CLARUS – THE NATIONWIDE SURFACE TRANSPORTATION WEATHER OBSERVING AND FORECASTING SYSTEM

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ABSTRACT

State Departments of Transportation (DOTs) have invested in Environmental Sensor Stations (ESS) primarily in support of winter maintenance activities. Most ESS, which are field components of Road Weather Information Systems (RWIS), have sensors that measure atmospheric, pavement and/or water level conditions. RWIS are used to observe conditions in locations that are prone to safety hazards resulting from rain, snow, fog, and other weather events.

The ability to fully utilize RWIS data for various applications is often hampered by suboptimal system design. For example, there are limited standards for ESS data reporting and instrument siting as well as inconsistent quality control. These conditions limit the utilization of these valuable data for both the transportation and meteorological communities.

The U.S. DOT Federal Highway Administration (FHWA) Road Weather Management Program, in conjunction with the Intelligent Transportation Systems (ITS) Joint Program Office, recognized that state investments could be better utilized if they were standardized and made available from one location. In 2003, the National Academy of Sciences released a report “Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services” (http://www.nap.edu/catalog/10893.html) describing the need for a robust, integrated observational network and data management system. The FHWA responded with a new initiative called “Clarus—the Nationwide Surface Transportation Weather Observing and Forecasting System”.

The objectives of Clarus are to reduce the impact of adverse weather for all road and transit users and operators by demonstrating an integrated road weather observation and forecast data management system, and to develop a partnership to establish a nationwide road weather observation network.

INTRODUCTION

For several decades weather observing networks have grown in number, sophistication, and level of detail. However, rather than concentrating on surface conditions, most observational networks focus their instrumentation, observations and resulting products in the atmospheric (above ground) and oceanic domains. Well established research programs in aviation and tropical cyclone prediction have contributed to a significant reduction in weather-related plane crashes and have increased the accuracy of hurricane track forecasts resulting in better information that increases safety.

In contrast, the efforts to invest in observations and products focused on the near surface, surface and subsurface have been inconsistent, less organized, and modestly funded, mostly via limited State resources. Federal efforts at "surface" observation programs focused on the aviation community and the deployment of ground sensors at airports. As a result, State Departments of Transportation (DOTs) have had to invest in Road Weather Information Systems (RWIS) along roadways and other transportation facilities to provide their agencies with observations on surface conditions to improve safety and mobility on the nation's roads.

The current challenge is that the available sources of RWIS data are not managed to develop a comprehensive and coherent picture of conditions in the surface transportation domain. Other stakeholder communities outside of transportation, such as agriculture, water management, sewage treatments, and power utilities, have made similar investments to compensate for their lack of surface observations and data management. The end result is a mosaic of discrete observation points owned by various public and private entities without interaction with the greater community. The Clarus initiative will not only provide for a robust, integrated observational network and data management system, but it will also fulfill the needs of the transportation community as well as other stakeholders such as the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Agriculture (USDA) and the private sector.

In addition to the integrated observational network of fixed sensors along roadways, the Clarus initiative will devote resources to the feasibility of obtaining data from cutting-edge vehicle-based and remote sensing technologies. The culmination of this effort will be a regional model deployment of the observation data sharing network and a suite of forecasting tools enabled through the Clarus system design. This regional deployment will serve as the first among several deployments, funded by the stakeholders, to achieve nationwide operations.

THE CLARUS INITATIVE

Clarus (which is Latin for "Clear") is a demonstration of a regional road weather observation, forecasting and data management system and a partnership to establish a nationwide road weather observation network. The initiative's overall objective is to reduce the impact of adverse weather for all road and transit users and operators. This is an ambitious initiative, with four defined tracks and a projected duration of six years.

Why is an initiative such as Clarus so important? Public investments in State DOT Environmental Sensor Station (ESS) are not being leveraged for 21st century transportation and weather operations. State DOT sensors are a potpourri of brands and models, producing data at varying levels of quality and with differing data formats, communication protocols, and polling frequencies. Expansion of RWIS networks usually does not take into account the assets or requirements of other agencies or the larger community. Clearly, the nation is not receiving the full benefit from existing road weather observing networks. Clarus seeks to change this paradigm by bringing together the nation's public investment in ESS with robust quality assurance and one-stop availability. Furthermore, Clarus will serve as a focal point of research for new public and private, in situ, mobile and remote sensing technologies to observe both the driving level environment and that of the lowest portion of the atmosphere called the planetary boundary layer. Finally, the deployment of Clarus will be more than just an Internet data portal. It is envisioned that both the public and private sectors will develop a suite of forecast tools enabled by the Clarus system design. These tools will demonstrate the utility of these new data sets and provide the genesis for new and enhanced weather information products for surface transportation.

