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REGIONAL DEMONSTRATIONS OF THE FHWA *CLARUS* SYSTEM

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1. INTRODUCTION

The U.S. Department of Transportation (USDOT) Federal Highway Administration (FHWA) Road Weather Management program, in conjunction with the USDOT Research and Innovative Technology Administration (RITA), Intelligent Transportation Systems (ITS) Joint Program Office established the *Clarus* Initiative in 2004 to reduce the impact of adverse weather conditions on surface transportation users (Pisano, 2007).

Clarus is a research and development initiative to demonstrate and evaluate the value of "Anytime, Anywhere Road Weather Information" that is provided by both the public and private weather enterprise to the breadth of transportation users and operators. The goal of the initiative is to create a robust data assimilation, quality checking, and data dissemination system that can provide near real-time atmospheric and pavement observations from the collective State Departments of Transportation's (DOTs) investments in Road Weather Information Systems (RWIS), Environmental Sensor Stations (ESS). It has been designed to also process mobile observations from Automated Vehicle Location (AVL) equipped trucks and passenger vehicles equipped with transceivers that will participate in the Vehicle Infrastructure Integration (VII) initiative (Stern et al., 2008).

During 2004-2005, the *Clarus* System was designed and constructed in coordination with an extensive stakeholder group comprised of transportation and weather professionals. During 2006, the system was extensively tested during a Proof-of-Concept (PoC) Demonstration utilizing ESS observations from three participating State networks. The system is now ready to be populated and for its data to be utilized by the transportation community and the weather enterprise. To reach this goal, the FHWA has begun a series of regional demonstrations.

The regional demonstrations contain three phases. The first phase involves teams of State DOTs preparing Concept of Operations (ConOps) tailored to their agency's needs for innovative new products and techniques that are enabled by the *Clarus* System. The second phase seeks to build public agency participation in the program by providing grants to State DOTs to connect their RWIS/ESS networks to the *Clarus* System. Finally, the third phase provides an opportunity for the private sector to build and test the concepts that were detailed in the Phase 1 ConOps. This paper will provide details about the phases of the regional demonstrations and provides an outlook for continued development of the *Clarus* System.

2. THE *CLARUS* INITIATIVE

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 observation networks focused their instrumentation, observations, and resulting products in the atmospheric (above ground) domain. Well established research initiatives (such as the Federal Aviation Administration's Aviation Weather Research Program) have contributed to a significant reduction in weather-related plane crashes and the increased meteorological knowledge has resulted in better aviation forecasts and warnings.

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In contrast, the efforts to invest in observations and products focused on the near surface, pavement and subsurface have been inconsistent, less organized, and only modestly funded, mostly via limited State resources. Federal administration of surface observation programs focused on the aviation community and the deployment of runway (ground) sensors at some airports. As a result, State DOTs have had to invest in ESS to obtain near surface atmospheric and pavement observations along their road networks. Most ESS are field components of RWIS. These ESS are deployed along roadways and other transportation facilities to provide their agencies with observations to improve safety and mobility on the nation's roads.

The current challenge is that the available sources of RWIS data are not managed in a manner that enable the development of a comprehensive and coherent picture of weather conditions in the surface transportation domain. Other stakeholder communities outside of transportation, such as agriculture, water management, 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 often without interaction with the greater community.

In 2003, the FHWA approached the National Academies of Science and described the problems and challenges. In 2004, they responded with their landmark report, *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services* (National Academies, 2004). In the report, the National Academies of Science acknowledged the troubling statistics associated with weather-related vehicle fatalities and delays, and recommended that the nation invest in a robust, integrated road weather observational network and database management system. This visionary idea was an impetus for the *Clarus* Initiative.

3. THE *CLARUS* SYSTEM

Clarus, which means "Clear" in Latin, is a data management system for the collection, quality checking, and dissemination of surface transportation-related observations from North America. Figure 1 shows a timeline of the *Clarus* System development process. From 2004 into 2006, the *Clarus* System progressed through a rigorous systems engineering process which extended from ConOps development and requirements gathering to design and implementation. All engineering documents can be found at the *Clarus* Initiative Web site, www.clarusinitiative.org.

