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FHWA's Clarus Initiative: Concept of Operations and Associated Research

Paul A. Pisano* and James S. Pol
Federal Highway Administration, Washington, D.C.

Lynette C. Goodwin and Andrew D. Stern
Mitretek Systems, Inc., Falls Church, VA

1. INTRODUCTION

In 2004, the National Academy of Sciences, Board on Atmospheric Sciences and Climate (BASC) completed a visionary document that highlighted an important bridge between the meteorology and surface transportation communities with their report, "Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services" (National Academies, 2004). A key recommendation of this report highlighted the need for a nationwide resource to better utilize surface transportation weather observations that would ultimately provide a more concise picture of current conditions on the surface transportation system (at the driver's level and below) and to energize efforts to improve forecasting for the roadway environment.

Soon after the BASC report was released, the Federal Highway Administration's (FHWA) Office of Transportation Operations and Intelligent Transportation Systems (ITS) Joint Program Office (JPO) created the concept for a nationwide surface transportation weather observing system. Rather than imposing another difficult project acronym on the community, the term "*Clarus*" (which means "Clear" in Latin) was selected as the official name for the initiative.

In its purest form, *Clarus* is envisioned to be a 'system of systems'; the regional or nationwide collection of all state-funded surface transportation-related observations (atmospheric, road surface and hydrologic) into a single or distributed database. It is an exercise in requirements gathering, systems engineering, communications, and database design across a wide spectrum ranging from federal and state agencies to academia and private sector weather service providers. The transportation-related services supported by *Clarus* are captured in seven different scenarios in the Concept of Operations (DOT, FHWA, 2005). All *Clarus*-related documents can be accessed at the *Clarus* Initiative Web site (www.clarusinitiative.org).

**Corresponding author address*: Paul A. Pisano, U.S. Federal Highway Administration, HOTO-1 Room 3408, Road Weather Management Program, 400 7th Street, S.W. Washington, DC 20590
Email: paul.pisano@fhwa.dot.gov

2. CONCEPT OF OPERATIONS

The *Clarus* Concept of Operations includes a representative set of functional scenarios to help define the needs for the *Clarus* system design. Each scenario consists of a detailed description, use case diagrams and sequence diagrams. The seven scenarios include:

- Roadway maintenance and construction operations
- Traffic operations
- Traveler information
- Transit management
- Emergency management and public safety
- Rail operations management
- Commercial vehicle operations

The *Clarus* system must be able to satisfy the operational requirements within these diverse communities. The technique used to evaluate the commonalities and unique requirements of the various user communities is through the use of use case and sequence diagrams. Figure 1 shows the *Clarus System* Framework Use Case Diagram as included within the Concept of Operations.