The potential benefits from the Clarus initiative include:

- A one-stop Internet portal for all surface transportation weather related observations
- Continuous quality control with feedback to State DOT engineers
- Data available in one common format, with full metadata
- Data provided without post-processing, ready to be incorporated into value-added products, weather or traffic models and decision support systems
- The Clarus data management system will support the inclusion of new technologies, such as:
    - Vehicle-based sensing technologies
    - Surface visibility and road obscuration information from traffic cameras
    - Remote sensing technologies such as low cost, low power radars

The potential benefactors of the Clarus initiative are many, ranging from State and municipal DOTs (including traffic and maintenance managers) to mass transit and rail. Public weather forecasting agencies such as NOAA will be able to use the data for their new high resolution National Digital Forecast Database (NDFD), while public weather consuming agencies (such as USDA, and the Departments of Homeland Security and Defense) will be able to utilize the data in their operations and decision support systems. Data from Clarus will spawn a host of new value-added weather information products and more accurate, customized forecasts by the commercial weather industry. Likewise, the data could be utilized by traffic reporters, TV and radio broadcasts as well as by emergency managers and law enforcement. Ultimately, the data and value-added products will be available to the general public and commercial vehicle operators across the nation as route-specific road weather information.

CLARUS INITIATIVE TRACKS

The Clarus initiative has been structured with four broad tracks (shown in Figure 1). At a high-level, these tracks include:

Track 1: Stakeholder Coordination
Track 2: System Design
Track 3: Multi-State Regional Demonstration
Track 4: Final Design and Model Deployment

The following subsections provide detail and context in describing each of these tracks.

Track 1: Stakeholder Coordination

The FHWA Road Weather Management program led a successful project called the Maintenance Decision Support System (MDSS) prototype from 1999 through 2004. A stakeholder group was used to keep the project visible to the maintenance community and grounded in the realities of present day science and operations. The stakeholder group was directed by FHWA, but it consisted of personnel from other federal agencies and laboratories, State DOTs, private sector vendors and academia. The stakeholder group model was instrumental in building partnerships, acceptance of the concept, project ownership and consensus in the design, demonstration and eventual technology transfer.

This same stakeholder group template will be used for the Clarus initiative. The stakeholder group will be called the Interagency Coordinating Committee (ICC). Similar to the MDSS project, the ICC will consist of personnel from various disciplines (public, private and academic sectors) with the FHWA acting as the lead agency. However, because the scope of Clarus is much broader than MDSS (which focused on the winter maintenance community) ICC participants will be broader, multi-modal, and interdisciplinary. Primary among all of the stakeholders is NOAA because of the breadth of their weather observation and forecasting experience and of their congressionally defined responsibilities. Members of the ICC will participate for the duration of the initiative and will meet at least annually with two meetings projected in the first and final years.

The ICC will support technical and programmatic considerations involving system design, design review, the multi-state regional demonstration, and the model deployment. The ICC panel of subject matter experts in weather observing and forecasting, transportation operations, networking and data management across business sectors will be coordinated to ensure that stakeholder interests are addressed through each development phase.

Key activities of the ICC will include:

- A review of the project requirements and concept of operations. The ICC will be briefed on the system design and preliminary testing of the design (FY 2005).
- A review of the overall system design and a debriefing on the multi-state corridor demonstration. This information will be used as consideration for site selection and implementation of the multi-state corridor demonstration (FY 2006).
- A review of the evaluation and lessons learned on the multi-state corridor demonstration. Next steps will determine design enhancements and plans for a more complex model deployment (FY 2007).
- A review of the final design and regional Clarus model deployment. Activities will transition into the development of guidance products for system implementation and technology transfer (FY 2008).

The remaining tracks of the Clarus development follow a proven systems engineering process that emphasizes extensive testing and evaluation. First, the system design addresses the basic issues and stakeholder needs that are to be supported and prepares extensive open system documentation to enable the broadest possible deployment. Second, the multi-state regional demonstration evaluates the design in a real-world environment to ensure that the observational and forecasting needs of the stakeholders are satisfied. Third, the final design provides a stable, open-source design that can be readily implemented, and a model deployment that serves as a catalyst for Clarus deployment nationwide.

Track 2: System Design

The system design of the project will begin with the writing of the requirements document called the concept of operations. This task will provide a description of the observational and forecasting needs of the stakeholders. It will also look at the requirements for the collection, quality assurance and archiving of the nation's inventory of data from State DOT ESS. The concept of operations will also determine the requirements of potential end users and of the Internet portal that will make the information available to the greater community.

