

Clarus

Concept of Operations



a Nationwide Surface Transportation Weather Observing and Forecasting System

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16. Abstract The <i>Clarus Initiative</i> establishes a vision for the leveraging of local and regional road/route weather observations to serve a greater community and enhance 21 st century transportation operations. Its goal is to provide broader weather information support for surface transportation system operators in their efforts to improve safety, reliability and security of transportation users. The <i>Clarus Initiative</i> consists of two development components. The first component is the development of the <i>Clarus System</i> – a network for sharing, quality controlling, and exchanging surface environmental data and relevant surface transportation conditions. The second component is the development of tools (such as decision support systems) that make effective use of the <i>Clarus System</i> . This document provides a high-level definition of how the system works. The focus of the Concept of Operations is establishing an understanding of the needs of the various stakeholders representing different weather data use market segments or groups and how the <i>Clarus System</i> can be structured to meet the users' stated needs. They exhibit different surface transportation weather data needs based on content, timeliness, level and type of value-added processing, reliability, and other related criteria. Central to this document are examples of functional scenarios for many of the market segments that will be served by the system. Each scenario is described in a narrative text and should be evaluated along with the overall <i>Clarus</i> Framework Scenario that includes an illustrated Use Case Diagram and a Sequence Diagram to model the typical concepts anticipated to exist in the application of <i>Clarus System</i> data.					
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1 Executive Summary

The *Clarus Initiative* is a Federal project that establishes a vision for the leveraging of local and regional road/route weather observations to serve a greater community and enhance 21st century transportation operations. The goal of the *Clarus Initiative* is to provide broader weather information support for surface transportation system operators in their efforts to improve safety, reliability and security of transportation users. This goal will be accomplished through the design, demonstration and deployment of a national surface transportation weather data collection and management system that complements the existing nationwide network known as the National Surface Weather Observing System (NSWOS) (12). NSWOS, operated by the National Oceanic and Atmospheric Administration (NOAA), is an evolving system designed to collect weather data (both surface and upper air) from disparate public and private networks. Through this effort, surface transportation-based weather observations can be integrated with NSWOS, thereby permitting broader support for surface transportation-specific operational needs and prediction models. The enhanced support capabilities offer the potential for greater safety and improved mobility for users of the surface transportation infrastructure.

The *Clarus Initiative* consists of two development components. The first component is the development of the *Clarus System* – a network for sharing, quality controlling, and exchanging surface environmental data¹ and relevant surface transportation conditions. The second component is the development of tools (such as decision support systems) that make effective use of the *Clarus System* data with NSWOS data, the benefit will be extended to promote enhanced general-purpose weather forecasting providing a wider range of benefits for the protection of life and property.

The value of *Clarus* to the public sector transportation community is two-fold. It offers a method to offset some of the deployment costs of new Environmental Sensor Stations (ESS) by integrating observations from other surface observation sources with those already generated by their own ESS. The *Clarus System*, in this case, acts as an asset multiplier for State DOT's gaining ready access to additional sources of data that otherwise would not be integrated. The other value to the public sector transportation community derives from utilization of quality-controlled data. Quality data lends itself to more effective decision-making, better forecasting, and thus more informed operations management of the State DOT's resources. The most obvious benefit of quality data is cost reduction through the efficient management of construction crews, routine maintenance operations, and related transportation support services. An associated benefit is public perception. Quality road weather information provided to travelers by public agencies shows them that the public agencies are taking a proactive approach toward providing their services.

The *Clarus System* will impact the services of a wide audience, both through direct and indirect use of the *Clarus System* data. Users having direct contact with the *Clarus*

¹ Surface environmental data in this context refers to weather (at or below 10 meters), pavement or subsurface conditions, including hydrologic (water-level) readings of gauges located near roads.

System will include the owners and operators of the observing systems that are sending information to the *Clarus System*, as well as the users directly accessing the data processed within the *Clarus System*. The following is an initial list of these stakeholders, which may be expanded as the initiative progresses.

- Observation system owners including federal, state, local and private institutions
- Instrument and observation platform suppliers
- Direct data users including system owners and their contractors
- Surface transportation weather service providers
- NOAA
- General weather service providers
- The research community
- Climate data warehouse and other non-surface weather interests

The *Clarus Initiative* is comprised of a comprehensive set of activities that will ensure efficient and effective design, development and deployment of the *Clarus System*. The following is a list of these activities.

- Development of the *Clarus* Vision and Management Infrastructure
- Creation of the *Clarus* Initiative Coordinating Committee (ICC)
- *Clarus* Concept of Operations
- System Design
- Proof-of-Concept Demonstration
- Research
- Evaluation during Multi-State Regional Demonstration
- Deployment Support and System Promotion

Upon deployment of the *Clarus System*, the following operational attributes are envisioned to exist.

- A one-stop Internet portal for all surface transportation environmental observations
- Data provided without post-processing, ready to be incorporated into value-added products including weather and traffic models as well as decision support systems
- Continuous quality control of data with feedback to State DOT engineers and other users
- Data transferred in one common protocol with appropriate metadata
- Management of user's rights to input or extract specific data components
- A set of data retrieval tools
- Support for the inclusion of new technologies such as vehicle-based sensing technologies surface visibility information from traffic cameras, and remote sensing technologies

The **Clarus Concept of Operations** document provides a high-level definition of how the system works. The focus of the Concept of Operations is establishing an understanding of the needs of the various stakeholders and how the *Clarus System* can be structured to meet the users' stated needs. The stakeholders represent different market segments or groups that comprise part of the envisioned weather data transfer chain. They have different surface transportation weather data needs based on content, timeliness, level and type of value-added processing, reliability, and other related criteria. The Concept of Operations identifies connections and attributes among the pieces of the *Clarus System* and its external interfacing entities.

The overall objectives of the Concept of Operations include:

- Describing the operational characteristics that the system needs to fulfill without explicit reference to the functions of the system, its hardware, and displays,
- Documenting the consensus goals achieved through an open discussion among stakeholders,
- Providing a long-range view of the *Clarus System's* capabilities that will serve as the basis for planning future enhancements, and
- Promulgating a mission for the system that is aligned with the missions of the stakeholder organizations.

Central to the Concept of Operations are examples of functional scenarios for many of the market segments that will be served by the system. Each scenario is described in a narrative text and should be evaluated along with the overall *Clarus Framework Scenario* that includes an illustrated Use Case Diagram and a Sequence Diagram to model the typical concepts anticipated to exist in the application of *Clarus System* data. A representative diagram showing typical *Clarus System* interfaces is shown in Figure 1.

The following are the application focus areas included in the functional scenarios.

- Roadway Maintenance and Construction Operations Function
- Traffic Operations Function
- Traveler Information Function
- Transit Management Function
- Emergency Management and Public Safety Function
- Rail Operations Management Function
- Commercial Vehicle Operations Function

The ICC membership has been a valuable asset in refining the Concept of Operations, and their continued participation throughout the *Clarus Initiative* will further strengthen the solutions that are developed.

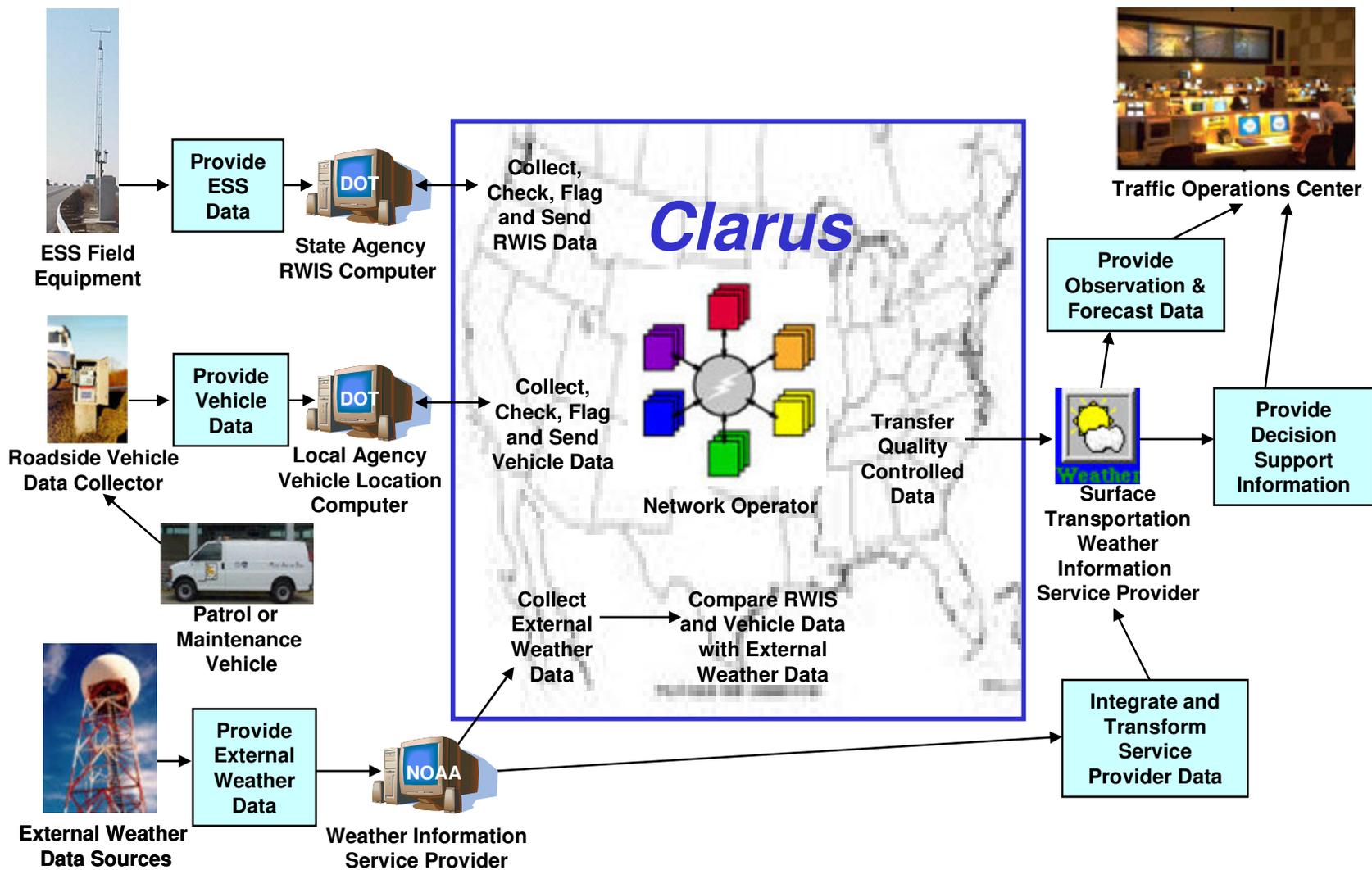


Figure 1. Graphical Depiction of Typical Clarus Interfaces. [D](#)

2 Introduction

2.1 *Clarus Initiative*

Clarus is an initiative sponsored by the Federal Highway Administration (FHWA) to organize and make more effective environmental and road condition observation capabilities in support of four primary motivations.

- 1) Provide a North American resource to collect, quality control, and make available surface transportation weather and road condition observations so that State Departments of Transportation (DOTs) can be more productive in maintaining safety and mobility on all roads.
- 2) Surface transportation-based weather observations will enhance and extend the existing weather data sources that support general purpose weather forecasting for the protection of life and property.
- 3) Collection of real-time surface transportation-based weather observations will support real-time operational responses to weather.
- 4) Surface transportation-based weather observations integrated with existing observation data will permit broader support for the enhancement and creation of models that make better predictions in the atmospheric boundary layer and near the Earth's surface to support more accurate forecasts.

The intent of the *Clarus* Initiative is to demonstrate how an open and integrated approach to observational data management can be used to collect, control the quality of, and consolidate surface transportation environmental data. The *Clarus* Initiative will address the necessary infrastructure to consolidate the data from a multitude of independent data collection systems. This process offers the prospect of enhancing data coverage, improving the performance of meteorological support services, and providing guidance to owners of these data sources regarding the quality of their data and performance of their data collection systems.

Clarus represents the next step in bringing together surface transportation best practices and the greater weather community. Surface transportation environmental data collected by the *Clarus* system will include atmospheric data, pavement data², and hydrologic (water level) data.

2.2 *Clarus Initiative Activities*

The *Clarus* Concept of Operations is an important piece in a much broader *Clarus Initiative*. The total initiative is comprised of the following activities.

- **Development of the Clarus Vision and Management Infrastructure**
This is a predecessor activity to the *Clarus Initiative* originated by the U.S. Department of Transportation (DOT) to address the needs of several interested

² "Pavement data" in this context includes surface and subsurface data specified in NTCIP 1204 (8).

stakeholders who desired a consolidated surface transportation weather data resource. The activity led to the definition of the initiative and the establishment of a series of steps to achieve the objective of a surface transportation weather data collection and management system. The *Clarus* Initiative Management Team (IMT) is lead by the FHWA's Intelligent Transportation Systems Joint Program Office (ITS JPO) and the FHWA Road Weather Management Program. Other members of the team include NOAA, the Intelligent Transportation Society of America, the American Meteorological Society (AMS), the Institute of Transportation Engineers (ITE), the Transportation Research Board (TRB), and the American Association of State Highway and Transportation Officials (AASHTO).

- **Creation of the *Clarus* Initiative Coordinating Committee (ICC)**

The initiative resulted from the needs of an established stakeholder community. One of the first steps was to formally establish a mechanism for stakeholders to participate in the initiative. The ICC will serve as an interdisciplinary source of expertise and guidance. The ICC provides a forum for participation of stakeholders, a means to permit input into the system design, and an opportunity to mold the initiative to address the individual needs of each stakeholder.

- **Concept of Operations**

The development of a *Clarus System* requires a high-level concept of the stakeholder needs and a vision of how a system will provide a solution to the stated needs. The *Clarus* Concept of Operations sets the stage for the development of a solution that meets the needs by defining the environment within which the system must operate. It defines the boundaries for *Clarus* and precedes system requirements and design. This document fulfills the definition of the *Clarus* Concept of Operations.

- **System Design**

The *Clarus System* design effort involves the following activities.

- Development of High Level System Requirements, such as detailed user interaction with the system for road weather information needs
- Development of Detailed System Requirements, such as communications protocols, programming interfaces, format translators, and data storage capabilities
- Architecture Analysis and a Design Gap Analysis to develop a high level design by examining alternative architectures and exposing potential limitations in Environmental Sensor Station (ESS) deployment, design, or observational capability
- Development of System Design Documents to define the hardware configuration and system software specifications

- **Proof-of-Concept Demonstration**

Once the system design is complete, it is necessary to implement, integrate, and test the *Clarus System* in a Proof-of-Concept Demonstration. This limited

demonstration will be conducted at a selected location so that system components, core functions, and information management processes may be tested and improved.

- **Research**

Research into new and evolving technologies is an ancillary function with the design and demonstration processes. The primary research threads will be to select and/or create instrumented corridors to promote and test cutting-edge observational technologies such as fixed, mobile, and remote sensors including Closed Circuit Television (CCTV) cameras, Vehicle Infrastructure Integration (VII) devices and radar technologies.

- **Evaluation during Multi-State Regional Demonstration**

The demonstration test is prototypical in nature. It will be necessary to evaluate and revise the system's design options until a blueprint for a deployable nationwide surface transportation weather observing system has been created.

- **Model Deployment**

The final activity is the support for the implementation and continued development of the nationwide network and the promotion of the use of the data for new products and services. Additionally, it will be necessary to educate users regarding the advantages of the new products and monitor the impact of these new products on surface transportation safety and mobility.

This report focuses on the *Clarus* Concept of Operations. It includes sections on background (setting the stage for *Clarus*), the *Clarus* vision and goals, stakeholders, user needs, and discussion of technical and institutional issues. It also presents core Use Case and Sequence Diagrams, which depict the potential behavior of the system and its interfaces, users, and boundaries.

2.3 Background

The present U.S. national observational network is the result of over one century of technological progress to improve the process of collecting, processing, and disseminating routine weather observations for protecting life and property through weather analysis, forecasts and warnings. The program was initially established in 1870 as part of the United States Army Signal Corps. U.S. Armed Services commanders needed accurate weather reports, so members of the Army Signal Corps made routine weather observations and telegraphed their observations to Washington D.C. where a national forecast was prepared. This program continued under the military until 1890, when public applications of this early national weather observation system began with the formation of the U.S. Weather Bureau within the U.S. Department of Agriculture. The Weather Bureau was established after an earthen dam broke near Johnstown, Pennsylvania, killing more than 2,200 people in May 1889. The U.S. Weather Bureau was transferred to the U.S. Department of Commerce under the

National Oceanic and Atmospheric Administration in 1970 and was renamed the National Weather Service (NWS).

The growth of commercial aviation and the increased number of observations from pilots augmented the growth of meteorological research and operational weather forecasting beginning in the 1930's. In 1942, the U.S. Navy gave the Weather Bureau surplus aircraft radars to use in the real-time observation of storms. These radars served as the seeds for a national radar observation network. In 1959, the first weather satellite was launched. Since the creation of NOAA, and in conjunction with the Department of Defense (DoD), the National Aeronautics and Space Administration (NASA), and the Federal Aviation Administration (FAA), national weather observing capabilities have been dramatically expanded. The inventory of weather observing tools includes a national network of Doppler weather radars, a constellation of advanced weather satellites, networks of surface-based atmospheric profilers and sounders, weather balloons, oceanic and intercoastal instrumented buoys, and a network of over 4,200 federally operated surface observation sites including nearly 1,000 Automated Surface Observation System (ASOS) stations. The latter effort highlights the tremendous focus placed over the past 20 years on enhancing observational capabilities with the focus of much of this effort on general public safety and the aviation community.

In recent years, an initiative was established by the NOAA Forecast Systems Laboratory to broaden the collection of federal and non-federal observations through a program known as the Meteorological Assimilation Data Ingest System (MADIS). Although considered to be experimental and primarily for support of research endeavors, MADIS provided the collection of surface mesoscale network (mesonet) data from locales not previously supported. In 2005, with the success of MADIS, NOAA has decided to evolve MADIS into an operational system called the National Surface Weather Observing System (NSWOS). FHWA and NOAA will work together to assure that the *Clarus* System and NSWOS develop on parallel and complementary tracks.

2.4 Clarus Vision

The goal of the *Clarus Initiative* is to provide broader weather information support for surface transportation system operators in their efforts to improve safety, reliability and security of transportation users. This will be accomplished through the design, demonstration and deployment of a national surface transportation weather data collection and management system. Observations from the *Clarus System* will serve the needs of the following stakeholders.

- Transportation system operators
- Communities who assimilate the data and provide weather-related surface transportation information
- General weather information providers
- Consumers served by these providers

Clarus is a federal vision for leveraging local and regional road/route weather observing networks to serve a greater community and enhance 21st century transportation operations. To accomplish this, the *Clarus System* will have the following characteristics.

