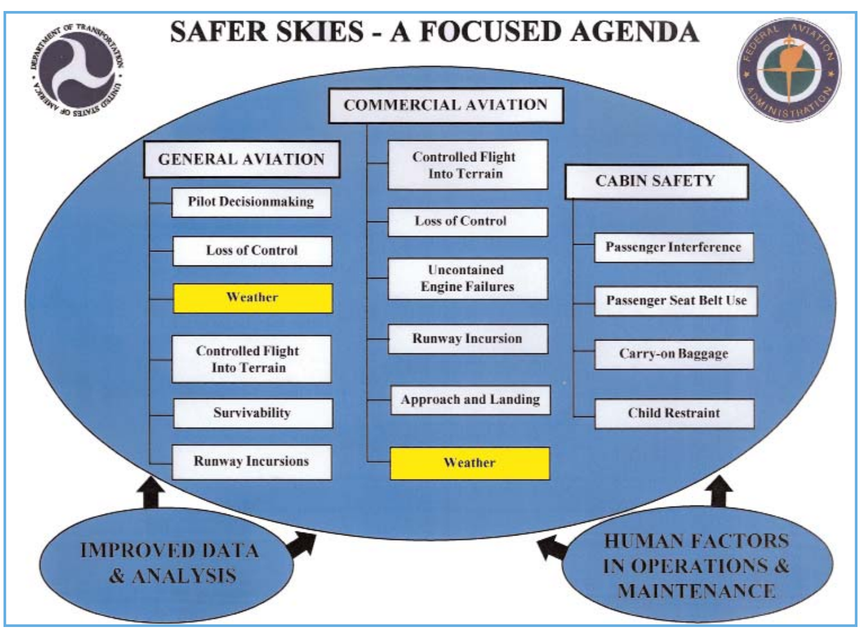
DEPARTMENT OF TRANSPORTATION WEATHER PROGRAMS

The Federal Aviation Administration (FAA) has the responsibility to provide national and international leadership in the optimization of aviation weather systems and services. This leadership is manifested through the management of a safe and efficient National Airspace System (NAS) and the encouragement of consensus and cooperation between government agencies, private weather services, research organizations, and user groups involved in aviation weather. The Federal Highway Administration (FHWA) manages programs that provide federal financial and technical assistance to the states, promotes safe commercial motor vehicle operations, and provides access to and within national forests and parks, native American reservations, and other public lands. Safety, efficiency, and mobility in these programs requires the incorporation and use of timely weather and road condition information. The Federal Railroad Administration promotes and regulates railroad safety. It also sponsors research to enhance railroad safety and efficiency, including support for improved collection, dissemination, and application of weather information to reduce hazards to train operations and to railroad employees. The Federal Transit Administration's mission is to ensure personal mobility and America's economic and community vitality by supporting high quality public transportation through leadership, technical assistance and financial resources.

FEDERAL AVIATION ADMINISTRATION

AVIATION WEATHER MANAGEMENT

The Federal Aviation Administration (FAA) has the leadership role for the national aviation weather program. As the leader, FAA must conduct continual coordination for identifying needs for aviation weather products and services among the Air Traffic Control organization, the aviation industry components and among service providers. The coordination process leads to opportunities to leverage efforts and resources to form partnerships in finding solutions in response to the needs. The National Aviation Weather Program Strategic Plan and the National Aviation Weather Initiatives are two documents that formalize the coordination and partnerships. These documents comprise the first two tiers in a four tier system where funding and development of the solution are the third and fourth tiers, respectively.



The FAA focus for Aviation Weather has been to promote safety first, then improve the National Airspace System (NAS) efficiency to reduce delays and re-routing due to weather. The Administrator has launched The Safer Skies, A Focused Safety Agenda which includes a government/industry Commercial Aviation Safety Team (CAST) and Joint Safety Analysis Teams (JSAT) to evaluate accident investigation reports to analyze the series of events leading to the accidents, and get a sense of what and how decisions were made in the course of the flight. Other teams, Joint Safety Implementation Teams (JSIT), using the findings of the JSAT, develop and recommend intervention actions to eliminate or reduce the causes or improve the actions in the decision making process. Training about the decision making process has been identified by these teams as a major part of the solution.

Aviation weather information, which is complex and highly perishable, is most useful when customers can successfully plan, act, and respond in ways that avoid accidents and delays. FAA will improve the ability of the aviation community to use weather information through a review and upgrade of airmen training and certification programs. FAA will also develop multi-media training tools to support aviation safety and training initiatives. Funding has been requested to further this effort.

Weather has been made a standard consideration in all aspects of the operation and architecture of the NAS. Aviation weather needs from the field, federal agencies, and industry are entered into the FAA Acquisition Management System (AMS) through which all new programs and changes to the NAS are processed, evaluated, validated, engineered to a requirement, and acquired. The new Air Traffic Organization (ATO) Service components have the responsibility to guide all initiatives through the AMS process and organization, including the Integrated Requirements Team, the Integrated Product Team, and the Decision Boards; to assure the development continues to meet the original need; and to guide the activity should the need evolve. Improvements to the AMS process facilitate non-system or non-hardware (e.g., service improvement or rule changes) solutions receiving the same rigorous evaluation and validation.

FAA has established an Aviation Weather Technology Transfer (AWTT) Board which addresses the key issues involved in bringing new capabilities in to the operational system. At key decision points, the board evaluates the maturity of the capability, its integration into the existing system, its supportability in the field, and the training program to prepare the users.

FAA relies on other federal agencies for weather services and support, especially NOAA's National Weather Service (NWS) and its Aviation Weather Center. Requirements validated by FAA for domestic and International Civil Aviation Organization (ICAO) users are coordinated annually and supported through the agencies and contractual arrangements. All agencies' efforts in the area of aviation weather services are coordinated for use by everyone, as appropriate. Aviation weather technology includes the ways in which aviation weather information is gathered, assimilated, analyzed, forecast, disseminated, and displayed. The development of this technology also demands that consideration be given to human factors and the application of decision-making tools. FAA will support the use of technology to improve aviation weather information through integration of federal and non-federal resources. Automation, improved product and graphics generation, and dissemination to the cockpit are being developed as early opportunities to achieve these goals.

AVIATION WEATHER ACQUISITION AND SERVICES

One of the primary functions of the FAA ATO organization is the development and management of requirements for the FAA Capital Investment Plan. Recent projects in the AMS have focused on weather detection and display systems for pilots and air traffic controllers to ensure that aircraft avoid hazardous weather. The following paragraphs describe many of those projects.

The Integrated Terminal Weather System (ITWS) will integrate weather data from sensors in the terminal area to provide and display compatible, consistent, real-time products that require no additional interpretation by controllers or pilots--the primary users. ITWS will use data from automated surface observing systems, Doppler weather radars, and low-level windshear alert systems, together with NWS data and products, to forecast aviation impact parameters, such as convection, visibility, icing, and wind shear, including down bursts.

ITWS has been installed at 10 locations, of which 9 are in service. Installations are planned at 11 additional locations by FY 2009. The current long range program has been limited to 22 ITWSs, which will cover about 30 high-activity airports that are supported by terminal doppler weather radars (Figure 3-DOT-1).

The Corridor Integrated Weather System (CIWS) is a demonstration program which will take some of the

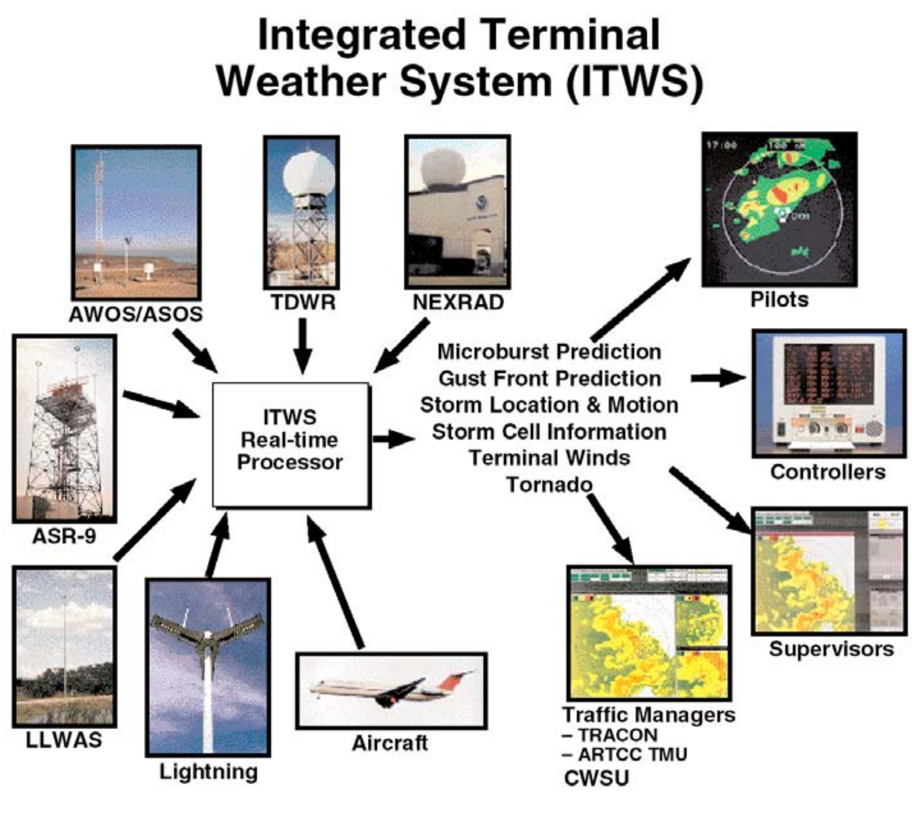


Figure 3-DOT-1. The ITWS integrates data from FAA and NWS sensors and systems to provide a suite of weather informational products.

capabilities of the integration software of the ITWS and expand it to cover larger areas beyond the terminals. 'Corridor' in the name implies the area covered will be an elongated zone which may include a number of terminal areas. The demonstration area extends from Boston southward over New York as far as Washington and westward over Pittsburgh and Cleveland connecting to Chicago. The CIWS is expected to integrate information from the WSR-88D and ASR-9 radars and other observing sensors in the corridor to produce weather information products focused on current conditions affecting enroute traffic in the corridor. It will produce two hour forecasts with trend information and a high-resolution echo tops product. There will be twelve sites, including six in the ARTCCs and one at the Command Center.

The Terminal Doppler Weather Radar (TDWR) program consisted of the development, procurement, and installation of a new terminal weather radar based on Doppler techniques. TDWR units have been located to optimize the detection of microbursts and wind shear at selected airports with high operations and frequent weather impacts.. In addition, TDWR has the capability to identify areas of precipitation and the locations of thunderstorms (Figure 3-DOT-2).