One of the most important developmental activities associated with *Clarus* was the creation of a group of interested practitioners who would be used as a resource throughout the Initiative. Coined as the Initiative Coordinating Committee (ICC), this multi-disciplinary group of stakeholders from the public, private, and academic communities across the transportation and weather sectors participated in the requirements gathering process, and served as evaluators of design documents and as members of subject-specific task forces. These task forces dealt with a number of issues ranging from reviewing the foundational ConOps documentation to metadata collection and data dissemination policies.

Once the *Clarus* System was built and operating, a PoC demonstration was held during the fall of 2006 using data from three State DOTs RWIS: Alaska, Minnesota, and Utah. The PoC showed that State DOTs could provide observation data files and site, station, and sensor metadata to the *Clarus* System. The demonstration also showed that each of the processing modules functioned properly allowing for the parsing, caching, quality checking, and dissemination of hundreds of observations.

By the end of 2006, initial development and testing of the *Clarus* System was successfully completed. Its internal memory and database was designed to cache millions of observations for a period of one week. The next steps were to create a Web portal to make interacting with the *Clarus* System easier and to begin populating the database with ESS observations from across the continent.

3.1 The *Clarus* Graphical User Interface

In order to facilitate use of the *Clarus* System and to promote data exploration by both the States and the weather enterprise, a simple graphical user interface (GUI) was developed. The GUI, which can be accessed on the Web at http://clarus.mixonhill.com, provided an easy way to retrieve and visualize the ESS observations. The home page for *Clarus*, shown in Figure 2, provides access to State DOT and Provincial ESS

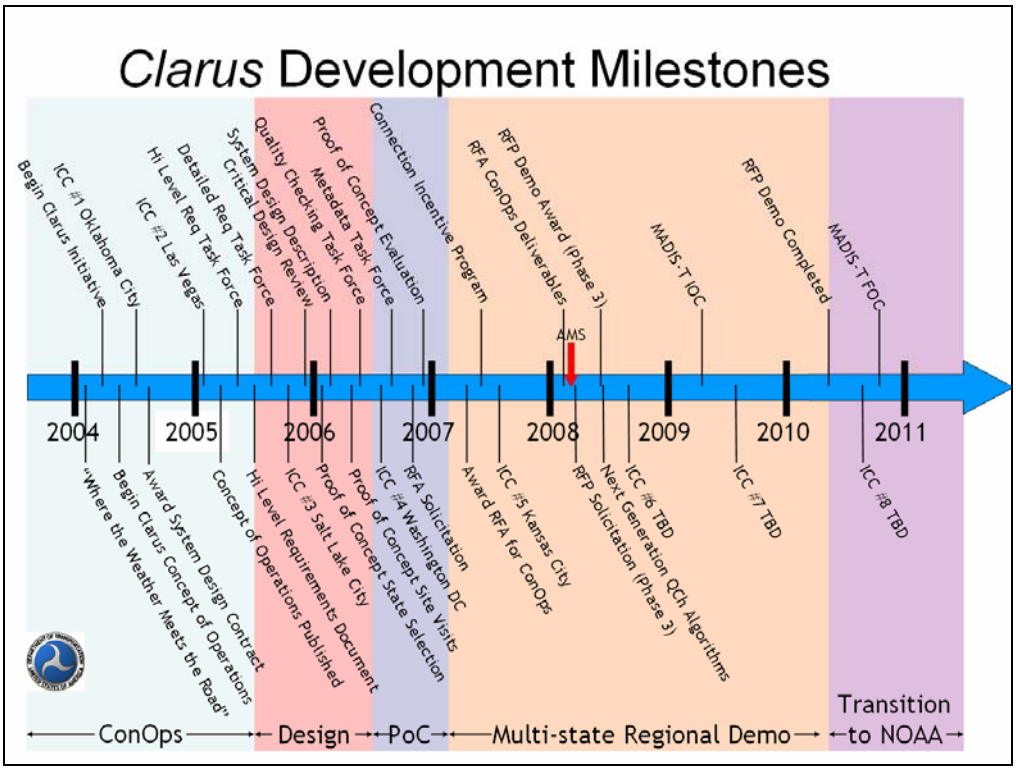


Figure 1. Timeline of the *Clarus* Initiative extending from the vision for the project (from the National Academies of Science study) to the eventual transition to operations. The transition to NOAA may take through 2011 to complete.