- A one-stop internet portal for all surface transportation environmental observations
- Data provided without post-processing, ready to be incorporated into value-added products including weather and traffic models as well as decision support systems
- Continuous quality control with feedback to State DOT engineers or transportation managers and other users
- Data transferred in one common protocol with appropriate metadata
- Management of user's rights to input or extract specific data components
- A set of data retrieval tools
- Support for the inclusion of new technologies such as vehicle-based sensing technologies, surface visibility information from traffic cameras, and remote sensing technologies (1)

The scope of *Clarus* is likely a new concept for system owners, maintainers, vendors, and primary users of road weather observing networks, but the successful deployment of the *Clarus System* will require extensive coordination from this group of data providers and users. Future practices and procedures will be affected by the operation of the *Clarus System*, including how the data enters the System, and how it is quality controlled, managed and retrieved. Adoption of the *Clarus System* Concept of Operations by these groups will be essential to the success of the *Clarus Initiative*.

2.5 *Clarus* Functional Scenarios Overview

The focus of the Concept of Operations is an understanding of the needs of the various stakeholders and how the *Clarus System* can be structured to meet the users' stated needs. Stakeholders who represent different market segments or groups that comprise part of the envisioned weather data transfer chain have different surface transportation weather data needs based on content, timeliness, level and type of value-added processing, reliability, and other related criteria. To assess the various stakeholder needs related to the *Clarus System*, this section outlines a set of representative functional scenarios considered necessary to help define the needs for the *Clarus System* Design. Section 2.5 of this report presents an overall framework scenario for the *Clarus System* followed by detailed descriptions of representative scenarios. Use Case Diagrams and Sequence Diagrams will illustrate the framework scenario and how the entities of a specific scenario relate to the overall framework.

It is important to reiterate that the *Clarus System* references the mechanism to collect, consolidate, and control the quality of surface transportation environmental data, and then makes these raw data and associated quality control information available to end users. The *Clarus Initiative* encompasses the broader view of how the *Clarus System*

fulfills the support function within the operational scenarios of the various stakeholder communities. These relationships are discussed in more detail in Section 3. In all of the scenarios discussed in this section and Section 3.5, the functionality of the *Clarus System* is, by design, the same. The *Clarus System* will collect a diverse set of surface transportation environmental data and it is expected that different users may want different components of these *Clarus* data sets to support the needs of their customers, the end user communities. This Concept of Operations document is the first step in obtaining stable, streamlined interfaces into and out of the *Clarus System*.

2.5.1 *Clarus System* Framework Scenario

The overall framework scenario for the *Clarus System* provides the foundation from which the *Clarus System* design phase can begin. The emphasis of *Clarus* is to provide better surface transportation operations. The framework scenario shows the relationships between the *Clarus System* and the surface transportation operations community as well as NOAA and Service Providers. In the framework scenario, all vehicles are generalized as well as the entire Weather Information User Community.

The framework shows the *Clarus System* providing support to and receiving support from NOAA and other service providers. NOAA serves as the government provider of hydro-meteorological support information in the form of warning and forecast services, collection of weather and hydrologic information, numerical modeling, hydro-meteorological research, and climatology. NOAA products and services are used by the media, the general public, state and federal government agencies, the private sector meteorological community, and the military. Similar to NOAA, Service Providers including both Public and Private, provide value-added weather information to the Weather Information User Community as depicted in the framework diagram. All of these functions will be enhanced by the addition of *Clarus* information.

Time critical weather operations necessitates that some environmental data be processed by *Clarus* in support of the user communities immediate decision process. The operational needs under consideration are those that require current data from *Clarus* and other sources that have a data age ranging from instantaneous to about 15 minutes. The framework scenario provides mechanisms to prioritize data processing for time-critical data to minimize the transfer time to the user community.

2.5.2 Scenario A - ROADWAY MAINTENANCE AND CONSTRUCTION OPERATIONS FUNCTION

The scenario for the *Clarus* roadway maintenance and construction operations function explores the possible interactions between actors (any external operators or systems interfacing with *Clarus*) and the *Clarus System* in the winter and seasonal (non-winter) maintenance and construction operations of the roadway. Using environmental data from maintenance and construction vehicles coupled with ESS data provided by the *Clarus System*, roadway maintenance and construction operations will be able to anticipate, observe and respond to hazardous conditions. Weather and pavement condition information can also be used as input to maintenance decision support systems.

2.5.3 Scenario B - TRAFFIC OPERATIONS FUNCTION

The scenario for the *Clarus* traffic operations function depicts how the *Clarus System* will help the management of traffic during diverse weather events. Data derived from service patrol vehicles, coupled with the ESS data, Closed-Circuit Television (CCTV) camera images, and other information that *Clarus* might process will give traffic management operations a better picture of weather impacts on traffic flow, as well as overall and specific roadway conditions for a region. Weather and pavement condition and transportation-related water level information can also be used as input to traffic management decision support systems.

2.5.4 Scenario C - TRAVELER INFORMATION FUNCTION

The scenario for the *Clarus* traveler information function explores the possible interactions between actors and the *Clarus System* to provide enhanced weather and road condition information to travelers. In the future, it is expected that a more extensive source of weather-related information from public and private vehicles will help create a highly detailed picture for travel information across regions. This data set may include operational states of the vehicle (headlight switch, wipers, braking systems), measured weather and pavement conditions, observed weather and road conditions, and traffic conditions (average speed, changes in speed, sudden decelerations). This data will be integrated by information service providers (ISPs) and be available to the traveling public to support their decisions (e.g., mode choice, route choice, vehicle equipment, speed, following distance).

2.5.5 Scenario D - TRANSIT MANAGEMENT FUNCTION

The scenario for the *Clarus* transit management function explores the possible interactions between actors and the *Clarus System* for improved transit management operations. The combination of environmental data from transit vehicles³ and ESS data will aid transit management operations with transit scheduling and operations. Weather and route condition information can also be used as input to transit decision support systems.

2.5.6 Scenario E - EMERGENCY AND PUBLIC SAFETY FUNCTION

The scenario for the *Clarus* emergency and public safety function explores the possible interactions between actors and the *Clarus System* in the handling of local and regional emergency and public safety situations. Emergency vehicles, instrumented to provide and receive environmental data, will improve local and regional incident management and response, as well as coordinated disaster response and evacuation operations, by taking into account existing weather, pavement and hydrologic conditions en-route and at the scene. Environmental information can also be used as input to emergency management decision support systems. Thus, the *Clarus System* will enhance public safety operations.

³ “Transit vehicles” include watercraft (ferries) and buses.

2.5.7 Scenario F - RAIL OPERATIONS MANAGEMENT FUNCTION

The scenario for the *Clarus* railroad operations management function explores the possible interactions between actors and the *Clarus System* to provide enhanced weather and rail condition information to support rail operations. *Clarus* will provide railroad management operations with better information for operating the rail system using environmental data from trains, other railroad vehicles and platforms coupled with ESS data. Weather and pavement condition information can also be used as input to rail operations decision support systems.

2.5.8 Scenario G - COMMERCIAL VEHICLE OPERATIONS FUNCTION

The scenario of the *Clarus* commercial vehicle operations function explores the possible interactions between actors and the *Clarus System* to provide improved road weather support for commercial vehicle fleet operations including just-in-time delivery. Scheduling of commercial traffic and distribution of goods and products will be improved through the use of environmental data from the *Clarus System* for route planning and resource management decision support.

2.6 Relationship of Clarus to the National ITS Architecture

There is a direct mapping between many of the external actors to the *Clarus System* that are influenced by weather and the subsystems and terminators in the National ITS Architecture. The National ITS Architecture is a guide to assist jurisdictions in the development of plans and deployments and operations of new technology, while providing a standard design to support technology implementation within and across jurisdictional boundaries. The Road Weather Data Collection (Figure 2) and the Weather Information Processing and Distribution Market Packages (Figure 3) best describe similar functionality to the *Clarus System*.

The following is taken from Version 5.1 of the National ITS Architecture regarding the Road Weather Data Collection Market Package illustrated in Figure 2: *“This market package collects current road and weather conditions using data collected from environmental sensors deployed on and about the roadway (or guideway in the case of transit related rail systems). In addition to fixed sensor stations at the roadside, sensing of the roadway environment can also occur from sensor systems located on Maintenance and Construction Vehicles and on-board sensors provided by auto manufacturers. The collected environmental data is used by the Weather Information Processing and Distribution Market Package to process the information and make decisions on operations.”*

The following is taken from Version 5.1 of the National ITS Architecture regarding the Weather Information Processing and Distribution Market Package illustrated in Figure 3: *“This market package processes and distributes the environmental information collected from the Road Weather Data Collection market package. This market package uses the environmental data to detect environmental hazards such as icy road conditions, high winds, dense fog, etc. so system operators and decision support systems can make decisions on corrective actions to take. The continuing updates of road condition*

information and current temperatures can be used by system operators to more effectively deploy road maintenance resources, issue general traveler advisories, issue location specific warnings to drivers using the Traffic Information Dissemination market package, and aid operators in scheduling work activity.”

MC03 – Road Weather Data Collection

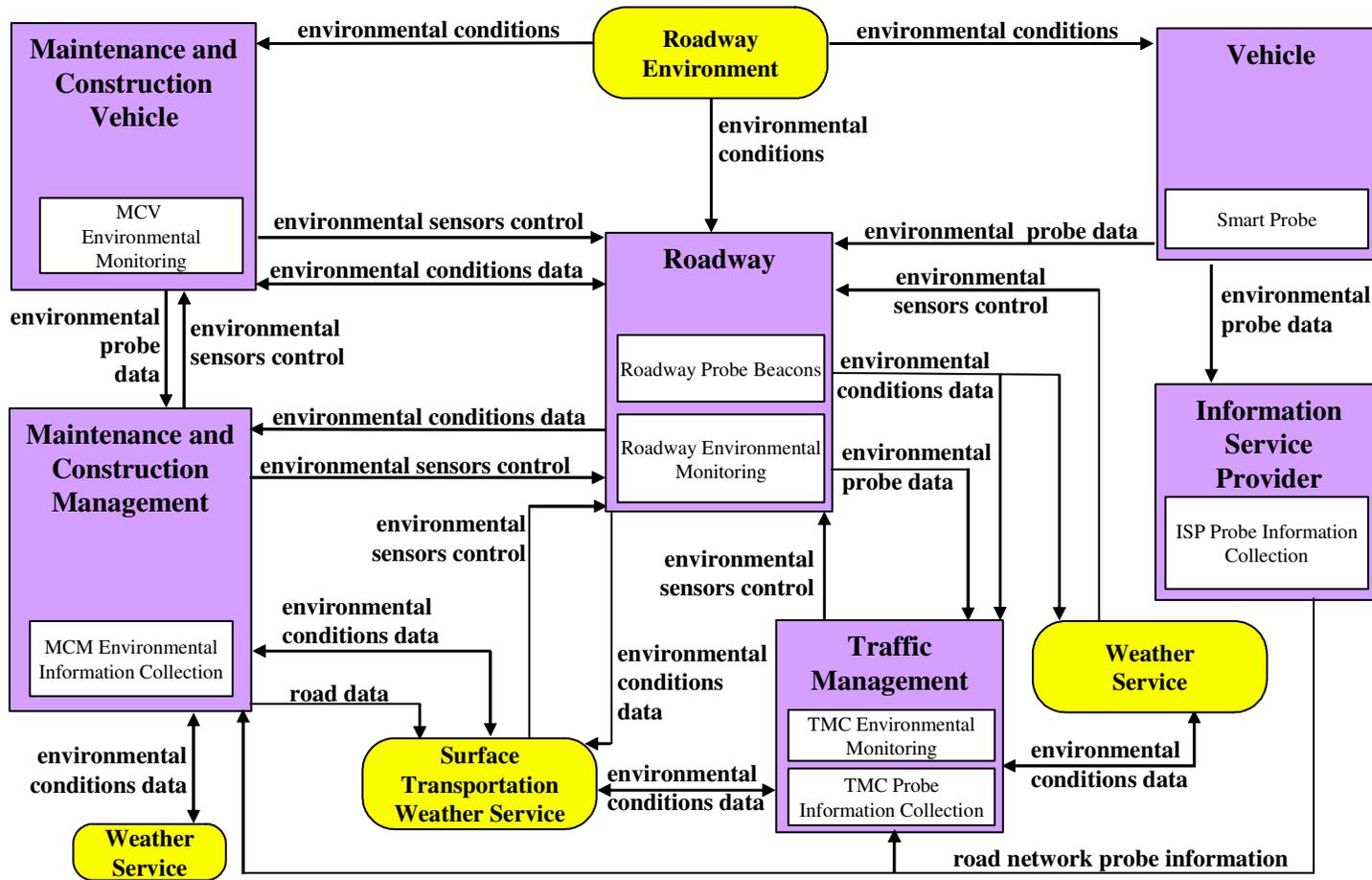


Figure 2. Road Weather Data Collection Market Package from the National ITS Architecture. [D](#)

MC04 - Weather Information Processing and Distribution

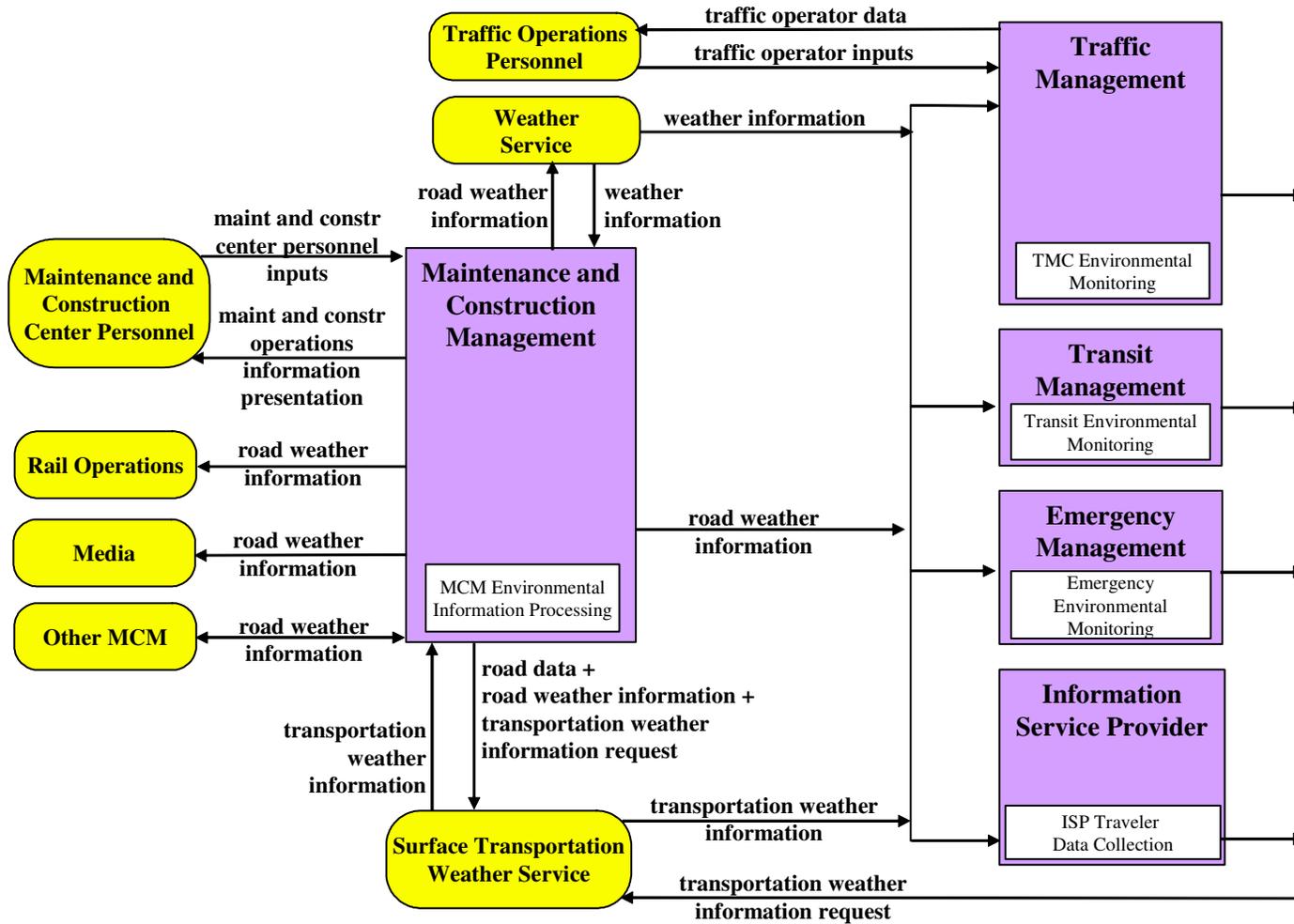


Figure 3. Weather Information Processing and Distribution Market Package from the National ITS Architecture. [D](#)

An evaluation of the linkages between stakeholders and road weather data sources within the National ITS Architecture (2) has been completed for the Intelligent Transportation Society of America (ITS America) (3). The findings of this evaluation, known as the *ITS America Weather Services Study*, are important in identifying user needs. The National ITS Architecture was derived based on ITS user needs that are linked to a set of ITS user services. However, at present there is no “weather” user service within the National ITS Architecture, but it does describe how weather information can affect the various ITS user services. The study investigated three key components of weather information applications within the National ITS Architecture.

- Identification of Market Packages and ITS User Services within the National ITS Architecture that currently utilize any form of weather information
- The spatial and temporal characteristics existing within surface transportation weather information
- The application of the different combinations of spatial and temporal scales of weather information within a decision-making environment to enhance safety, mobility, and productivity

Specifically, Market Packages in the National ITS Architecture address service-oriented issues and are designed to operate individually or with other Market Packages. The ITS America study identified a clear requirement for weather and surface transportation weather information within the framework of the National ITS Architecture with a recommendation that a designated ITS Market Package be considered for Surface Transportation Weather.

2.7 Clarus Initiative Coordinating Committee (ICC)

The ICC serves as an interdisciplinary source of expertise and guidance for the *Clarus Initiative*. The ICC is comprised of members of the meteorological and transportation communities, including those from the public, private, and academic sectors. Members of the ICC will be consulted for expert advice related to *Clarus*, be asked to undertake project reviews, participate in topic-specific task forces, and conduct a variety of outreach activities.

This representative body will remain in place for the duration of the *Clarus Initiative* to guide its development. The ICC will support technical and programmatic considerations involving system design, design review, system proof-of-concept, the Multi-State Regional Demonstration, and the Model Deployment. The ICC panel of subject matter experts in weather forecasting, transportation operations, networking, and data management across public and private business sectors will be coordinated to ensure that stakeholder interests are addressed through each development phase.

The ICC is structured to provide technical and policy guidance to the *Clarus Initiative* Management Team (4). The position of the ICC is illustrated in the *Clarus* Management Structure diagram (Figure 4). ICC members may provide input at any time directly to the *Clarus Initiative* leaders; however, the initiative incorporates two distinct

opportunities for members to participate in an organized forum for exchange of ideas. These two forums include scheduled ICC meetings and Project Task Forces organized to address specific initiative topics.