Figure 3-DOT-2. FAA Terminal Doppler Weather Radars provide supplementary wind and precipitation conditions for airport approach and departure.

Microbursts are weather phenomenon that consist of an intense down draft with strong surface wind outflows. They are particularly dangerous to aircraft that are landing or departing. TDWR scanning strategy is optimized for microburst/wind shear detection. The radars are located near the airport operating areas in a way to best scan the runways as well as the approach and departure corridors. The displays are located in the tower cab and Terminal Radar Approach Control (TRACON).

The FAA has 47 TDWR systems. A software upgrade which integrates TDWR and low level wind shear alert system data has been integrated at 9 high traffic/high weather threat airports.

The Low Level Wind Shear Alert System (LLWAS) provides pilots with information on hazardous wind shear events that create unsafe conditions for aircraft landings and departures. A total of 110 airports have LLWAS. The 101 basic systems, LLWAS-2, consists of a wind sensor located at center field and 5 to 32 sensors near the periphery of the airport (Figure 3-DOT-3). A computer processes the sensor information and displays wind shear conditions on a ribbon display to air traffic controllers for relay to pilots. The improvement phase, referred to as LLWAS-Relocation/Sustainment (LLWAS-RS), will include expanding the network of sensors, developing improved algorithms for the expanded network, and installing new information/alert displays. The new information/alert displays will enable controllers to provide pilots with head wind gain or loss estimates for specific runways. These improvements will increase the system's wind shear detection capability and reduce false alarms. Improvements are also expected to reduce maintenance costs. LLWAS–RS deployment was completed this year.

The Weather Systems Processor (WSP) program provides an additional radar channel for processing weather returns and de-alias returns from the other weather channel in the ASR-9. The displays of convective weather, microbursts, and other wind shear events will provide information for controllers and pilots to help aircraft avoid those hazards. A prototype has been demonstrated and limited production has commenced. All 34 units are in place and operating except a few which will complete operational testing by the end of CY 2004. Also, there is one mobile system in operation.

The Terminal Weather Information for Pilots (TWIP) program provides text message descriptions and character graphic depiction of potentially hazardous weather conditions in the terminal area of airports with installed TDWR systems. TWIP provides pilots with information on regions of moderate to heavy precipitation, gust fronts, and microburst conditions. The TWIP capability is incorporated in the TDWR software application. Text messages or character graphic depiction are received in the cockpit through the Aeronautical Radio Incorporated (ARINC) Communication Addressing and Reporting System (ACARS) data link system. A total of 47 TDWR systems are deployed, installed and commissioned. The TWIP capability is operational at most of the TDWR sites. Activation of TWIP at the remaining sites is dependent on availability of National Airspace Data Interchange Network (NADIN) II connectivity and program funding.

The Flight Information System (FIS) Policy was implemented during FY 2001, through Government-Industry Project Performance Agreements (G-IPPAs) with two industry FIS data link service providers (ARNAV Systems, Inc. and Honeywell International, Inc.). Through the government-industry agreements, the FAA provides access to four VHF channels (136.425-136.500) in the aeronautical spectrum while industry provides the ground infrastructure for data link broadcasts of text and graphic FIS products at no cost to the FAA. Under the agreements, a basic set of text products are provided at no cost to the pilot users while industry may charge subscription fees for other value-added text and graphic products.

The FAA FIS data link program will continue development of necessary standards and guidelines supporting inter-operability and operational use. In addition, the need and feasibility for establishing a national capability for collecting and distributing electronic pilot reports (E-PIREPs) from low-altitude general aviation operations is being evaluated. A concept analysis has been initiated to define the need for transition and evolution of FIS data link services supporting the future NAS architecture including Free Flight operations.

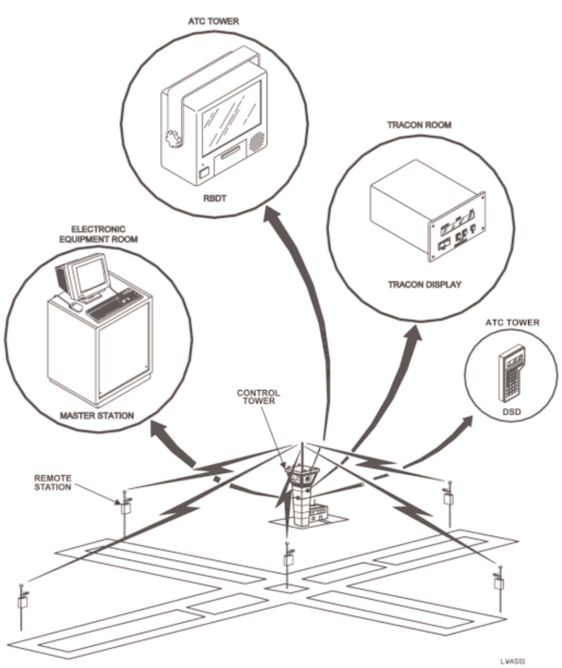


Figure 3-DOT-3. LLWAS equipment on an airfield.

SURFACE WEATHER OBSERVING PROGRAM

Aviation Weather Observations. The FAA has taken responsibility for aviation weather observations at many airports across the country. To provide the appropriate observational service, FAA is using automated systems, human observers, or a mix of the two. It has been necessary to place airports into four categories according to the number of operations per year, any special designation for the airport, and the frequency at which the airport is impacted by weather.

• Level D service is provided by a stand-alone Automated Weather Observing System (AWOS) or an Automated Surface Observing System (ASOS). In the future, Level D service may be available at as many as 400 airports.

• Level C service includes the ASOS/AWOS plus augmentation by tower personnel. Tower personnel will add to the report observations of thunderstorms, tornadoes, hail, tower visibility, volcanic ash, and virga when the tower is in operation. Level C service includes about 250 airports.

• Level B service includes all of the weather parameters in Level C service plus Runway Visual Range (RVR) and the following parameters when observed--freezing drizzle versus freezing rain, ice pellets, snow depth, snow increasing rapidly remarks, thunderstorm/lightning location remarks, and remarks for observed significant weather not at the station. Level B service includes about 57 airports.

• Level A service includes all of the weather parameters in Level B service plus 10-minute averaged RVR for long-line transmission or additional visibility increments of 1/8, 1/16, and 0 miles. Level A service includes about 78 airports.

Automated surface aviation weather observing systems will provide aviation-critical weather data (e.g., wind velocity, temperature, dew point, altimeter setting, cloud height, visibility, and precipitation type, occurrence, and accumulation) through the use of automated sensors. These systems will process data and allow dissemination of output information to a variety of users, including pilots via computer-generated voice.

Automated Weather Observing Systems (AWOS) was deployed at over 200 airports to provide the basic aviation weather observation information directly to pilots approaching the airport. The majority of these systems were installed at various non-towered airports to enhance aviation safety and the efficiency of flight operations by providing real-time weather data at airports that previously did not have local weather reporting capability. These systems are built to the standards of quality necessary to ensure the safety of flight operations and are available off-the-shelf as a commercial product. There remain 198 AWOSs.

Automated Surface Observing Systems (ASOS). In a joint program with NOAA NWS, the FAA has procured, installed, and operates ASOS at the remaining airports where the FAA provides observations and at additional non-towered airports without weather reporting capabilities in accord with the levels of service listed above. Production is complete and the FAA has 569 systems installed and commissioned.

Aviation Weather Sensor Systems (AWSS), a new program, will have capability similar to ASOS. However, the AWSS is a direct acquisition of the FAA--not from the joint ASOS program. Full production is underway with completion expected in CY 2005

The AWOS/ASOS Data Acquisition System (ADAS) functions primarily as a message concentrator and will collect weather messages from AWOS and ASOS equipment located at controlled and non-controlled airports within each ARTCC's area of responsibility. ADAS will distribute minute-by-minute AWOS/ASOS data to the Weather and Radar Processor (WARP) within the air route traffic control center in which it is installed. ADAS will also distribute AWOS data to the NADIN which will in-turn forward the data to the Weather Message Switching Center Replacement (WMSCR) for further distribution. Field implementation of ADAS is complete.

The Automated Lightning Detection and Reporting System (ALDARS) is a system adjunct to the ADAS. ALDARS collects lightning stroke information from the National Lightning Detection Network (NLDN) and disseminates this data to AWOS/ASOS for the reporting of thunderstorms in METAR or SPECI observations, when appropriate. The use of ALDARS eliminates the need for manual reporting of thunderstorms and increases the number of airports where thunderstorms will be reported. ALDARS is completely operational.

Stand Alone Weather Sensors (SAWS) are back-up systems for some AWOS/ASOS sensors at locations where no other back-up capability is available. SAWS have been demonstrated and full delivery is nearly completed. The full deployment will comprise up to 307 units.

ASOS Controller Equipment- Information Display System (ACE-IDS) is an electronic cabinet of displays available to the controller at his work station. It provides graphics of information which comes from many sources that originate at many nodes of an LAN which includes, but is not limited to, weather related parameters, observations, and other automated weather products. This system is designed specifically to support operations in high-volume, high-tempo Terminal Radar Approach Control (TRACON) facilities. They are installed at the following TRACONs: Atlanta, Boston, Dallas-Fort Worth, Honolulu, Northern California (San Francisco), Oklahoma City, Potomac (Wash. D.C.), Saint Louis, and Seattle (Figure 3-DOT-4).

AWOS for Non-Federal Applications. Under the Airport Improvement Program (AIP), state and other local jurisdictions may justify to the FAA their need to enhance their airport facilities. Upon approval, these improvements may be partially funded

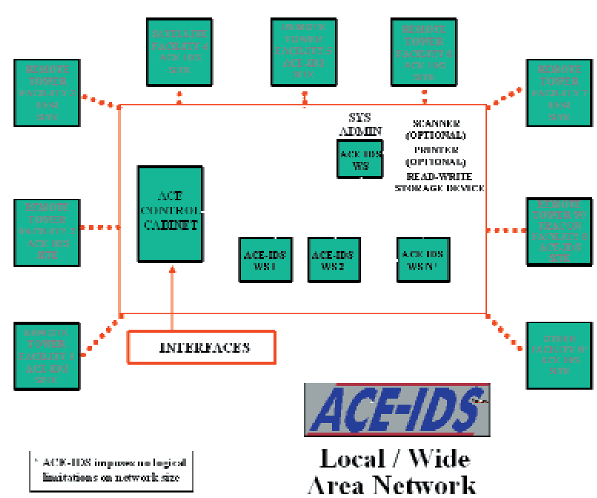


Figure 3-DOT-4. ASOS Controller Equipment- Information Display System (ACE-IDS)

by the FAA using resources from the Airway Trust Fund. The local airport authority becomes responsible for the remainder of the funding necessary to complete the procurement, as well as the funding for the regular maintenance. The addition of an AWOS is one of the improvements that qualify for AIP funding assistance. Systems that qualify must meet certain standards which are defined in an FAA Advisory Circular on Non-Federal Automated Weather Observing Systems.