Along with the concept of operations document, there are several other significant engineering documents that are required for Clarus. An Operational Concept Description (OCD) will be created from the concept of operations that will provide a description for the multi-phased implementation of a nationwide observing network, the utilization of multi-state corridors for evaluating new technologies and the engineering and logistics required to create an Internet data portal. A Preliminary Interface Requirements (PIR) document will analyze and catalog the many different types of ESS that are deployed around the nation. The PIR will also indicate how many "data format translators" will need to be created to bring all ESS data into one common format and database. The PIR will provide requirements for the data storage format, communications protocols, interface specifications for new observation technologies, and define application programming interfaces so that data can be accessed from the Internet data portal.

A design gap analysis will be performed to determine if there are technological issues that may hinder the successful conclusion of the Clarus initiative and eventual deployment of the nationwide network. The OCD, PIR and gap analysis will be used to create a preliminary system design and associated Interface Control Documents (ICD) to support a demonstration and evaluation.

A test of the preliminary system design is scheduled to take place late in FY 2005. Using all of the engineering documentation compiled in this track, the preliminary system design test will establish a limited ESS data collection network to exercise system performance and characteristics. An example of a conceptual regional data collection network is illustrated in Figure 2.

In addition to the engineering documents and the preliminary system design testing, the second track includes resources to integrate data from a number of State DOT RWIS into a NOAA database. NOAA's Forecast Systems Laboratory has been supporting a program called Meteorological Assimilation Data Ingest System (MADIS). MADIS was used successfully during the MDSS project to collect, process and forward State DOT RWIS data from the north central plains states in support of the project demonstrations. For Clarus, MADIS will create a core proof of concept database that can be used in the preliminary system design test.

The result of track 2 will be an open-source system design that is moderately stable and ready to be introduced into a real-world working environment. The design will be extensible to accommodate current observational techniques and emerging vehicle-based and remote sensing technologies. The core functions of the Clarus network will be tested to ensure that the network design can support the observational data sharing needed to support new forecasting tools.

Track 3: Multi-State Regional Demonstration

Conducting the multi-state regional demonstration will enable the FHWA and the ICC to evaluate the performance of the Clarus design. The stability of a system design rests in the design's ability to withstand unanticipated events. Rigorous testing of the system will expose performance limitations in an operational environment, when users are placing demands on the system for access to observational data, and when decision-makers are using forecasts from the observations.

Evaluation of the demonstration will consider the outputs of the network and the forecasting tools that Clarus enables. In addition, there will be an evaluation of how output of the Clarus network impacts roadway mobility and safety as well as agency productivity.

In addition to the evaluation, there will be parallel efforts to integrate new and emerging technologies into the extensible Clarus database. These activities include:

- An investigation into the use of Vehicle Infrastructure Integration (VII) technologies to capture real-time weather and road condition information from moving vehicles. This includes identifying the infrastructure needed to support these new technologies (such as power, communications, and installation requirements).
- Research on the use of Closed Circuit Television (CCTV) traffic cameras for the determination of driver-level visibility and pavement condition (such as obscuration by snow or ice).
- Research into the use of low cost, low power Phased Array Radars for near surface observing. These new radars are small enough to fit on a cellular telephone tower and can provide valuable information on the state of the lower atmosphere, which is otherwise not being sampled by National Weather Service (NWS) Doppler radars. This information could be used for both short range forecasting and as input into new land-air numerical weather prediction models.
- Exploring remote sensing technologies such as surface fog detection or Earth surface temperature from satellites.
- Data Collection Enhancement which will identify any new instrumentation that is needed to fill any additional observational gaps.

The result of this track is a Clarus system design and a package of observing and forecasting tools that have been evaluated in a real-world environment. The limitations of the design will have been identified so that a final design solution can address the remaining deficiencies. Additionally, the real-world evaluation will identify how the system design is effective for improving safety, mobility and productivity.

Track 4: Final Design and Model Deployment

The final design effort is focused on preparing a stable, open-source system design that can be readily implemented by interested public and/or private sector organizations to share road weather observation data. This effort depends upon the ICC members updating the system design and interface control documents based on lessons learned from the multi-state regional demonstration. The final design will also feature specifications for any new mobile and remote sensing technologies.

The final design will be applied in a model deployment to showcase the true implementation costs and realistic implementation effort. The model deployment must consist of multiple states and an instrumented corridor that traverses the states. Geographic considerations for the model deployment will include the diversity of weather events and terrain.