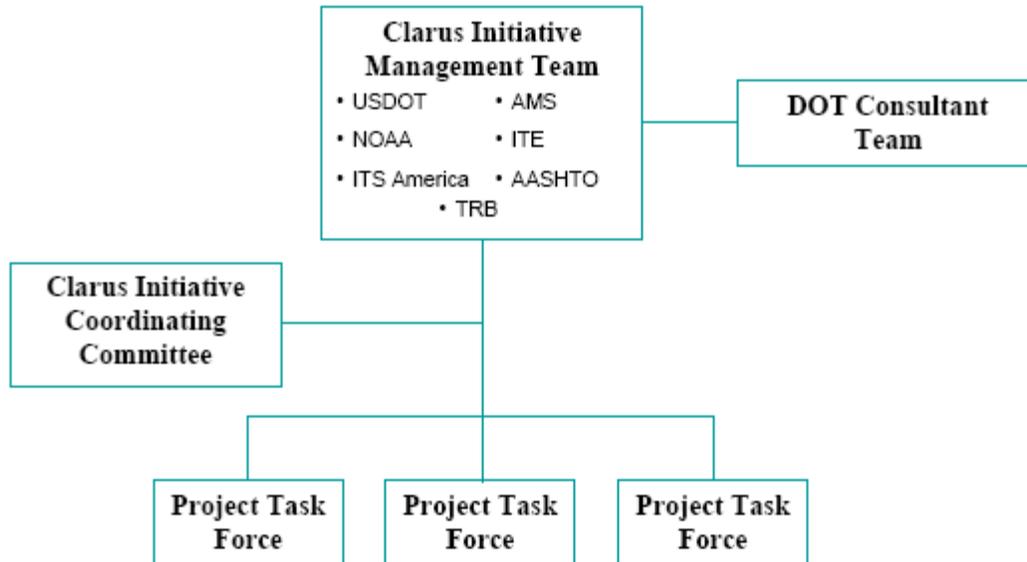


Figure 4. Clarus Initiative Coordinating Committee Relative to the Overall Clarus Management Structure.

- **ICC Meetings**

The *Clarus Initiative* Management Team will schedule meetings on an ongoing basis to permit ICC members to gain a more in-depth understanding of the purpose of the *Clarus Initiative*, its progress, and future direction. The meetings are also intended to engender discussion on specific issues pertinent to the project in the current and succeeding phases of the *Clarus* implementation process. The agenda for these meetings will be a balance between presentations on key topics and an open forum for stakeholder input on *Clarus*. The Management Team will invite specific speakers to discuss key topics germane to the *Clarus* project and/or issues associated with the current phase of the Initiative. The open forum component of the meeting will permit stakeholders to provide their guidance on specific issues facing the Initiative.

In order to facilitate an open exchange of ideas, ICC members will have an opportunity to share their thoughts and recommendations in breakout sessions containing a small number of individuals. Key points extracted from these breakout sessions will be summarized and presented to the entire group to create a consolidated set of user statements and recommendations. It is anticipated that these discussions will define specific topics that need further discussion and evaluation. Once these topics are isolated and clarified, they will become the subject matter for a more thorough evaluation within a Project Task Force. The ICC will determine the specific items that the task force needs to address and create the

infrastructure to facilitate the implementation of the task force (leader, task force membership, roles and responsibilities, products and schedule).

- **Project Task Forces**

A *Clarus* Project Task Force is any subset of ICC stakeholders that focuses attention on a specific *Clarus* issue and provides feedback on specific approaches, options, or recommendations to address or resolve the issue within the *Clarus Initiative*. The ICC will have the responsibility to determine the need for specific task forces and to define their roles and responsibilities. Guidelines for task forces include the following characteristics.

- Small groups of 10 or fewer persons
- Address specific objectives and deliverables
- Direct association with on-going contracted activity
- Periodic reporting requirements to *Clarus Initiative* Management Team
- Reporting on deliverables at ICC Meetings

A specific task force will remain intact until it has fulfilled its obligation to the initiative or the mission of the task force is no longer pertinent.

The following two project task forces started in the first ICC meeting have met and participated in the evaluation of documents being developed for the Concept of Operations phase of the *Clarus Initiative*.

- User needs assessment review
- Use cases/application areas review

The two project task forces have reviewed and provided extensive input on the two primary documents comprised within the Concept of Operations phase of the *Clarus Initiative*, namely, the User Needs Assessment and Concept of Operations documents.

3 Clarus Concept of Operations

3.1 Introduction

The Concept of Operations sets the stage for the development of the requirements, by defining the setting within which the system must operate. The *Clarus* Concept of Operations is a high-level overview that will address three categories.

- 1) The system's fit into agency responsibilities
- 2) The physical infrastructure
- 3) Expectations on how the system will work

The Concept of Operations defines, at a high level, how the system works, as well as all interfacing systems and people. The Concept of Operations features Unified Modeling Language (UML) use cases to show the visual connections and attributes among the pieces of the *Clarus System* and its external interfacing entities.

The Concept of Operations results from review and research of the relationships within the system, among the system and the various agencies and stakeholders, the expectations for the system, and the physical environment in which the system operates. The *Clarus System* will support the design and establishment of a portal that allows access to:

- Weather and hydrologic data relevant to the roadway
- Road surface condition information
- Data characterizing the type of instrumentation, siting characteristics, and operational state
- Quality control information
- New surface transportation-related observational or derived data sets that are not generally stored in a database elsewhere (e.g., CCTV-derived visibility data and VII data)
- All NWS watches, warnings and advisories

The overall objectives of the Concept of Operations include:

- Describing the operational characteristics that the system needs to fulfill without explicit reference to the functions of the system, its hardware, and displays
- Documenting the consensus goals achieved through an open discussion among stakeholders
- Providing a long-range view of the *Clarus System's* capabilities that will serve as the basis for planning future enhancements
- Promulgating a mission for the system that is aligned with the missions of the stakeholder organizations

3.1.1 Systems Engineering Process

A concept of operations is one of the initial stages in a system life cycle based on the “Vee” diagram, illustrated in Figure 5, widely used in the National Highway Institute (NHI) Systems Engineering course.

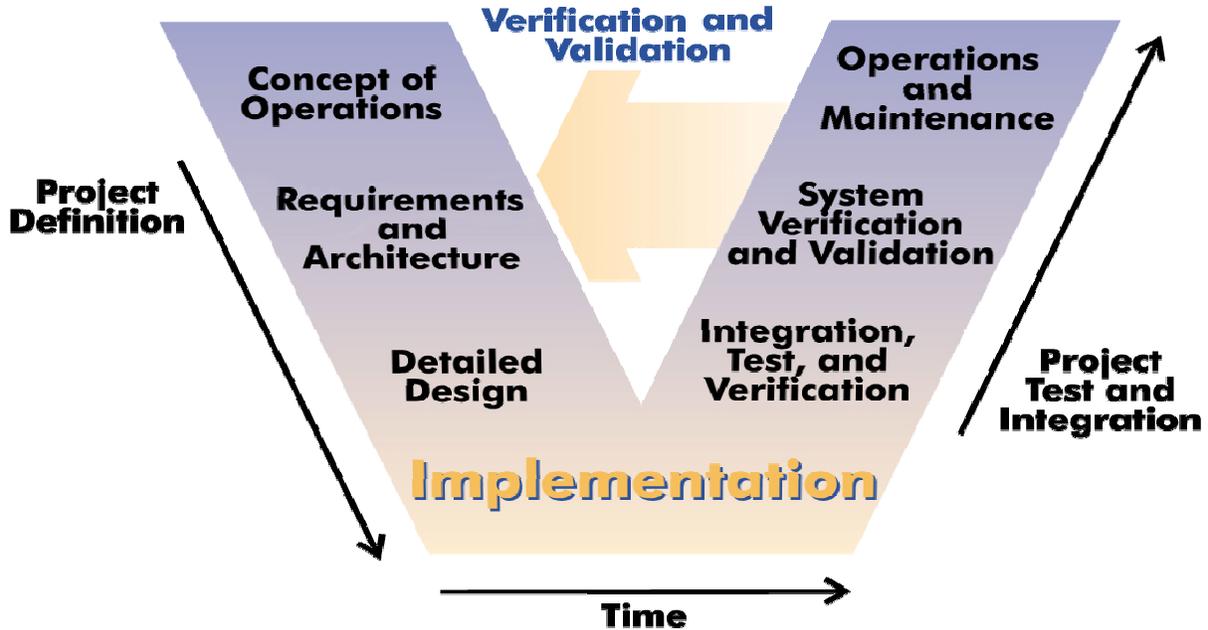


Figure 5. Systems Engineering Process.

The Systems Engineering Process (SEP) provides a path for improving the cost effectiveness of complex systems as experienced by the system owner over the entire life of the system, from conception to retirement. It involves early and comprehensive identification of goals, a concept of operations that describes user needs and the operating environment, thorough and testable system requirements, detailed design, implementation, rigorous acceptance testing of the implemented system to ensure it meets the stated requirements (system verification), measuring its effectiveness in addressing goals (system validation), on-going operation and maintenance, system upgrades over time, and eventual retirement. The process emphasizes requirements-driven design and testing. All design elements and acceptance tests must be traceable to one or more system requirements and every requirement must be addressed by at least one design element and acceptance test. Such rigor ensures nothing is done unnecessarily and everything that is necessary is accomplished.

3.1.2 Audience of the Clarus Concept of Operations

A concept of operations is useful to many audiences and must represent a broad range of stakeholder interests. The following perspectives are important to the concept of operations development.

- **Owners:** to facilitate understanding of objectives and form a basis for system acceptance criteria
- **Users/operators/maintainers:** to describe technical attributes related to human-machine interfaces, interactions among systems, sequences, functions, etc.
- **System engineers and architects:** to establish system context, particularly as it relates to interfaces
- **System implementers:** to provide insight into the role of the system within the overall environment
- **Testers:** to ensure proper test focus, based on understanding operational philosophies; to ensure their thorough testing through understanding operational attributes of external interfaces
- **Managers:** to achieve consensus on system objectives, provide perspective on the role of the system in the overall regional integration/strategic plan, and to manage expectations for everyone, particularly users and managers, decision makers, and executives

3.1.3 Benefits of the Concept of Operations

Development of a concept of operations realizes the following benefits.

- Ensures that users and supporters have the same understanding – By writing a description of operations, misunderstandings should be minimized. Expectations can also be managed.
- Ensures that conditions for use are clearly defined – A written description will clarify who may use the system(s) and the associated information/data and under what conditions.
- Describes the operational needs of users (and other stakeholders) without being bogged down in the technical issues that belong in other systems analysis activities.
- Documents the operational needs and the proposed characteristics of the system such that the user can verify these without needing any more technical knowledge than that required to perform normal job functions.
- Describes user expectations for the system functionality and performance without having to provide testable, quantified requirements.

3.2 Clarus Users

Direct and indirect use of the *Clarus System* can be applied to a wide audience. Because a wide array of users can derive benefit from the *Clarus System*, it is necessary to focus upon those users that have the immediate contact with the system components. **Thus, the principal users whose needs are discussed in this document are users who directly interact with the Clarus System.** These stakeholders include the owners and operators of the observing systems sending information to *Clarus*, as well as the users directly accessing the data contained within the *Clarus System*. The following is an initial list of stakeholders whose user needs are considered.

- Observation system owners including federal, state, local and private agencies, institutions, and organizations.
- Instrument and observation platform vendors
- Direct data users such as system owners and their contractors
- NOAA
- Surface transportation weather service providers
- General weather service providers
- Research community
- Climate data warehouse and other non-surface weather interests

This list of direct users of data from the *Clarus System* is a subset of the entire population of stakeholders interested in the *Clarus Initiative*. The needs of the broader stakeholder community are essential to the *Clarus Initiative* and these interests must serve as a framework for the core *Clarus System*. From information in the Surface Transportation Weather Decision Support Requirements (STWDSR) (5), Weather Information for Surface Transportation (WIST) (6), and 511 Deployment Coalition (7) documents, it is possible to separate stakeholder groups into a condensed list based upon the user's interface or interaction with *Clarus* data. The users are viewed as defining layers in the process of transferring raw field observations to various levels of data use. The following are the inherent layers in this transfer process.

- Autonomous Layer
- Service Providers Layer
- Service Provider Customer Layer

The **Autonomous Layer** is comprised of operational entities who utilize weather and transportation data to make plans, decisions, and/or take action based upon sensor data within their control. These data include observations collected by ESS, mobile data acquisition platforms, cameras, and other transportation-related measurement devices. The owners of these observation systems, by definition, have complete control over the collection of data from their data platforms and will this will not change under the *Clarus Initiative*. Further, the access to data collected from their systems will be controlled by these operational entities. Additionally, these operational entities will not have to go through the *Clarus System* to use their own data. The Autonomous Layer data comprises the vast majority of the raw input data to the *Clarus System*.

The **Service Providers Layer** is composed of both public and private entities that provide basic and value-added weather support services to support the weather information needs of the broader surface transportation community. These support services rely on *Clarus* data (raw and processed) combined with other environmental, road condition or traffic information products to develop or provide road weather information and enhanced products. **The Service Providers Layer is the principal user interacting with the *Clarus System*.** In some instances, the Service Provider Customer Layer includes entities and agencies also found within the Autonomous Layer.

The **Service Provider Customer Layer** includes those groups who are direct consumers of products generated by Service Providers and are generally not a direct user of *Clarus* data. The members of this Layer can be from any user community, but are largely found within the surface transportation community. The support received comes from basic and/or value-added weather support utilizing a combination of *Clarus* and non-*Clarus* data. In some instances, the Service Provider Customer Layer includes entities and agencies also found within the Autonomous Layer who receive quality control information of the data they originally provided to *Clarus*.

The **Clarus Layer** lies between the Autonomous and Service Providers Layers and represents the nationwide system and architecture to accomplish the previously outlined goals of surface transportation environmental data collection and management. This is illustrated in Figure 6.

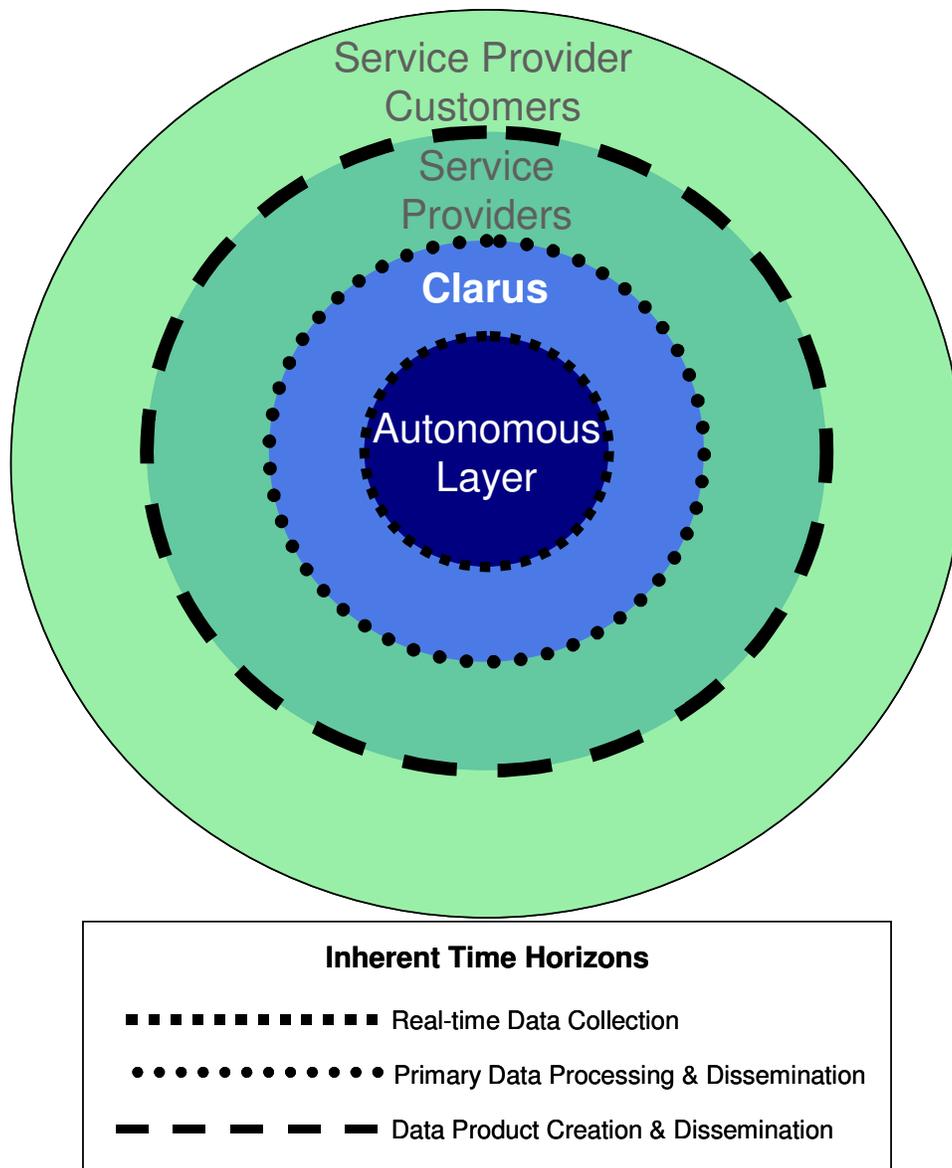


Figure 6. The *Clarus System* and its Relationship to Data Time Horizons.

Figure 6 is a conceptual diagram of the *Clarus System* and the data time horizons that separate the stakeholder groups contain an inherent time scale emanating from the center of the diagram outward, representing the flow and processing of data through the *Clarus System* and between the layers. These not only represent the temporal limits of data collection, quality control, processing, and redistribution, but also the period for which the Service Provider Customers have needs. The design of *Clarus* will need to consider both of these time horizons when considering the technical limitations of the system architecture. These data time horizons are illustrated in Figure 7. The average elapsed time for the Autonomous Layer varies because of configuration and communications latencies that are inherent within the operation of the system to collect the data. The *Clarus* Layer includes the time required to communicate data from the Autonomous Layer to the *Clarus System* ingest process as well as the time required to

process the input data into a database structure. Further, the variation in the Service Provider Layer includes the time required to add other data to the *Clarus* data and to perform the required human- and/or machine-based product generation. The average data age grows because of the aggregated times required to move through the various layers and eventually to the Service Provider Customers. The *Clarus System* design must address how best to minimize these times to optimize the flow of data in a timely manner.