There are more than 275 non-Federal AWOS locations. Some of these are capable of reporting through a geostationary communications satellite; many more will acquire that capability during CY 2004. These observations will be entered into the national network for use in support of the NAS and the national weather network.

The New Generation Runway Visual Range (NRVR) program provides for a new generation RVR sub-element of the NAS. The NRVR provides runway visual range information to controllers and users in support of precision landing and take-off operations. The NRVR incorporates state-of-the-art sensor technology and embedded remote maintenance monitoring. The FAA plans to procure and install these NRVR systems at all new qualifying locations. FAA plans also call for the replacement of many existing RVRs in the NAS inventory.

The NRVR provides for near real-time measurement of visibility conditions along a runway (up to three points along the runway can be measured-- touchdown, midpoint, and roll-out) and reports these visibility conditions to air traffic controllers and other users. The system automatically collects and formats data from three sensors: a visibility sensor--forward scatter meters will replace the transmissometers currently in use; a runway light intensity monitor for both runway edges and center-line lights; and an ambient light sensor which controls computer calculations using a day or night algorithm. The data processing unit calculates runway visibility products and distributes the products to controllers and other users.

NRVR visibility sensors will be deployed at 308 airports. Delivery of the NRVR sensors began in November 1998. To date, 208 units have been delivered and 172 have been commissioned. At the current levels of annual funding, the program will have completed the deployment by the end of CY 2009.

The FAA is procuring the Operational and Supportability Implementation System (OASIS) to improve weather products, flight information, aeronautical data collection, analysis, and timeliness of dissemination, thereby enhancing the safety and efficiency of the NAS. OASIS will replace the Model-1 Full Capacity Flight Service Automation System, which includes the Aviation Weather Processor. OASIS will also integrate the Interim Graphic Weather Display System functions and include several automated flight service data handling capabilities. This configuration will be an initial deployment capability. Operational testing began in 1999; 16 systems have been deployed from the original plan of 61. Future enhancements leading to the full capability deployment will include: interactive alphanumeric and graphic weather briefings; direct user access terminal (DUAT) service functionality; automated special use airspace; and training support. OASIS will support flight planning, weather briefings, NOTAM service, search and rescue, and pilot access terminal services. (Some fielding delays are expected pending the outcome of an A-76 study currently underway.)

The Next Generation Weather Radar (NEXRAD), known operationally as the Weather Surveillance Radar-1988 Doppler (WSR-88D), is a multi-agency program that defined, developed, and implemented the new weather radar. Field implementation began in 1990 and was completed in 1996. There are a total of 161 WSR-88D systems deployed. The FAA sponsored 12 systems in Alaska, Hawaii, and the Caribbean. DOC and DOD WSR–88Ds provide coverage over the continental United States.

The FAA emphasized the development of WSR-88D algorithms that take advantage of the improved detection of precipitation, wind velocity, and hazardous storms. The FAA also stressed that these algorithms provide new or improved aviation-oriented products. These improvements in detection of hazardous weather will reduce flight delays and improve flight planning services through aviation weather products related to wind, wind shear, thunderstorm detection, storm movement prediction, precipitation, hail, frontal activity, and mesocyclones and tornadoes. WSR-88D data provided to ATC through the WARP will increase aviation safety and fuel efficiency.

In addition, the three funding agencies support the field sites through the WSR-88D Radar Operations Center (ROC) at Norman, Oklahoma. The ROC provides software maintenance, operational troubleshooting, configuration control, and training. Planned product improvements include a shift to an open architecture, new antenna design, dual polarization, and the development of more algorithms associated with specific weather events, such as hurricanes.

The Air Route Surveillance Radar (ARSR-4) provides the ARTCCs with accurate multiple weather levels out to 200 nautical miles. The ARSR-4 is the first enroute radar with the ability to accurately report targets in weather. The ARSR-4 can provide weather information to supplement other sources. The ARSR-4 is a joint FAA/USAF funded project. Forty joint radar sites were installed during the 1992-1995 period.

The Weather and Radar Processor (WARP), has replaced the Meteorologists Weather Processor to provide aviation weather information to the Center Weather Service Units. WARP automatically creates unique, regional, WSR-88D-based, mosaic products, and sends these products, along with other time-critical weather information, to controllers through the Display System Replacement and to pilots via the FIS. WARP greatly enhances the dissemination of aviation weather information throughout the NAS. WARP underwent operational testing and evaluation in early FY 2003 and is operationally fielded at the 21 ARTCCs and the command center. Others systems used for enhancements, testing, and software support bring the total to 25 systems.

The Direct User Access Terminal (DUAT) system has been operational since February 1990. Through DUAT, pilots are able to access weather and NOTAMs and also file their IFR and/or VFR flight plans from their home or office personal computer. This system will eventually be absorbed into OASIS.

AVIATION WEATHER COMMUNICATIONS

It should be noted that FAA communications systems are multi-purpose. Weather data, products, and information constitute a large percentage of the traffic, as do NOTAMS, flight plans, and other aeronautical data.

The National Airspace Data Interchange Network (NADIN II) packet-switched network was implemented to serve as the primary inter-facility data communications resource for a large community of NAS computer subsystems. The network design incorporates packet-switching technology into a highly connected backbone network which provides extremely high data flow capacity and efficiency to the network users. NADIN II consists of operational switching nodes at two network control centers (and nodes) at the National Aviation Weather Processing Facilities at Salt Lake City, Utah, and Atlanta, Georgia. It will interface directly to Weather Message Switching Center Replacement (WMSCR), WARP, ADAS, TMS, and the Consolidated NOTAM System. NADIN II also may be used as the intra-facility communications system between these (collocated) users during transition to end state.

The Weather Message Switching Center Replacement (WMSCR) replaced the Weather Message Switching Center (WMSC) located at FAA's National Communications Center (NATCOM), Kansas City, Missouri, with state-of-the-art technology. WMSCR performs all current alphanumeric weather data handling functions of the WMSC and the storage and distribution of NOTAMs. WMSCR will rely on NADIN for a majority of its communications support. The system will accommodate graphic data and function as the primary FAA gateway to the NWS' National Centers for Environmental Prediction (NCEP)--the principal source of NWS products for the NAS.

To provide for geographic redundancy, the system has nodes in the NADIN buildings in Atlanta, Georgia, and Salt Lake City, Utah. Each node supports approximately one-half of the United States and will continuously exchange information with the other to ensure that both nodes have identical national databases. In the event of a nodal failure, the surviving node will assume responsibility for dissemination to the entire network.

Currently, specifications for an upgrade or replacement for the WMSCR are being formulated. The needs, when developed, will be entered into the AMS process for validation and acceptance into the NAS architecture.

The Flight Information Service (FIS) is a new communication system to provide weather information to pilots in the cockpit. FIS is a partnership program among the government and private industry with the government providing the base information and the bandwidth while the private companies provide the broadcast and value-added products. New products are screened for technical suitability and value to the pilots. Two companies have demonstrated preliminary products and capability.

The Worldwide Aeronautical Forecast System (WAFS) is a three geosynchronous satellite-based system for collecting and disseminating aviation weather information and products to/from domestic or international aviation offices as well as in-flight aircraft. The information and products are prepared at designated offices in Washington, District of Columbia, and Bracknell, United Kingdom. The United States portion of WAFS is a joint project of the FAA and NWS to meet requirements of the ICAO member states. FAA funds the satellite communications link and the NWS provides the information/product stream.

Two of the three satellites are funded by the United States. The first is located over the western Atlantic with a footprint covering western Africa and Europe, the Atlantic Ocean, South America, and North America (except for the West Coast and Alaska). The second United States-funded satellite is positioned over the Pacific and covers the United States West Coast and Alaska, the Pacific Ocean, and the Pacific rim of Asia. The third satellite, operated by the United Kingdom, is stationed over the western Indian Ocean and covers the remaining areas of Europe, Asia, and Africa. The data available via WAFS include flight winds, observations, forecasts, SIGMETs, AIRMETs, and hazards to aviation including volcanic ash clouds.

AVIATION WEATHER RESEARCH PROGRAM

Working closely with the Integrated Product Team for Weather/Flight Services Systems, ATO sponsors research

