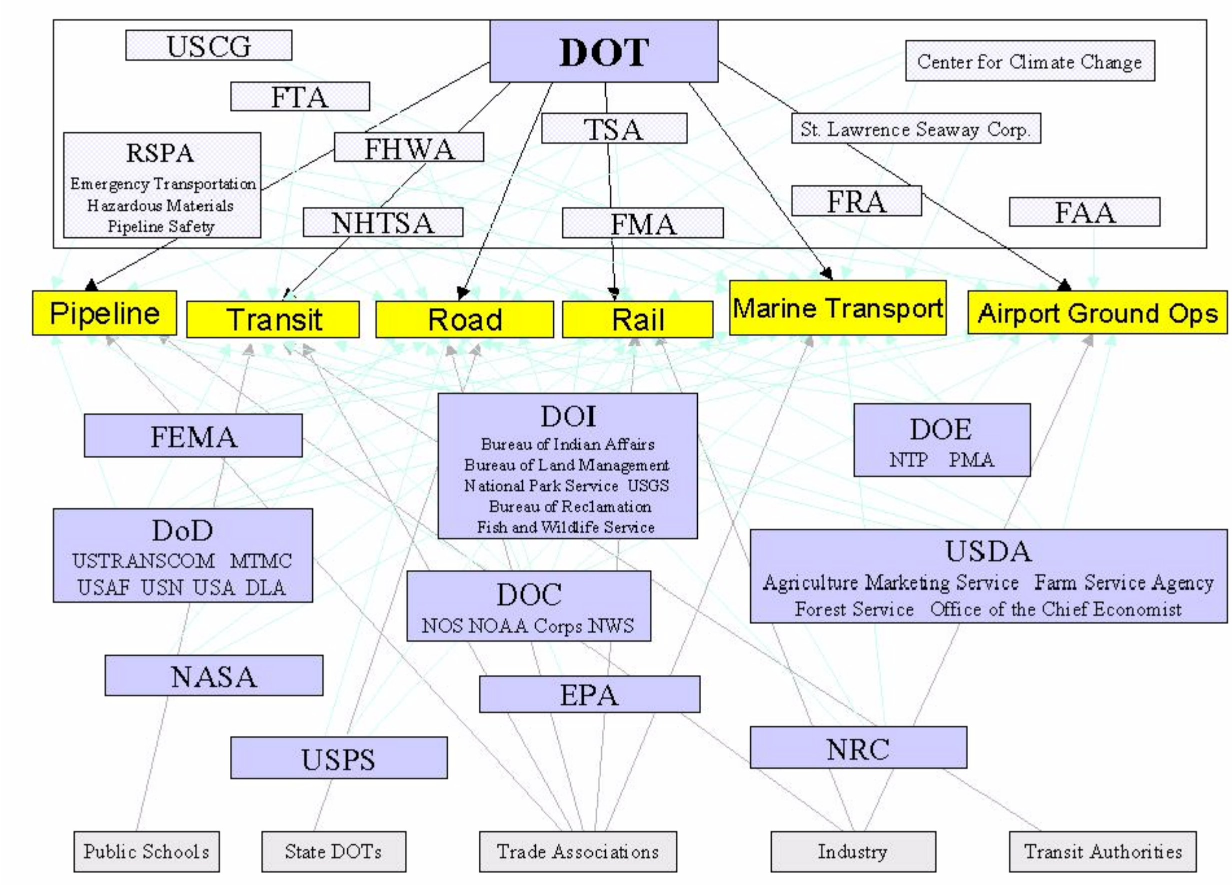


Figure 5-1 WIST users in each of the transportation sectors.

5.2.2 Next Steps for Strategic Thrust Area 2

Goal for Coordinating R&D and Technology Transfer. Expand and improve the coordination and communication among both WIST-relevant R&D programs and field implementation programs and projects aimed at incorporating WIST elements in the decision processes and decision support systems used by transportation activities in all sectors. New and expanded partnerships among government entities, the private sector, the academic R&D community, and public-private entities for provision of WIST services and products should aim at increasing the efficiency and effectiveness of translating R&D results into operational value for WIST users.

Next Step 2A. Coordinate the WIST-related R&D research efforts and technology transfer programs of federal agencies, including but not limited to the U.S. Weather Research

Program, the national Intelligent Transportation Systems research efforts, and a WIST R&D Program as proposed in Section 5.4 of this report. Transfer of research results and technology demonstrations to operational capabilities, services, and products available to WIST users should be a major component of this expanded coordination effort.

Next Step 2B. Prepare for and form strategic partnerships and alliances among government entities (federal, state, and regional/local), the private sector, the academic R&D community, and public-private entities.

Next Step 2C. To provide the legislative basis and funding support for expanded coordination, the provider communities, with the support of the WIST user communities, should give immediate attention to:

- Reauthorization of the U.S. Department of Transportation surface transportation program under the Transportation Equity Act for the 21st Century (TEA-21)
- Full support for the MTS as proposed by the Marine Transportation System National Advisory Council and the Interagency Committee for the Marine Transportation System.

5.3 Strategic Thrust Area 3: Clarifying and Defining Provider Roles and Responsibilities

5.3.1 Barriers and Challenges to Clearly Defined Roles and Responsibilities

In all of the surface transportation sectors, information and communication linkages between transportation system users and providers are proliferating. The challenge is to use these new capabilities to maximize management and efficiency in the nation's surface transportation systems. WIST products and services are one piece—but an important piece—of this infusion of information and communications technologies into surface transportation systems.