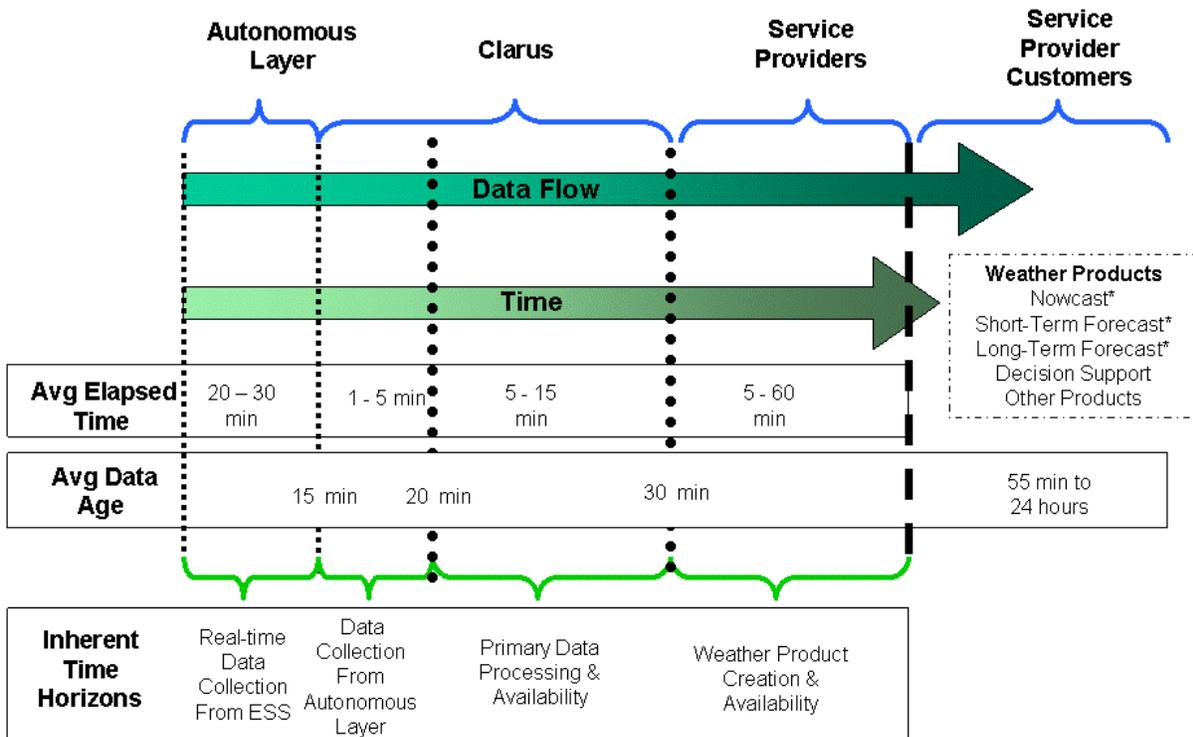


Figure 7. Time Scale Associated with User Needs and the Inherent Latencies in Data Collection of Environmental Data.

Definitions:

- Average (Avg) Elapsed Time is the estimated time for the process within a given layer or layer sub-division to take place. It implies that observed and recorded values may have an age in the transfer process that represents the extremes of the time range.
- Average Data Age is the estimated average age of an ESS observation as it is transferred from the ESS to the end user.

The context diagram in Figure 8 illustrates the relationship of the entities interfacing with *Clarus*. The diagram also describes the flow of data between the entities and the *Clarus System*. The data provider organizations (e.g., State DOTs, local traffic management organizations, and rail/transit agencies) maintain data collection systems. These organizations define the Autonomous Layer - the primary contributors of surface transportation data to the *Clarus System*. These stakeholders can also benefit from *Clarus* by receiving quality-controlled data returned from the *Clarus System*. This quality-controlled data is not value-added data, but data with flags indicating that data elements do not meet quality assurance thresholds.

The private and public sector Service Providers are the principal *Clarus* users. These Service Providers generate value-added services of road/route weather information to the transportation community. Additional Service Providers having direct access to *Clarus* data resources include research organizations, archival agencies, and other related weather service providers.

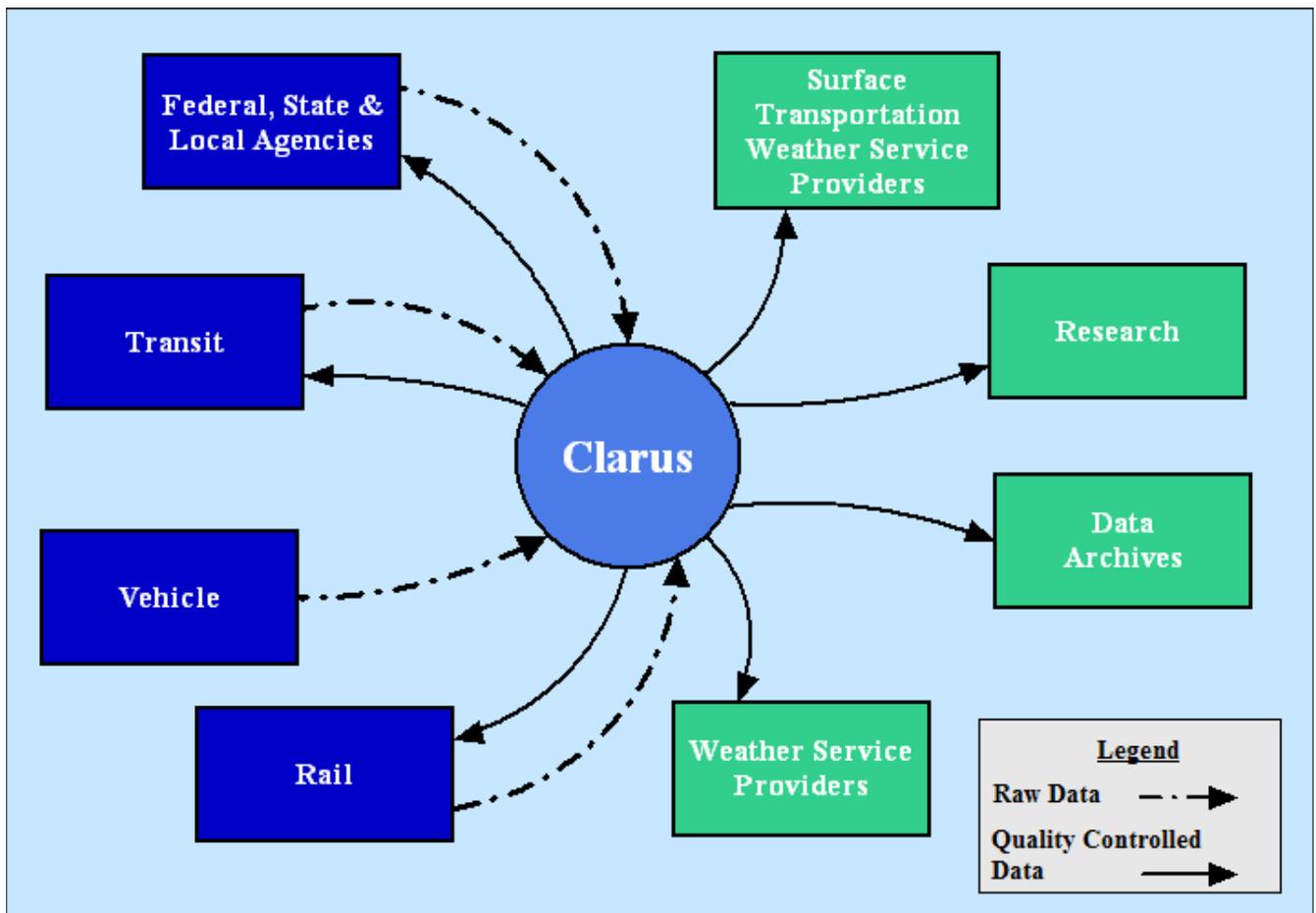


Figure 8. Context Diagram of Clarus User Needs.

The *Clarus* users shown in Figure 8 are summarized in the following descriptions.

- **Federal, State and Local Agencies**
These are the transportation system and ESS network operators and owners who directly provide the *Clarus* data. This group places considerable emphasis on the pavement-specific component of the data at the observational level to make immediate decisions. In addition, these individuals are the principal consumers of information provided by surface transportation weather service providers. Personnel include those within maintenance, transit and traffic operations. Additional data from this group includes CCTV imagery, road condition information, and treatment activities such as plowing and chemical application.
- **Transit**
These are the owners and operators of transit systems who contribute data to the *Clarus System*. This group places considerable emphasis on understanding weather-related conditions along designated routes.
- **Rail**
These are the owners and operators of rail systems who contribute raw data to the *Clarus System* and may receive quality-controlled data from it. This group places considerable emphasis on understanding weather conditions along designated routes plus weather-induced effects such as rail temperatures, frozen switches, and drifting snow.
- **Vehicle**
Emerging technologies are developing that will encourage a greater level of data collection from vehicles for the purpose of understanding the nature of the transportation system state including the impacts of weather. As this method of data collection matures, the information obtained on weather and pavement conditions from instrumentation on-board vehicles will be important *Clarus* data.
- **Surface Transportation Weather Service Providers (STWSP)**
These surface transportation weather service providers are the private and public weather service providers who assimilate the *Clarus* data with other available data to generate value-added products and services used by the surface transportation decision-makers at state and local transportation agencies.
- **Weather Service Providers (WSP)**
These include the weather support services that are primarily interested in the meteorological and hydrologic components of the *Clarus* data. This group includes the efforts in public forecasting by NOAA and the NWS along with private sector weather services and their value-added support to markets such as agriculture, power utilities, and construction.
- **Research**
This category incorporates federal, academic, and private sector researchers who are working to improve the state of knowledge and practice through the research of surface transportation weather.

- **Data Archives**

This category includes operational and non-operational interests who choose to include the *Clarus* data in their endeavors. The archiving of *Clarus* data will be most effective when combined with other meteorological archives beyond the scope of *Clarus*, but is not restricted to such efforts.

In summary, each stakeholder group will bring unique perspectives and experiences to the table. In some cases, these will present competing views or needs. However, the commonality of the ultimate goal to reduce the impact of adverse weather will lead toward group consensus. The involvement of the ICC will play a vital role in merging the competing needs of this group.

3.3 User Needs

Clarus provides the fundamental process of transporting data from members of the Autonomous Layer to a point where the Service Providers gain access to the data. However, Service Providers become an instrumental component in the total flow of the data within the *Clarus* construct because a large audience exists for surface transportation weather data. These users want the raw form of the data transformed into more usable compositions. Service Providers perform this function by using the *Clarus* data in conjunction with data from other sources to create products that extend from reformulations of observations to forecasts out to several days. The STWDSR and the 511 Deployment Coalition Deployment Assistance Report #6 documents relate a time horizon definition to the fundamental type of surface transportation weather resource illustrated in Table 1. The documents delineate the Service Providers that provide output or services within each category or cell. The Service Providers defined in these two documents include NOAA/NWS, and STWSP. The time horizon extends from real time on the left, near-term in the middle, and long-term to the right corresponding to the microscale, mesoscale, and synoptic spatial and temporal scales. The definition of the preceding spatial and temporal scales are taken from STWDSR (5) as:

- Micro scale: sub-hour (minutes) time horizons and local areas (<few kilometers). Typifies severe convective events (e.g., micro-bursts) and safety-critical controls (e.g., vehicle operation) or local adaptations of treatments (e.g., speed- and surface-temperature controlled chemical applications).
- Mesoscale: approx. 1-12 hour time horizons and few-to-hundreds of kilometers areas. Typifies convective storms and moderately high gradients of effects (e.g., snow bands with large spatial variation). Includes many operational decisions of interest in transportation (e.g., resource dispatching).
- Synoptic scale: 12 hour-week(s) time horizons and continental areas. Typifies large air masses and frontal weather. Transportation-operational decisions tend to overlap between synoptic and mesoscale, but decisions for surface transportation in this scale generally concern response-preparation or travel planning.

Table 1 illustrates the relationship among the time of various weather data collection and forecast efforts and the information they provide to weather and road condition phenomena (modified from 511 Deployment Coalition, 2003).

Table 1. Relationship Among Various Weather Data Collection and Forecast Efforts. [D](#)

	Current conditions / Observations	Near-term Weather Forecast and Nowcasts	Middle to Long-term Weather Forecast
Atmospheric weather (e.g., precipitation, general winds, etc.)	Observations from ESS, NWS, vehicles, etc.	Nowcasts from Service Provider	Medium to longer term forecasts from Service Provider
Road weather (e.g., pavement temperature, winds at a bridge, fog at the road surface, etc.)	Observations from ESS, CCTVs, etc.	Nowcasts from Service Provider	Forecasts from Service Provider
Specific conditions (e.g., pavement or rail temperatures, icy, treated with salt, plowed, water depths, etc.)	Manual or automated observations (e.g., reported by field personnel or readings from sensors)	Reports from automated sources (e.g., decision support systems)	Predictions from decision support sources or contracted from Service Provider

The 511 Deployment Coalition and WIST reports provide a basis in identifying the needs of Service Providers for the generation of these weather elements. These Service Providers will require real-time access to ESS data in order to satisfy the extensive demands by the surface transportation user community. However, because of the variable sources of transportation weather data, simple raw data must also contain substantial metadata information to permit Service Providers to selectively integrate data from the *Clarus* data stream. The surface transportation weather product types defined within each of the cells in Table 2 are quite extensive and illustrate the diverse set of parameters incorporated in the *Clarus* data stream.

Table 2 identifies a basic list of data elements, including pertinent metadata elements that constitute the user needs to be supported by *Clarus*. These data embody the range of ESS observations presently supported through the National Transportation Communications for ITS Protocol (NTCIP) 1204 standard *Object Definitions for Environmental Sensor Stations* (8) used for data collection.

Table 2. ESS Data Elements Sumarized from NTCIP 1204 Standard Document. [D](#)

Type	Data Element
Fixed ESS Data	Station Category
	Type of Station
	Location of ESS
	Location of sensors
	Sensor Configuration
	Pavement ⁴ Treatment Information
	Time of Observations
Mobile ESS Data	Location of ESS
	Sensor Configuration
	Speed of Platform
	Direction of Platform
	Pavement Treatment Information
	Time of Observations
Atmospheric Sensor Data	Sensor Data
	Air Temperature
	Atmospheric Pressure
	Humidity
	Long and Short Wave Radiation
	Precipitation Occurrence, Type, Rate, Amount
	Visibility
	Wind Speed and Direction
	Wind Gust
Pavement Sensor Data	Sensor Data
	Pavement Condition
	Pavement Temperature
	Pavement Chemical Solution Freeze Point
	Pavement Ice Thickness
	Snow Depth (off roadway)
	Water Depth (on road, in adjacent stream)
Subsurface Sensor Data	Sensor Data
	Subsurface Temperature
	Subsurface Moisture
Air Quality	Sensor Data
	Air Quality Condition
Bio-Hazards	Bio-Hazards
Camera Imagery	Camera Imagery

As such, they represent the data collected through ESS for roadway, rail (route) and transit activities. They also serve as the foundational data types, including metadata, which will flow into the *Clarus System*. Not shown here are conceptual new data elements that will continue to evolve as technologies progress for the collection of road/route information and as the users' needs become more sophisticated. An important user need of the Service Providers is that the ESS data provided in support of

⁴ "Pavement" in this context includes bridges.

forecast weather element development is quality controlled. This may take the form of data quality flags incorporated during the quality control process to be designed into the *Clarus System*.

3.3.1 Additional User Needs

Accessing pertinent data from *Clarus* represents the single largest user need. However, data alone does not define the complete list of user needs. The user needs of any data system extend beyond the data to include satisfactory method(s) of data access, support for customer service and resolution of any problems associated with the data and its accessibility. Figure 9 shows these different user needs and the affiliated *Clarus* subsystems that must be included to satisfy these needs.

As important as recognizing the user needs for information, it is essential for *Clarus* to meet the decision specific deployment requirements and constraints of the regional road weather observation network. It is this topic where successful deployment of *Clarus* will result from buy-in from the funding and deployment group of data providers and users. To accomplish this, an understanding of the high-level data formats, communications capabilities, and technical/functional concerns of each of the stakeholder groups will need to be catalogued and addressed.

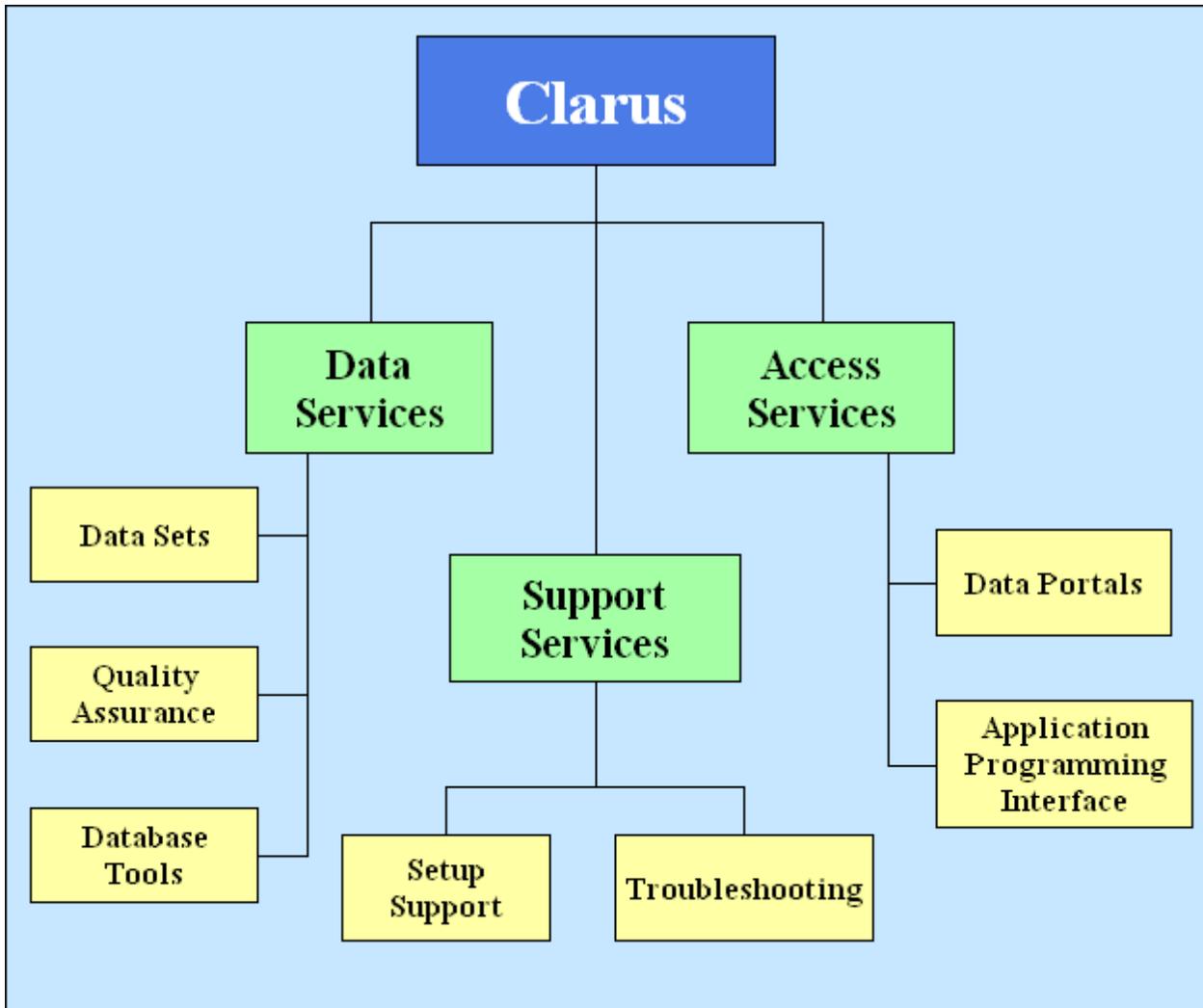


Figure 9. Organization of Clarus User Needs Categories and Sub-Categories.