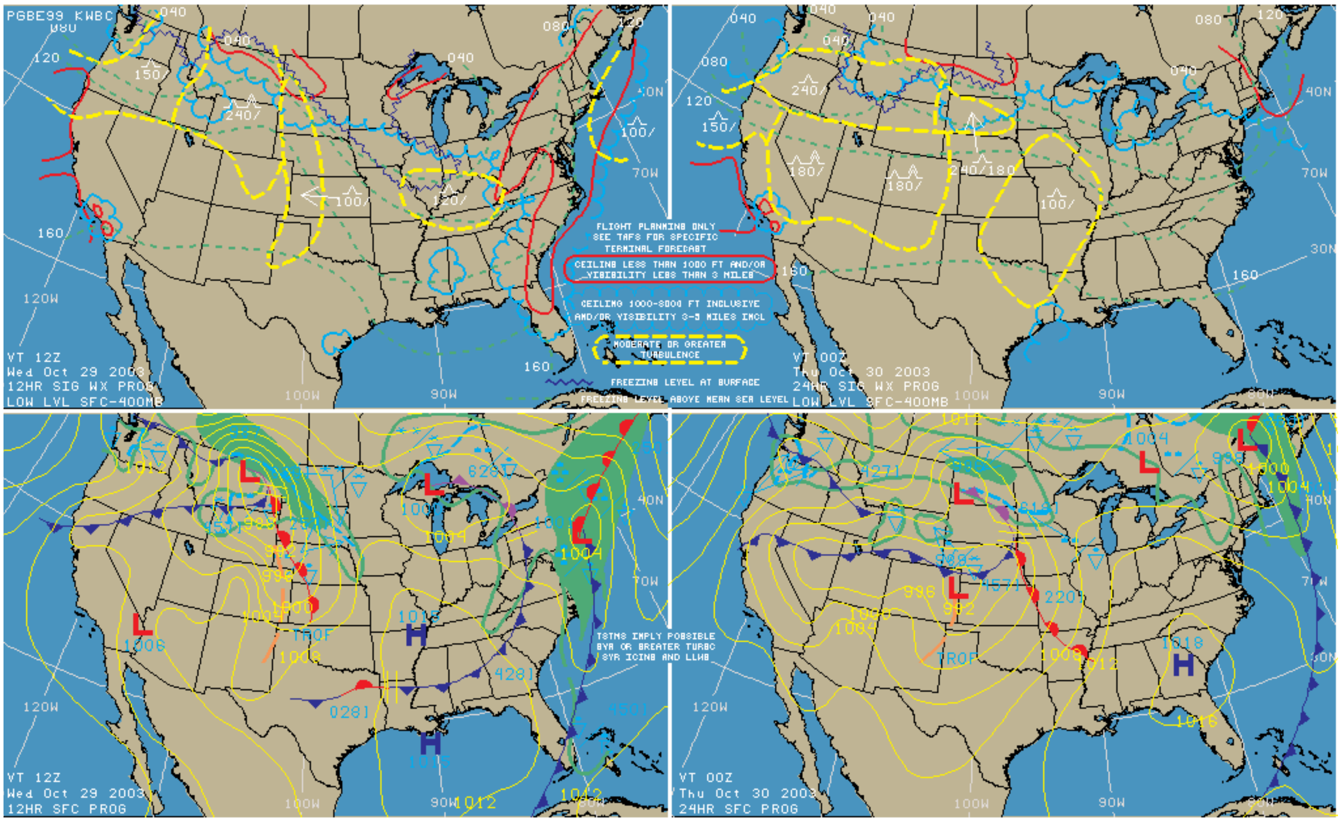


Figure 3-DOT-5. 4-panel Low Level Significant Weather graphics are produced by the Aviation Weather Center and accessible to pilots from their web site. (Source: AWC web site)

on specific aviation weather phenomena which are hazardous and/or limiting to aircraft operations. This research is performed through collaborative efforts with the National Science Foundation (NSF), NOAA, NASA, and the Massachusetts Institute of Technology's Lincoln Laboratory. A primary concern is the effective management of limited research, engineering, and development resources and their direct application to known deficiencies and technical enhancements.

Improved Aircraft Icing Forecasts. The purpose of this initiative is to establish a comprehensive multi-year research and development effort to improve aircraft icing forecasts as described in the FAA Aircraft Icing Plan. The objectives of this plan are to develop: (1) an icing severity index, (2) icing guidance models, and (3) a better comprehension of synoptic and mesoscale conditions leading to in-flight icing. The result of this effort will be an improved icing forecasting capability that provides pilots with more timely and accurate forecasts of actual and expected icing areas by location, altitude, duration, and potential severity.

Convective Weather Forecasting. The purpose of this research effort is to establish more comprehensive knowledge of the conditions that trigger convection and thunderstorms and, in general, the dynamics of a thunderstorm's life cycle. The program will lead to enhanced capability to predict growth, areal extent, movement, and type of precipitation from thunderstorms. Gaining this forecast capability will allow better use of the airspace and help aircraft avoid areas with hazardous convective conditions (Figure 3-DOT-5).

Model Development and Enhancement. This research is aimed at developing or improving models to better characterize the state of the atmosphere and stratosphere in general, with specific emphasis on the flight operation environment specifically, with the aim to provide superior aviation weather products to end users.

Aviation Forecast and Quality Assurance. The Product Development Team (PDT) for the Aviation Gridded Forecast System is working on the development of products for dissemination on the Aviation Digital Data System. New algorithms will be developed to present hazardous conditions in the flight operations environment. They will develop a process for automated production of the SIGMETs. There will be capability to assure quality and a real-time verification process.

Weather Support to Deicing Decision Making (WSDDM). This system develops products that provide forecasts on the intensity of snow and freezing rain, and how or when these phenomena will change in the short term. This information is needed by airport management to determine when an aircraft will require deicing before take-off. The water content of snow is believed to be an important factor. The output product is designed for non-meteorological aviation users and has been demonstrated at three different airports. Development work has been completed and FAA has made this system available to airport authorities who wish to use it as a decision aid.

Ceiling and Visibility. A development and demonstration is underway in the San Francisco Bay area. The project will have unique sensors and the data will be used in new algorithms to develop improved forecasts. The project will continue over a number years as the progress is evaluated. This project is a joint effort with other federal agencies and some of the effort is performed by academic researchers.

Turbulence. In addition to the work being performed by the JSAT under the Safer Skies Program, a PDT has a seven year plan to evaluate wind shear and turbulence around and on the approaches to Juneau, Alaska. Also, they are working with certain airlines to install instruments on aircraft with the capability to measure turbulence as sensed on the aircraft and report this information automatically. The data will be used to verify forecasts and to develop a standard index to report and warn for turbulence.

NEXRAD Enhancements. Work is continuing to develop improvements to the existing products and to develop new graphic products. Hardware and software pre-planned product improvements are are being pursued. This is a joint effort among DOT, DOD, and DOC.

Space Weather. Space Weather is of concern to the FAA in several areas of operations and regulations. Ionospheric scintillation creates certain errors in the Global Positioning System that affects navigation, especially for instrument approaches to airports. In programs for Wide Area and Local Area Augmentation Systems (WAAS and LAAS) corrections for these effects are being developed. This will be a very important advance to promote the Free Flight management of the National Airspace System. In addition, the effects on the ionosphere have grave impacts on the use of high frequency communications which are essential in air traffic control of flights across the oceans and over the poles of the Earth.

FAA is embarking in research at the Civil Aeromedical Institute in Oklahoma City, OK, on the radiation effects on fetuses of newly pregnant women when flying at high altitudes and at high latitudes where exposure is increased. The exposure of flight crews to this hazard will be measured to determine if repeated flights in this regime may accumulate deleterious results.

FAA planners for commercial space operations are working on the weather requirements to set criteria for space launch activities. The commercial launch sites in California, Florida and Virginia are co-located with government sites where the weather support is available. However, at the new commercial space launch site in Kodiak, Alaska new criteria must be developed and established for standard procedures.

FEDERAL PROGRAMS IN SUPPORT OF ROAD WEATHER

The Road Weather Management Program. The Federal Highway Administration (FHWA) coordinates a number of activities aimed at improving safety, mobility, productivity, environmental quality and national security on the nation's highways during weather threats. These activities include identification of weather impacts on the roadway environment, traffic flow and operational decisions to build the case for road weather management programs. It also includes research to advance the state of the art concerning road weather management tools, as well as documentation and promotion of the best practices. The FHWA acts through federal aid and national coordination since it does not operate the highway system or environmental observing systems that serve state and local highway operators, private road users, and the traveling public. FHWA activities are conducted as partnerships with other public agencies, private sector vendors, and universities.

Weather cuts across many FHWA and related surface transportation modal activities. Coordination is centered in the Road Weather Management Program within the FHWA's Office of Transportation Operations. Road weather management activities are closely associated with the Intelligent Transportation System (ITS) Program as the framework for advanced road weather information and decision support. Road weather management activities are dependent on, but distinct from, general meteorological activities in two respects. In terms of the geophysical focus, weather must be related to what happens near, on, and under roads as it affects pavements, structures, vehicles, traffic flow and ITS components. In terms of operations, the focus is on the decisions that use road weather information as one of many resources. This has led to a decision-centered approach for defining the program, with road weather information on one side and effective strategies to deal with adverse weather on the other. Program activities are then organized primarily by the ITS subsystems and operational decisions: maintenance management, traffic management and traveler information, and to a lesser extent, emergency management. However, a common information infrastructure, or "infostructure", within ITS includes road weather observations. Environmental observing systems are emerging as contributors to the national weather information system that underlies all general weather products. The FHWA expects that as road weather products advance, there will be a need for greater integration of observation, prediction and science in the total land/air/sea/space environment.

FHWA road weather management activities extend back to the 1970s, but the current coordinating program began in 1997. Over the entire period, the FHWA has achieved practical successes, as well as an expanded vision for the road weather management agenda. There is no question that among modes, surface transportation has the most lives, time, and commercial value at risk due to weather threats. The challenge has been to identify distinct and useful roles with respect to weather within FHWA jurisdiction. The Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003 (SAFETEA) obligates funds through FY 2009, to improve the performance and durability of our nation's roads and improve highway operations. This will enable a more vigorous attack on the many issues associated with Road Weather Management Program activities, which are described in the following sections.

The Strategic Highway Research Program. The United States Congress established the Strategic Highway Research Program (SHRP) under the 1987 Surface Transportation Act. This Act obligated $150 million over five years to improve the performance and durability of our nation's roads. The SHRP program examined a number of different subject areas, but the one most closely related to road weather management was winter maintenance within the highway operations subject area. The research program was active until 1993, producing specifications, testing methods, equipment, and advanced technologies. Following the success of the five-year effort, the FHWA coordinated a national program to work with state and local highway agencies to implement and evaluate the products. This phase, entitled SHRP Implementation, was funded through the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). This Act obligated $108 million over six years, and was administered jointly by the FHWA, the American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board (TRB).

The SHRP developed products encompassed various technology areas. Reports on Anti-icing and Road Weather Information Systems (RWIS), published by 1993, were instrumental in raising awareness of the state of the art among highway operating agencies. Anti-icing techniques, requiring chemical application to pavements before snow fall and ice formation, have had a vital synergy with predictive road weather information, and have in turn led to demand for improved observation and prediction through RWIS.

The SHRP Implementation web site (www4.trb.org/trb/dive.nsf/web/shrp_implementation) contains information on the SHRP Lead States Program, SHRP products under evaluation and implementation, and SHRP in general. An important adjunct to the SHRP anti-icing studies was a follow-up field evaluation of techniques, conducted under the FHWA Test and Evaluation Program. Results appeared in 1998 as Project No. 28: Anti-Icing Technology.

After two and a half years of study and outreach, the TRB Committee for a Future Strategic Highway Research Program (F-SHRP) published "Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life." Based upon the strategic direction in this report, the AASHTO Board of Directors passed a resolution in December 2001, supporting F-SHRP and authorizing an NCHRP project to develop detailed research plans. FHWA matched the NCHRP funds and work began on the planning phase of F-SHRP in January 2002. In September 2003, TRB released the report entitled, "Providing a Highway System with Reliable Travel Times," that outlines the Reliability Research Program to address the root causes of unreliable travel times. These causes include adverse weather, traffic incidents, work zones, and special events. By concentrating research resources over the six-year life span of F-SHRP significant gains can be made in effectively dealing with these causes of unreliable travel times. Implementation of the F-SHRP plan is dependent upon its level of support within SAFETEA.

