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THE *CLARUS* REGIONAL DEMONSTRATIONS

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1. INTRODUCTION

Imagine having a single Web portal where all public surface transportation weather observations are collected, quality checked and made available to the transportation/weather enterprise. Through several years of investing in system design, implementation and testing, the *Clarus* System is operating in an experimental mode and is being populated with Environmental Sensor Station (ESS) observations from State, municipal and Provincial transportation agencies from across North America.

Clarus, which means "Clear" in Latin, is the U.S. Department of Transportation's (USDOT) ESS data management system. The *Clarus* System uses state of the art algorithms to quality check atmospheric and pavement observations from both fixed and mobile platforms. Data contributors can receive information on the health of their ESS networks as well as the calibration of their sensors. Data users can receive a full suite of observations, quality checking flags and metadata information.

As part of the developmental process of the *Clarus* System, the USDOT began a multi-phased regional demonstration in 2007. The first phase included having teams of State and Provincial Departments of Transportation (DOT) provide concepts for new products and services which would use *Clarus* data to support and enhance DOT operations. The second phase involved recruiting public transportation agencies to join the *Clarus* community.

The third phase began during the summer of 2008. At that time, a request for proposals (RFP) was issued to the weather enterprise. Using ideas which originated within the first regional demonstration phase, five different use cases were presented to foster new products, algorithms, decision support tools and innovations that use *Clarus* data and support transportation operations. This paper will provide details about both the original regional demonstration use cases as well as those innovations that will be implemented as a result of awards from the RFP.

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2. BACKGROUND

Each year on average, 7,400 people are killed in fatal crashes during adverse weather conditions in the United States. In 2003, the USDOT/Federal Highway Administration (FHWA) approached the National Academies of Science (NAS) and described the problems and challenges associated with forecasting road weather conditions. In 2004, they responded with their landmark report, *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services* (National Academies of Science, 2004). In this report, the NAS acknowledged the troubling statistics associated with adverse 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 the impetus for the *Clarus* Initiative.

Clarus is intended to facilitate and improve the value of 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 public Departments of Transportation's investments in Road Weather Information Systems (RWIS), Environmental Sensor Stations (ESS).

This paper is a continuation of a series of publications which are intended to document the progress of USDOT initiatives as well as update both the weather and transportation communities on a project of mutual interest. A discussion of plans and a layout for the *Clarus* Initiative was first published in Pisano, 2005. This paper provides the vision and estimated timeline for the development, testing and deployment of the *Clarus* System. Pisano, Pol et al, 2006 discussed the Concept of Operations document for the Initiative and the proof of concept demonstration that followed the implementation of the prototype. Stern, 2008 provided a technical discussion about creating a new generation of quality checking algorithms for both atmospheric and pavement data within *Clarus*. Finally, Pisano, 2007 and 2008 provided a roadmap toward having the weather enterprise innovate using *Clarus* System data to benefit public transportation agency operations through regional demonstrations.

3. *CLARUS* REGIONAL DEMONSTRATIONS

The *Clarus* Regional Demonstrations are focused on building partnerships between the private sector and the transportation agencies. It is believed that this relationship will help the weather enterprise create new and improved Business-to-Government or Business-to-Traveler innovations based upon the actual needs of the users. To be eligible to participate in the USDOT-sponsored *Clarus* Regional Demonstrations, private sector participants must have shown expertise in surface transportation meteorology, systems engineering and an understanding of transportation agency operational practices.

During 2007, three teams of public transportation agencies were asked to draft Concepts of Operations for new products and services which would both enhance their operations and be enabled through the availability and use of *Clarus* data (Figure 1). A RFP based on the contents of these documents was posted during the summer of 2008 on the FedBizOpps website (www.fbo.gov). In all, five use cases were proposed. These included:

- **Use Case 1: "Enhanced Road Weather Forecasting Enabled by *Clarus*."** This use case is focused on raising the state of the science for surface transportation meteorology. Innovations can focus on the road pavement or on the lower atmosphere to create new or improved observing or forecasting capabilities.
- **Use Case 2: "Seasonal Weight Restriction Decision Support Tool."** This use case focuses on the availability of pavement and subsurface temperature data within *Clarus*. This information could be used, along with historical data and forecasts to provide weight restriction recommendations during critical freeze/thaw periods.
- **Use Case 3: "Non-winter Maintenance and Operations Decision Support Tool."** This use case seeks to expand the capabilities of the successful winter Maintenance Decision Support System (Pisano, Huft et al, 2006) to include year round activities to support traffic flow, mobility and construction-related scheduling decisions.
- **Use Case 4: "Multi-state Control Strategy Tool."** This use case focuses on improving intra and interstate coordination during adverse weather and evacuations by creating a new data management system. This system would include *Clarus* and road condition data which supports control strategies across multiple jurisdictions.
- **Use Case 5: "Enhanced Road Weather Content for Traveler Advisories."** This use case focuses on improving content for traveler information and advisories and provides a warehouse of traveler information which includes *Clarus*-based observations and route-specific weather and road forecasts.