3.4 Operational Objectives

3.4.1 Reliability / Robustness

The National Academy of Sciences report *Where the Weather Meets the Road* (9) admonishes that system robustness is a major objective of an integrated road weather observation and data management system.

The primary considerations that need to be addressed from an information technology perspective for success of the *Clarus System* are **volume of data, timeliness of information, and reliability** of the system.

The volume of data involved in this process has the potential to become very large, which leads to a significant challenge in developing a system that can effectively gather, store, process, and disseminate the data. The *Clarus System* should be a data collection system capable of handling a vast range of data in a flexible manner that

permits new data types to be added. The biggest challenge will be to determine data types. The Concept of Operations needs to take into account, to the extent possible, potential future products that are dependent on the *Clarus* dataset.

Choice of database vendors is always critical as each has its own strengths and drawbacks. Proper understanding of the available data versus the required information will dictate how the data gathering processes and the database itself should be designed for greatest efficiency. Finally, choice and configuration of hardware will also play a critical role in the effectiveness of the overall system.

Timeliness of information and reliability of the system are the other critical factors of this system. Both of these factors can be addressed through appropriate design architecture and deployment of the system. To address the timeliness factor, the system should be architected such that it can both retrieve and disseminate large volumes of data from copious sources and at potentially high rates in an environment that supports around-the-clock (e.g. 24/7) *Clarus Systems* operations. The ability of the system to spread its data collection and dissemination processes across multiple servers and communication channels will address this issue. The inherent scalability of such a design will also enable the system to expand and new data sources and end-users to be added.

Reliability is achieved through a variety of design and deployment considerations. Choice of hardware, operating systems, and development environment has impacts on the inherent reliability of the system. To maximize system uptime, redundancies can be built into the system at both the hardware and software levels.

3.4.2 Regional vs. National Focus

The *Clarus Initiative* is inherently a national effort to build a stronger operational effectiveness of surface transportation weather data utilization. The challenge in the design and construction of the *Clarus System* is determining the proper structure to achieve a national initiative that accomplishes this data utilization objective while meeting the operational needs of all stakeholders. A dominant portion of the stakeholders' needs exist at the local level. In contrast, the issues associated with surface transportation weather represent a fabric of interest that is national in scope. The result is a need for the *Clarus System* to satisfy both a regional and a national focus. The best solution to the overall needs will be determined in the system design that addresses both the logical and physical infrastructure.

The regional focus of the *Clarus System* concentrates on the operational uses of data by the local stakeholder. Some of these uses are described in the next section where use case scenarios are presented. In these use case scenarios the application of *Clarus System* data, either alone or in combination with additional data, provides solutions to local challenges/problems for local entities. Many of the applications of *Clarus System* data at the regional level respond to short-term problems, suggesting the design priority must be on rapid acquisition, processing, and retrieval of data. It is important to recognize that much of the data flowing through the *Clarus System* comes

from members of the Autonomous Layer who have processing networks in place to consolidate and display the source data that will be transferred to the *Clarus System*. Therefore, a certain level of the needs of the Autonomous Layer members will be satisfied independent of the *Clarus System*. For example, the triggering of automated bridge deck sprayers or the rapid activation of Dynamic Message Signs (DMSs) are two possible examples of how the ESS data may be applied in the field simultaneously with the data collection at the ESS. Further, the central collection of data from multiple ESS sites by a given jurisdiction or Autonomous Layer entity provides in-house access to ESS data that often satisfy their internal needs even prior to transfer of the data to the *Clarus System*.

From a regional perspective, an existing challenge lies in how the data collected by one member of the Autonomous Layer can be effectively shared with other jurisdictions or data users outside the network infrastructure of that member. An example of this is the sharing of ESS data collected by a State DOT pertinent to evolving storm conditions with the State DOT immediately down range of a moving storm system. This inability for the latter State DOT to 'see' in the direction from which the storm is moving has created numerous problems over time. Problems associated with data sharing have led to efforts by various State DOTs (10) to investigate more effective methods of data sharing. These studies identify the nature of the regional ESS data sharing problems that exist including the challenges associated with data formats, communications, and costs.

The sharing of data between an Autonomous Layer entity and public and private service providers also presents a regional focus issue. State DOTs frequently contract with private surface transportation weather service providers for transportation weather support. To utilize the ESS data collected within a state, it is necessary for the weather service provider to gain access to the State's ESS data. This is generally not a difficult process, as established methods often exist to provide access to these data as part of the service contract. However, the process of gaining access typically must be repeated every time a new service provider works with the State DOT. Further, the weather and road condition information of adjacent jurisdictions are equally important to fully resolve the weather elements within weather and pavement forecast efforts. Unless existing relationships exist with the adjacent jurisdictions or a method of sharing data between jurisdictions exists, the ESS data utilized can be isolated and incomplete.

The national focus of the *Clarus System* addresses the interoperation of regional users and the broader incorporation of surface transportation weather data within a national context of weather data resources. The formation of the *Clarus System* will constitute a critical component of the national weather observing infrastructure for four primary reasons.

- 1) Surface transportation-based weather observations will enhance and extend the existing observational database supporting public weather service (e.g., NOAA) efforts to provide weather forecasting for the protection of life and property.

- 2) A national collection of real-time surface transportation-based weather observations will provide for unfettered access of data for support of real-time responses to observed weather conditions.
- 3) Integration of surface transportation-based weather observations with existing observational networks would permit broader support for surface transportation specific models predicting impacts of weather on maintenance and traffic-related concerns.
- 4) Having a national database of surface transportation-based weather observations will promote improved research on surface transportation weather-related issues.

For the four reasons cited above, the *Clarus Initiative* will result in a broader utilization of ESS data within a wide range of weather support activities, both in the public and private sectors. The national focus of the *Clarus System* will promote greater unity in the transportation community for data acquisition and integration. This will likely include better acceptance of standards for data exchange in the weather and transportation communities. Adherence to these standards will help to eliminate unnecessary complexities within the *Clarus System*. Until these standards are more widely adopted, the *Clarus System* will also need to communicate with the ESS network databases and/or their individual ESS through application programming interfaces (API) special to those systems. However, a successful *Clarus System* has the potential of fostering a much more rapid adoption of standards within the industry. Regardless of how it is accomplished, the system design must include diverse and innovative ways of collecting data from these systems without unduly inconveniencing or costing the data providers.

Further, the national focus of the *Clarus System* will invigorate the demand for more and improved surface transportation weather services, expanding the marketplace for private sector services in surface transportation. The process of increasing demand will stimulate greater competition with more private sector participants and will result in new innovations in technologies as broader surface transportation weather research is conducted in the public, private and academic sectors. In addition, NOAA will benefit greatly from the data available from *Clarus* to enhance public weather service activities associated with the protection of life and property.

It is important in the deployment of the *Clarus System* to provide the support for regional weather-related data sharing while providing a mechanism to maintain a national clearinghouse of weather-related data. The contrast between these two scales conceptually translates into possible differing concepts in the infrastructure required to deploy the *Clarus System*. Regional databases have the advantage of breaking the quantity of data into a size that is easier to manage, and can potentially reduce latencies in retrieving data for regional users. Since many users will likely seek the data only from small regions, this method could work well. The structure of regional databases would provide for more active participation with the regional data centers by the local Autonomous Layer entities. Further, the regional data centers could reflect localized special requirements for a given region that might be related to either climate

or transportation application emphasis. The regional centers could serve as backup facilities for adjacent centers and provide a mechanism of system redundancy.

Compelling reasons do exist for a national database. First, users may need access to data from multiple regions, and accessing multiple databases to acquire the data defeats one of the fundamental purposes for developing *Clarus*, which is to have a one-stop shop for surface transportation weather data. Second, the quality control within the *Clarus System* modules will need to make use of data over a continuous plane. Thus, arbitrary divisions into regions could hamper quality control efforts, unless there is overlapping of regions, which could increase overhead through duplication. Finally, the operation of several smaller regional database centers would undoubtedly cost more in the long run than one larger national center. It may be possible to create one national virtual center that appears to the user to be one center.

The advantages of regional centers could be facilitated by redundant centralized systems. Further, selected major stakeholders may desire to host *Clarus System* mirror servers on a regional basis or even on their internal networks. This latter configuration could be used by a State DOT to make *Clarus System* data available to its personnel without the problems associated with Internet access while having the additional benefit of reducing bandwidth loads on the *Clarus System*. There are numerous options. The system design will determine whether the *Clarus System* should be a centralized national system or if it should consist instead of a network of regional centers or some sort of hybrid.

3.4.3 Extent of Data Types

Fundamentally, the *Clarus System* is a data acquisition, processing, and distribution mechanism for all surface transportation weather-related data. Data collected and distributed by the *Clarus System* will span both traditional fixed sensors along the roadway and those collected from mobile platforms. The fixed sensors along the roadway are a predominant part of the existing 2,500+ ESS deployments nationwide. Mobile ESS platforms are increasing in popularity, and over time will likely become more predominant than fixed sensors for collection of road weather data. These mobile platforms, including data that become available later this decade from the developing VII, will provide an additional level of complexity in data collection and will present challenges associated with quality control and database design, as the location metadata becomes highly time dependent.

In addition, new sensor design and deployment for both fixed and mobile platforms will continue as the emphasis on more advanced applications of surface transportation weather increases over the coming decades. This will influence sensor configurations and will require the *Clarus System* to be adaptive to storage and dissemination of information from emerging sensor technologies. One such technology that is presently growing in use is video capture from ESS locations. Other technologies that will evolve in time include a new generation of non-invasive pavement condition sensors, improved roadway visibility sensors, and the use of phased-array weather radar for surface transportation weather monitoring.

One of the central issues for the *Clarus System Design* will involve the handling of the large volume of observations that will result as the data collection technologies progress. For example, vehicle-based observations will present a major data storage challenge, as the sensors may report data at intervals of one second or less. It is important that the database methods for the *Clarus System* be abstracted and modularized to the point that any new data stream can be handled with minimal effort and without disruption to the streams that are already present within the system.

Not all *Clarus System* data will be from external sources. The *Clarus System* will produce data elements through quality control processing and through generation of special user notifications. The quality control information will be associated with all input data and will provide an important measure of data utilization. It will also be a source of information to Autonomous Layer entities of data quality of their measurement systems. While not a data store *per se*, event notification from the *Clarus System* will be a database concept that plays a critical role in providing user support. Many applications utilizing weather data are driven by the arrival of particular data sets. Since these applications would often have no knowledge of when data are arriving in the *Clarus System*, they would be forced to query for new data at regular intervals even if none have arrived. By allowing these applications the ability to register with a *Clarus System* notification service, the data can be automatically processed and prepared for users as it arrives. This can dramatically reduce the load these event driven applications place on the database.

3.4.4 Time Horizon Viability

Surface transportation weather, pavement, and hydrologic data have a finite shelf life. Thus, the perceived value of any element within the surface transportation dataset decreases with time. The rate of decrease in value is dependent upon the eventual user application. Observed values used for climatological studies retain their value for years; however, values that trigger immediate response actions may retain their worth to the user for only minutes. For most users studied in the following use case analyses, the value is perceived to range from a few minutes to several hours.

The value of a specific observation may be judged from two perspectives: 1) the value of the observation as a stand-alone element, and 2) the value as a member of a group of the same observed parameter from multiple locations within a region. The innate value of a single observation typically decreases over time exponentially. Observed values from certain parameters lose their value very quickly because of the inherent rate of change in the observed value. Other observed elements retain their value for extended periods of time. For example, soil temperatures directly beneath a roadway surface are slow to change, especially during winter situations. On the other hand, the surface temperature of highway pavement may change very quickly, especially in response to changes in cloud cover. Therefore, from a mathematical perspective the value of the pavement temperature would drop from its maximum value to a very low value in a short period of time whereas the soil temperature would retain value to the user several hours after the observation.

This simple approach would be effective if observed parameters changed at a constant rate. Since they do not, the value analysis becomes even more complex. The valuation analysis that users perform is affected by the stability of the observation in specific situations. Users will utilize pavement temperature values reported during the pre-dawn hours of the morning for a longer time than observed values made once the sun rises and pavement temperatures rapidly change.

The other value judgment deals with the analyses of multiple observations of a single parameter over a region (e.g., the air temperature over a multi-state region). The value of the analysis depends upon all of the values being made at essentially the same time. The value of the analysis decreases as the time spread of permissible observations increases. The value is also a function of the number of entries used to perform the analysis. Finally, the value of the analysis follows similar rules as the time-value of the individual entries discussed in the previous paragraph. In an operational situation, analyses of multiple elements must be done at some cutoff time to meet user needs. Any delay in the delivery of elements normally integrated into the analysis negatively affects the perceived value due to the reduced dataset.

The viability of data creates a substantial challenge to the design of *Clarus*. The existing collection processes within the various ESS networks tend to be sequential in nature and create datasets that do not contain observations at discrete time steps. Significant latency also occurs between the time when the actual field observations are made and the time when the observed parameters reach the central collection point. Similar issues occur with data collected from mobile platforms. Data collected and stored on vehicles are currently transferred to a central repository when the communications are possible from the vehicle to the central site. Depending upon the communications medium chosen for the data transfer, the update rate can vary from once each minute or less, up to once every several hours. Typical rates in this evolving technology cluster around once an hour.

The actual movement of the surface transportation data from each of the Autonomous Layer providers through the *Clarus System* should not be the major design challenge of the *Clarus Initiative*. Rather, to achieve data viability, *Clarus* will need to address the broader collection process to meet the expectations of the direct and indirect users of *Clarus*.

3.5 Representative Clarus Operational Scenarios

The *Clarus System* must satisfy the operational requirements within multiple user communities (maintenance, construction, transit, road/route, emergency management, traveler information, commercial services, general public, etc.). But, the operational requirements and *Clarus* data needs for each of these user communities are driven by the types of services each of these user communities provide to their constituents. Thus, different user communities view *Clarus* from a different perspective and assess *Clarus* requirements from slightly different perspectives. Fundamental data processing

within *Clarus* is common but each community brings unique processing requirements specific to that community. The technique chosen to evaluate the commonalities and the unique requirements of the various user communities are Use Case and Sequence diagrams of operational scenarios for each community. Since different scenarios contain substantial redundancy, the discussion presents the common framework of the *Clarus System* and then highlights the unique features of specific communities in separate discussions.

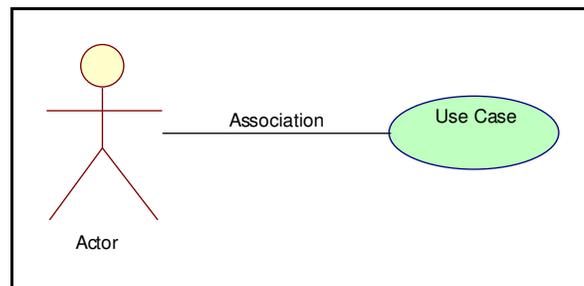


Figure 10. A Simple Use Case Diagram.

The *Clarus System* framework sets the stage for a representation of the overall *Clarus Initiative* operations. As indicated, the *Clarus* framework is depicted using Use Case and Sequence Diagrams. The framework generalizes the different vehicle types as well as the Weather Information User Community. This means that in the *Clarus* framework diagrams generic actors have been defined for both the Vehicle and the Weather Information User Community. Subsequent diagrams will show the specific vehicle and weather information user community actors. Each specific *Clarus* scenario in this section is described in narrative text from an operations perspective and contains one or more of the specific actors that were generalized at the framework level. Use Case and Sequence diagrams are based on the UML standard. The Use Case Diagrams are used to describe the outwardly visible operations of a system and in this Concept of Operations they define the system boundary. The Use Case Diagrams in this section have four primary elements: actors, use cases, associations and generalization/specialization.

- 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 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/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”).

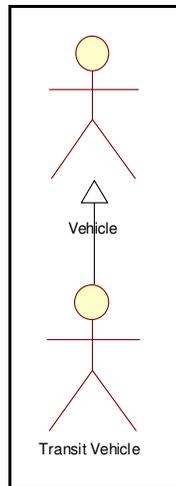


Figure 11. Illustration of Specialized Entity (Transit Vehicle) Inherited from General Entity (Vehicle).

In general, Use Case Diagrams should reflect scenarios from each actor’s point of view. **Even though the symbol for the actor is a stick figure, an actor not only can represent a person, but also can represent an agency or system.** For *Clarus*, one framework scenario and multiple, separate representative scenarios have been defined for Roadway Maintenance and Construction, Traffic Operations, Traveler Information, Transit Management, Emergency and Public Safety, Rail Operations Management, and Commercial Vehicle Operations. The intent of the separate scenarios is to address specific surface transportation operations unique to those scenarios. The *Clarus System* framework approach shows the *Clarus System* commonality reducing the redundancy among scenarios. For the diagrams in this section, actors and use cases that do not directly interface with the *Clarus System* have been defined to show end-to-end scenarios and help the user community see where *Clarus* fits in the whole scheme of the weather information space.

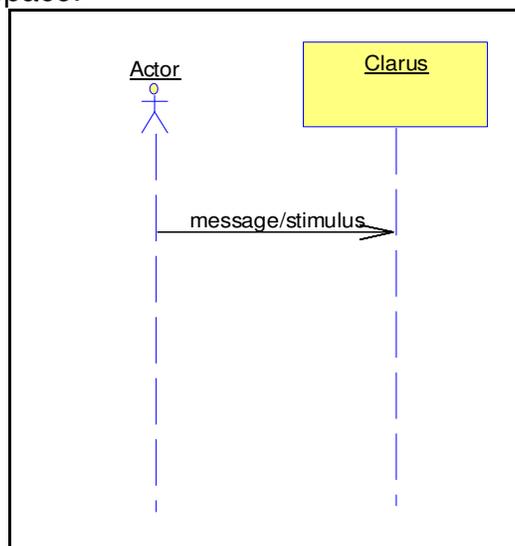


Figure 12. Illustration of Sequential Action.

Whereas the Use Case Diagram defines the things that the actors want the system to do, the sequence diagram portrays a typical sequence of operation between the actors and *Clarus*. The sequence diagram contains vertical lines with a label at the top representing the same actors from the use case diagram for that scenario. For the framework scenario, the *Clarus System* and NOAA are represented by a rectangular box and vertical line from the box. Arrows represent the action or message/stimulus between the actors and the *Clarus System* and NOAA. The arrow's directionality represents the direction of data flow. Time begins at the top of the sequence diagram and goes down to the bottom of the diagram.

Use case and sequence diagrams are part of an iterative process and should be continued in more detail past the Concept of Operations phase of *Clarus*. The representative use case and sequence diagrams in this document have been developed at a level of detail sufficient for broad stakeholder review and do not contain the rigorous detail that would be found in a design.