The Intelligent Transportation Systems (ITS) Program. The synergy of road treatment strategies and RWIS development continues in the FHWA Road Weather Management Program and is strongly allied with the ITS Program. The ISTEA of 1991 established the ITS Program, including its research program that funds most of the FHWA Road Weather Management Program activities. The ITS Program in the United States is overseen by the ITS Joint Program Office (ITS-JPO), which is a cross-modal program hosted in the FHWA.

While ITS initially focused on automated highways and metropolitan areas, a rural focus was initiated in 1996. The rural ITS Program identified maintenance and weather as additional ITS focus areas, and recognized the need for total integration of the maintenance, traffic, and emergency management functions across wide areas and between states. Maintenance management continued the SHRP heritage as the main focus of road weather concerns when the Road Weather Management Program was formed, initially as the FHWA's "Weather Team", in 1997. However, the long-term agenda continues to integrate road weather across management functions, across modes, and for traveler information. The research activities below are within this overall weather-across-ITS strategy. Intelligent Transportation Systems are also the logical informational interfaces with the national weather information system.

The ITS-JPO has also begun the Vehicle Infrastructure Integration (VII) initiative to explore the potential of cooperative vehicle highway systems to provide real-time information, and support advanced safety applications. VII could be a significant enabler of weather-related applications, such as vehicle-based sensors that gather environmental data system-wide. This resulting communications network would allow weather, traffic and other information to be transmitted to transportation operators providing a real time view of the conditions on every major road within the transportation network. Such concepts will be explored as the initiative matures.

National ITS Architecture and ITS Standards. Intelligent Transportation Systems use open system principles: a uniformly defined modular structure of information processes with known protocols for exchanging information between modules. The information may be free or provided for a price, but all ITS applications should be able to get the information needed to support transportation management decisions.

The National ITS Architecture is the modular structure and was one of the earliest tasks of the ITS program. Several equipment interfaces are standardized under the category of National Transportation Communications for ITS Protocol (NTCIP) standards, and there are associated data object and message set standards. The ITS program is promoting use of the National ITS Architecture and its communication standards as requirements for federal aid to ITS deployments by highway operating agencies.

Road weather information was not an original focus of the National ITS Architecture, and was defined as flowing from external sources with their own architecture and standards. As road weather gains significance in the ITS, and as the interfaces between road weather and atmospheric weather need to be coordinated, the National ITS Architecture is being adapted. Version 2 of the Environmental Sensor Station (ESS) standard will soon be approved. This NTCIP standard specifies data objects and formats between ESS in the field and central processors for the data (e.g., RWIS and traffic management systems). The ESS standard will be effective in the integration of different vendors' systems, and create a uniform format for ingest of road weather data into general environmental observing systems. Another standard that is being considered, but is not yet developed, is the Weather Report Message Set for ESS. If deemed necessary, this standard will define message sets for exchange of environmental data between management centers.

Following the rural ITS program definition of weather and maintenance as ITS application areas, the National ITS Architecture has developed the Maintenance and Construction Operations (MCO) user service. User services are the application-oriented requirements clusters for the architecture. Detailing of the architecture with respect to road weather and its maintenance applications, through the MCO user service requirements, was completed in 2002. Among the changes is definition of a Road Weather Information Service terminator in addition to the existing Weather Service terminator. Together, these represent the division of responsibility for road weather information, provided largely by private vendors and based on ESS observations, and weather generally. The interfaces between the two types of services is then defined as being outside of the ITS. However, the FHWA maintains an interest in specific improvement in environmental information that will enhance road weather prediction, such as higher resolution numerical modeling and better characterization of precipitation at the road surface. The interface from the ESS, which is within the ITS, to both the road weather and general weather services, is also of interest to FHWA.

It is hoped that further detailing of weather applications in traffic and emergency management will lead to further architecture developments in the years ahead. As the interface between the ITS and the evolving national weather information system becomes closer, the National ITS Architecture and standards will provide a technical basis for integration and promotion of open system principles. Version 5.0 of the National ITS Architecture can be found at http://itsarch.iteris.com/itsarch/. Modifications made to the National ITS Architecture for Version 5.0 include a new Security Monitoring subsystem, support for 511 traveler information systems, and updated mappings to the ITS standards activities such as efforts in 5.9 GHz dedicated short-range communications that will be vital to VII activities.

Environmental Observing Systems. Surveillance is fundamental to the ITS. The state of roadways and traffic is basic to almost all ITS applications. The capabilities to observe traffic, road infrastructure, and the roadway environment are becoming a necessary part of roadway facilities themselves. The information-generating part of road infrastructure on the National Highway System is dubbed the "infostructure". In 2003, the Road Weather Management Program defined the fundamental data needs of the Weather Response component of the "infostructure" to estimate an aggregate cost for deployment of ESS in 61 metropolitan areas across the nation.

Road weather sensing, through the ESS, will be a part of the "infostructure". However, there are many aspects to environmental observation, and some substitutability between methods of observation. The authorizing legislation is focused on metropolitan ITS. Clearly, the need for ESS observations extends further. ESS can be a vital part of homeland security, as well as more prosaic hazardous material (HAZMAT) spill and environmental management. Many types of fixed, mobile, and remote platforms can observe relevant environmental conditions (i.e., atmospheric, pavement, subsurface, and water level conditions). But all observations ultimately support predictive information for decision support applications. In the case of pavement temperature, the critical predictor for anti-icing strategies, heat balance models relying on high-resolution numerical modeling of insolation and radiation can substitute for ESS observations. However, the use of ESS for localized hazard warning versus general area prediction, and the value of reinitializing heat balance models by ESS data require some level of deployment. Over 2,000 ESS's are owned by state transportation agencies in the United States as shown in Figure 3-DOT-6. More than 1,400 of these ESS's are field components of Road Weather Information Systems.

Remote ESS are generally fixed, with in situ sensors for the usual atmospheric weather variables as well as pavement and subsurface temperature probes, and pavement chemical concentration or pavement freezing point. In some cases, and potentially over all road mileage, mobile environmental sensors are deployed to observe weather and pavement conditions from vehicles. An important application of the mobile, and potentially remote, sensing is thermal mapping of road segments. This technique provides snapshots of complete pavement temperature profiles and is used both to select fixed ESS sites and to spatially predict temperatures based on time series predictors at the fixed stations. There are future possibilities for remote sensing of "skin temperature" on roads and adjacent surfaces, by Unmanned Aerial Vehicles (UAVs) and satellites (especially the next generation polar orbiters). This could make a limited deployment of fixed sensors more effective and improve the initialization of heat balance models.

At present, ESS data across the United States are neither integrated nor open. The data are not centrally collected, in standard format, available to all users, nor uniformly used. However, regional and national efforts are paving the way for both openness and integration. Mesoscale environmental monitoring networks (or mesonets) within states and across states, usually under university auspices, are integrating the data across many observing systems. The data are used in some cases to validate weather forecasts and analyses, and in the rare case, for ingest into numerical weather prediction models. The new FHWA initiative, *Clarus*, aims to reduce the impact of adverse weather for all road and transit users and operators by designing and demonstrating an integrated road weather observational network, and establishing a partnership to facilitate deployment of a nationwide surface transportation weather observing system. The long term vision of

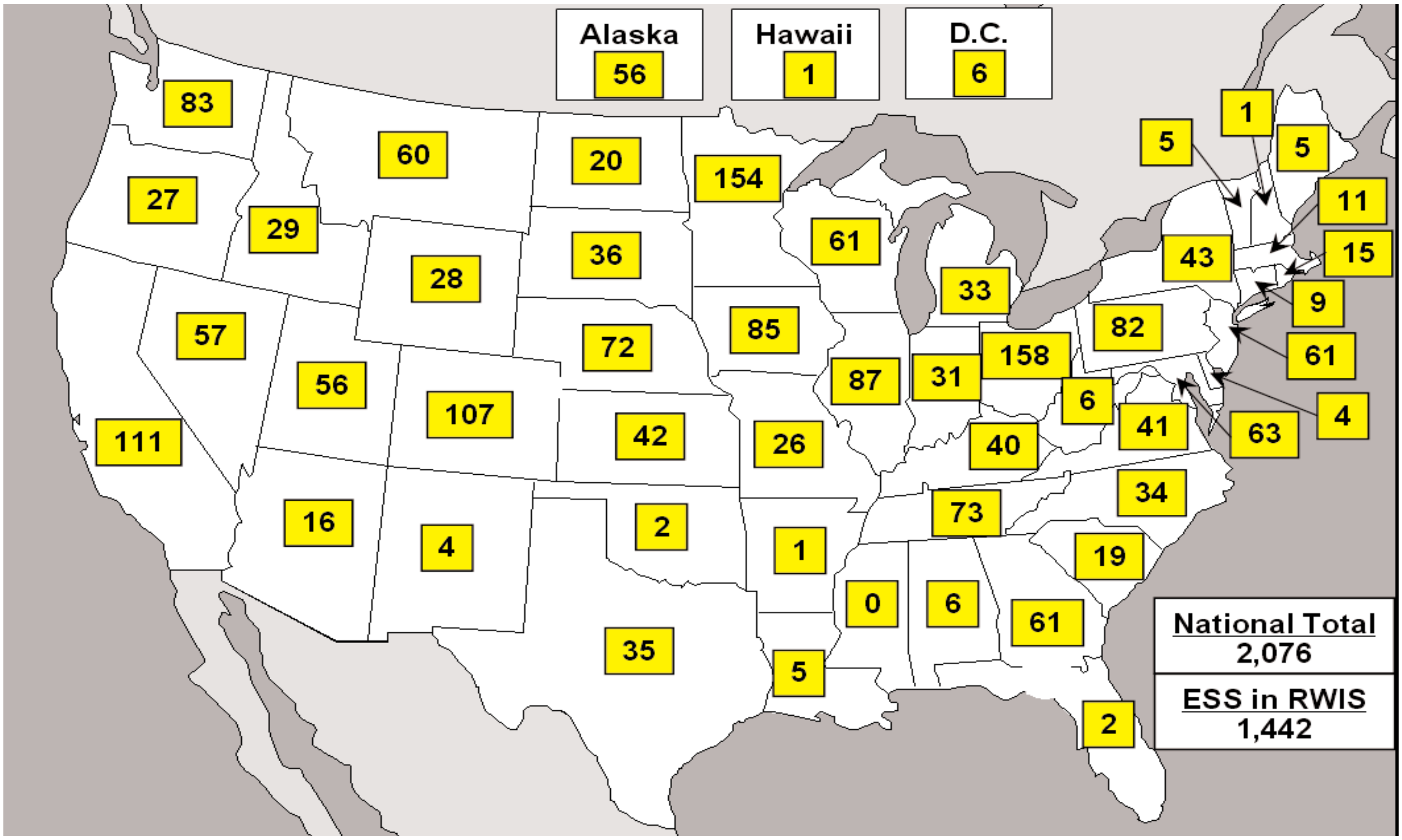


Figure 3-DOT-6. Census of deployed Environment Sensor Station (ESS) units. An ESS is a site measuring atmospheric, pavement and/or water level conditions. Many state transportation agencies deploy ESS as field components of Road Weather Information Systems (RWIS). As shown on the map, there are over 2,000 ESS owned by state transportation agencies. Most of these stations (i.e., 1,442) are part of RWIS and used to support road maintenance activities. The other environmental sensor stations are deployed for various applications including flood monitoring and aviation.