The regional demonstration awards are for a period of two years, which includes one year of research and development, and one year of implementation and evaluation with partnering public transportation agencies and teams of independent evaluators. In total, two awards were presented in October 2008. The contracts were awarded to:

- **Meridian Environmental Technology, Inc.** of Grand Forks, ND with
  - University of North Dakota (UND) Surface Transportation Weather Research Center (STWRC),
  - Iteris, Inc., and
  - DOT partners from the states of Idaho, Minnesota, Montana, North Dakota and South Dakota

- **Mixon/Hill, Inc.**, of Overland Park, KS with
  - National Center for Atmospheric Research (NCAR),
  - Nortel Government Solutions,
  - KMJ Consulting,
  - Athey Creek Consultants, and
  - DOT partners from the states of Illinois, Indiana and Iowa

Both prime contractors have been involved in the design and development of the *Clarus* System. Meridian created the initiative Concept of Operations document. Mixon/Hill engineered, implemented and maintains the prototype system. Figure 2 graphically depicts the developers and their State DOT partners. The public agencies will work with and provide feedback on the new innovations.

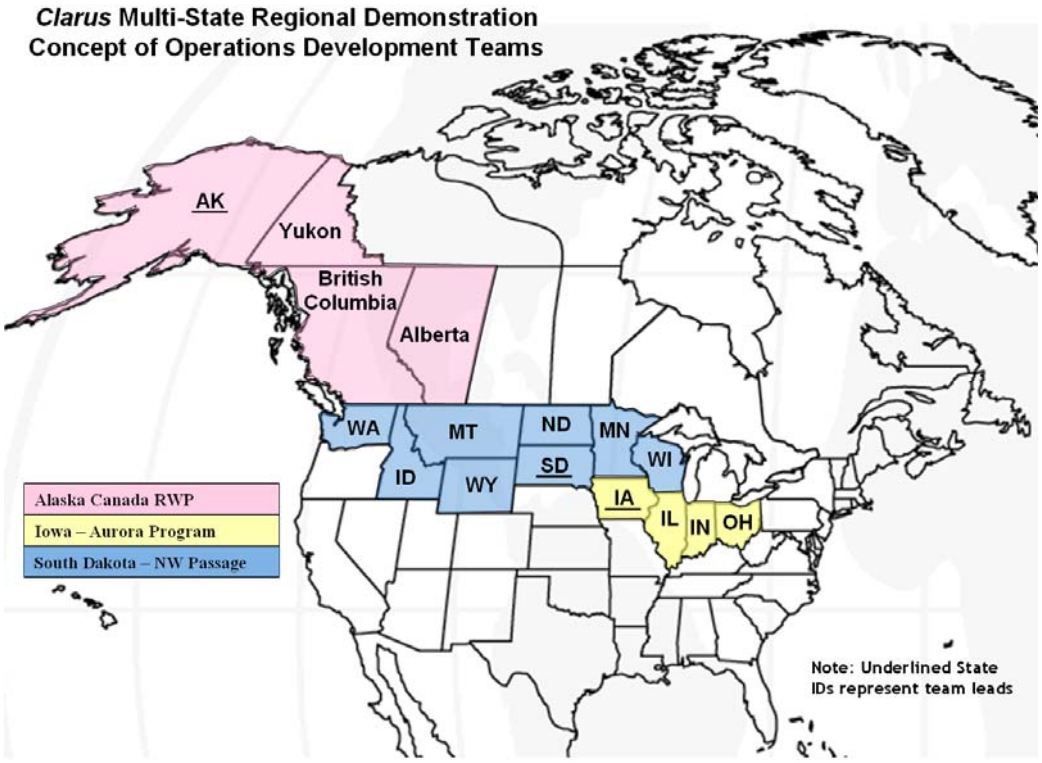

Figure 1 – The *Clarus* Regional Demonstration teams which developed the Phase 1 Concept of Operations Documents