A significant barrier to improving the products and services available to WIST users is that the roles of federal entities versus those of state and local governments or the private sector are neither clear nor consistent. Fuzzy boundaries in the roles and responsibilities of the public and private sectors in generating, tailoring, and communicating WIST to users have at times fostered strained and even adversarial relationships between these sectors. For example, some commercial weather services have disagreed about the type or amount of products or services that should be provided to the public by NOAA's National Weather Service (NWS). The disagreements reflect differences between broad and narrow interpretations of NWS responsibilities.

Continued cooperative efforts by all parties in the WIST provider community will be necessary to resolve these conflicts and gaps in the service, guidance, and regulatory structures that influence delivery of weather information to WIST user communities. Explicit policy guidance on the roles and responsibilities of public and private sector participants in providing and tailoring weather information would provide a solid basis for expediting provision of new and improved products and services to WIST user communities.

The two subsections below describe avenues through which provider roles and responsibilities can be clarified:

- Supporting data standards and a national data collection system
- Pursuing an open systems approach in WIST information systems.

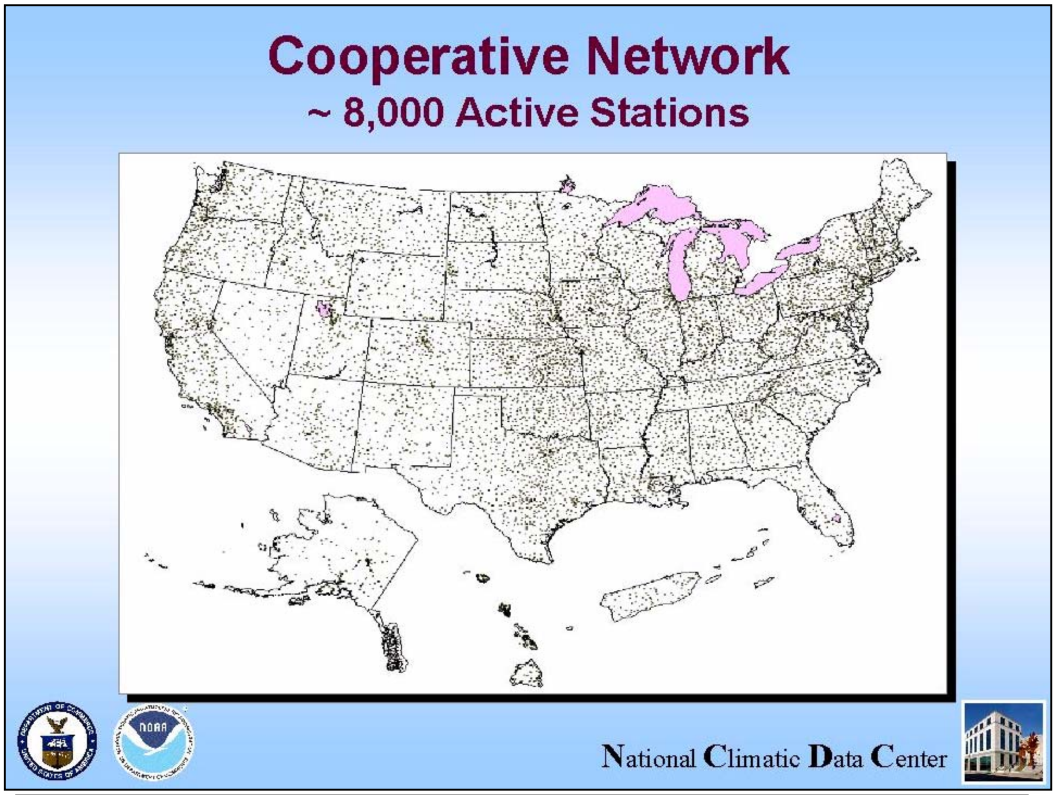
5.3.2 Next Steps for Data Standards and a National Data Collection System

Surface transportation operations require timely and reliable data. However, the means of generating, obtaining, transferring, and applying weather information are not standardized at present. This lack of standards significantly hinders dissemination and application. Nonstandard or erratic updates to observations and forecasts undermine the value of weather information for transportation-related decision processes and systems. Restrictions on the radio frequency spectrum complicate the choice and availability of the communication system used to report and distribute data.

The WIST user communities to be supported with timely data are numerous and diverse. This diversity presents a special challenge for standardization efforts. Nearly every user has unique aspects of its operation, so any specific solution is unlikely to be broadly applicable across all the WIST user communities. Some users are seeking and obtaining high-resolution weather observations from nontraditional sources, but data standardization and quality control issues may encumber wider dissemination and broader application.

Mesonets have been implemented in several states to support state and federal programs, as well as academic research and private sector applications. Issues associated with increasing the value of such networks include standardizing sensor technology and calibration methods, siting the sensors, collecting and processing the data (whether it is proprietary or public), access to the data, and integration of mesonet data with data from federal systems. Through the Meteorological Assimilation Data Ingest System (MADIS) program, the FHWA has been working with the NOAA Forecast Systems Laboratory to highlight the benefits of making observations from roadway weather information systems, operated by state departments of transportation, available to other surface transportation and meteorological communities. MADIS access to mesonets provides for data acquisition and data quality control. In selected cases, the information is made available to users for further processing. To date, 10 states have agreed to participate in MADIS. The Cooperative Observer Network, operated by the NWS, is a nationwide weather and climate observing network that, when modernized, will provide a useful framework for more extensive national collection and integration of weather and environmental data from regional mesonets.