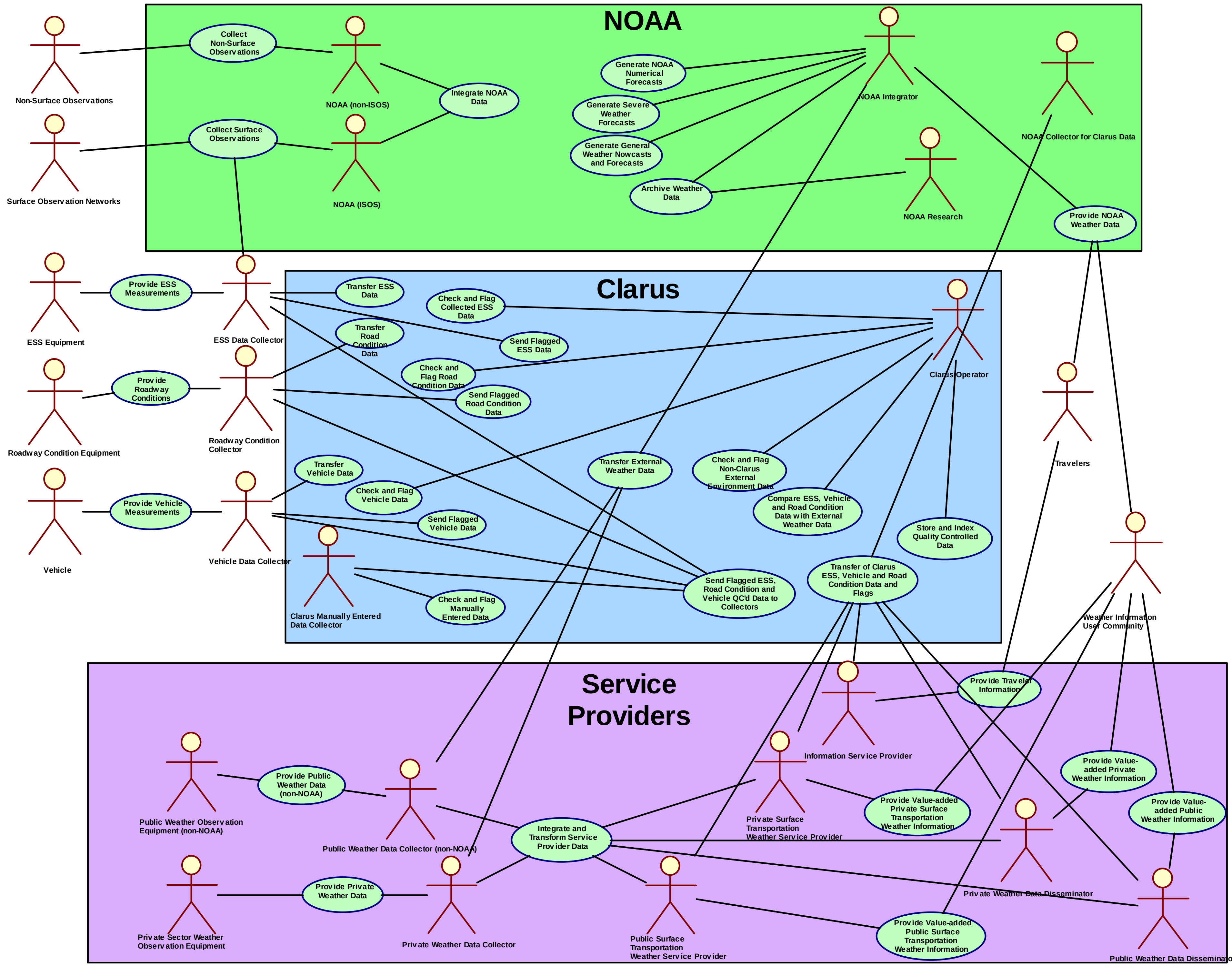

Figure 1 *Clarus* System Framework Use Case Diagram.

The use case diagram is used to describe the outwardly visible operations of a system and within the Concept of Operations they define the system boundary. The use case diagram has four primary elements: actors, use cases, associations and generalization or specialization as described below:

- Actors, represented by the stick figures, represent any external operator or system interfacing with *Clarus*.
- Use Cases, represented by ovals, describe the things the actors want the system to do, such as querying the Environmental Sensor Stations (ESS) in order to retrieve data from an ESS Data Collector.
- The lines connecting actors with use cases are associations. Associations indicate that there is some sort of interaction between the actor and the use case. The use case diagrams are based on the narrative text of the scenario.
- The lines, which are attached to a triangle symbol, depict generalization or specialization relationships. The triangle symbol is attached to the actor (or use case) that is the generalized entity (e.g., “vehicle” is generalized from the specific “transit vehicle”).

To the data user, *Clarus* will provide a “one stop” Internet location (portal) where all surface transportation-related weather observations can be accessed in a timely manner, with or without quality control flags and metadata. The availability of these data through the *Clarus* portal has the potential to significantly improve traveler information through 511, add detail to Highway Advisory Radio (HAR) broadcasts and Variable Message Sign (VMS) alerts, and provide new clarity to transportation agency Web sites, all of which support the variety of end users.

