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CLARUS – THE NATIONWIDE SURFACE TRANSPORTATION WEATHER OBSERVING AND FORECASTING SYSTEM

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1. INTRODUCTION

For the past several decades, environmental 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 public 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) had to invest in Environmental Sensor Stations (ESS). Most ESS are field components of Road Weather Information Systems (RWIS). These ESS are deployed 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 capabilities. The end result is a mosaic of discrete observation points owned by various public and private entities without interaction with the greater community.

In 2004, the National Academy of Sciences released a report "Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services" describing the need for a robust, integrated observational network and data management system (NRC, 2004). In addition, numerous State DOTs and other practitioners were coming to the same conclusion, as captured in a report prepared under the Aurora and Enterprise pooled fund studies entitled "Road Weather Information Systems (RWIS) Data Integration Guidelines" (Aurora, 2002). The Federal Highway Administration (FHWA) responded with a new initiative called "Clarus—the Nationwide Surface Transportation Weather Observing and Forecasting System." By providing for a robust, integrated observational network and data management system, the Clarus Initiative fulfills the needs of the transportation community as well as other stakeholders such as the National Oceanic and Atmospheric Administration (NOAA) and the private sector.

In addition to the integrated observational network of fixed sensors along roadways, the Clarus initiative will devote resources to investigating 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 advanced road weather information products enabled through the Clarus system design and the suite of forecasting tools within it. This model deployment will serve as the first among several deployments, funded by the stakeholders, to achieve nationwide operations.

2. THE CLARUS INITATIVE

Clarus (which is Latin for "Clear") is a demonstration of a regional road weather

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observing, 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 such as State DOT ESS procurements 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. Deployment and expansion of RWIS 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 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
- Tools to create new surface transportation weather analysis and forecast products

In addition, the Clarus data management system will support the inclusion of new technologies, such as:

- o Vehicle-based sensing technologies
- o Surface visibility and road obscuration information from traffic cameras
- o Remote sensing technologies such as low cost, low power radars

The potential beneficiaries 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 high resolution products (e.g., NOAA's 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, for TV and radio broadcasts, as well as by emergency managers and law enforcement.

3. CLARUS INITIATIVE TRACKS

The Clarus initiative has been structured into four broad tracks (as shown in Figure 1) and are described below in the following subsections. At a high-level, these tracks are:

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

3.1 *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 stakeholder group template will be used for the Clarus initiative, and in this case will be called the Initiative Coordinating Committee (ICC). Similar to the MDSS project, the ICC consists 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) the ICC will be broader, multi-modal, and interdisciplinary. Primary among all of the stakeholders is NOAA because of the breadth of its weather observation and forecasting experience and its congressionally defined responsibilities. Members of the ICC will participate for the duration of the initiative and will meet at least annually.

The ICC kickoff meeting was held in September 2004. Nearly 50 participants traveled to Norman, Oklahoma to learn about near-term plans for the Clarus initiative (ITSA, 2004). An Initiative Management Team was also created to provide leadership, direction and approval for ICC activities. The Initiative Management Team is comprised of personnel from federal agencies such as FHWA and NOAA and from professional societies such as the Institute of Transportation Engineers (ITE), the American Meteorological Society (AMS), ITS America and the American Association of State Highway and Transportation Officials (AASHTO). The professional organizations will bring a mix of meteorological and surface transportation expertise from state and private sector resources.

One of the main functions of the Initiative Management Team is to provide oversight and support to Clarus project task forces. A project task force is a subcommittee of ICC members that meet for a finite amount of time with very specific objectives. During the kickoff meeting, three project task forces were created. These were the User Needs Assessment Review task force, the Use Cases/Application Areas Review task force and the Leveraging Opportunities task force. Results from these subcommittees will have a direct impact on the development of the Clarus concept of operations document.

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 and their anticipated schedules will include:

- A review of the user needs and concept of operations. The ICC will be briefed on the system design and proof-of-concept demonstration (FY 2005 and 2006).
- A review of the overall system design and a briefing 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 initiative 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 observing 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.

3.2 *Track 2: System Design*

The system design for Clarus will begin with a task to develop a requirements document called the concept of operations. At its conclusion, this task will provide a description of the observing and forecasting needs of the stakeholders. It will also examine the requirements for the collection, quality assurance and archiving of the nation's inventory of data from State agency ESS. The concept of operations will also determine the requirements of potential end users and 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. A high level system requirements document will specify the environment and operating state for each phase of the Clarus system implementation including the proof-of-concept demonstration and the multi-state regional demonstration. A detailed system requirements document will be created to describe computer resources and information flows for all functions described in the high level system requirements document. This document will examine all types of information needed by the system and cover all relevant data flows from environmental sensors, flows within the system and flows between the system and end users. Together, the high level system requirements and detailed system requirements documents will contain all functional, performance, organizational, hardware, software, interface and testing requirements.