Goal for Data Standards. Provide guidance on the roles and responsibilities of the public and private sectors for various types of observations and networks, particularly in light of better understanding of the accuracy needed to support the nontraditional weather/environmental elements and the new higher-resolution observation and modeling products required by WIST users.



The NOAA/NWS Cooperative Observer Network spans the nation. Each dot represents an observing location. Source: National Climatic Data Center.

A nationwide collection of local weather data does not exist and has not been mandated. These data are usually of greatest value locally, but ideally they should then be passed to a national collection location, where the data can be subjected to quality controls, aggregated, synthesized, and archived. Lack of advocacy by the states and other users has hampered funding and development of a national collection process. Other factors inhibiting a national collection process include commercial profit requirements of the private sector and the sometimes adversarial relationship between the public and private sectors with respect to roles and responsibilities.

Goal for Nationwide Data Collection. Integrate proliferating surface weather observations and networks and incorporate their data, along with data from the Cooperative Observer Network, into a nationwide data system. This data system should provide access to related geophysical data of value to surface transportation operations. This effort should address:

- Equipment (measurement/sensor adequacy and accuracy, siting criteria, calibration, metadata, and legacy systems)
- Communications protocols and standards
- Data standards for quality control, accessibility, compatibility, interoperability, and archiving.

Next Step 3A. Determine the roles of NOAA/NWS and/or other public and private sector partners in pursuing the above Goal for Nationwide Data Collection.

Next Step 3B. Address issues of observation standards and protocols, equipment siting, data collection, processing, archiving, access, and proprietary data through the use of a task force or similar action group.

Next Step 3C. Examine, test, and implement operationally current and emerging technologies for system definition and transition, system optimization, modal optimization, and environmental considerations.

5.3.3 Next Steps for an Open Systems Approach for WIST

For an information network with many providers of services and products, serving a diverse community of consumers, there are technical advantages to open systems architectures for communications and interfaces. Decision support tools should be implemented as an application layer on top of this open-systems foundation. Education of users and providers about these advantages is critical to efficient delivery of WIST services and products that are tailored to the needs of surface transportation decision makers and their decision support systems.

The national Intelligent Transportation System (ITS) architecture and other elements of the ITS initiative can provide a framework and starting point for deciding on technical issues of data management and accessibility (e.g., format standards) for WIST communications in all surface transportation sectors. These elements of technical infrastructure can also aid in resolving the more difficult issues of the boundary between public information and commercial or proprietary tools for presenting and interpreting information to support users with special needs and interests. There must also be attention to security issues, including protecting the integrity of shared data resources and managing the risk that open information will be used in hostile actions.

Goal for Open Systems in WIST Communications. Resolve the technical aspects of providing open access to weather information in a manner that benefits diverse WIST users fairly, while providing commercial or mixed public-private value-added suppliers with a level playing field and reasonable incentives for participating. Address issues of data system security.

Next Step 3D. Work toward full compatibility of transportation-related communications and information systems with the national Intelligent Transportation system Architecture.

Next Step 3E. Establish a task force to develop a security strategy for national weather information networks, addressing issues of data integrity and the balance between open access to data and restrictions to avoid hostile use of data systems and resources.

5.4 Strategic Thrust Area 4: Translating Research Results and New Technologies into WIST Applications

A number of currently unmet WIST user needs can be met in the near term (within 5 years) through applied research or development of technology applications. Some of these technologies incorporate advances in observing or forecasting meteorological parameters; others involve weather-affected conditions such as black ice on highways or railbed ground heave. Still others involve information technology and software to make WIST data easier to incorporate and apply in users' decision processes. For these areas, translating research results and science into practical information for users is the near-term objective.

User needs that will require more fundamental research—such as major advances in misoscale forecast models—are likely to require longer time horizons. These needs are addressed by Strategic Thrust Area 5.

5.4.1 Highlights of Applied Research and New Technology with Near-Term Payoffs for WIST Users

Appendix E provides a detailed list of research topics and technology development relevant to WIST user needs. The following bullets highlight some of the areas in which significant results for WIST users appear feasible within the next 5 years:

- Integration into operational transportation information systems of newly developed technologies for observing and predicting fine-scale weather-related hazards such as:
  - Temperature-dependent effects on infrastructure that are difficult for operators to identify with unaided visual information, such as black ice on roadways or railbed frost heave
  - Sun glint and glare
- Better forecasts of MTS weather and environmental conditions by improving and expanding oceanographic sensor systems and improving models that incorporate weather data with water levels, tides, and currents

Vehicles pass through a flooded underpass in Chicago on August 22, 2002, after 5-8 inches of rain fell. Copyright AP Wide World Photos.

- Weather elements and related conditions that can be observed with existing technology as point measurements but require accurate fine-scale spatial distribution modeling for surface transportation applications such as:
    - Frost heave of road surfaces and railways
    - Spatial distribution of pavement or rail/railbed conditions (temperature, frost, ice, etc.) between the point measurements available with roadway or railway monitoring sites
    - Spatial variability in rainfall and rainfall rates, leading to hydroplaning and other localized flooding hazards along transportation routes
    - Hydrologic implications of rainfall for surface transportation infrastructure and systems (all transportation sectors)
    - Spatial distribution of blowing or drifting snow and its impact on transportation route visibility (roadways, railways, waterways)
    - Dissipation of anti-icing chemicals

- Information technology for access to and applications of WIST, including WIST inputs to intelligent transportation systems and the MTS, such as:
    - Refined in-vehicle and in-vessel displays for WIST and for decision support tools that incorporate WIST information in their graphical output
    - Filtering and fusion processes to tailor meteorological, environmental, and route condition data and information for decision support systems and user procedures specific to surface transportation applications
    - Advanced communication technologies (e.g., wireless, automatic voice response) and graphical products applied to decision support systems, particularly those for mobile and remote nodes of intelligent transportation systems
    - Development and distribution of tools and guidance to assist decision makers when contaminants or hazardous materials in transit are released to the ground, the atmosphere, or surface waters

- Improved sensing and measurement technologies and collection/processing of observation data, including:

Road weather information can be integrated into "intelligent dashboard" information systems for highway travelers. Courtesy OnStar Corp. Copyright 2002, all rights reserved.