Clarus is that all data from State DOT ESS will be routinely collected, quality-controlled, and translated into an open standard format. Quality assurance algorithms and direct feedback to state points of contact will improve agency support of the ESS system. Access to robust and calibrated data will be provided through an open Internet data portal.

In order to address all these observing issues, the FHWA is participating in multiple OFCM bodies, including the new WIST Working Group, as well as the Committee on Integrated Observing Systems (CIOS). FHWA is also participating in NOAA efforts to explore the modernization of the cooperative observer network.

The focus of the FHWA remains on the application of ESS observations to road weather management decision-making. From 2001 to 2003, the FHWA sponsored five research projects, under the Cooperative Program for Meteorological Education and Training (COMET) (www.comet.ucar.edu), which became the first to add state DOTs to the traditional partnerships of NWS forecast offices and universities. The COMET projects in Iowa, Nevada, New York, Pennsylvania, and Utah fostered sharing of environmental data and facilitated advanced meteorological modeling to enhance road weather forecasts. Ultimately, these efforts will contribute to the development of decision support tools for winter maintenance managers, traffic managers, and the traveling public. Lessons learned from these projects can help all state DOTs better manage RWIS networks and achieve maximum utility from RWIS data.

In order to enhance observation capabilities and define requirements for road weather observing systems, the Road Weather Management Program is working with transportation and weather partners to develop siting guidelines for ESS in the roadway environment. The ESS Siting Guidelines project will produce consistent guidance for state and local agency personnel responsible for procuring, siting, operating, and maintaining ESS along the nation's roads.

Decision Support. Under previous efforts within the program, road weather users identified information requirements as the trinity of "relevance, accuracy and timeliness". Those criteria were selected primarily in reaction to synoptic scale forecasts that were: (1) not relevant to climatically localized road hazards; (2) not accurate at such points or at the long time horizons predicted for; and (3) not delivered more than the twice daily nor at frequent prediction times in between. Improvements in that situation, including National Centers for Environmental Prediction (NCEP) models at mesoscale resolution updated as frequent as hourly, are significant. The related improvements in regional and private numerical prediction are also helpful, but only partially driven by road weather information requirements. This is what motivated the attention away from environmental prediction to the fusion and presentation of existing information, whatever its quality. This was in response to the evident problem that almost all weather-related transportation decisions do not rely on one information source, nor on atmospheric information alone. The gap most in need of attention--between increasingly good and plentiful information, and operational decision-making--is the area of FHWA decision support research and development.

Decision support is where road weather data tailoring occurs. Each operational decision is specific to a type of road weather management strategy, a particular place and time, and the characteristics of the decision maker (their expertise, their location, their information processing equipment). Road weather management strategies mitigate weather impacts by advising motorists of prevailing and predicted conditions (e.g., traveler information), controlling traffic flow and roadway capacity (e.g., weather-responsive traffic signal timing, road closure), and/or treating roads to minimize or eliminate weather threats (e.g., anti-icing/deicing). Such strategies are consistent with the FHWA's Office of Transportation Operations' vision of creating 21st century highway operations using 21st century technology. In most cases, projects to support decisions about weather threats have also made some contribution to the environmental prediction inputs. The following are several important projects undertaken with FHWA support.

In 1999 and 2000, decision support requirements, first generally and then specifically for winter road maintenance, were studied in the Surface Transportation Weather Decision Support Requirements (STWDSR) project. This project used weather threat scenarios to identify specific decisions made in winter road maintenance, their timing, and the expected confidence of the decisions at various time horizons. General requirements for emergency managers, traffic managers, and road users were also defined. The STWDSR project became an important contributor to the OFCM's Weather Information for Surface Transportation (WIST) needs analysis, the National ITS Architecture modifications, and to Maintenance Decision Support System (MDSS) prototype project.

In 2004 and 2005, the Missouri DOT will prototype a Weather Response System to support transportation system operations. The Weather Response System will use products from the NWS, the private sector, state agencies and other sources to create and demonstrate decision support tools. These tools will be tailored for different types of users including traffic managers, transit agencies, maintenance supervisors, and law enforcement agencies.

<u>Support for Maintenance Managers</u>. The Maintenance Decision Support System (MDSS) project is a multi-year effort to prototype and field test decision support components for winter maintenance managers that began in late 1999. The MDSS was designed by a consortium of national laboratories, based on the requirements articulated by maintenance managers, to help the managers improve roadway level of service during winter weather, and to minimize road treatment costs (by optimizing use of labor, materials, and equipment). This data management tool has advanced weather prediction and road condition prediction capabilities, including air and pavement temperatures, precipitation start/stop times, precipitation types and accumulation amounts. These predictions are fused with customized winter road maintenance rules of practice to generate route-specific treatment recommendations (i.e., strategy, timing, and material application rates).

From February to April 2003, the first functional MDSS prototype was demonstrated and evaluated in three Iowa DOT maintenance garages. The main display of the demonstration prototype, shown in Figure 3-DOT-7, includes predicted weather and road conditions, a weather parameter selection menu, a map of roads and weather alerts, as well as forecast animation controls. Lessons learned from the preliminary demonstration were used to enhance the prototype prior to a second demonstration from December 2003 to March 2004. Version 2.0 of the MDSS software was released in the fall of 2003. Lessons learned and recommendations for additional enhancements were documented and presented at the MDSS Stakeholder Meeting in July 2004. The focus of this project has changed from prototype development to proactive outreach, deployment assistance, technology transfer, and target enhancements for other surface transportation sectors. In concert with the July 2004 stakeholder meeting, there was a technology transfer workshop for private sector companies that are interested in integrating one or more MDSS prototype modules into their product lines. Such efforts support the FHWA deployment strategy, which consists of the private sector building end-to-end products based on the core MDSS prototype functionality. These products will be procured by public agencies (e.g., state DOTs), enabling both the private and public sectors to benefit from millions of dol-

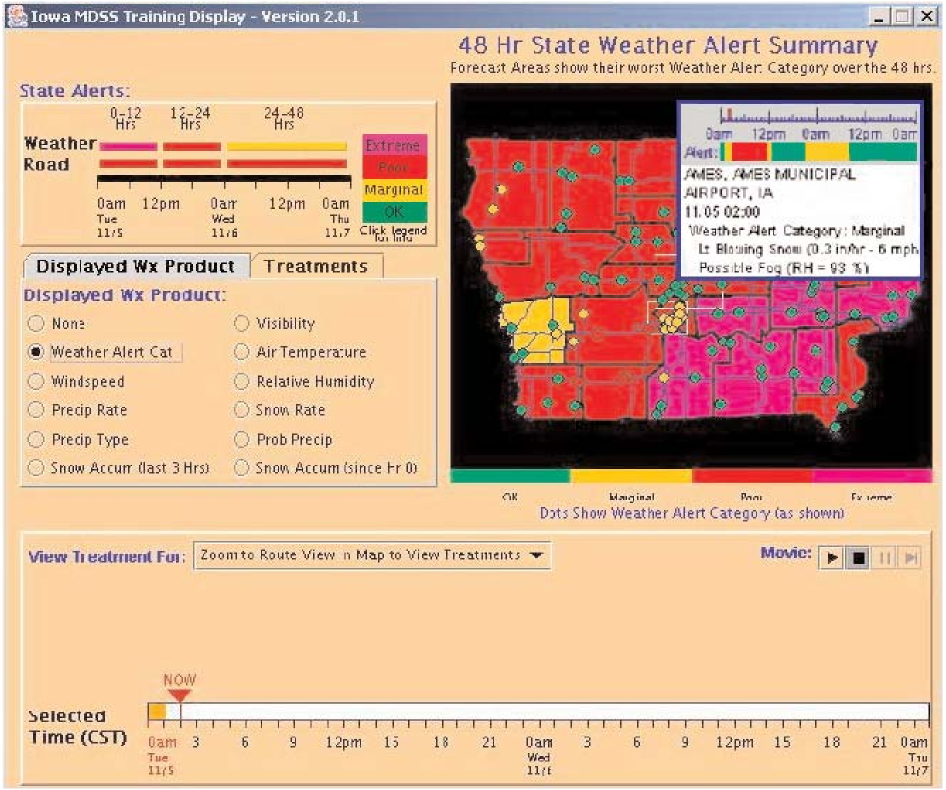


Figure 3-DOT-7 . Schematic of FHWA's Maintenance Decision Support System.

lars of high-risk research. Version 3.0 of the MDSS software, used in the second demonstration, will be made available during the fall of 2004. Additional information on the MDSS project can be found at www.rap.ucar.edu/projects/rdwx_mdss.

Support for Traffic Managers. A 2001 survey of 21 traffic management centers found that nearly 90 percent received some general weather information and over 60 percent used customized weather data. In January 2003, the Road Weather Management Program released the "Weather-Responsive Traffic Management Concept of Operations" highlighting the weather-related needs of managers responsible for freeway and arterial route operations. This draft concept of operations addressed road weather data collection, assessment of weather impacts on roadway networks, operational strategies to control traffic and advise motorists during adverse weather, and research needs. It serves as the basis for future work to develop, test, and evaluate these mitigation strategies. The need for a systematic approach to the significant challenge of managing traffic during inclement weather is discussed in the "Research Needs for Weather-Responsive Traffic Management" paper presented at the TRB Annual Meeting in January 2004.

Empirical studies of traffic flow and driver behavior during inclement weather are planned in 2004 and 2005. The Road Weather Management Program will work with FHWA's Office of Operations Research and Development to collect empirical traffic, weather, and pavement condition data on both freeway and arterial routes to quantify weather impacts on driver behavior, traffic speeds, traffic volumes, and travel time delay. This research is needed to understand changes in traffic flow and driver behavior under adverse weather conditions. Once these factors are better understood, the information can be incorporated into traffic simulation models and, ultimately, end user tools. In 2005 the FHWA expects to disseminate study results to increase awareness of weather impacts among operating agencies, to sponsor and encourage others to conduct subsequent studies on weather and traffic modeling, and to promote deployment of weather-responsive traffic management strategies and tools.