Information from *Clarus* can be used to create enhanced decision support tools for DOTs and travelers, as well as spawn new technologies that can provide road conditions and forecasts remotely via devices such as in-vehicle displays and handheld personal digital assistants (PDAs) (Figure 2). However, the *Clarus* concept does not stop with the collection of data from the nation’s 2,500+ ESS operated by state and local transportation agencies. The database will also store a variety of derived (from current technologies) and new observation-related data sets from all modes of surface transportation. The result is envisioned to be new data sets and products for transportation agencies, weather service providers and researchers.

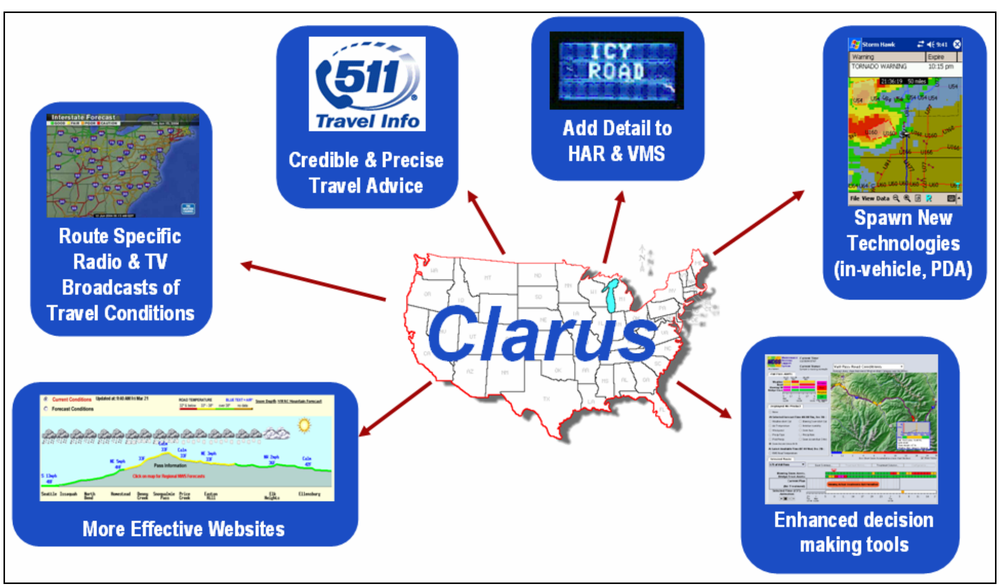

Figure 2 The vision for Clarus to enhance and improve many aspects of surface transportation weather information.