An evaluation of such a model deployment will demonstrate the true benefits to transportation operations (i.e., mobility, safety and productivity) to State DOT personnel and private sector road weather information providers. To provide step-by-step instructions on how to implement the Clarus network in different regions of the country, a detailed implementation guide will be provided. In addition, a network deployment cost estimation tool will be made available.

The culmination of this effort will be a regional deployment of the observation data sharing network and a suite of forecasting tools enabled through the Clarus system design. This regional deployment will serve as a model for other networks to achieve nationwide operations.

ISSUES AND CHALLENGES

As with any complex project, there are additional challenges to address. Some of these challenges include:

- Education – Consumers must be educated on the benefits of new information to effectively utilize the technology.
- Liability – Some data providers may feel a liability exposure by releasing observational or forecast data to a community that may not know how to use it (e.g. road temperature information). This may initially limit the public distribution of some observational parameters.
- Policy – Some private network data providers may hold the data as proprietary, preventing its public distribution.
- Data Franchise Agreements/Licensing – Some network data providers may have contracts that either restrict data distribution or require a license for its use.
- NOAA/NWS Cooperative Network Modernization – The NWS is undertaking a modernization of its cooperative observation network. In doing so, the Clarus design must work in conjunction with the NOAA to allow for ease of data transfer and integration.
- VII and Other Emerging Technologies – New, high resolution data sets will be evolving during the course of the Clarus initiative. The system must be robust and extensible to be able to ingest, process and archive data sets whose formats have yet to be defined.
- Institutional Barriers for Sharing – There are some institutional barriers among agencies and private networks that must be overcome for the good of the entire user community.

VISION OF SUCCESS

The long term vision of the Clarus initiative is far reaching. It includes a broadened participation and resource sharing by both the public and private sectors across the transportation and weather communities. NOAA and other federal agencies will be able to better address the demands of the surface transportation community with secure, quality-controlled data that share a common format that is easily used in many applications.

State DOTs will be able to deploy new RWIS to maximize observing and forecasting capabilities. New observational technologies will continue to fill data gaps to give atmospheric scientists a better understanding of the weather conditions near the ground. Complex decision support systems and numerical models that create more accurate forecasts can then easily use these data. Finally, a stable Clarus design, implementation guidance and a deployment cost estimation tool will facilitate the establishment of a self-sustaining nationwide implementation that benefits all stakeholders.

CONCLUSION

The U.S. DOT FHWA Road Weather Management Program, in conjunction with the ITS Joint Program Office, has embarked on a new multi-year initiative. The initiative, called Clarus, will combine rigorous engineering techniques, network design, emerging technology research, and increasingly complex field demonstrations to produce a plan for the nationwide deployment of advanced surface transportation weather observing networks.

Data from Clarus will be used to create new observational products and will foster the generation of more accurate, route-specific forecasts of road weather conditions. It is anticipated that the Clarus network will improve the safety and mobility of the nation's roadways, and the productivity of operating agencies.