3.5.1 Framework Scenario - *CLARUS SYSTEM OPERATIONS*

3.5.1.1 Introduction

The *Clarus Initiative* is driven by the needs of the customers of the various service providers and these needs or interests are incorporated into a use case analysis. The formal *Clarus System* includes data acquisition, data integration, quality control, and service provider interface components. For the surface transportation user community, value-added products created by members of the service provider community become an essential part of their decision support tools. Service providers acquire quality-controlled *Clarus* data and integrate it with data from other sources (e.g., observed meteorological data from NOAA and other public and private sources, numerical weather prediction model data, road condition reports, and camera imagery) to produce consumer products. Observed data from *Clarus* enhances and complements the observed data set acquired from the national and private weather observation networks creating a refined analysis of existing conditions. Service providers integrate all observation sources into a composite presentation of each key parameter. They further enhance the presentation by adding analyzed fields using color gradations to represent small ranges of values in the total spectrum of observed values.

Many of the surface transportation user community's decision support needs are focused on the future impact of observed conditions projected forward in time and the impact of observed and forecasted weather conditions on route or road surface conditions. The quality controlled route or road surface condition and weather condition information from *Clarus* become essential initialization parameters for these surface condition models. In return, members of the surface transportation user community benefit from improved forecasts of route and road conditions and weather conditions.

In general, support for surface transportation operations by *Clarus* involves weather- and road/route-related data collected from diverse sources owned and/or operated by surface transportation organizations. The data are transferred at routine intervals to

one or more data fusion centers forming the *Clarus* database. During the data collection process, the *Clarus* System will be expected to perform a quality assurance evaluation to flag data anomalies. The manner of this quality control and assurance process will need to be designed during the *Clarus* System Design process such that it reflects accepted practices found within the meteorological community for such practices. The resulting quality-controlled data become available to a group of users designated as Service Providers. Service Providers are the private and public organizations that have a direct need for the observed *Clarus* data as a resource to create enhanced data presentations used by the various user communities. Key Service Provider organizations include NOAA, private weather firms, and public agencies that reformat weather data. The *Clarus System* returns the quality-controlled data to the provider agencies with indicators of potential data anomalies within their data set. This quality control feedback is part of a process to assure a dynamic metadata characterization.

3.5.1.2 NOAA

NOAA provides a unique function in the transfer of *Clarus* data to the final consumers of weather information due to their extensive involvement in the collection, processing, quality controlling and assimilation of hydro-meteorological data from both domestic and global sources. The acquisition of data from non-*Clarus* surface observation systems provides a foundation for the database necessary to support the quality control function within the *Clarus* processing function. Data from *Clarus* will also become an integral part of this observational database. The enhanced weather information base engendered by the combination of data from existing hydro-meteorological sources and *Clarus* will provide better definition of observed surface conditions.

These data enhance NOAA's public safety mission by providing higher resolution information to support and verify hydro-meteorological forecasts and warnings. This more robust data set also contributes better definition of existing conditions to help improve the initialization of numerical model processing runs done by the National Centers for Environmental Prediction. Improvement in the model initialization has the potential to enhance the performance of the numerical modeling and thereby improve the accuracy of the forecast fields used by both public and private sector meteorologists to create value-added products for the customer communities of all service providers. The higher resolution data set offers an opportunity to evaluate the effect of additional data on the performance of the models, an important research function done by research organizations within the academic community and NOAA.

Over extended periods of time, data meeting certain quality requirements will contribute to the Nation's climate record. The data will be archived and aid research done by NOAA, universities and external research foundations. NOAA has involvement in a substantial part of all meteorological data processing, so the integration of *Clarus* data offers to enhance the capabilities within NOAA and within the hydro-meteorological community that utilizes NOAA services to support its customer base.

3.5.1.3 Time Critical Weather Operations

The *Clarus Initiative* is driven by the needs of the customers of the various service providers and these needs or interests are incorporated into a use case analysis. The formal *Clarus System* includes data acquisition, data integration, quality control, and service provider interface components. Certain operational decisions require information resources that come from measured or observed data that is acquired instantaneously or has an age of just a few minutes. The design of the *Clarus System* provides the infrastructure to facilitate the transfer of weather, pavement, and hydrological data resources to meet the needs of time critical operations but it is likely that significant modifications in the current processing schemes will be necessary to assure the transfer of field data to the ultimate user within the required timeframe. Since timeliness becomes the critical factor, the use case analysis permits evaluation of the actors, use cases, and interactions that are involved in the collection and transfer of *Clarus* data before and during the movement of the *Clarus* data through the *Clarus System*. These will be the critical steps in assuring the data reaches the service providers quickly enough to permit the service providers to reformulate the presentation modes to support customer needs.

There are finite delays that exist in the *Clarus* data collection, transmission, and processing scenario. The primary delays occur in the collection and consolidation process that is currently inherent within the data collection networks indigenous in the Autonomous Layer. Figure 7 in section 3.2 illustrates potential latencies associated with the acquisition of ESS data from existing ESS networks and the anticipated time delays in gathering information from the multiple Autonomous Layer networks. Existing latencies in the ESS data collection include the following steps.

- Collection cycle to collect all parameters for a single “observation” at the ESS
- Storage of observations at defined intervals (usually once each 10 or 20 minutes) on the ESS processor
- Transfer of data from the ESS to a central location at a defined interval (usually once every 20 minutes but may be once an hour or more); inherent in this transfer is the communication protocol interactions and data transfer rates
- Data storage in a central database for access by autonomous agency
- Extraction of data from this central database inside the agency’s firewall with a subsequent write to a computer outside the firewall for access by external users

These steps account for the average 15 minute latency in the collection of ESS data in its present design. The estimated latencies within the *Clarus System* are associated with:

- The collection of data from all of the independent ESS networks and individual ESS
- Processing and storing the data
- Organizing the data into extractable datasets
- Performing quality control analyses
- Responding to user requests or queuing and delivering broadcast packets

The average collection time of 2.5 minutes and the 10 minutes for the ESS processing steps are only estimates at this time. It is quite plausible these times can be reduced. The latency times indicated prior to the *Clarus* ingest process are real. The latency is primarily due to the method of sampling data at the ESS on a cyclical basis and then transferring the data to the central site based upon a data collection cycle driven by the central system. There is no inter-process connection between the two cycles so observations tend to sit for several minutes before they are transferred to the database that supports the user interface to the data. As indicated in section 3.4.4, collection of data from mobile platforms located on maintenance vehicles also has its own inherent data transfer latencies depending upon the mode of communication used to transfer the data. The FHWA Vehicle Infrastructure Integration initiative has an even broader view of surface transportation data collection. VII envisions the acquisition of weather, pavement, traffic, and vehicle-related information by public and private vehicles with routine data transfer via a dense network of data collection points. The VII data offers the potential to greatly augment the existing surface transportation dataset. However, the infrastructure to support this initiative is not well defined yet, so it is not possible to determine potential data latency issues associated with the proposed VII design.

Time critical operational decisions require that these latencies be minimized. In order to accomplish a substantial reduction in current latencies, the design of the collection system needs to be modified to reduce data communications times and eliminate those steps where data are held pending acquisition by the next sequential step in the transfer process. The greatest reduction in latency would accrue from the collection of data from all ESS sites at essentially the same time on a regular basis either directly by the *Clarus System* or by Autonomous Layer organizations with immediate transfer to the *Clarus System*. However, the solution will not be simple, because there are a number of barriers to this approach, including:

- Communications costs for direct access to each ESS site
- Communications costs for acquisition of data at short intervals (e.g., every 10 or 20 minutes)
- Communications costs to acquire data from all sites at roughly the same time
- Inadequate communications infrastructure to support data transfer rates desired
- Hardware costs to upgrade older ESS processors to permit more efficient communications
- Hardware costs to permit direct acquisition of data at a central site with immediate pass-through to the *Clarus System*
- Security issues associated with gaining access to Autonomous Layer equipment inside of the agencies firewall
- Data ownership rights
- Legal concerns over dissemination of certain data types

Collection scenarios that substantially reduce the existing latencies will likely require significant investment in ESS network infrastructure and communications capabilities that currently are not in place. How this cost is covered will be a definite consideration in the design process. Security concerns, ownership rights, and legal concerns are

issues that affect a broader audience in the DOTs and all three of these issues can generate substantial resistance if not addressed as part of the initial design.

One approach to building a resource that meets time critical operational requirements may be to design for the future. New systems need to be designed to optimize the communications function. The time differential between observation at the ESS and receipt of the data at a central collection point needs to be nearly instantaneous. Communication solutions to accomplish this exist; ESS processing modules will need to be redesigned to utilize the transfer facility.

3.5.1.4 Clarus Framework Step-by-Step

Service providers and NOAA will receive quality-controlled data and associated metadata, as needed, from the *Clarus System* following methods and protocols defined during the *Clarus System Design*. They receive quality-controlled data and associated metadata information for the specified data request. Service providers then integrate the *Clarus* data with other pertinent weather and non-weather data to produce specific products and services that respond to the needs of the surface transportation community. These products and services are distributed to the users following accepted procedures that satisfy their particular needs.

The information that follows provides a step-by-step flow of activities that depicts how *Clarus* data are collected, processed, and distributed to the various user communities in a general sense. This general scenario focuses on the common features of *Clarus*; the unique, community-specific steps are discussed later in this section. The discussion is essentially sequential. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity responsible for each is noted on the line before each set of bullets. The one exception to the sequential process is the first three headings prior to the *Clarus* heading; the collection processes in all three can occur contemporaneously.

AUTONOMOUS ENTITY - ESS

ESS MEASUREMENT – TRANSPORTATION AGENCY/PRIVATE SECTOR

- Weather, pavement and hydrologic (water level) values measured in the field ESS
- Weather, pavement and hydrologic values stored in the field ESS as a current report
- Aggregated weather, pavement and hydrologic values stored in the field ESS as a series of reports

ESS COLLECTION– TRANSPORTATION AGENCY/PRIVATE SECTOR

- ESS Data Collector polls each ESS and transfers all stored reports not collected previously
- ESS Data Collector stores reports in database

AUTONOMOUS ENTITY – MOBILE PLATFORMS

VEHICLE COLLECTION – TRANSPORTATION AGENCY

- Vehicle systems automatically detect and time-stamp location, weather and route/road conditions
- Vehicle systems accept and time-stamp location of manually entered route/road condition reports, and weather conditions
- Vehicles upload stored reports to Vehicle Data Collector
- Vehicle Data Collector stores aggregated vehicle-based data in database

ROADWAY CONDITION COLLECTION - TRANSPORTATION AGENCY

- Transportation Agency transfers data about surface conditions, road conditions and CCTV images

EXTERNAL DATA SOURCE

NOAA

- NOAA collects, consolidates, assimilates, quality controls and disseminates surface and upper-air weather observations, hydrologic observations, radar imagery, and satellite imagery
- NOAA initializes various numerical models with the observed data and then computes forecasts of the state of the atmosphere for specific periods and time steps

PRIVATE WEATHER DATA COLLECTION

- Private weather data collector transfers data from private sector weather equipment and consolidates the observations

PUBLIC WEATHER DATA COLLECTION

- Public weather data collector transfers data from public sector weather equipment and consolidates the observations

CLARUS

MANUAL DATA COLLECTION

- *Clarus* collects data that is manually entered

DATA CONSOLIDATION

- *Clarus* server directly transfers data from the ESS Data Collector, Vehicle Data Collector, Roadway Conditions Collector and the Manually Entered *Clarus* Data Collector
- Collection process performs gross quality control checks on incoming data and flags obvious errors (out-of-range errors)
- *Clarus* server stores the data with quality control flags
- *Clarus* server accepts and stores data from NOAA, other Public Weather Service Providers, and Private Weather Service Providers for quality assurance check
- Data from multiple sites are sorted into data sets having common date, time and location reference

QUALITY CONTROL CHECK

- Data from *Clarus*, NOAA, other Public Weather Data Collectors, and Private Weather Data Collectors are arrayed spatially and transformed into a field representation of each parameter for each observation time
- *Clarus* observations are then compared to the field values for each *Clarus* observation point
- Observations deviating from expected values by a specified amount are flagged as potential errors
- *Clarus* stores the error flags with the data
- *Clarus* sends notification to the data provider (e.g., State DOT) when suspect data occur

DATA TRANSFER

- Quality controlled *Clarus* data are returned directly to each Autonomous Layer data provider and provided as data displays and/or alerts indicating exceptions found during the *Clarus* quality control routine
- Data in the *Clarus* database are acquired by members of NOAA, the STWSP community and the WSP community based on timeframe and location
- Error flags are acquired by members of NOAA, the STWSP community, and the WSP community
- Metadata are acquired by members of NOAA, the STWSP community, and the WSP community

SERVICE PROVIDERS

DATA INTEGRATION

- The Service Providers collect, store, and consolidate the *Clarus* road- and route-specific data along with observed meteorological data from various sources
- The Service Providers acquire forecast guidance products to complement the observed data
- Observed data are consolidated and composed into presentations showing the data from various sites displayed on a geo-referenced background
- The observed and forecasted data are composed into weather and pavement condition forecast products
- The forecasts are organized into textual and geographical presentations

DATA TRANSFORMATION

- Meteorological, hydrological, and pavement data are processed through models that transform the weather forecast and observed weather and pavement condition components into projections of industry specific representations (pavement temperatures, road conditions, stream flows, energy demands, rail conditions, etc.)
- Computed conditions are integrated with observed and forecasted weather condition displays and organized into tabular and geographical representations of current and forecasted conditions

END USER OPERATIONAL DECISION SUPPORT

- The observed weather and weather integrated, industry-specific guidance are coupled with reported operational activities to assess the current status of the end user operational system
- Using the forecasted weather conditions, the operations decision support system assesses the most effective operational approaches to accomplish the necessary actions to provide the highest level of service
- The operations decision support system provides notification techniques to advise users of adverse weather or industry specific conditions that are developing or that have developed recently
- Each of these products are either composed into value-added deliverables and made available for acquisition by end-users or are sent immediately to end users for display via a graphical user interface

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

DATA INTEGRATION

- NOAA collects, stores, and consolidates the *Clarus* data with observed hydro-meteorological data from its data collection network and various other surface observation networks
- The surface data are utilized with data from upper air, radar, satellite imagery, profilers, hydrologic, and other sources
- The data are combined to form field analyses of various direct and derived parameters

SEVERE WEATHER AND RIVER WARNINGS AND SHORT RANGE FORECASTS

- High resolution surface hydro-meteorological data contributes to the severe weather and flood warning decisions at NOAA's Weather Forecast Offices and River Forecast Centers
- High resolution data also contribute to both the NWS short term (nowcast) program
- The National Centers for Environmental Prediction assess the existing and future potential for severe weather, flooding and weather pattern changes and publishes the necessary warnings, watches, advisories and forecast guidance
- NOAA National Weather Service composes and disseminates these warnings, watches, advisories, statements and forecasts in support of its public safety mission and support to the nation's commerce

GENERATION OF NUMERICAL FORECASTS

- The meteorological data from the integration phase are used to initialize numerical weather prediction models and provide a more complete weather analysis
- The hydrological data from the integration phase are used to initialize numerical flood models
- The initialization incorporates current observations and trends over the last several hours
- The numerical models are run using the surface and upper air initialization values

PRODUCT GENERATION

- The observed data are composed into routine observation lists and prepared for distribution
- The observations and numerical model output are used to generate and verify various forms of hydro-meteorological warnings and forecasts
- The observed data set is used to assess local anomalies or events that occur outside of the general flow pattern
- Data from extended periods are composed into climatological analyses and composed into various reports

ARCHIVAL

- The observation, forecast and warning products, numerical forecast data, and general observations are archived for future purposes, e.g. planning, forensic support and development of the official record

RESEARCH

- The observation, numerical forecast data, and general observations are archived for future research purposes.
- NOAA's research organizations use the data for a wide range of hydro-meteorological research.

PRODUCT CONSUMER

TRANSPORTATION OPERATIONS

- Weather and maintenance planning information is acquired from Service Providers and NOAA
- Decisions are made on transportation operations
- Affected Vehicle operators are directly notified of current and forecasted weather and road/route information

WEATHER INFORMATION USER COMMUNITY

- Consumers in the following sectors acquire information from NOAA and other public/private weather support groups:
 - General public
 - Government meteorological centers – domestic and international
 - Government river forecast centers

- Government agencies (federal, state, local emergency management, transportation, law enforcement and Homeland Security)
- Media
- Military
- Private sector weather service providers
- Climatological and archival services
- Academia and Research organizations
- Users receive warning and notification services for severe weather and flooding from NOAA and other public/private services through a loose partnership composed of NOAA, the media, the private sector, and other government agencies
- The products and services received by users from these weather service providers includes weather data summaries, analyses, forecasts (grid, numerical and text), and related hydro-meteorological support products

TIME CRITICAL OPERATIONAL ACTIVITIES

- Time critical weather information is acquired from Service Providers and NOAA
- Decisions are made that address the specific time critical operational need

3.5.1.5 Use Case and Sequence Diagrams

3.5.1.5.1 Weather Information User Community Actors

In the *Clarus* framework scenario, the Weather Information User Community Actor is shown as a generalization of the following specialized actors:

- Commercial Vehicle Fleet Operations
- Emergency Management Operations
- Railroad Management Operations
- Roadway Construction Operations
- Roadway Seasonal (Non-Winter) Maintenance Operations
- Roadway Winter Maintenance Operations
- Transit Management Operations
- Traffic Management Operations

The Weather Information User Community actors are depicted in Figure 13.

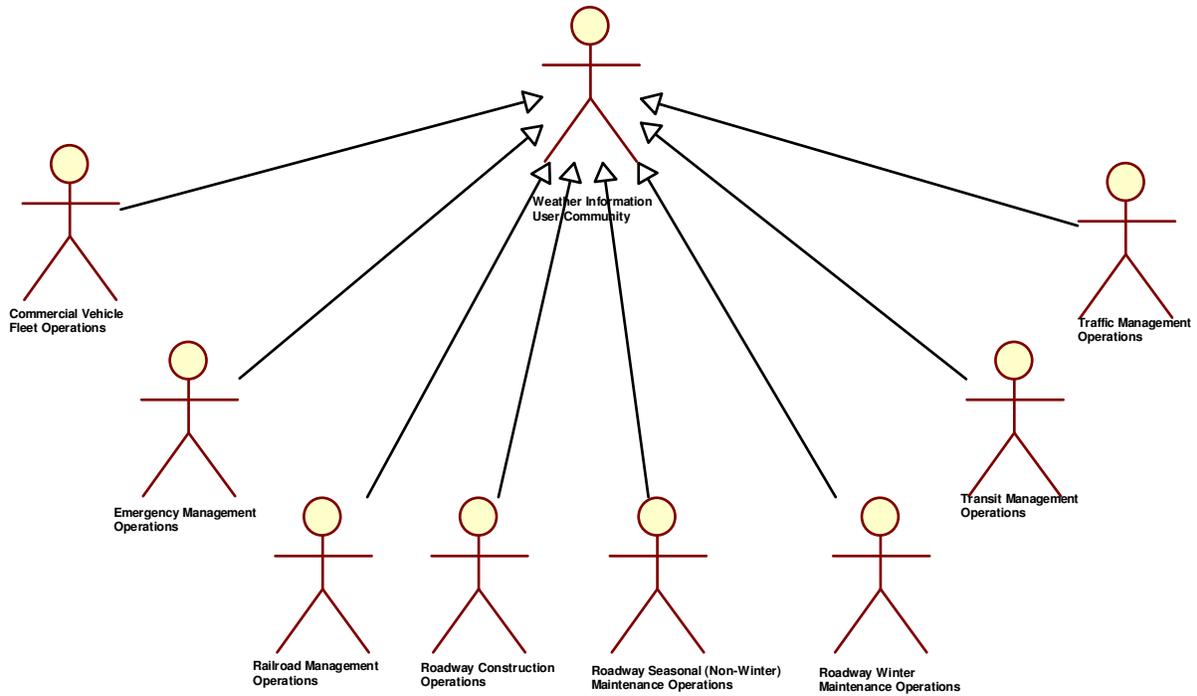


Figure 13. Weather Information User Community Actors.