511-The National Traveler Information Telephone Number. Just as dialing 911 is the standard way to access emergency aid over the telephone, it was thought that a standardized number for travel information would be beneficial. Accordingly, a broad coalition of ITS interests, with technical support of the FCC docket submission by the FHWA, achieved in 2001 the allocation of a national 511 traveler information telephone number. In 2002, the FHWA sponsored a number of grants to plan for state deployment of 511 services, and guidelines were issued on service content (Figure 3-DOT-8). A survey on traveler information conducted by ITS America indicated that weather and road condition information was highest in demand by travelers. Therefore, road weather information should be a key component of 511 services. The means of delivering information through 511 are still being developed, including ways to serve peak demands for emergency evacuation information, as part of the homeland defense or other threat capability.

In June 2003, The 511 Deployment Coalition released a Deployment Assistance Report, "Weather and Environmental Content on 511 Systems," to recommend basic content and provide for consistency in 511 systems as they are deployed across the country. Since these systems are in their infancy, gaps exist in defining the types of road weather information travelers desire, appropriate data formats, and the frequency and detail needed for travelers to make safe and effective decisions. The Road Weather Management Program participates in 511 Deployment conferences to help establish road weather data requirements and close

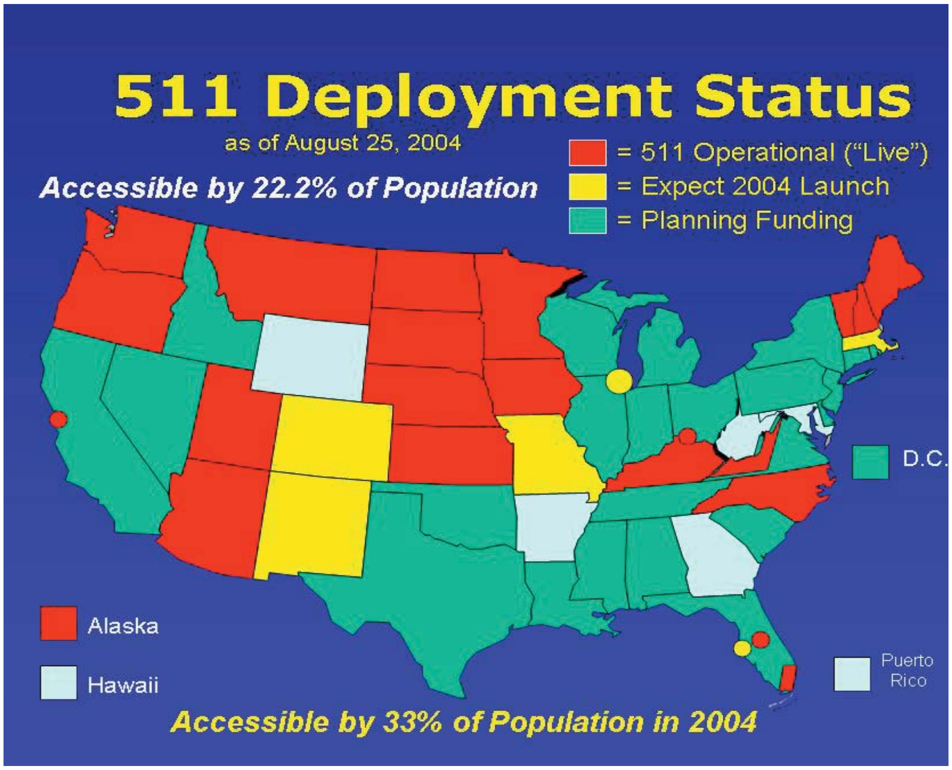


Figure 3-DOT-8 . 511 National Traveler Information Telephone Number Deployment.

these gaps. The 511 program also must find ways to complement NOAA Weather Radio broadcasts (and eventually an all-hazards warning system), and use the NWS official watches and warning information. The 511 capability is just one more way in which ITS is becoming a significant dissemination means for road weather information. As of August 2004, 511 services were operational in 20 states and available to almost 57 million Americans. 511 services are expected to be launched in five more states during 2004.

Weather Impacts on Roadway Safety, Mobility & Productivity. While the costs of weather to surface transportation are immense, it has been difficult to quantify specific costs or the benefits (as avoidable costs) through better information to support better weather response and mitigation strategies. It is likely that the costs to mobility, in terms of delay due to weather, are the largest component. Initial estimates of the economic impact of weather-related delay on trucks in the 20 major metropolitan areas most affected by adverse weather is on the order of $2 billion per year. Some delays are due to well-defined closure events. These are due to storms that swamp reasonable treatment activities, but could benefit from more authoritative travel-demand management techniques. This leaves the much more prevalent, and subtle, delays due to more minor threats, like rain, residual snow, or visibility impairments that are difficult to treat in any way. Traffic management strategies to address them must be based on very good, dynamic predictions of weather, pavement and traffic conditions. However, it is clear from traffic flow theory that with heavy volumes, as in metropolitan areas at peak times, very small changes in effective capacity (as may be due to a change in road friction) or very small changes in traffic volume can have large delay effects.

The FHWA is sponsoring closer analysis of delay effects due to weather, work zones and incidents. Paucity of good traffic and road weather data sets has hindered the analysis, but in 2001 and 2002, analyses were conducted for Seattle, Washington and Washington, DC metropolitan areas. These analyses combined surface weather observations with traffic speed data, both empirical and modeled. The results have been consistent in showing about a 12 percent increase in travel time averaged over a wide range of weather events. A second analysis of delay effects in Washington, DC was conducted with archived Doppler radar data for more precise and more dynamic inference of road weather conditions. Analysis results indicated that during peak periods travel time increases by roughly 24 percent when precipitation is present. Better understanding of weather-traffic interactions can, in turn, lead to a stronger attack on delays through traffic management practices, including speed management, access control (e.g., road closure), motorist warning systems, and weather-responsive signal timing.

Road Weather Management Program Outreach and Training. The Road Weather Management Program web site (www.fhwa.dot.gov/weather/) was redesigned in January 2004. The site contains information on program objectives and initiatives, weather impacts, benefits of road weather management strategies, technologies to help mitigate weather impacts, training, upcoming events, and other resources such as a listing of over 200 road weather related publications. Among the most useful resources on the site are the best practices of maintenance managers, traffic managers and emergency managers in response to various weather threats. This resource contains 30 case studies of systems in 21 states that improve roadway operations in adverse weather, as well as an overview of environmental sensor technologies. Each case study has six sections including a general description of the system, system components, operational procedures, resulting transportation outcomes (i.e., improved safety, mobility and/or productivity), implementation issues, as well as contact information and references. Examples of successful road weather management strategies follow.

A maintenance division of the Montana DOT employed mobile anti-icing and de-icing strategies to proactively respond to winter storms. When performance was compared to a maintenance division that used reactive treatment after storms, it was found that average treatment costs (i.e., labor, materials, and equipment costs) for the proactive division were 37 percent lower. Additionally, a higher level of service was achieved on road sections treated by the proactive division resulting in safety and mobility improvements.

On a 19-mile section of Interstate 75 in Tennessee, a fog detection and warning system collects data from two ESS, eight fog detectors, and 44 vehicle speed detectors to predict and detect conditions conducive to fog formation. When established threshold criteria are met, traffic managers may select pre-programmed dynamic message sign (DMS) messages, pre-recorded highway advisory radio (HAR) broadcasts, and/or alter speed limits via variable speed limit signs based upon response scenarios proposed by the system (Figure 3-DOT-9). When visibility is less than 240 feet, the worst-case scenario, the Highway Patrol activates eight automatic ramp gates to close the affected interstate section and detour traffic to US Route 11. Between 1973, when the interstate opened, and 1994; there were over 200 crashes, 130 injuries and 18 fatalities on this highway section. Since the fog detection and warning system began operating in 1994, safety has been significantly improved and no fog-related accidents have occurred.

During the Hurricane Floyd evacuation in 1999, traffic and emergency managers with South Carolina DOT and the State Highway Emergency Patrol had not agreed on a lane reversal plan for Interstate 26 prior to hurricane landfall. As a result, there was severe congestion on this route with a maximum per lane volume of roughly 1,400 vehicles per hour. Managers quickly developed a lane reversal plan for reentry operations. Portable DMS and HAR transmitters were deployed to alert travelers of closures and alternate routes, and westbound lanes were reversed. Maximum volumes during reentry exceeded 2,000 vehicles per hour per lane-a 43 percent increase over evacuation volumes. The use of lane reversal and traveler information techniques improved mobility by significantly increasing roadway capacity.

A key outreach activity is the annual Eastern Winter Road Maintenance Symposium & Equipment Expo (or Snow Expo). Over the past nine years, FHWA has partnered with state agencies to host the Snow Expo, which provides a forum for sharing information and technologies used to counter the effects of winter weather. More information on the Snow Expo can be found at www.easternsnowexpo.org.

The FHWA sponsors training programs and conducts outreach to promote Road Weather Management Program products and activities. In 2005, a one-day training course on the "Fundamentals of Road Weather Management" will be offered through the National Highway Institute (NHI course No. 137030A). The objectives of the course are to provide background on the fundamentals of meteorology as they pertain to RWIS, to provide participants with the skills to recognize crosscutting weather impacts on roadway operations, to explain the range of effective and open RWIS solutions for various management practices, and to identify the technical and institutional challenges of implementing RWIS. Additional course details will be listed on National Highway Institute web site when course content and schedules are finalized.

The computer-based Anti-Icing/RWIS Training Program is a comprehensive, interactive training program for winter operations that was jointly developed by AASHTO, with support from FHWA and Aurora (a pooled-fund research program). The training program covers an introduction to anti-icing and winter maintenance, winter road maintenance management, winter roadway hazards and principles of overcoming them, weather basics, weather and roadway monitoring for anti-icing decisions, computer access to road weather information, and anti-icing practice in winter maintenance operations.

Figure 3-DOT-9. Dynamic message signs enable drivers to take precautionary actions based on weather conditions.

The Federal Railroad Administration (FRA) supports improving the collection, dissemination, and application of weather data to enhance railroad safety through the Intelligent Weather Systems project, as part of the Intelligent Railroad Systems and Railroad System Safety research programs. These programs address safety issues for freight, commuter, intercity passenger, and high-speed passenger railroads.

Intelligent Weather Systems for railroad operations consist of networks of local weather sensors and instrumentation - both wayside and on-board locomotives - combined with national, regional, and local forecast data to alert train control centers, train crews, and maintenance crews of actual or potential hazardous weather conditions. Intelligent weather systems will provide advance warning of weather caused hazards such as flooding; track washouts; snow, mud, or rock slides; high winds; fog; high track-buckling risk; or other conditions which require adjustment to train operations or action by maintenance personnel (Figure 3-DOT-10).