LIST OF FIGURES

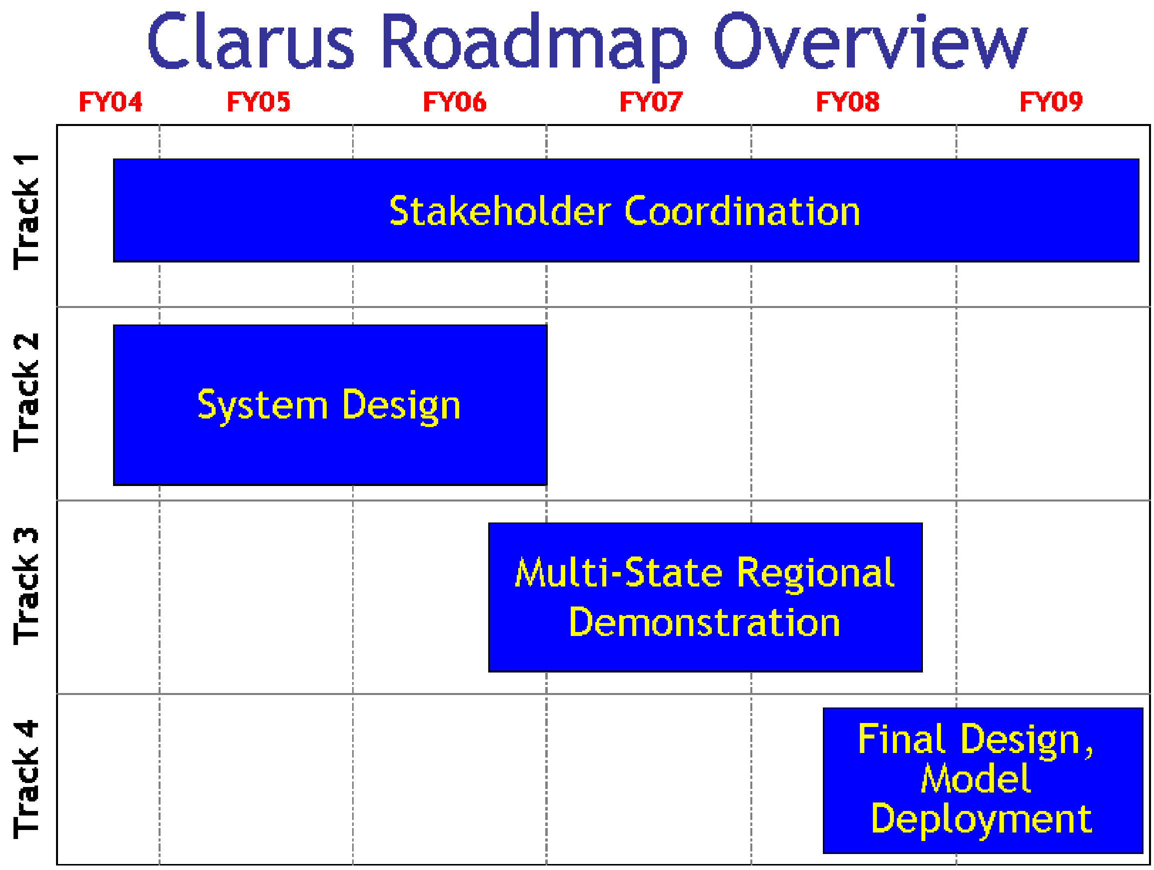

FIGURE 1 The Clarus roadmap.

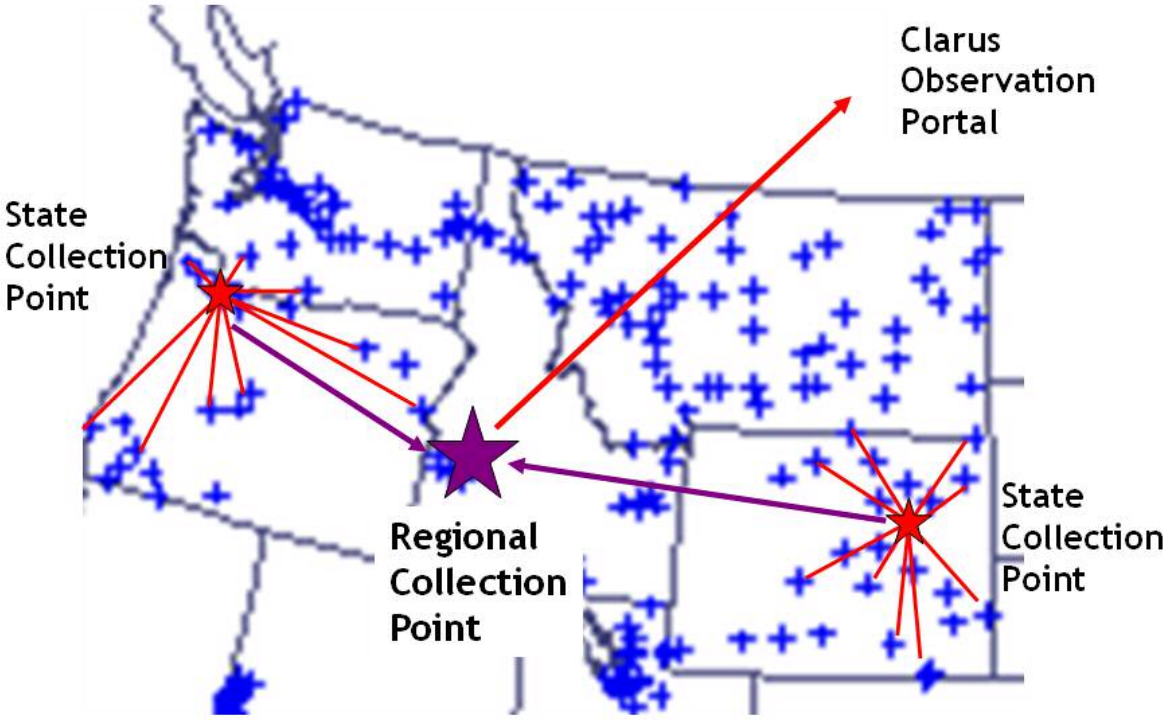

FIGURE 2 Conceptual regional collection network for a observation and forecasting data management system.