3.5.1.5.2 Vehicle Actors

In the *Clarus* framework scenario, the Vehicle Actor is shown as a generalization of the following specialized actors:

- Commercial Vehicle
- Emergency Vehicle
- Maintenance and Construction Vehicle
- Private Vehicle
- Railroad Vehicle
- Roadway Service Patrol Vehicle
- Transit Vehicle

The Vehicle actors are depicted in Figure 14.

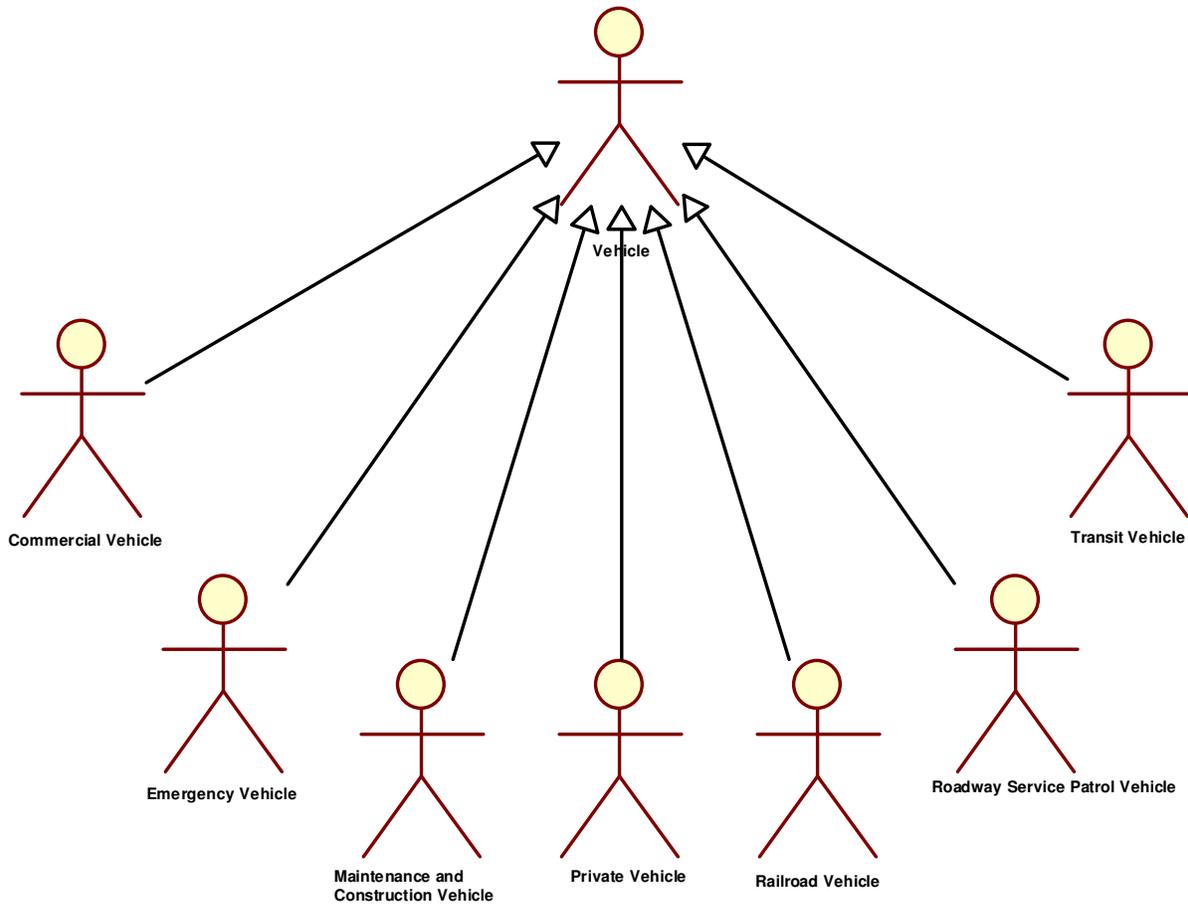


Figure 14. Vehicle Actors.

3.5.1.5.3 Overall Clarus Framework UML Diagrams

The Use Case and Sequence Diagrams based on the above functionality are depicted below in Figure 15 and Figure 16.

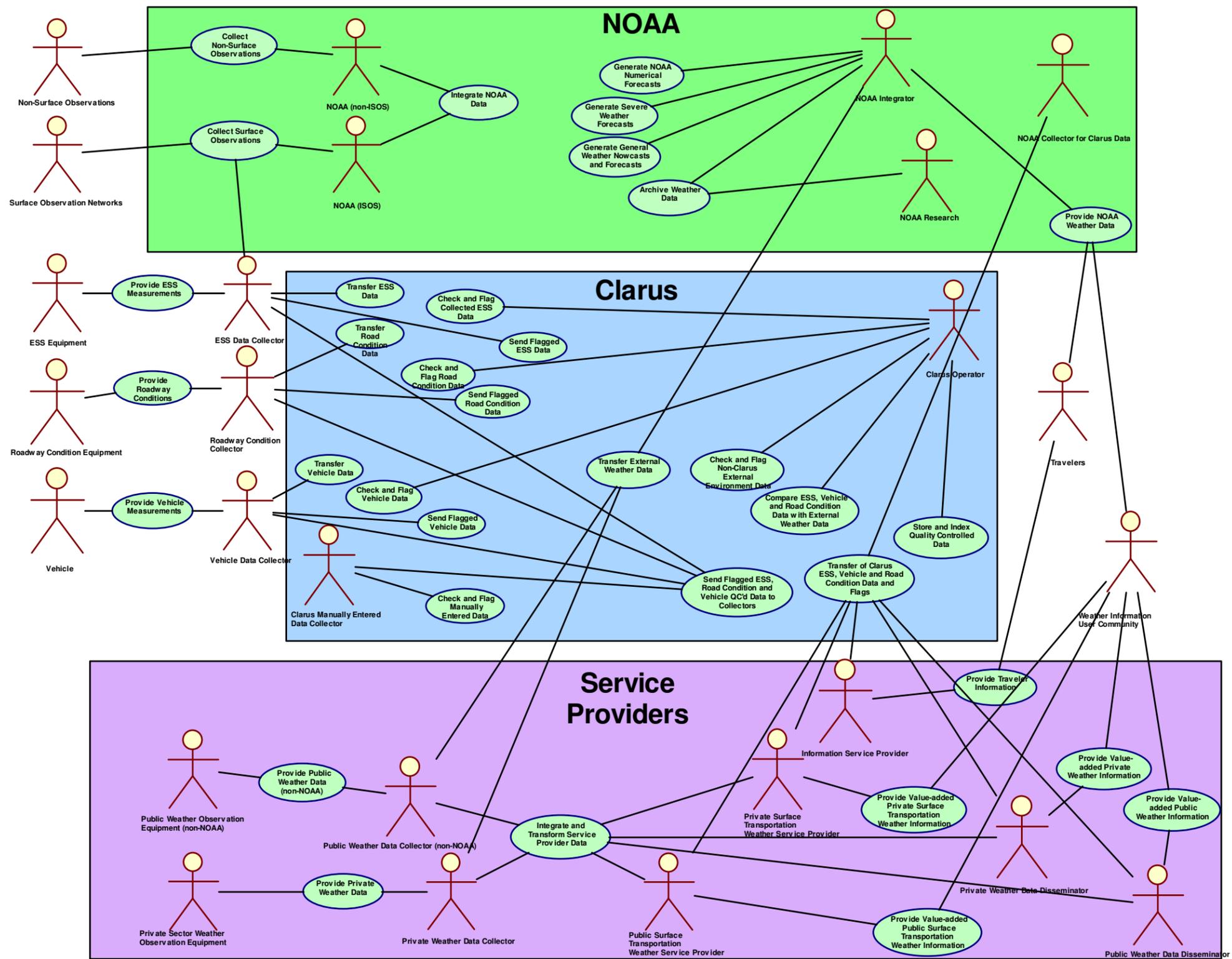


Figure 15. Clarus System Framework Use Case Diagram. [D](#)

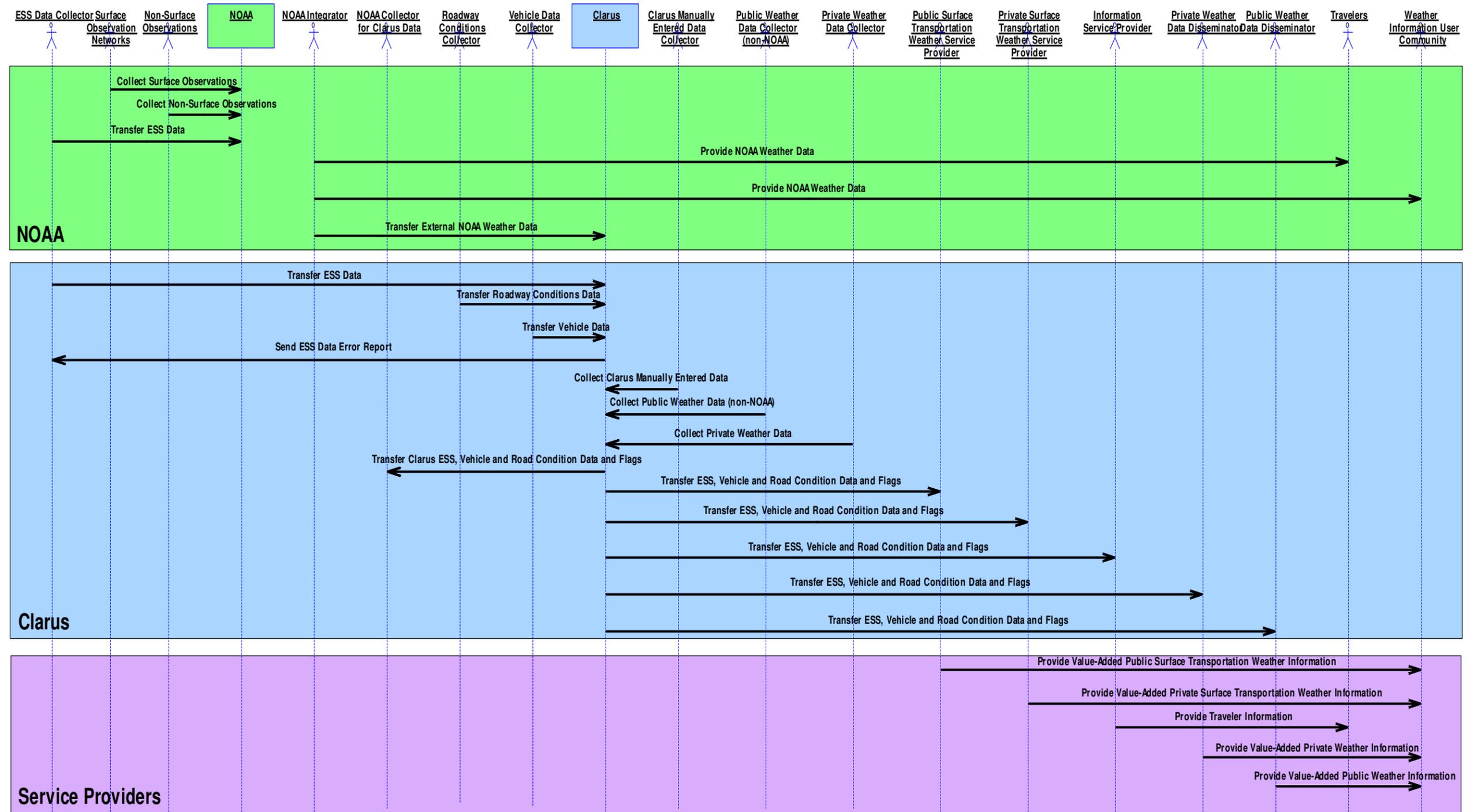


Figure 16. Clarus System Framework Sequence Diagram. [D](#)

3.5.2 Scenario A - ROADWAY MAINTENANCE AND CONSTRUCTION OPERATIONS FUNCTION

3.5.2.1 Roadway Maintenance and Construction Operations Representative Scenario Description

Rocky, the maintenance manager responsible for maintaining the roadways for the City of Frostbite Falls, Minnesota has been monitoring the progress of a major winter storm that developed in the southeast Colorado – northeast New Mexico region and has moved northeast across the central plains. The media has given extensive coverage of heavy rains in southern California along with one of the worst snowstorms in the mountains across California, Arizona, and southern Utah in recent history. Rocky has been able to watch the progression of Winter Storm Watches and Warnings issued by the National Weather Service on television and via the website provided by his weather service provider. He has found it especially helpful to check-in on the progress of the storm both in his office and through his PC at home.

Just two hours ago, Rocky's beeper went off and he received a text message from his service provider that the Winter Storm Watch had been upgraded to a Winter Storm Warning and snow was expected to start in roughly four hours or shortly after noon. Rocky feels his maintenance crew is prepared for the projected storm; the equipment is all operational and properly configured for the forecasted storm. Now he needs to determine whether to split his crew and send part of the staff home so they can return for the second shift if needed after midnight. He also needs to establish a treatment plan for the storm. The projected start time of the storm and the intensity of the storm in the first few hours are critical to Rocky's decisions.

Rocky turns to his PC and checks forecasts from several sources available on the Web. All sources seem to be in agreement that the storm will dump 6 to 8 inches of snow and will be followed by strong northwesterly winds and falling temperatures. The Maintenance Decision Support System (MDSS) supported by his weather service provider indicates that the snow will start just before the evening rush hour as light snow, but the intensity will not increase until near the end of the rush hour traffic flux. The MDSS recommends an anti-icing treatment 1 to 2 hours before the storm followed by a series of plowing and pre-wet salt treatments about every two hours (the normal route cycle time) during the storm.

Rocky agrees that treatment plan makes sense if the forecast timing is correct, but he needs to be absolutely confident that the storm is approaching as predicted. He pulls up a regional MDSS display that puts radar imagery, current weather symbols from NWS sites, and pavement condition information from the **Environmental Sensor Stations** in Minnesota, Iowa, South Dakota, and North Dakota. By looping through this composite imagery for the last four hours, Rocky is able to get a good sense of the timing of the start of the storm in Frostbite Falls. Rocky is amazed at the improvement in the display from last year when most of the ESS network data was not available or he had to pull data from each ESS site separately. This display became available after the new

Clarus System went operational last June. With access to data from all four states, Rocky's service provider was able to take the consolidated data from all of the states and create this nifty composite display.

The forecasted start time of the storm appears to be correct and the initial NWS and ESS network observations suggest the first 2 to 3 hours of snow are relatively light. However, Rocky notes that further back in the storm stations across Nebraska, southeast South Dakota, and western Iowa are reporting heavy snow. With this information Rocky is now confident that the MDSS forecast and recommendation are reasonable. Based upon the length of the forecasted snowfall and the strong winds projected to follow the storm, he decides to send part of the crew home. He also instructs the remaining staff to gear up to anti-ice the streets prior to rush hour. Rocky also opts to increase the anti-icing liquid application over the MDSS recommendation to make sure the anti-icing chemical will carry them through the rush hour.

3.5.2.2 Roadway Maintenance and Construction Operations Technical Description

For the roadway maintenance community, value-added products created by members of the service provider community become an essential part of their decision support tools. Many of the maintenance community's decision support needs are focused on the future impact of observed conditions projected forward in time and the impact of forecasted weather conditions on pavement surface conditions. The prediction of pavement conditions requires the application of sophisticated energy and mass balance models that transform projected or forecasted meteorological conditions into predicted surface conditions based upon maintenance actions completed or projected by maintenance crews. The quality controlled pavement and weather conditions from *Clarus* become essential initialization parameters for these pavement condition models. The continued improvement of systems such as the Maintenance Decision Support System (MDSS) depends upon the continual input of surface transportation-specific observations (ESS reports, road condition reports, and maintenance activity reports). In return, members of the roadway maintenance community benefit from improved forecasts of pavement and weather conditions, plus guidance regarding effective treatment options to address the anticipated pavement conditions.

Service providers extract data, as needed, from the *Clarus System*. They receive quality-controlled data and associated metadata information for the specified data request. Service providers then integrate the *Clarus* data with other pertinent weather and non-weather data to produce specific products and services that respond to the needs of the maintenance community such as pavement treatment actions. These products and services are distributed to the maintenance user following accepted procedures that satisfy their particular needs. The resulting *Clarus* support for the Roadway Maintenance and Construction Operations Function include:

- Provide support for winter and non-winter maintenance decision making
- Real-time verification of upstream conditions
- Enhance construction operations scheduling
- Data with quality control flags or metadata to *Clarus* users, and

- Improved forecast of weather and pavement conditions.

The information that follows provides the roadway maintenance and construction operations flow of activities that depicts a general scenario for how this function would work in conjunction with the *Clarus* Framework scenario. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity responsible for each is noted on the line before each set of bullets.