Figure 2. Home page for the *Clarus* System can be found at http://clarus.mixonhill.com prior to the transition to NOAA. This Web portal allows access to the Google Maps-based graphical user interface and to the cache for data exploration.

data through links. Once selected, a series of menu-driven queries allows users to access observations from individual stations or entire states, from one point in time to a large time window.

The GUI provides for easy spatial visualization of the ESS data by using Google Maps geo-navigation tools. As an example, Figure 3 displays air temperature data from ESS sites in Minnesota and Wisconsin. The purple “thumb tacks” indicate that current data are available in the system. Gray “thumb tacks” show where the current receipt of data has been interrupted or stopped. This may be an indication of sensor failure or a communications problem.

Quality checking output and location-specific metadata can be easily displayed from the GUI. Figure 4 shows the result of clicking on a purple “thumb tack”. All of the observation fields are shown in a table. Quality checking algorithm titles can be seen along the top. Within the table matrix, green circles represent a quality checking test that passed. A red “X” indicates that the results of the quality checking test were beyond thresholds set within the metadata. Receipt of a failure icon does not necessarily mean that the data or sensors are bad. It does, however, provide an easy way for State DOT ESS administrators or even end users to spot sites that may require additional investigation.

The *Clarus* System also allows for the creation of subscriptions through the GUI. A subscription is a convenience process that can be used primarily with automated data retrieval systems. Once a subscription has been invoked, a selected group of observations will be placed into an open or protected directory at a known time interval. Hence, an external data collection system would be able to retrieve only the most recent observations for a specific time period from one constant Web address.

The GUI is an experimental product that is being used for evaluation and demonstration purposes only. The portal does not provide any value-added information or content. It is expected that external interests in the transportation and weather enterprise will eventually construct a much more sophisticated Web portal. By providing this basic service today, it enables the transportation and weather communities to pursue development of their own Business-to-Business solutions. In addition, the USDOT is funding the development of Business-to-Government solutions through *Clarus* Multi-state Regional Demonstrations.

4. *CLARUS* MULTI-STATE REGIONAL DEMONSTRATIONS

During the second half of 2006, as the *Clarus* System was undergoing its PoC demonstration and evaluation, the FHWA introduced to the stakeholder community a series of activities which are called the *Clarus* Multi-state Regional Demonstrations. Through the demonstrations, FHWA aims to achieve the following objectives:

1. Demonstrate that the *Clarus* System functions as designed by incentivizing a large number of State and local agencies to contribute data from their ESS networks;
2. Enable proactive transportation system management through utilization of the *Clarus* System; and,
3. Provide an environment so that the private sector and academic organizations can create innovative and improved products that will benefit the public, academia, and the entire weather enterprise.

The *Clarus* Multi-state Regional Demonstrations contain three distinct phases. The phases are:

- Phase 1: Concept of Operations development;
- Phase 2: Connection Incentive Program; and,
- Phase 3: Application Development and Deployment.

4.1 Phase 1 – Concept of Operations Development

The first phase of the regional demonstrations was initiated in 2006 and is scheduled for completion in January, 2008. In this phase, groups of State DOTs (or Provincial transportation ministries) were given the opportunity to form teams along a common corridor (such as an Interstate highway). The teams would need to develop a ConOps of Business-to-Government solutions which were enabled by utilization of the *Clarus* System. The ConOps could describe any number of innovative new products, services, algorithms, or systems which would improve surface transportation safety, mobility, or productivity.