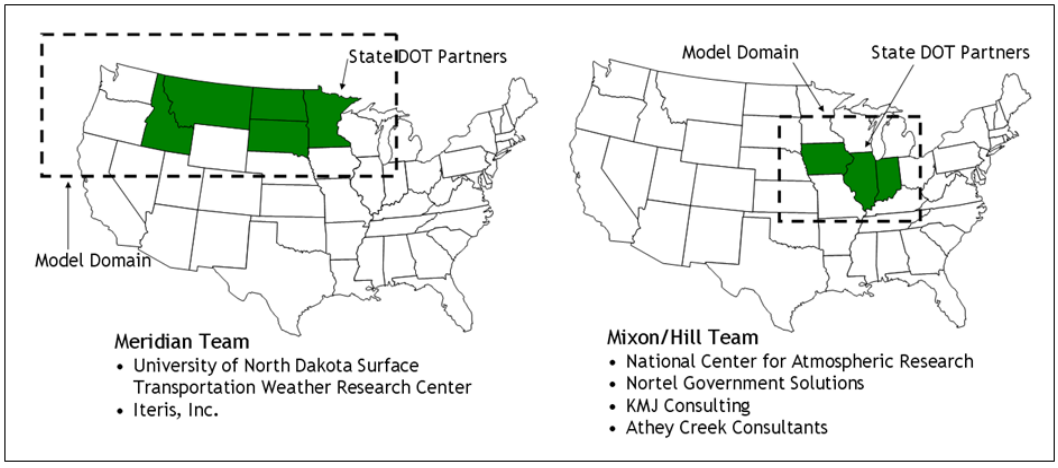

Figure 2 – The *Clarus* Regional Demonstration teams who were awarded contracts to implement new innovations utilizing *Clarus* data.

Both teams submitted proposals to implement new tools and products based upon the use cases described within the RFP. Use case 1 provides the scientific foundation from which all of the other use cases will be implemented. Hence, both teams will build innovations for use case 1. The remaining four use cases were split among the development teams. The Meridian team will implement use case 2 (Seasonal Weight Restriction Tool) and use case 5 (Enhanced Road Weather Content for Traveler Advisories). The Mixon/Hill team will implement use case 3 (Non-winter Maintenance and Operations Decision Support Tool) and use case 4 (Multi-state Control Strategy Tool). The following sections provide high level descriptions of each team's plans.

3.1 Meridian Team Implementation

Use Case 1 – "Enhanced Road Weather Forecasting Enabled by *Clarus*"

The Meridian team is taking a multifaceted approach in use case 1, and will be leveraging several ongoing projects to create improved capabilities for surface transportation weather. Their goal is to utilize *Clarus* data to construct a more detailed and representative analysis of current meteorological conditions along highways. *Clarus* data will play an important role in improving the resolution of their meteorological analysis, provide ground truth validation and be used as an input for numerical weather prediction models.

Their first innovation will be to improve upon a system that is being developed by the UND/STWRC which is used to estimate the occurrence and accumulation of freezing and frozen precipitation on road surfaces. This system uses data from a number of in situ and remote sensing platforms such as Doppler radar, weather satellites, upper air soundings and surface weather observations. *Clarus*-based atmospheric and pavement observations will be used both as input into the system as well as to validate its forecasts. Output from this system will be used as input to the Local Analysis and Prediction System (LAPS) where *Clarus* data will provide an improved surface analysis of precipitation parameters along roads.

The LAPS analysis field will be used to initialize mesoscale weather prediction models and will also be used to forward-correct forecasts made from these models. The team will use the Advanced Weather Research and Forecasting Model (WRF ARW) over a demonstration region of several coincident states (domain shown in Figure 2). Road weather forecasts will be constructed through a combination of mesoscale model output and subjective adjustments from team meteorologists.

The Meridian team will also develop a validation monitor to provide support and traceability within a road weather forecasting environment and to promote forecasting decision support activities. *Clarus* data will also be used to improve the forecasting of blowing snow and pavement condition modeling through the prediction of snow mass flux potential along highways.

It is hypothesized that the use of data from the *Clarus* system will improve the spectrum of surface transportation meteorology by providing more ground truth of both the atmosphere and pavement conditions, by creating more realistic analysis and initialization fields and improving forecasts both through validation and forward correction techniques.

Use Case 2 – "Seasonal Weight Restriction Decision Support Tool"

There are many locations across the northern tier of the country and in Alaska where the permafrost provides a firm foundation for roadbeds which allows for the safe traversal of large or loaded trucks without causing damage to the infrastructure. However, toward the end of the winter season or during significant freeze/thaw cycles, there may be times when the permafrost begins to thaw. Under these conditions, heavy vehicles may cause damage to road surfaces or the roadbed (Figure 3). Departments of transportation must monitor these conditions and be able to issue weight restriction advisories for heavy vehicles to avoid this damage. The seasonal weight restriction support tool will combine *Clarus*-based pavement and subsurface observations with advanced pavement temperature models to provide DOTs with improved decision support.