- Metadata standards for all observational systems
- Definition of roles for remote sensing technologies in planning for sensor systems and in complementing, supplanting, and expanding in situ sensing
- Standardized methodologies for collecting, processing, and archiving observation data.

There are many more research requirements listed in Appendix E for which some near-term results with operational value are likely, but longer-term R&D effort will probably be needed to meet WIST user needs completely. These requirements are indicated as both near-term and far-term in Appendix E.

5.4.2 Challenges to Current Technological Capabilities and Understanding

Uncertainty and risk in predictive information pose challenges for both weather research and information technology developers. Uncertainty in predictions of environmental conditions depends in part on the quality and density of observations on which predictions are based. The uncertainty usually increases as the predictive time horizon increases. Many operational decisions for transportation systems and activities require lead times of 12 to 24 hours. Although current mesoscale (grid points separated by 10 km or less) weather models provide forecasts out to 48 hours, the spatial and temporal accuracy of the forecasts is not high enough to meet the reliability needs of many transportation decision makers. Forecasts at longer times are available only at synoptic-scale resolutions, which are much less useful for many transportation decisions and still do not provide the reliability (forecast skill) WIST users need.

Decision support systems will need to incorporate techniques for working with the predictive uncertainty inherent in high-resolution forecasting at longer lead times. For example, various predictive sources can be weighted according to their reliability, and risks can be represented in ways that are useful for decision making (Nelson 2001, p. 6).

For a number of activities in the surface transportation sectors, an accurate forecast of favorable weather is often just as important as a forecast of adverse or mission-limiting weather. For understandable reasons, most meteorological research and technology development have focused on understanding the precursors for adverse weather, to aid in predicting it more reliably. In many respects, the basis already exists in observational data and model predictions for more detailed predictive information on favorable weather, including measures of uncertainty in forecasts of fair weather.

A major challenge in translating advances in meteorological and related science into practical and useful information is to present the information in terms that users understand and can incorporate effectively in their planning and operational decisions. Advanced decision support systems will be increasingly important in translating observations and forecast data into useful inputs to decision processes. However, more professionals will be needed who have training in meteorology and related science fields but also understand and can communicate in the ***perspective of the users***. These "WIST communicators" are an essential complement to the software tools. They will play a major role in developing better tools, applying them to specific users' needs, and continuing to improve them.

5.4.3 Opportunities in Current and Emerging Technologies

Opportunities in Weather-Related Research and Technology Development

As the principal source of meteorological observations and forecasts for the nation, the NWS benefits from continuing improvements to its NEXRAD radar system, Advanced Surface Observing System (ASOS), weather satellites, and AWIPS—the information processing and networking system that ties all these observation platforms to the national forecast centers and local forecast offices. The broad range of users of NWS data and products—including end users, communications media, and providers of value-added meteorological services—benefit from this new technology as it improves NWS capabilities.

This weather satellite in geosynchronous Earth orbit uses advanced technology to provide weather and environmental information to the National Weather Service and many other users. Courtesy NOAA Photo Library

The U.S. Weather Research Program plays a key role in providing the fundamental knowledge and application development that feed this ongoing and vital stream of new meteorological technology (see text box next page). This program has substantial value as an umbrella program through which all federal entities with weather-relevant program objectives contribute resources to a coordinated R&D effort. Increased support for areas in which the U.S. Weather Research Program is ***clearly addressing WIST needs*** is an efficient and effective option for coordinating the federal R&D effort.

A multi-faceted WIST research and development program, coordinated with the U.S. Weather Research Program, is needed to address validated user needs.

However, the limited portfolio of the U.S. Weather Research Program, together with its emphasis on research rather than operational implementation, constrains its capability to serve all the WIST R&D needs of federal agencies. The range of R&D required, and particularly the specificity of applications tailored to the needs of the surface transportation communities, argues for a separate ***WIST Research and Development program***. This program would address issues relevant to weather impacts on surface transportation (all sectors) and to improving the capability to move meteorological and other weather-related information into users' decision processes. A major focus should be near-term and longer-term technology development and transfer, and the related applied research, to address validated WIST user needs.

An important objective for a WIST R&D program would be to exploit relevant scientific and technical capabilities across the country. These capabilities can be tapped through partnerships

U.S. Weather Research Program

The U.S. Weather Research Program is a partnership of federal entities—currently NOAA, the National Aeronautics and Space Administration, the National Science Foundation, and the Navy participate—with the academic and commercial communities. The program's overarching goal is to accelerate improvement in high-impact weather forecasting capability—in particular improvement in forecast timing, location, and specific rainfall amounts associated with hurricane landfall and flood events that significantly affect the lives and properties of U.S. inhabitants (USWRP 2001, p3.).