Figure 3-DOT-10. Track washed out by flood waters from Hurricane Alberto.

Weather data collected on the railroad could also be forwarded to weather forecasting centers to augment their other data sources. The installation of the digital data link communications network is a prerequisite for this activity.

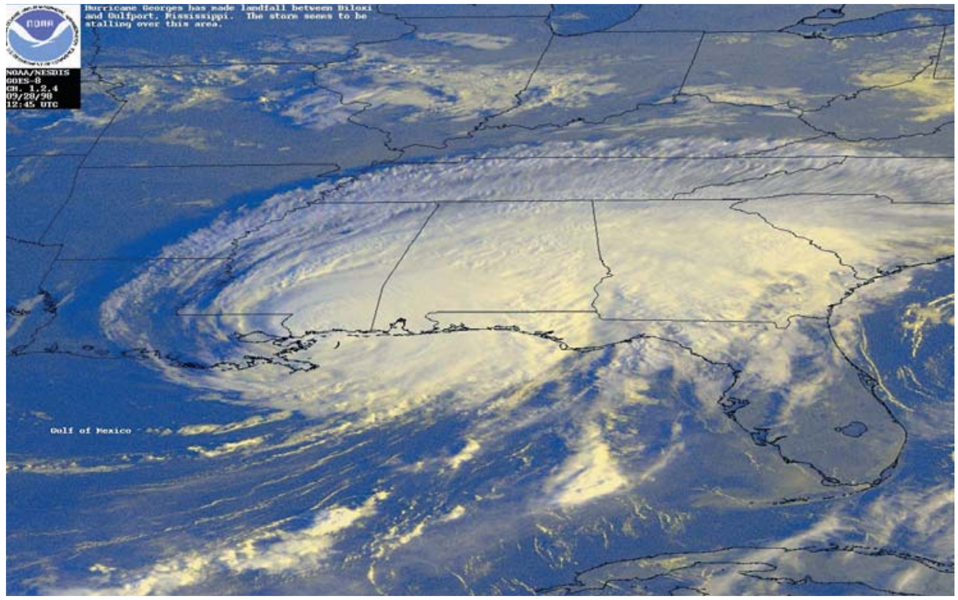
FRA intends to examine ways that weather data can be collected on railroads and moved to forecasters, and ways that forecasts and current weather information can be moved to railroad control centers and train and maintenance crews to avoid potential accident situations. This is one of the partnership initiatives identified in the National Science and Technology Council's National Transportation Technology Plan.

<u>Weather Forecasting Enhanced by Nationwide Differential Global Positioning Systems</u>. Nationwide Differential Global Positioning System (NDGPS) is a system of reference stations that monitors GPS and broadcast corrections, which can be used by the GPS receiver to improve the accuracy, integrity and availability of the GPS position. NDGPS is used in a myriad of applications including: maritime navigation, positive train control, precision farming, dredging, graphic information systems and surveying. The Forecast Systems Library (FSL) in the National Oceanic and Atmospheric Administration (NOAA) developed a unique system that very accurately measures the amount of water vapor in the atmosphere by taking advantage of the dual-frequencies, reference station receivers at the NDGPS sites and a suite of weather sensors added to each reference station. The weather sensors, circled in the photo to the right, measure temperature, relative humidity and barometric pressure. The GPS satellites broadcast on two frequencies, L1 and L2. The FSL uses these two frequencies to correct for the ionospheric delay that is caused by changes in the refractive index associated with the concentration of free electrons in the upper atmosphere. The ionospheric delay is usually about 6-10 times greater than the signal delay caused by the neutral, non-electrically conducting, atmosphere. FSL can than

estimate the signal delays caused by the neutral atmosphere by comparing the errors in position between sites that are over 500 km apart by viewing the same satellites for about 30 minutes. Most of the delay in the troposphere (lower atmosphere) is caused by the mass of the atmosphere, or the hydrostatic component, while the induced dipole moment of the water vapor molecules in the atmosphere is responsible for the rest of the delay.

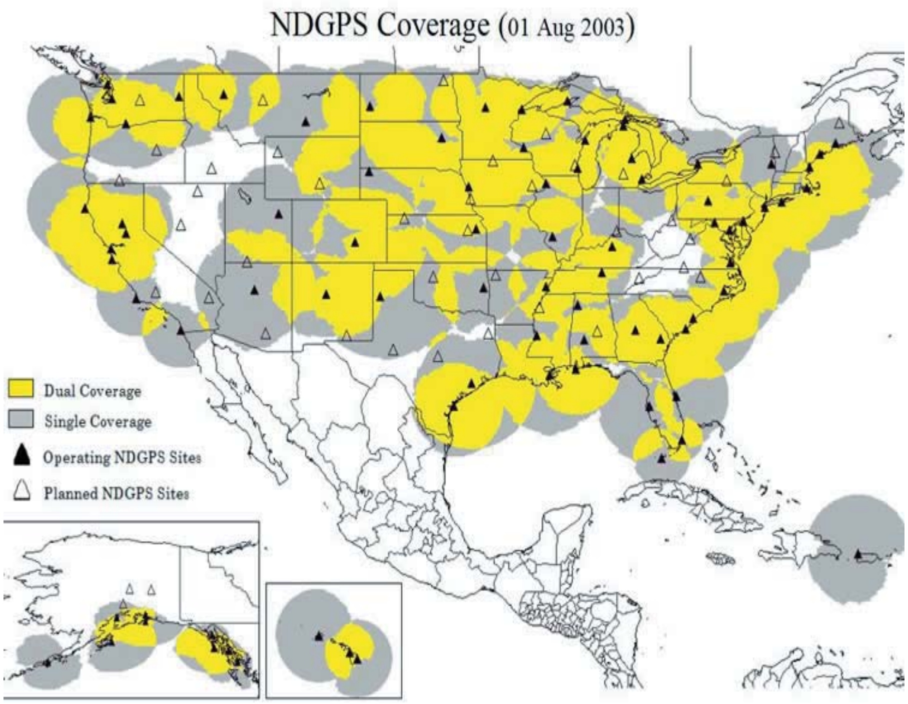
The FSL can accurately estimate the hydrostatic delay by putting a pressure sensor at the NDGPS site and mapping the surface pressure into signal delay using well-known physical relationships. Subtracting the hydrostatic delay from the observed tropospheric delay gives the wet signal delay caused by water vapor in the atmosphere. Then, the wet delay is mapped into the quantity of water vapor responsible for the delay using information about the temperature of the atmosphere and the characteristics of the air at microwave frequencies.

This results in the equivalent height of a column of water that would form if all of the water vapor in the atmosphere were to fall or precipitate. The total precipitable water vapor content is a direct measure of how much raw material is in the atmosphere in the form of rain, snow, hail and clouds. As the water vapor changes state from gas to liquid to solid and back again, it releases or absorbs energy associated with the latent heat bound-up in the molecules. This energy release and absorption is the primary energy responsible for weather. The reason that water vapor is hard to measure is that it only manifests itself when it changes state, and most instruments that can observe water in its gaseous state do not work well under all weather conditions. However, NDGPS works remarkably well in all weather conditions.



Water vapor is the most important component of weather and the least observed. NDGPS reference stations provide real-time continuous water vapor measurements to NOAA's weather models, greatly improving the short-term weather forecasts, especially during periods of active weather such as fronts, hurricanes or tornadoes.

The Federal Railroad Administration will continue to work with NOAA's Forecast Systems Laboratory and the Coast Guard to install weather sensor systems at all of the NDGPS reference stations as they are built.



<u>Nationwide Surface Transportation Weather Observing and Forecasting System - *Clarus*</u>. The weather products available today through both public and private resources are insufficient to meet the demands of transportation operations. Nearly all weather forecasting today is based on observations of the atmosphere. However, the greatest impact of weather events on the safety and mobility of travelers and freight occurs on the surface. Many state DOT's have invested in road weather information systems that provide their agencies with observations on conditions at the surface and just below the surface. Other entities such as agriculture, water districts, electric utilities, and railroads also operate weather observation stations. FRA is developing a partnership with Federal Highways Administration (FHWA), state DOT's, NOAA and others to establish a nationwide road weather observation network known as *Clarus*. The goal of the *Clarus* project is to tie this mosaic of private and public observation stations into a cohesive weather forecasting system that is specifically focused on surface conditions.

The Federal Transit Administration's (FTA) mission is to "provide leadership, technical assistance and financial resources for safe, technologically advanced public transportation which enhances all citizens' mobility and accessibility, improves America's communities and natural environment, and strengthens the national economy."

FTA's vision for public transportation is clearly making it the transportation mode of choice in America. Public transportation in America can set the standard for "world-class" transportation service, where thriving communities grow with public transportation and access is provided for everyone to fully participate in American life. Through the more than $7 billion annual assistance to the nation's transportation system, FTA maintains the Federal commitment to public transportation.

Daily, transit systems safely and efficiently move millions of people, reducing congestion, facilitating economic development, and connecting people to their jobs and communities. When combined with state and local funding, FTA's assistance promotes sustainable community development, while addressing critical safety and security issues.

Several major initiatives are underway to achieve make vision reality,

Figure 3-DOT-11. A city transit bus attempts to maintain its schedule while safely navigating snow-covered downtown streets.

including: designing and delivering an assistance program for the multibillion dollar-effort to support the lower Manhattan Recovery project; implementing strategies to annually increase transit ridership; and creating a national portfolio of security products and services for transit systems.

Figure 3-DOT-12. Minnesota Metro Transit's Hiawatha Light Rail will operate along a 12-mile track from downtown Minneapolis to the southern suburbs of Bloomington.

Buses form the backbone of our nation's transit systems. About 58 percent of all transit users take the bus, and even in many cities with extensive rail systems, more people ride the bus than take the train (Figure 3-DOT-11). One hundred gallons of fuel can be saved each year for every person riding the bus instead of driving. The savings by rail riders are even greater. In this context, FTA assists in providing an energy efficient means of transporting people, thereby, reducing emissions caused by transportation and lessening the Nation's dependence on fossil fuels, including foreign oil (Figure 3-DOT-12).

The United States Department of Transportation has a variety of research development and demonstration programs and initiatives that are targeted at reducing the emissions and improving the efficiency of vehicles including trucks, buses, marine vessels, airport support equipment, and other specialty vehicles. One of FTA's newest initiatives will also look at enhancing research in these and other areas, as a means to support increased annual transit ridership, increased readiness, and more effective program planning and oversight that is responsive to industry needs.