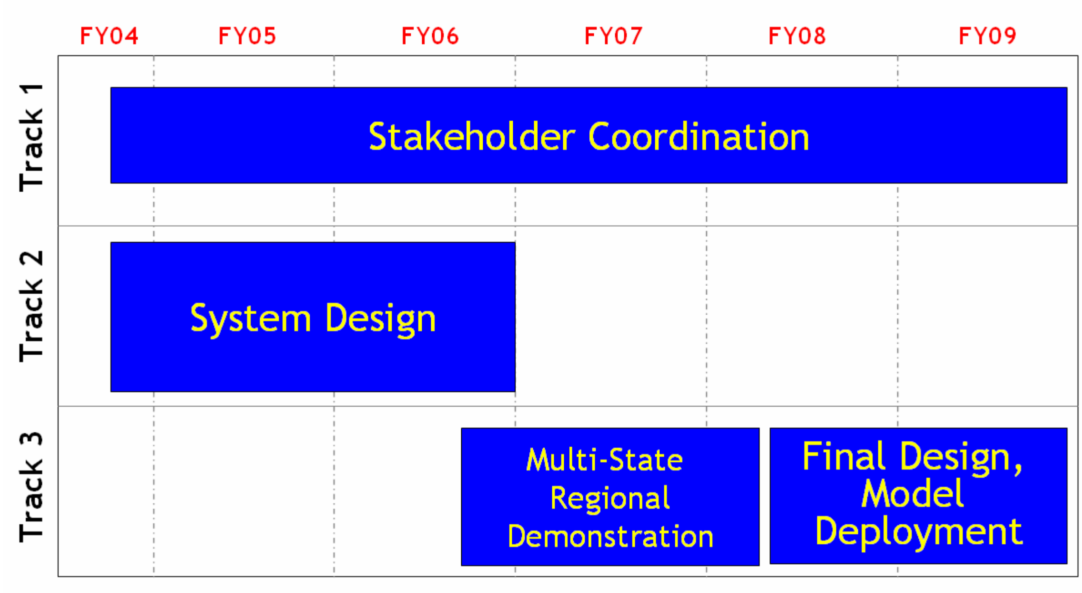

Figure 3 The Clarus Initiative Road Map and development tracks

3. CLARUS ROADMAP

The *Clarus* Initiative has an aggressive timetable for system design, demonstration and deployment. The Concept of Operations was completed in May 2005. The high level and detailed system requirements were completed during the fall of 2005. The system design and proof-of-concept demonstration will be completed by the end of 2006. Following the proof-of-concept demonstration, a formal multi-state regional demonstration and evaluation will occur. This will lead to refinement of the system design and a second regional demonstration.

The *Clarus* Initiative roadmap (Figure 3) consists of stakeholder coordination and participation through the Initiative Coordinating Committee (ICC) in Track 1. The ICC is a diverse group of stakeholders interested in the development and deployment of the *Clarus* system. The remaining tracks provide a high level view of a rigorous systems engineering process that is involved in the creation of the *Clarus* system. Track 2 includes the creation of a Concept of Operations, preliminary system design and a proof-of-concept demonstration. Track 3 includes a regional demonstration, evaluation and update to the system design. Track 3 also provides for a model deployment and final series of evaluations followed by updates to the system design.

At the completion of the *Clarus* Initiative in 2009, the FHWA will have a comprehensive and tested design ready for nationwide deployment. The final step will be to identify one or more hosts for a sustainable nationwide deployment of the *Clarus* system. Success will be measured by the level of “buy-in” by those organizations that see value in the potential solutions that the *Clarus* Initiative could bring.

These users include:

State and local agencies: The state and local road and transit agencies must see the value in participating in the *Clarus* Initiative by making their ESS data available to collection servers, by providing metadata and maintenance information, and in some cases increasing data polling frequencies.

Private sector service providers: The private sector weather industry and service providers must see the value in having a one-stop location to obtain quality controlled surface transportation-related observations. *Clarus* data sets can be used as input to weather or road condition models, real-time collectives or as input into new value-added forecast and decision support products. Additionally, streamlined accessibility enables greater flexibility in value-added products since a common framework for interface design will be specified.

A deployment benefactor: Some entity such as a collective of organizations or another federal agency (e.g., NOAA) must see the value in integrating and maintaining the *Clarus* system so that there is a viable path to sustainable operations. Depending on the origin of the benefactor, different business models can be used for providing data, tools and decision support capabilities.

4. *CLARUS* RESEARCH

Clarus will be a dynamic initiative, growing and changing with the needs of its customers and with evolving technologies during its six year project time span. Tied with the development of the *Clarus* system design are three specific research activities to explore new and existing technologies that could provide better insight into the environment of the road and the lower atmosphere. These activities include:

- inclusion of data from environmental sensors on vehicles,
- examining the use of Closed Circuit Television (CCTV) cameras for driver level visibility estimation, and
- testing the feasibility of using low cost, low power radar to enhance observing in the lower atmosphere.

The following three sections discuss these areas of research.

4.1 Vehicle Infrastructure Integration Research

Vehicle Infrastructure Integration (VII) (DOT, JPO, 2005) is an independent initiative funded and directed by the ITS JPO, and directly linked to *Clarus* through its planned database and quality control capabilities. The VII Initiative, whose participants include the US DOT, state DOTs, local government agencies, and a consortium of automobile manufacturers, has the potential to change the way that drivers receive information from their vehicles and how their vehicles interact with other vehicles in nearby proximity.

The VII Initiative will examine the feasibility of creating an “enabling communications infrastructure” to support vehicle-to-vehicle and vehicle-to-infrastructure communications across the nation (FHWA, 2005). The primary goal of VII is to provide a safer driving environment (e.g., reducing the number of crashes, injuries and fatalities). However, the dozens of onboard sensors represent a significant opportunity to sense the weather and road conditions along the nation’s surface transportation system.