Portfolio development for the program begins with a ***prospectus development team*** of experts, which identifies research needs and opportunities related to a topic of importance to the program goal. The second step is to develop an ***implementation plan*** for the research identified by this team. Just two of the program's highest priorities, hurricanes at landfall and quantitative precipitation forecasting (QPF), have reached this second stage. Research projects to address the hurricanes at landfall implementation plan are underway, but funding constraints have limited implementation of the QPF research plan.

In August 1998, a new prospectus development team met to "identify and delineate critical issues related to the short-term prediction of weather in urban forecast zones" (Dabberdt et al. 2000). Funding limitations have kept the recommendations of this and other prospectus development teams from moving to the implementation plan stage, after which actual research would be funded. Even within this limited portfolio, the U.S. Weather Research Program is pursuing some of the research required to meet some WIST user needs validated in this study. If the prospectus development team's priorities for research on short-term weather prediction in urban forecast zones could be implemented, the research investment with direct application to WIST needs would be even greater. Close coordination between the U.S. Weather Research Program and other efforts to support WIST-relevant R&D is essential.

However, there are two structural reasons why the U.S. Weather Research Program by itself is insufficient to provide the R&D required by WIST needs. First, its overarching goal constrains it to just a subset of the weather and environmental elements of interest to WIST user communities, particularly in the context of funding limits that prevent it from pursuing fully even its highest priorities. Second, the program is intended to complement, not substitute for, agency-specific implementation programs that move the results of research into operations and services. Many of the technology development requirements listed in Appendix E are thus outside the intended scope of this research program.

with the private sector and mixed public-private service providers, where appropriate, as well as through university-based R&D consistent with the program's portfolio. Finally the two multi-agency programs—a new WIST R&D program and the existing U.S. Weather Research Program—should be fully coordinated to ensure that federal R&D investments are made wisely and productively.

In addition to the U.S. Weather Research Program, R&D programs under a number of federal departments and agencies provide technology for various surface transportation communities. (See Appendix F for a detailed description of these federal R&D activities.)

- The FHWA has major R&D initiatives in Intelligent Transportation Systems, Road Weather Information Systems, and decision support systems that exploit WIST and related information about roadway conditions.
- NOAA's National Ocean Service has programs to improve the observation systems and modeling capability for water levels, currents, and under-keel clearances in the MTS.

Greater coordination of the R&D effort across these and other intramural programs, as discussed in Section 5.2, in conjunction with an interagency WIST R&D program, would leverage the federal investment in improving and expanding WIST.

Partnering between federal agencies and the academic community will continue to play a key role in translating research into practical WIST applications. The Collaborative Science, Technology, and Applied Research Program (CSTAR) was established to provide structure to the variety of collaborative research and education efforts sponsored by the NWS. All CSTAR efforts are meant to enhance scientific interactions leading to a transfer of improved scientific understanding and technological advances into the total forecast system. CSTAR includes the NWS Cooperative Institutes, which are long-term agreements between NOAA and a university to share the costs of an institute focusing on a limited number of agreed-upon research topics. Also within the CSTAR Program is the Cooperative Program for Operational Meteorology, Education, and Training (COMET), administered by the University Corporation for Atmospheric Research. These CSTAR efforts represent important avenues for improving educational opportunities related to transportation weather and WIST applications. In addition, more than a dozen NWS Weather Forecast Offices are located on or near university campuses, including five of the Collaborative Institutes.

The Department of Transportation supports 33 University Transportation Centers, which conduct research or related support for the nation's transportation systems. However, only a few of these centers now focus on weather-related research for surface transportation.

With respect to both general meteorology and transportation systems, these examples show that an academic research and education infrastructure already exists. What is missing is substantial commitment within this infrastructure to surface transportation weather and addressing the needs of WIST users.

Many federal agency laboratories and academic research centers participate in WIST R&D. In some cases, they are partners in a consortium of investigators and researchers, as in the National Consortium on Remote Sensing in Transportation, which is addressing infrastructure; traffic flows; environment; and disaster assessment, safety, and hazards. The consortium includes representatives from the University of New Mexico's Earth Data Analysis Center, the University of Utah's Center for Natural Technological Hazards, George Washington University's Space Policy Institute and Center for Disaster Management, and Oak Ridge National Laboratory's Center for Transportation Analysis. The aim of this consortium is to expand applications of spatial and spectral technologies in transportation. Its strategy is to expedite the development of innovative remote sensing applications through proof-of-concept and demonstration phases, then quickly make the successful applications operational and available to commercial entities, which will become the ongoing suppliers of the information to specialized WIST users. The challenge for this and similar consortia and their associated technology projects is to serve as bridges linking the interests of state, local, and federal entities in mapping and spatial information with the private sector's capabilities to provide the information in relevant formats and interpretations.

Another aspect of applied R&D is the international nature of transportation problems and solutions. Many R&D efforts are in progress in Europe and other areas. These efforts and their results are shared through participation in various national and international meetings and through publication in the scientific and technical literature. However, mechanisms for more sustained interaction and cooperation are possible and worth exploring.

The bottom line is that many avenues for R&D exist. Cooperative planning and participation by all levels of government, the university research community, and the private sector can leverage the investments made in research to obtain the greatest benefit for and from the transportation systems of the future.

Information Technologies

Interest in weather information for surface transportation has its roots in the growth of information technology, as well as in better observation systems and forecasting. The demand by transportation managers for more accurate and timely weather information has been stimulated by innovations in telecommunications, improved computer capabilities at lower prices, and dissemination via the Internet of weather and environmental information packaged in useful formats by commercial providers. These technology applications represent just the leading edge of emerging possibilities. The ultimate goal in incorporating new technologies is to aid transportation system managers and operators, system maintenance personnel, and vehicle/vessel operators involved with any mode of surface transportation in making decisions that enhance the safety and efficiency of their transportation-related activities. This goal requires putting information into the hands of these decision makers when and where they need it, in forms they can understand and use.