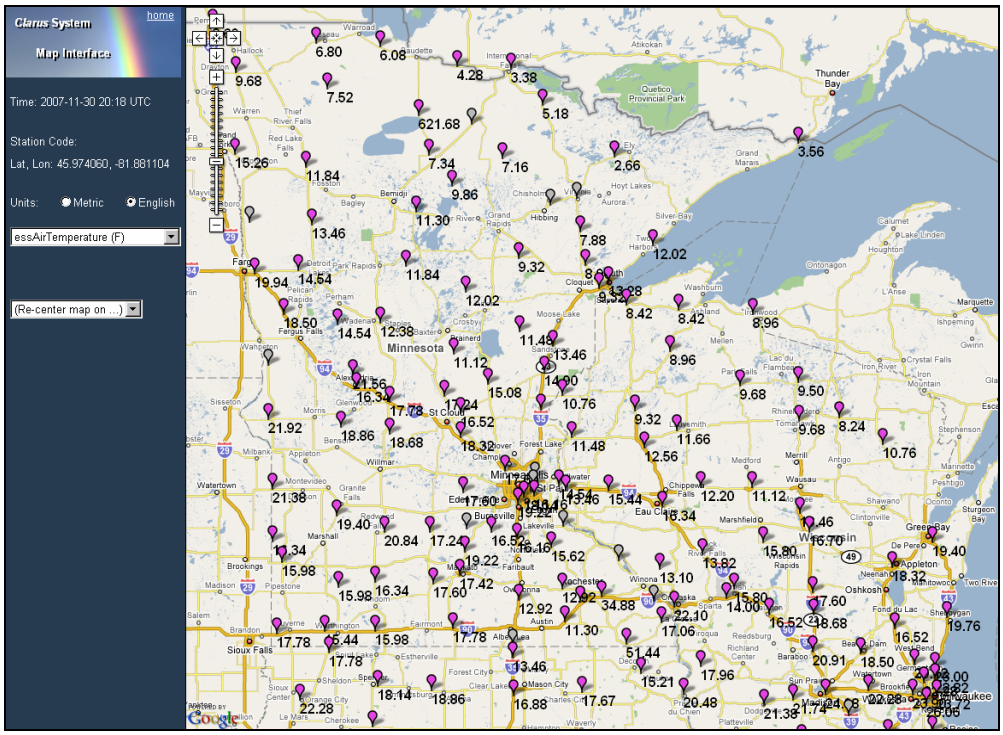
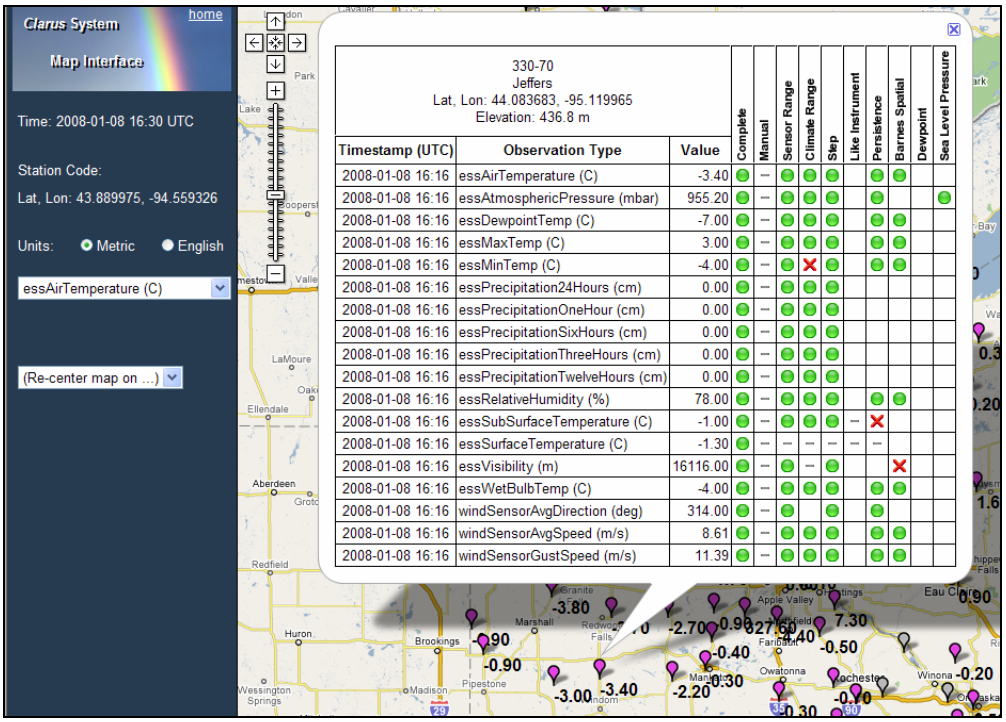


Figure 3. A *Clarus* display using Google Maps as the display tool. In this example, air temperature data from Minnesota DOT and Wisconsin DOT ESS are shown in degrees Fahrenheit.