An architecture analysis and design gap analysis will be conducted to identify technological deficiencies and gaps that may hinder the deployment of the Clarus system or prevent it from obtaining a complete picture of road weather conditions. The design gap analysis report will also document deficiencies associated with communications and central systems (i.e., hardware and software) used to transmit, process and disseminate ESS data to transportation managers, as well as deficiencies in potential commercial-off-the-shelf components and other software. System design documents, including software specifications, will be developed based upon the system requirements documents and results of the architecture and gap analyses.

The proof-of-concept demonstration is expected to take place in FY 2006. Using all of the engineering documentation compiled in this track, the demonstration will involve establishing a limited ESS data collection network to test (or analyze) system performance and characteristics. Lessons learned during the proof-of-concept will be used to correct and enhance the system design.

In addition to the engineering documents and demonstration, 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) (FSL, 2004). 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.

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 demonstrated and tested to ensure that the network design can support the observational data sharing needed to support new forecasting tools.

3.3 *Track 3: Multi-State Regional Demonstration*

Conducting the multi-state regional demonstration will enable the Initiative Management Team and the ICC to evaluate the performance of the Clarus design. The stability of a system design rests on its 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, using forecasts and decision support products enabled through Clarus.

In addition, there will be an evaluation of how output of the Clarus network affects operational decisions that improve roadway mobility and safety as well as agency productivity. Further, 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 vehicle platforms. 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 conditions (e.g., wet, dry, plowed, flooded).
- 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 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.

- Data collection enhancements that will identify any new instrumentation that is needed to fill any observational gaps.

The result of this track is an enhanced 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.

3.4 *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 or private sector organizations to share road weather observation data. The final design will also feature specifications for incorporating data from 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 operational benefits (i.e., improved mobility, safety and productivity) to State DOT personnel and private sector weather information providers and the traveling public. 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 developed. In addition, a network deployment cost estimation tool will be made available.

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

4. 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.

5. 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 Clarus initiative will combine systems engineering techniques, network and software design, emerging technology research, and increasingly complex field demonstrations to produce a plan for the nationwide deployment of advanced road weather observing networks and decision support applications.

The long term vision of the Clarus initiative is far reaching. It includes 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 shares a common format and is easily used in many applications.

State DOTs will be able to deploy new ESS 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.

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.

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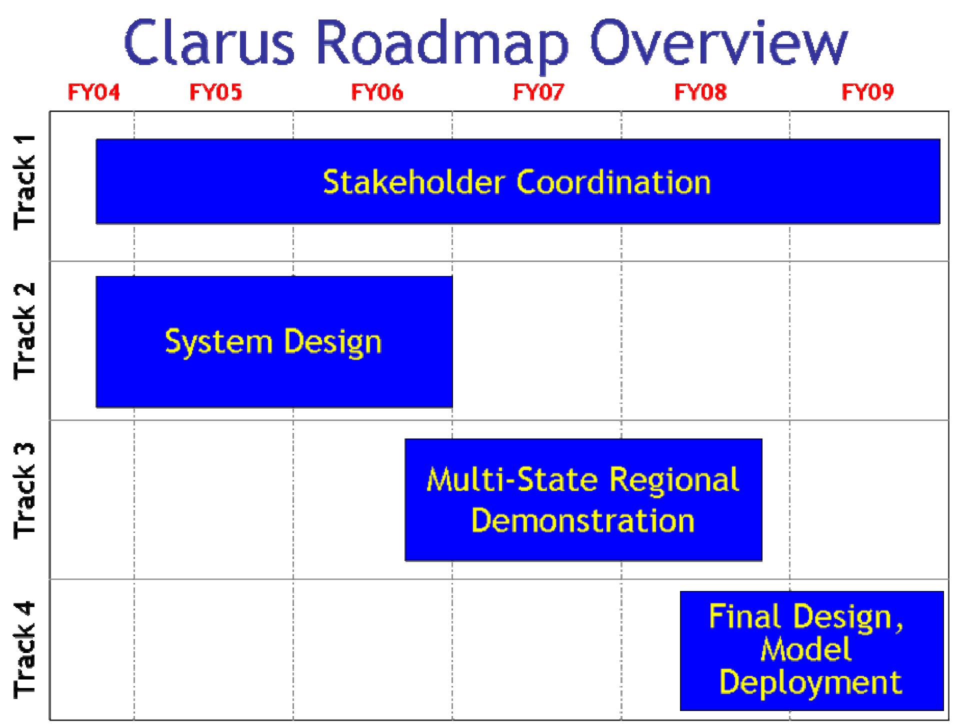

FIGURE 1 The Clarus Initiative roadmap.