> The ultimate goal in incorporating new technologies is to put information into the hands of decision makers when and where they need it, in forms they can understand and use.

Users require weather information tailored to their specific decision or operation. Reliable and timely information about current and future weather conditions can enable people to make better decisions about their activities and contribute to their safety, as well as improving the efficiency and effectiveness of those activities. Adoption of an open systems philosophy, together with the recognition and development of decision support software as a distinct application layer on top of open systems, will facilitate the tailoring of weather information to meet the diverse and specialized needs of different user groups.

The enabling information technologies have supported applications of weather information in decision support systems for winter road maintenance and in travel information systems. Improvements in mesoscale weather prediction models, road condition models, and forecasting systems that incorporate artificial intelligence have facilitated more extensive use of weather information in the surface transportation community.

Although current off-the-shelf technologies do not address the information needs of all surface transportation communities fully, a number of current information technologies and applications already provide substantial benefits. Examples include the Internet, display and visualization technologies, wireless communications, and global positioning satellites. Among the services incorporating these information technologies are pagers, cell phones, NOAA Weather Radio, weather news and information on cable and broadcast television stations, "511" telephone advisory services for road information, the FHWA-funded decision support systems described in Section 1.3.1, and proprietary in-vehicle systems that provide personalized, real-time traffic and road condition reports. The attributes desired in systems using new technologies include capabilities for data aggregation and integration, ease of distribution to consumers and businesses, two-way sharing of data with public and private sector partners, and ease of operation and maintenance of the supporting infrastructure.

Among the emerging information technologies for WIST applications is the use of Dedicated Short Range Communications (DSRC) to provide safety and traffic advisory information directly to the traveler in a private vehicle or other transportation conveyance. On-board displays and audio systems would provide real-time data to the traveler. Prototype systems are being developed and tested in the United States, Canada, and Europe.

The roadway transportation community has expressed support for the opportunities represented by concepts such as integration, interoperability, and intermodalism as ways to foster the development of intelligent transportation systems. The *National Intelligent Transportation Systems Program Plan: A Ten-Year Vision,* builds on past major ITS initiatives such as the national ITS architecture, the Standards Development program, the Metropolitan Model Deployment Initiative, and others. The stakeholders called upon by this ITS program plan to contribute to its realization include the public sector at all governmental levels, the private sector, and the academic research community. The plan describes the impacts of weather on transportation systems and issues in weather information needs for transportation. Among the actions it calls for are creation of a Surface Transportation Weather Applications Research Program and a National Surface Transportation Weather Observing System (ITSA 2002a, pp. 1, 7–11, 44, 52, 55).

There are also significant near-term opportunities to translate technology advances into operations supporting the MTS. Ensuring safe and efficient port operations is vital to maintaining the competitiveness of the U.S. port industry and U.S. exports. One key to reducing risks while increasing efficiency is to invest in the national information infrastructure that supports the maritime movement of goods and people. This infrastructure includes weather predictions and forecast models that use both meteorological and oceanographic data to forecast oceanographic conditions for navigation.

A traffic advisory sign warns users of Interstate 70 in Denver that the highway is closed east of the city due to a winter storm. Copyright AP Wide World Photos.

5.4.4 Next Steps for Strategic Thrust Area 4

Goal for Translating R&D into WIST Applications. Establish a WIST R&D Program. This program should be coordinated with and complement the U.S. Weather Research Program, as well as other R&D programs in transportation weather, including work in progress, planned, or funded by federal entities, state and local public sector entities, universities, or private sector organizations.

Coordinating the federal R&D programs relevant to WIST will provide the nation with a comprehensive, multifaceted R&D effort that addresses information needs of the full range of current and potential WIST users in surface transportation sectors. In conjunction with this coordination, a WIST R&D Program should include mechanisms for transitioning research results and new technology into WIST applications. Special attention should be given to leveraging research that has linkages, synergy, or applications in other high priority programs such as homeland security.

This goal emerged over the course of WIST meetings and symposia, as described in Chapter 2. Potential research topics for a WIST R&D program include the highlights listed in Section 5.4.1. Appendix E provides a more comprehensive list of applied R&D topics with potential for near-term payoffs (indicated by an '**NT**' after the list item).

The following actions are proposed as next steps and enabling mechanisms for Strategic Thrust Area 4. The order of actions is not chronological; they can and should be undertaken in parallel.

Next Step 4A. Users and providers need access to information about the technology developments and research initiatives relevant to their WIST needs.

- This information must be structured and presented in ways that allow users to understand how they can best exploit available and emerging technology and information resources.
- Access to the information can be facilitated through interdepartmental cooperation at the federal level, coupled with strategic partnerships and alliances within and among the weather information provider communities of the public and private sectors.

Next Step 4B. The federal partners in FCMSSR should propose a significant, cohesive research and development program that will provide the basis for improved, integrated weather information, tailored to supporting users' decision processes across all surface transportation sectors and activities.

5.5 Strategic Thrust Area 5: Providing the Fundamental Knowledge to Support Future Technology Development and Application

As noted in Section 1.3.2 and overarching theme 4 (Section 4.9.4), substantial benefits to the nation, in terms of safety, reduced economic losses, and increased productivity, are possible with (1) better spatial and temporal resolution in both forecasts and observations and (2) better forecast accuracy. This improved observational and predictive information must also be available to users within their planning and operational lead times. And the information must be provided through products that users can readily understand and incorporate in their decision processes.