The proposed seasonal weight restriction decision support tool will incorporate the improved weather prediction and sub-pavement temperature prediction capabilities from use case 1 to provide an effective platform to assist state agencies in the determination of appropriate times when to impose and remove seasonal weight restrictions. A seasonal weight restriction prediction system developed by the UND/STWRC for use in North Dakota will be

expanded and improved for use and evaluation in both South Dakota and Montana.

The Meridian team will integrate each state's rules of practice, policies and guidelines with the seasonal weight restriction tool so that the recommendations can be customized for each jurisdiction. The result of this integration will yield a state-specific decision support system which will be installed within an operations facility at each partnering state agency (Meridian Environmental Technology, 2008).

Figure 3 – Road damage caused by frost heave (Credit: Washington State DOT)

Use Case 5 - "Enhanced Road Weather Content for Traveler Advisories"
The availability of traveler information varies across the nation, and in some cases can be quite different within one state. Its availability can be spotty and information may not be current. In addition, it is rare that anticipated road conditions are provided to travelers due to the critical time and space variations of these conditions. This use case will utilize the improved surface transportation weather capabilities created in use case 1 and the availability of near real-time observations available within the *Clarus* System to demonstrate enhanced road weather content for traveler advisories.

In this use case, the Meridian team will demonstrate a fine spatial resolution road condition prediction capability which will generate value-added enhanced pavement condition information for travelers. In particular, this capability will be of interest to those making travel plans when pavement and travel conditions could be variable. Particular attention will be placed on the most effective use of the existing 511 traveler information systems which are in use by each of the five participating states.

This use case does not propose to change the framework of existing traveler information systems. Instead, it is intended to enhance the pooling of informational resources already in use and improve its accessibility and content by each state's service provider for improved data, advisory and forecast delivery over the width of a corridor. This includes interstate, route-specific weather forecast information, road condition data, and the ability to provide actual atmospheric and pavement conditions and advisories enabled through use of the *Clarus* System.

The traveler advisory information will be aggregated across state boundaries to provide methods for extending the use of the information to travelers crossing state borders and to improve the total trip planning process.

3.2 Mixon/Hill Team Implementation

Use Case 1 - "Enhanced Road Weather Forecasting Enabled by *Clarus*"
Similar to activities proposed by the Meridian team, the Mixon/Hill team will utilize *Clarus* data within cutting edge numerical models and assimilation techniques to improve forecasts for surface transportation meteorology. The Mixon/Hill team will also utilize the Weather Research and Forecasting (WRF) model in this task. However, building upon NCAR's experience with cutting edge data assimilation routines, *Clarus* data will be used as input into their Real-time Four Dimensional Data Assimilation system to create improved road weather forecasts.

NCAR will perform a parametric study to determine the best mix of model physics packages and system configurations to optimize the numerical weather prediction system for road weather applications. Then, five actual weather cases will be analyzed in detail running the prediction system with and without *Clarus* data and its quality checking flags. Validation of the output will be performed using nearby airport observations.

An investigation will be performed to optimize the prediction of several parameters that are very important to surface transportation weather forecasting. These are the prediction of solar insolation, cloud cover, precipitation type and amount, air temperature, wind speed and direction, and relative humidity.

Utilizing NCAR's Road Weather Forecast System (RWFS) component of the Maintenance Decision Support System (MDSS) and the Model of the Environment and Temperature of the Roads (METRo) pavement model, advanced statistical post-processing techniques will be used to optimize the pavement condition predictions.

Use Case 3 - "Non-winter Maintenance and Operations Decision Support Tool"
The Mixon/Hill team will leverage the tools, approaches, and lessons learned during the creation and field testing of the winter MDSS prototype which was developed under contract to USDOT. This effort will take the base functionality of MDSS and expand its capabilities to provide recommendations for non-winter maintenance operations.

The focus for this improved decision support tool will be maintenance and construction operations. These tools will have the capacity to supply guidance across a wide range of activities. For instance, applications will be created to provide weather-related recommendations for pavement striping, pavement preservation (including crack sealing, pothole repairs, and pavement overlays), vegetation management, and mowing. Each one of these activities is sensitive to different aspects of the weather (Mixon/Hill, 2008).