Timestamp (UTC)	Observation Type	Value	Complete	Manual	Sensor Range	Climate Range	Step	Like Instrument	Persistence	Barnes Spatial	Dewpoint	Sea Level Pressure
2008-01-08 16:16	essAirTemperature (C)	-3.40	●	–	●	●	●		●	●		
2008-01-08 16:16	essAtmosphericPressure (mbar)	955.20	●	–	●	●	●		●			●
2008-01-08 16:16	essDewpointTemp (C)	-7.00	●	–	●	●	●		●	●		
2008-01-08 16:16	essMaxTemp (C)	3.00	●	–	●	●	●		●	●		
2008-01-08 16:16	essMinTemp (C)	-4.00	●	–	●	✕	●		●	●		
2008-01-08 16:16	essPrecipitation24Hours (cm)	0.00	●	–	●	●	●					
2008-01-08 16:16	essPrecipitationOneHour (cm)	0.00	●	–	●	●	●					
2008-01-08 16:16	essPrecipitationSixHours (cm)	0.00	●	–	●	●	●					
2008-01-08 16:16	essPrecipitationThreeHours (cm)	0.00	●	–	●	●	●					
2008-01-08 16:16	essPrecipitationTwelveHours (cm)	0.00	●	–	●	●	●					
2008-01-08 16:16	essRelativeHumidity (%)	78.00	●	–	●	●	●		●	●		
2008-01-08 16:16	essSubSurfaceTemperature (C)	-1.00	●	–	●	●	●	–	✕			
2008-01-08 16:16	essSurfaceTemperature (C)	-1.30	●	–	–	–	–	–	–			
2008-01-08 16:16	essVisibility (m)	16116.00	●	–	●	–	●			✕		
2008-01-08 16:16	essWetBulbTemp (C)	-4.00	●	–	●	●	●		●	●		
2008-01-08 16:16	windSensorAvgDirection (deg)	314.00	●	–	●		●		●			
2008-01-08 16:16	windSensorAvgSpeed (m/s)	8.61	●	–	●	●	●		●	●		
2008-01-08 16:16	windSensorGustSpeed (m/s)	11.39	●	–	●	●	●		●	●		

Figure 4. The graphical user interface allows users of the *Clarus* System to monitor the results of the quality checking tests. In this example, the test names are shown vertically along the top of the displayed table. Test results are shown as green circles (passed), red X's (failed), dashes (test available, but not run), and white space (not scheduled to run for this observation type). A failed result may mean that a sensor is bad, or it could mean that there are metadata threshold problems or communications issues.

During late 2006, the FHWA issued a Request for Applications (RFA) from public transportation agencies to develop the ConOps. In early 2007, three teams of transportation agencies were selected for participation in the regional demonstrations. These groups were:

- Group 1: Northwest Passage. This team consisted of State DOTs along the I-90/I-94 corridor extending from Wisconsin through Washington State including Minnesota, North Dakota, South Dakota, Wyoming, Montana, and Idaho.
- Group 2: ALCAN (Alaska-Canada). This team consisted of the Alaska DOT and Public Facilities and Environment Canada representing the Provincial transportation ministries in Yukon, British Columbia, and Alberta.
- Group 3: Aurora Consortium. This team consisted of Aurora members along the I-80 corridor extending from Iowa through Ohio including Illinois and Indiana.

ConOps documents from each of the groups were delivered to FHWA in January 2008. The use and disposition of the ConOps is explained below in the third phase of the regional demonstrations.

The second part of the first phase of the regional demonstrations promoted the population of the *Clarus* System with transportation agency ESS observations and metadata by the successful RFA awardees.