5.5.1 Highlights of Longer-Term Research Topics

From the list in Appendix E of R&D needed to meet WIST user needs, the following bullets highlight gaps in the knowledge base that will require fundamental research to address WIST user needs fully.

- High-resolution detection and prediction of roadway and railway conditions in complex terrains, including interpolation schemes for measurement systems, data fusion techniques, and numerical models
- Advanced decision support systems that incorporate high-resolution, quantitative models for complex factors such as the effects of traffic volume on road conditions, snow depth, snow drift, subsurface moisture near roadways, and effects of chemical–precipitation mixtures on road temperature and condition
- Data fusion and analysis systems for detecting and forecasting low visibility, at high resolution and accuracy, from multiple information sources, including ground and space based sensors and numerical models
- Validated models for the uncertainties, risks, and cost–benefit outcomes involved in incorporating weather and other environmental/geophysical observations and predictions in surface transportation decision processes

Hazardous materials spills on a highway require emergency managers to consider how weather conditions affect plume transport and diffusion. In some cases, such as this accident during heavy fog on a coastal highway, weather can also be a factor in causing the accident. Copyright AP Wide World Photos.

- Determination of the total observational requirements, including those from transportation facilities, to achieve the quality of numerical weather prediction sufficient for all WIST user needs.

With respect to ***meteorological*** R&D, whether for observing systems or modeling, the research focus for WIST is the entire boundary layer of the atmosphere (roughly, up to about 1 km), not just ground-level conditions. In addition, much of the needed R&D will require investigating land-air-water interactions that affect transportation system conditions not represented by traditional meteorological parameters. Table 2-1, which lists the weather and weather-related elements identified during development of the WIST Needs Templates, indicates the range of "weather elements" of interest to WIST users.

As noted in Section 5.4, many of the research topics listed in Appendix E, if promptly addressed, would produce near-term results of operational value, as well as longer-term results from continuing R&D efforts. These requirements are shown with both **Near Term (NT)** and **Far Term (FT)** indicators in Appendix E.

5.5.2 Barriers and Challenges

Prior to this WIST study, there was little definitive information on the spatial and temporal scales required for WIST products to be useful in the decisions and actions of potential users. Nor were there specific thresholds defined for weather and related elements that impact surface transportation. The information gathered during this study and compiled in the WIST Needs templates represents a major advance in defining these thresholds and spatial and temporal scales. However, more work is needed to determine the scales and thresholds of input data and computational parameters necessary to provide information products with the reliability, as well as the spatial and temporal specificity, required by users.

The spatial and temporal resolution of weather information needed for surface transportation applications in general and for decision support systems in particular is typically in the misoscale horizontally (grid spacing of 40 meters to 4 km) and in a very shallow layer vertically (from ground level to about 2 meters above it). To meet operational time lines, updates must be rapid—on a scale of minutes to hours—and coupled with lead times of 48 hours. These spatial and temporal requirements present formidable scientific challenges. Meeting them will require improved understanding in areas such as boundary layer meteorology, misoscale thermodynamics, the effects of small local variations, probability and statistics, high-resolution numerical modeling that includes land-air-water interactions, the verification and quality control of nonstandard data, and the preparation and communication of probabilistic forecasts. Processing data at these finer scales will require expanded computational capabilities.

5.5.3 Next Step for Strategic Thrust Area 5

Goal for Providing the Fundamental Knowledge Base. Identify and support fundamental research representing a longer-term investment in acquiring the knowledge base needed to meet important WIST user needs that cannot be fully satisfied on the basis of current knowledge.

This goal emphasizes the value of including some longer-term research areas, aimed at addressing limitations in the fundamental knowledge needed to meet WIST user needs, in the R&D programs discussed in Section 5.4.3. Often, the research questions that are strong candidates for these longer-term investments are described as "basic research." However, even though the increase in knowledge resulting from such research may not deliver operational results to WIST users in the near term, the topics should be selected and tested for ***strategic***

potential in addressing validated needs. Examples of areas where this type of longer-term investment is warranted are indicated in Appendix E by an '**FT**' indicator after the research item.

> **Next Step 5a.** Include in the coordinated R&D programs for WIST a substantial level of fundamental research with strategic potential for expanding the fundamental knowledge needed to meet WIST users' needs.

> **Next Step 5b.** The federal agency partners in the FCMSSR should present a unified rationale to Congress and the Administration for the strategic potential of the fundamental research topics included in the WIST R&D Program and other coordinated R&D programs, similar to what has been done in the past for the U.S. Global Change Program.

5.6 Strategic Thrust Area 6: Expanding Outreach and Education

5.6.1 Barriers and Challenges in WIST Outreach

There are major cultural differences between the meteorology and transportation disciplines. As noted in Section 4.1.4, potential WIST users vary widely in their knowledge about the availability and sources of weather information. In the course of this study, there was significant variation among the transportation sectors, as well as within each sector, in the range and detail of needs that representative users were able to bring to the effort, particularly in initial meetings. Understanding how weather affects a transportation activity does not automatically give users an understanding of how better weather information can benefit the activity. Users need assistance and training to achieve maximum benefit from applications of weather information.

At the same time, those with training in the meteorological and environmental sciences, as well as expertise in the technologies and techniques of observing and forecasting weather and related phenomena of concern to WIST users, must do better at communicating the significance of their knowledge and technology to the users. A two-pronged approach is essential if "weather professionals" are to provide the information and tools to support surface transportation decision processes. Formal training in the conceptual frameworks, operational environments, and technical systems within which transportation decision makers work should be coupled with direct experience working with these user communities.