The new tool will also use *Clarus*-enabled ESS data from applicable sensor sites in near real-time as input to the decision support tools. Heuristics will be developed for selected non-winter maintenance and traffic management activities based on the established rules of practice within each of the participating state transportation agencies. In turn, the team will develop algorithms that present specific guidance to the users in terms of scheduling maintenance and construction activities based on forecast weather and road conditions.

Use Case 4 – "Multi-state Control Strategy Tool"
Today, interstate coordination among transportation agencies can be less than efficient, if they even take place at all. And, actions performed in one state (e.g., closing a major road) may cause significant backups or disruptions in neighboring states or jurisdictions. The creation of a multi-state control strategy tool will be used to improve this coordination and provide much more multi-jurisdictional information on weather and pavement conditions and control activities implemented by DOTs.

It is envisioned that the following information will be sent to a new data management system:

- Enhanced road weather forecasting capabilities developed in use case 1, based on the RWFS and METRo systems which will generate weather and road condition forecasts
- *Clarus*-enabled ESS data from sensor sites across the upper Midwest will be made available in near real-time
- Other relevant transportation datasets will be sent from the originating agency. This may include data on active restrictions or road closures in the participating states; information on major incidents and delays; or active construction and maintenance activities

The decision support module will be developed to provide two distinct capabilities. First, the tool will provide heuristics and logic based on an individual agency's rules of practice. For example, weather and road condition forecasts together with *Clarus*-enabled near real-time ESS data will be used in rules to determine if tire controls should be implemented under freezing roadway conditions; roads closed under flood conditions; or bridges closed to high-profile vehicles under high wind conditions. Once an agency implements a closure or restriction, an alert will be pushed to the other participating agencies through the Multi-State Control Strategy Tool.

The second capability in the decision support module will provide guidance to a participating agency based on closure and restriction decisions that have been made in neighboring states. This decision process will allow a state to make their own closure or restriction decisions based on the impacts of events, conditions, and decisions in neighboring states, as well as regional weather and road conditions and forecasts. These decisions will also take into account other transportation datasets that reside in the data management system, such as the location and duration of incidents or work zones, so that a more comprehensive decision making process considering multi-state impacts on the transportation network can be undertaken.

4. REGIONAL DEMONSTRATION EVALUATIONS

The USDOT plans on having two teams perform independent evaluations of these innovations. The first team will have significant expertise in atmospheric science and numerical prediction and will focus on the scientific improvements made for surface transportation meteorology through innovations from use case 1. Their evaluation report will seek to quantify improvements to any aspect of atmospheric or pavement forecasting through use of validation data sets and data denial experiments.

The second team will focus less on the science and more on how the innovations may improve operations within DOTs and on the roads. This part of the evaluation will attempt to document the quantitative (tangible) benefits of using *Clarus*-enabled services, with a lesser focus on identifying the qualitative (intangible) benefits. This evaluation will provide quality system impact data in such areas as productivity, mobility, and customer satisfaction along with qualitative documentation as to how the projects were completed successfully.

At the conclusion of the *Clarus* Regional Demonstrations, the development teams, along with their DOT agency partners will demonstrate each of the innovations to the USDOT. The independent evaluation teams will then provide their results and a summary of lessons learned.

5. CONCLUSION

Following a recommendation from a 2004 National Academies of Science report, the U.S. Department of Transportation (USDOT) created the *Clarus* Initiative. *Clarus*, which means “clear” in Latin, is data management system for surface transportation weather observations. The *Clarus* System uses state of the art algorithms to quality check atmospheric and pavement observations from both fixed and mobile platforms. Data contributors can receive information on the health of their ESS networks as well as the calibration of their sensors. Data users can receive a full suite of observations, quality checking flags and metadata information.

As part of the developmental process of the *Clarus* System, the USDOT is conducting a multi-phased regional demonstration. Two teams were selected to engineer and implement new innovations (e.g., products, techniques, decision support tools, etc). Each team will be given one year to design and build their innovations. During the second year of their contract, partnering public transportation agencies will use the new or improved products and provide feedback on their utility. At the end of the two year period, the teams will present their innovations and testimonials to USDOT.

Two independent teams will evaluate the new products. One team will focus on the scientific value or benefits that may result from the improvements made for surface transportation meteorology. The second team will focus on how the innovations may improve operations within the public agencies.

It is hoped that at the conclusion of the *Clarus* Regional Demonstrations, the nation will have a valuable resource to aid the public sector in operational decision-making, to provide the academic sector with a consolidated and quality checked data source, and to provide the private sector with near real-time data that translates into higher impact products and services.

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