4.2 Phase 2 – Connection Incentive Program

The second phase of the *Clarus* Multi-state Regional Demonstrations is the Connection Incentive Program (CIP). The objectives of the CIP are to both incentivize public transportation agencies into providing their ESS data (observations and metadata) to the *Clarus* System and to provide financial assistance to agencies to help offset some of the expenses associated with connecting to the *Clarus* System. The latest information and an application to participate in the CIP can be found at http://www.clarusinitiative.org/ConnectionProgram.htm.

Funding has been set up to be streamlined in the form of federal grants to State DOTs. Funding can be used to offset travel expenses to each ESS for the purpose of collecting and organizing site and sensor metadata. In order to contribute ESS data to *Clarus*, a certain amount of metadata must be obtained and entered into the System. Specifics about required and optional metadata fields can be found on the *Clarus* Initiative Web site at www.clarusinitiative.org/documents.htm under “Metadata Dictionary.”

Grant funds can also be used to procure hardware such as handheld GPS units or digital cameras to aid in collecting and documenting site metadata. Funding can also be used to acquire a consultant to compile climate metadata or to have software developed to put ESS observations into a standard format (such as comma separated value (CSV) or eXtensible markup language (XML)).

Under the streamlined application process, transportation agencies need only create a technical plan and a financial plan. The technical plan affirms the agency’s eligibility to receive the funds and provides details about their ESS network. The financial plan provides expenditure details and includes information about the required 20 percent State match. Funds cannot be used to purchase new ESS sensors. The CIP will be available through the end of USDOT’s fiscal year 2008.

4.3 Phase 3 – Application Development and Deployment

The third phase of the *Clarus* Multi-state Regional Demonstrations involves implementation of innovations that were described in Phase 1 ConOps documents. Each ConOps will undergo an internal evaluation at FHWA. Each concept within a ConOps will be evaluated based upon the following criteria:

- Strengths and weaknesses
- Similarities (with other proposals)
- The probability of successful completion
- The potential business model

At the time this paper was written, the plan is to post a Request for Proposals (RFP) in late winter/early spring of 2008 for members of the transportation and weather communities to implement selected “concepts” within the ConOps documents. The successful awardee(s) will be given 24 months to work on implementation details which include utilization of a full systems engineering process.

In addition to implementation activities, participants in Phase 3 will take part in an

independent evaluation of the *Clarus* System and the services it enables.

5. *CLARUS* TRANSITION TO OPERATIONS

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) has been very interested in the *Clarus* Initiative since its inception. They are working on creating a new operational processing system that collects, quality controls, and disseminates observations from a diverse set of platforms ranging from space-based (satellite data) to remotely sensed data (e.g., from radar, sounders, balloons, aircraft, etc).

Observations from the surface, which includes airport automated systems and transportation ESS are also planned for inclusion. The transition from *Clarus* to the NWS operational system is expected to occur into 2011.

6. SUMMARY

The Road Weather Management program of the Federal Highway Administration has been working on developing, testing, and populating the *Clarus* System. *Clarus*, which is Latin for "Clear", is a data management system for all public transportation agency (U.S. and Canada) surface transportation-related weather observations. This paper has provided a brief history on the life cycle development of the *Clarus* System and its evaluations. Access to the *Clarus* Web portal can be found at http://clarus.mixonhill.com.

The *Clarus* System is currently being populated through the use of regional demonstrations and incentivizing programs. There are three phases of the *Clarus* Multi-state Regional Demonstrations. The first phase involved the creation of Concepts of Operations (ConOps) documents whose purpose was to explore potential Business-to-Government solutions that will be enabled through use of the *Clarus* System. The second phase is a Connection Incentive Program (CIP) which provides some funds to State Departments of Transportation to ease connection issues with the *Clarus* System. One example on the use of CIP funds includes expenses associated with the collection and organization of metadata. The third phase of the regional demonstrations involves the evaluation of the ConOps created within the first phase, and the implementation of one or more concepts presented within these documents. A Request for Proposals associated with the third phase is expected to be posted during the late winter or early spring of 2008.

The latest documentation on the *Clarus* Initiative can be found at the program Web site, www.clarusinitiative.org.

7. REFERENCES

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