To help with educating WIST users, universities can offer surface transportation weather courses in programs for transportation management degrees. Training programs for users and managers of transportation systems that provide emphasis on weather factors and the use of weather information will clearly benefit the transportation industry and its consumers. Just as important are courses in both degree programs and continuing education programs that educate meteorologists and other scientific specialists to understand surface transportation systems and management processes.

As traveler-oriented weather information services evolve, the general public needs to be informed about them. Broad support for WIST initiatives can be fostered by communicating the values of WIST, in improving both transportation safety and economic efficiency, beyond the communities of transportation system managers and operators. Outreach to the public served by these systems can be accomplished through the media and embedded in primary and secondary (K–12) education. Only through a range of educational activities such as these will the full potential of WIST applications be realized.

5.6.2 Next Steps for Strategic Thrust Area 6

Goals for WIST Outreach and Education. (1) Incorporate mechanisms for education of potential WIST users, including interactions between the users and providers of weather information, in WIST service delivery processes. Include current information on WIST applications and the value of WIST in transportation systems operations in the training for surface transportation professionals. (2) Provide and promote educational opportunities for meteorologists and related professionals to learn about surface transportation systems where weather and related environmental information can improve system performance. (3) Include information about WIST applications and ways that the public can access and use WIST in their own transportation activities in "weather education" outreach to the general public and in school weather education programs.

Next Step 6. Conduct a WIST Education Forum on the status of and directions for expanded efforts in, education, training, and outreach for delivery of services and products to meet WIST user needs. There should be broad participation from the provider and user communities, as well as from the FCMSSR partners. Include topics on:

- Mechanisms for education of WIST users
- Opportunities for meteorologists and related professionals to learn about surface transportation systems
- Outreach to the general public through the media and school programs.

5.7 A Vision for Surface Transportation Weather in the Future

> The vision is to be able to move anyone or anything, anywhere, anytime, on time, whatever the weather may be!

Transportation demand is predicted to double in the next 20 years and triple in 50 years. No substantial increase in the nation's transportation infrastructure is planned. Innovative solutions to meet this anticipated growth in demand include new technology and concepts, such as the expansion of information technology, nanotechnology, and technologies that are more energy-efficient and environmentally friendly. Implementing solutions will require a joint effort that includes critical roles for the Congress, state and local government, industry, labor, academia and nongovernmental organizations, all working together to set priorities and solve problems.

This study envisions a national capability to provide timely, accurate, and relevant information on surface transportation weather. This information will be tailored to specific transportation needs, allowing all users to anticipate and exploit the weather, for maintaining the national surface transportation infrastructure efficiently and for moving anyone or anything, anywhere, anytime, on-time, efficiently, safely, and securely.

Technologies for collecting, storing, processing, communicating, and managing information can revolutionize transportation. These technologies generate information on physical parameters at a given time; temporal trends in these parameters; geographic location of transport carriers, goods, and physical conditions of interest; and the overall environmental and situational context of the transportation system. They will be included in all facets of transportation—vehicles, vessels, and infrastructure. Not only will they improve efficiency in the individual transportation sectors; they will improve the efficiency of interfaces between the sectors and the efficiency of the nation's entire intermodal transportation system. The result will be true intermodal service, providing transportation options to maximize safety, convenience, and efficiency for travelers by facilitating seamless transitions in the use of all transportation modes. However, most of these technologies will require a much more advanced and capable weather information support system than is currently planned or funded for the future.

Weather information must be an integral part of transportation systems of the future that can safely and economically move anyone and anything, anywhere, anytime, on time. This vision is compatible with the FHWA strategic goals of improving the infrastructure and operations of the highway system in a manner that promotes productivity, safety, and national security, as well as mobility without jeopardizing the quality of the natural environment. Tailored weather information will facilitate decision processes in a transportation system with far fewer fatalities or injuries per mile traveled.

The WIST user needs identified by this study (see Appendix B and Chapter 4) set the stage for the vast improvements in weather information products and services that will be required for decision support in activities across the spectrum of surface transportation systems. The future WIST infrastructure will evolve from developments that exploit the open Intelligent Transportation System and the national weather information infrastructure. Environmental sensors and networks in parallel with explosive growth in computer and communications capabilities will provide the basis for a high-resolution weather data collection system. The resulting database, coupled with advanced numerical and transportation models and modernized distribution systems, will make real-time, accurate, and timely weather information available for integration with other key information elements useful to every traveler and every transportation system decision maker.

For this advanced WIST infrastructure and array of tailored WIST services and products to become a reality, attention must be given to the overall system architecture. This architecture must comprehend the optimal mix of weather observations with mesoscale and misoscale modeling; the definition, development and testing of tailored products and information; and the infrastructure that supports the entire system. Explicit policy guidance will be needed to resolve public and private sector issues regarding roles and responsibilities in the generation and application of weather information. Planning and implementation should also provide for education, outreach, and advocacy for users and providers of WIST services and products.

The vision of a vastly improved, safe, and efficient transportation system requires WIST users and providers to leverage research plans and funding in a mutually beneficial way. These communities must work together to apply the results of weather research and technology development to the spectrum of decision processes involved in surface transportation activities.

Adopting, advocating, and implementing the thrust area goals and next steps outlined in this report can provide a basis for achieving the vision of moving anyone or anything, anywhere, any time, on time, whatever the weather may be.