The automobile manufacturers participating in the VII Initiative are working toward a common data formatting and communications standard. Early in the next decade, many new vehicles may be equipped with a short range radio transceiver. With a typical range of a half mile (0.8 kilometers), vehicles will be able to transmit data from dozens of onboard sensors to the roadside infrastructure. It is envisioned that in an initial implementation, there may be 100,000 roadside transceivers at signalized intersections and at strategic intervals along the nation’s freeways, with a mature full implementation of over 400,000 units. This flow of information could literally “light up” the nation’s transportation arteries with millions of data messages (including road weather information) and change the way meteorologists view weather observing and forecasting in the lower atmosphere and at the surface.

The draft VII Functional Architecture and Requirements document (FHWA ITS JPO, 2005) describes some of the many data items that are envisioned to be available for transmission. Table 1 provides a subset of those items that either directly or indirectly measure environmental (atmosphere and road surface) conditions and their potential uses.

Table 1. VII Environmentally-related data elements.

Onboard Vehicle Sensor	Derived Information
GPS vehicle location	Location, driving direction and traffic data
Wiper system state	Precipitation detection
Headlights	Lighting conditions
Exterior air temperature	Estimated ambient air temperature
Vehicle speed	Traffic data/implied road conditions
Rain sensor	Precipitation detection
Light sensor	Lighting conditions
Fog lamp usage	Fog or visibility information
Traction control state	Road traction state/mobility
Anti-lock brake system state	Road traction state/mobility

Some of the parameters listed in Table 1 include values that are directly measured (such as external air temperature or the rain sensor). For other elements, one might be able to infer certain conditions (such as road icing with the use of the traction control system or the anti-lock braking system). The National Center for Atmospheric Research (NCAR) will evaluate and validate the use of directly measured and derived elements and their potential value for road weather observing and forecasting.

4.2 CCTV Research

Most state DOTs have deployed Closed Circuit Television (CCTV) cameras at intersections and along freeways to aid in traffic management operations. These cameras provide images of not only traffic but also convey the condition of the roadway and even some weather information. The Massachusetts Institute of Technology (MIT) Lincoln Laboratory will study the feasibility of using these images to estimate driver level visibility and create a set of portable algorithms that could be customized for any location in the country (Hallowell, 2005). If successful, this research could use existing technologies and infrastructure to provide a new and valuable observational element which would eventually reside within the *Clarus* system database.

4.3 Radar Research

A consortium of universities, and public and private sector organizations known as the Collaborative Adaptive Sensing of the Atmosphere (CASA) (CASA, 2005) are performing research into deploying low cost, low power radars as “gap-fillers” for the network of weather surveillance radars operated by the National Weather Service (NWS) and the Federal Aviation Administration (FAA). A study performed by the University of Oklahoma indicated that 72% of the lower atmosphere (below 0.6 miles or 1 km) is not sampled by NWS/FAA radars due to their spacing (18.7 miles versus 62.2 miles or 30 km versus 100 km) and the effects of Earth curvature (Brotzge, 2005).

The surface transportation weather community would benefit if this research indicated that these new surveillance radars would help atmospheric scientists better understand the complex weather and wind flow conditions close to the ground. Results from this research could be used directly in the routine analysis of the atmosphere, in the grid initialization of weather models or even spur the next generation of new boundary layer (land surface) models. It is hoped that this next generation of models will have more focus on creating improved forecasts for surface transportation.

5. THE *CLARUS* FUTURE

The FHWA Office of Transportation Operations and ITS JPO are funding and directing the *Clarus* Initiative during a six year period from 2004 to 2009. It is envisioned that *Clarus* will leverage investments in ESS to collect, quality control, archive, and disseminate surface transportation weather observations. In addition, *Clarus* will fund three research threads that could add millions of new observed and derived weather elements through the use of existing and emerging technologies. *Clarus* will have the ability to change surface transportation weather observing and forecasting, foster the development of new decision support tools, and eventually create a more efficient and safe surface transportation system.

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