AUTONOMOUS ENTITY

VEHICLE COLLECTION – TRANSPORTATION AGENCY

- Maintenance and Construction Vehicle systems automatically detect and time-stamp location, weather and pavement conditions, and maintenance actions
- Maintenance and Construction Vehicle systems accept and time-stamp location of manually entered road condition reports, weather conditions, and maintenance actions
- Maintenance and Construction Vehicles upload stored reports to Vehicle Data Collector
- Vehicle Data Collector stores aggregated vehicle-based data in database

CLARUS

See the *Clarus* Framework Scenario

PUBLIC AND PRIVATE SURFACE TRANSPORTATION WEATHER SERVICE PROVIDERS

DATA TRANSFORMATION

- Meteorological and pavement data are processed through a pavement condition model that transforms the weather forecast and observed pavement condition components into projections of pavement temperatures and road conditions
- Pavement conditions are computed for segments of a given highway having relatively uniform physical and environmental characteristics
- Computed pavement temperatures and road conditions are integrated with forecasted weather conditions and organized into tabular and geographical representations of current and forecasted conditions

MAINTENANCE DECISION SUPPORT

- The observed weather and pavement conditions are coupled with reported maintenance actions to assess the current condition of the road surface for numerous representative points along a segment of highway
- Using the forecasted weather conditions, the MDSS assesses the most effective maintenance approaches to accomplish the necessary maintenance actions to provide the highest level of service
- The MDSS also provides the user with the capability to provide “what-if” scenarios of possible maintenance response strategies
- The MDSS provides notification techniques to advise users of adverse conditions that are developing or that have developed recently

- These products are composed into value-added deliverables and stored for distribution to end-users or sent directly to users

PRODUCT CONSUMER

ROADWAY MAINTENANCE OPERATIONS (WINTER AND SEASONAL)

- Weather and maintenance planning information is acquired from Service Providers and NOAA
- Decisions are made on winter road maintenance treatment strategies for pavement affected by weather events
- Decisions are made on seasonal (non-winter) road maintenance strategies (e.g., road striping) affected by weather events
- Crew shifts are set and the timing of activities planned
- Maintenance activities are conducted
- Maintenance Vehicle operators are directly notified of current and forecasted weather and pavement information

ROADWAY CONSTRUCTION OPERATIONS

- Weather and construction planning information is acquired from Service Providers and NOAA
- Decisions are made on construction activities
- Construction activities are conducted
- Construction Vehicle operators are directly notified of current and forecasted weather and pavement-related conditions

3.5.3 Scenario B - TRAFFIC OPERATIONS FUNCTION

3.5.3.1 Traffic Operations Representative Scenario Description

The Traffic Management Center (TMC) in Frog Creek, Pennsylvania deals with a maximum traffic volume of 124,000 vehicles per hour on its four regional interstates and divided highways. Twice each day the facility receives a weather forecast from its local **weather service provider**. It's been a busy late October week for Jack, the manager of the TMC, with several level 4 incidents snarling rush hour traffic with one requiring multi-hour detours and extra overtime by staff. The weekend is just around the corner and, with it, some welcome relief. Jack has not paid much attention to the weather forecast with all of the paperwork he had to handle in conjunction with the incidents, but he has overheard on the radio that rain showers are likely over the weekend, possibly mixed with a little snow.

However, the warm sunny Friday highlighting the vibrant fall colors make any hint of rainy or wintry weather a remote thought. Jack's only concern for the weekend is the Saturday traffic for the football game. Traffic management for the usual sellout crowd of 84,000 people is handled by the University and city police and only causes minimal congestion on his feeder highways. The normal congestion occurs in the area around the stadium and only has minimal effects on Jack's arterial system in and out of Frog Creek unless significant precipitation occurs. Jack expects the projected rain showers to slightly slow the movement of traffic but not to have significant impacts on TMC operations, so the normal weekend staff is scheduled.

However, at 9:17 AM on Saturday morning Annie, the person on call for the weekend, hears her pager go off. The automated warning system provided by the TMC's weather service provider indicates that ESS sites along the interstate in eastern Ohio are receiving heavy rain that is changing to snow. Annie is surprised by the details on her text message and remembers that Frog Creek has initiated a winter advisory service from its weather provider starting this fall. The decision to implement this premium service was made after the TMC became aware that surface transportation weather had been consolidated through the **Clarus** program and the piecemeal process the TMC used to follow was replaced by a single source of weather and pavement information.

Annie checks the wall of video monitors in front of her at the TMC command center and verifies that light rain is falling at most locations in Frog Creek. Roads are wet but traffic is moving just a bit slower than normal. Traffic flow rates are near normal for 9:00 - 10:00 AM on a football Saturday and average speeds are only down 5%. Annie then switches to the camera views along an interstate in Ohio and finds the roads water-covered near the border and slushy with snow falling 50 to 100 miles west. Reports from the new traction sensors along the interstate indicate the traffic safety index on the interstate is down to 60% of normal in the slushy area and traffic speeds have dropped from an average of 72.4 mph down to 58.3 mph. With growing concern about the developing storm, Annie looks at the morning forecast on the TMC weather support monitor and sees that a weather forecast update has been issued. It indicates the light

rain and showers expected through the morning are now projected to change to heavier rain about an hour before game time followed by a period of wet snow during the time of the football game before ending late in the afternoon.

Annie initiates the TrafFlow program with the updated weather forecast and finds that the rain will create significant congestion both prior to and after the game for all roads in the metropolitan highway system. TrafFlow indicates the forecasted conditions will slow traffic to near 70% of normal as people attempt to get to the game. The TrafFlow model also indicates the heavy rain will drastically reduce mobility on the roads leading to the parking areas which will in turn cause traffic to queue on the exit ramps, eventually spilling back onto the highway. This is really the first time Annie has had a chance to use the integrated tools that evolved from the integration of surface transportation weather information from around the region as part of the **Clarus System**. Annie recalls how much trouble it would have been to acquire and sort through this data just last year.

All guidance indicates that traffic flow could become a major issue if the weather forecast is correct. Annie is aware that Jack worked with members of the Frog Creek and Mullet County Public Works Associations, and the University Maintenance group to formulate game plans for situations such as this. Annie knows that the TrafFlow program was designed to assist in the generation of messages on the series of DMS over roads approaching Frog Creek and the creation of messages for the Highway Advisory Radio (HAR) network. Part of the program recommends alternate routes to the stadium to minimize congestion. In addition, the TrafFlow program will generate messages to pass to the 511 system to provide guidance for travelers coming from some distance away. This program was coordinated with the Ohio DOT as well to permit the integration of messages on the Ohio 511 program. Since this situation could pose a major test of the new advisory tools available this year and will have a high degree of visibility, Annie decides to call Jack and get him involved as they experience their first real test of the expanded weather support system.

3.5.3.2 Traffic Operations Technical Description

The information that follows provides a step-by-step flow of activities depicting a general scenario unique to a traffic operations function in conjunction with the *Clarus* Framework scenario. Similar to other functions, each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity responsible for each is noted on the line before each set of bullets.

AUTONOMOUS ENTITY

VEHICLE COLLECTION – TRANSPORTATION AGENCY

- Roadway Service Patrol Vehicle systems automatically detect and time-stamp location, weather and pavement conditions
- Roadway Service Patrol Vehicle systems accept and time-stamp location of manually entered road condition reports, weather conditions

- Roadway Service Patrol Vehicles upload stored reports to Vehicle Data Collector.
- Vehicle Data Collector stores aggregated vehicle-based data in database

CLARUS

See the *Clarus* Framework Scenario

PUBLIC AND PRIVATE SURFACE TRANSPORTATION WEATHER SERVICE PROVIDERS

TRAFFIC MANAGEMENT DECISION SUPPORT

- The observed weather, pavement and water level conditions are correlated with traffic data to assess the current and future conditions for numerous representative points along a segment of highway
- Using forecasts, the decision support system (DSS) provides recommended control strategies (i.e., traffic operation activities) for specific road segments to maintain mobility and ensure safety
- Using observations and forecasts of visibility distance and/or pavement conditions, the DSS provides recommended modifications to signal timing plans and incident detection algorithms
- Using observations and forecasts of visibility distance, wind speed/direction and/or pavement conditions, the DSS provides recommended messages to disseminate via DMS and HAR
- Using traffic data, visibility distance and/or pavement condition data, the DSS provides recommended speed limit reductions to post on Variable Speed Limit (VSL) signs and DMSs for specific road segments
- Using observations and forecasts, the DSS provides notifications to alert traffic managers of potential flooding or other hazards and recommendations on the location and timing of road closures, traffic detours and lane reversal for evacuation operations
- These products are composed into value-added applications and stored for distribution or sent directly to end-users (i.e., product consumers)

PRODUCT CONSUMER

TRAFFIC OPERATIONS ACTIVITIES

- Weather, pavement, and hydrologic forecasts are acquired from Service Providers and/or NOAA
- TMC staffing reviewed for weather incident coverage
- Traffic Operations collects, stores, and analyzes the *Clarus* data. Traffic managers add *Clarus* data to existing Traffic Management decision making methods
- Traffic managers alerted of change in road weather conditions 2 to 3 hours “upstream” at selected ESS reporting through *Clarus*
- Traffic managers alerted when ESS weather or road condition thresholds are exceeded
- TMC manager confirms conditions by viewing CCTV images from affected region
- Traffic managers confirm staffing and weather incident plan preparedness

- Traffic flow is monitored for changes due to weather and pavement conditions
- Traffic managers modify traffic signal timing and incident detection algorithms based upon weather and pavement conditions
- Traffic managers use VSL signs and DMS to reduce speed limits based upon weather and pavement conditions
- Traffic managers use DMS and HAR to advise drivers of road weather conditions
- Traffic operators restrict high-profile vehicles from traveling specific routes/bridges based upon wind speed and direction
- Traffic managers restrict vehicles without snow tires or tire chains from traveling specific routes based on pavement conditions
- Traffic managers close hazardous roads, ramps and bridges
- Traffic managers coordinate with emergency managers and law enforcement to detour traffic or modify lane use for evacuation operations (e.g., lane reversal)

3.5.4 Scenario C - TRAVELER INFORMATION FUNCTION

3.5.4.1 Traveler Information Representative Scenario Description

Getting ready for her trip home over the long weekend from college, Kerry is in such an excited hurry that she forgets to check the weather forecast and road conditions on her PC. She had been concerned about the trip home because of the heavy rains that seemed to persist all week. Now as she dashes out of her dormitory into the cool fall air, her duffel bag slung over one shoulder, she notices that the gray skies have finally given way to a sky full of twinkling stars and only the first hints of sunrise are peaking over the hills. Realizing that the rains may have caused some problems in the narrow Appalachian valleys, she feels it would be wise to check the weather and road conditions using the 511 system. After starting her car and while waiting for the engine to warm, Kerry takes out her cell phone and dials in 5-1-1.

Hearing the familiar introduction to the regional traveler information system, Kerry uses the interactive voice response features of the system to indicate that she will be traveling on State Route 200, heading east from Rowley up the Ripple River gorge. The 511 voice response system immediately advises her that State Route 200 is closed between Haggars Crossing and Porkys Bluff due to flooding. She then checks US Route 12, which is a longer drive that takes her south along the western slopes of the Appalachians before turning east at the National River and over Freedom Gap. The weather report indicates clear and cool weather along each segment of her route with local areas of fog, but no problems with road conditions. Kerry has no idea that behind the scenes the 511 system is tapping into the nationwide **Clarus System** and the state's Road Condition Reporting System. Information from these data collection networks coupled with weather information from the National Weather Service network and high-resolution weather and pavement condition forecasts form the core for the weather and road condition component of the State DOT's 511 system. Had she taken time before leaving her dorm, she could also have accessed the information from the State DOT web page.

Hanging up, Kerry gives a brief call to her parents before starting her drive home to tell them that she will be a bit later arriving because Route 200 is closed due to flooding and road conditions are better on US Route 12. As Kerry heads south on US-12 driving conditions are good except for occasional areas of fog that she seems to run into each time she drops into a valley. Even though she passes through these zones of fog, some of them seem to be getting a little denser as the first light of morning begins to appear. Kerry knows that there are a couple of deep valleys to cross before she gets to the National River, so she stops briefly in Whiskey Run to check the weather conditions once more. The report for the segment of US-12 from Devils Ridge to Highland indicates that there is dense fog in the Tumbling River valley.

Kerry is not aware that a network of visibility sensors and video cameras are installed along US-12 to monitor for dense fog areas. The data from these sensors is transmitted routinely over the Clarus network and made available to weather service providers, who

then transform the reports and images into advisory messages along specific segments of the highway. Currently, the visibility sensors in the Tumbling River valley are reporting visibilities under 1/8 mile. Kerry continues south and as she approaches the crest of Devils Ridge, she sees the fog advisory message on the dynamic message sign the stretches overhead across the highway. It reads, "DENSE FOG 2 MILES AHEAD, DRIVE WITH CAUTION". As she starts dropping into the valley, Kerry can see the bottom of valley shrouded in fog with the first rays of sunshine streaming across the ridgeline to the east. As the road winds down the side of the valley, it finally becomes partially obscured in the fog. Another DMS pops out of the fog, this one with a flashing warning, "VISIBILITY LESS THAN 100 FEET, 2000 FEET AHEAD". Kerry checks to make sure her low beams are on and she slows her vehicle.

As she reaches the bottom of the valley, the visibility drops to near zero making it difficult to even see the superstructure on the bridge over the Tumbling River. Kerry cautiously picks her way through the fog and up the south slope of the valley toward the Highlands. As she drives out of the fog and back into the first rays of the day, Kerry is pleased that the fog monitoring system is there and that it provided her the necessary warning to permit her to adjust her driving habits appropriately.

3.5.4.2 Traveler Information Technical Description

For the traveling public, a wide range of weather-related decision aides are available that have become an essential part of evolving advanced traveler information systems (e.g. web sites, 511, and traveler information kiosks). The information provides important weather-related travel planning information both pre-trip and en-route. Often the information provided to travelers comes from existing data and information resources collected by State DOTs (Autonomous Layer) and are provided to travelers through mechanisms such as web sites describing current weather and road conditions. Some State DOTs have folded this information into 511 traveler information systems where the information is often included with weather forecast information acquired from public and private service providers.

Travel decisions rely upon the availability of timely road conditions and weather information. The preparation of travel information requires the use of a broad range of weather data to formulate how weather conditions will evolve over an entire road network. This information is consolidated with the latest road condition reports from State DOTs and State Law Enforcement to provide an information service to travelers conveyed through various communications methods.

Service providers extract data, as needed, from the *Clarus System*. They receive quality-controlled data and associated metadata information for the specified data request. Service Providers then integrate the *Clarus* data with other pertinent weather and non-weather data to produce specific products and services that respond to the needs of the traveler such as road condition information. These products and services are distributed to the traveler through various devices and communications methods to satisfy their particular needs.

The information that follows provides a step-by-step flow of activities that depicts a general scenario unique to the traveler information function in conjunction with the *Clarus* Framework scenario. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity responsible for each is noted on the line before each set of bullets.

AUTONOMOUS ENTITY

VEHICLE COLLECTION – INFORMATION SERVICE PROVIDER (ISP)

- Private Vehicle systems detect and time-stamp location, weather, and pavement conditions
- Private Vehicle systems upload stored reports to Vehicle Data Collector
- Vehicle Data Collector stores aggregated vehicle-based data in a database

CLARUS

See the *Clarus* Framework Scenario

INFORMATION SERVICE PROVIDERS

DATA INTEGRATION

- The Information Service Providers collect, store, and consolidate the *Clarus* data with observed meteorological data from various other sources
- The Information Service Providers acquire forecast guidance products to complement the observed data
- Observed data are consolidated and composed into presentations showing the data from various sites displayed on a GIS background
- The observed and forecasted data are composed into route-specific weather and road condition analyses and forecasts

DATA TRANSFORMATION

- Weather condition and forecast data for specific route segments are stored in a database on information delivery systems ready for access by travelers, transportation agencies and the media. Maintenance activity and weather-related road closure information are collected and added to *Clarus* data and stored in a database for use in generating road condition information
- Pavement and hydrologic conditions are computed for segments of a given highway, combined with reported road condition information, and stored along with the weather condition and forecast information

TRAVELER INFORMATION DECISION SUPPORT

- The observed weather, pavement and water level conditions are correlated with traffic data to assess the current and future conditions for numerous representative points along a segment of highway
- Using observations and forecasts as well as road closure, vehicle restriction, and transit/rail service information, the DSS provides recommended messages/content for dissemination via DMS, Highway Advisory Radio (HAR), interactive telephone systems (e.g., 511) and traveler information web sites based upon visibility distance, wind speed/direction and/or pavement conditions.

- These products are composed into value-added applications and stored for distribution to or immediate delivery to end-users (i.e., product consumers)

PRODUCT CONSUMER

TRAVEL INFORMATION

- Weather, pavement condition, road closure, vehicle restriction, transit/rail service and maintenance activity information are acquired from Information Service Providers and NOAA
- Calls to statewide 511 systems and other interactive telephone systems support decisions on travel plans and en-route travel activities
- Information is displayed on DMS regarding adverse travel conditions or rapidly changing weather and road conditions anticipated along the traveler's direction of travel. Similar information is transmitted via HAR.
- Information on adverse travel conditions is provided to State Patrol for use in planning activities.
- Information is displayed on traveler information web sites (e.g., DOT web pages).
- Information is displayed on in-vehicle devices and Personal Digital Assistants (PDAs) regarding changing weather and road conditions anticipated along current direction of travel and driver-selected route
- Roadside kiosks provide geographical display and printed outputs of current and forecasted travel weather conditions
- Media outlets access traveler information systems and relay the information on radio and television supporting traveler planning activities

3.5.5 Scenario D - TRANSIT MANAGEMENT FUNCTION

3.5.5.1 Transit Management Representative Scenario Description

Buster, the manager for the Transit Authority in Mobile Flats, supervises a recently completed, rapid transit train service designed to minimize congestion in the downtown business district and assure easy access to the renowned medical research center and hospital complex near the heart of the city. The success of the transit program revolves around the well-orchestrated coordination between the bus feeder system and the modern train service. The Transit Authority teamed with a local company to create a sophisticated scheduling system that monitors the position of all buses and trains and attempts to keep all buses and the trains on the prescribed schedule. The scheduling module uses a complex traffic model to determine the effects of traffic volume and occasionally adjusts the schedules to account for changes in traffic patterns.

Prior to the installation of the new transit service, sporadic storms and especially decaying tropical depressions hit the city causing local flooding that totally disrupted the bus service schedule. The new scheduling program now deals with these events and adjusts schedules to account for delays along specific routes. Since modifications in the schedules affect the user base of the Mobile Flats public transportation system, the Transit Authority implemented a thorough schedule information system. Monitors are located at train terminals and numerous bus waiting shelters throughout the city. Users may also access the Transit Authority website from any location and find when a bus or train is expected at a specific location in the city. In addition, the information is available via a handheld device, which a user may already own, or one the Transit Authority will provide as part of their Regular Riders program. In addition, anyone can call the Transit Authority's Schedule Line and get the current arrival time at any point via an interactive voice response telephone system.

Since weather is the primary factor affecting scheduling adjustments, the Transit Authority integrates observed and forecasted weather and pavement conditions into the scheduling program. Occasional flooding also affects routing so the Transit Authority, in conjunction with the City of Mobile Flats, has invested in an extensive network of **Environmental Sensor Stations (ESS)** to monitor both road weather and hydrological conditions. ESS sites near flood prone streams have been instrumented with water depth sensors that determine the depth of water in the stream. Mobile Flats has also deployed an additional network of sensors that just monitors water depth in flood prone areas. The information from the city's ESS sites and water depth sensors has become part of the new nationwide **Clarus System**. Data from the State DOT ESS network also is collected and integrated by the **Clarus System**.

Ready access to all of this data from one source has permitted the Transit Authority's weather service provider to more efficiently access environmental information and assimilate it into an assessment of weather and pavement conditions within and around the city. The weather service provider continually updates the existing conditions and short-term weather and pavement forecasts. Although the scheduling program can

ingest the weather and pavement input automatically and modify the scheduling without human intervention, Buster and his staff monitor the conditions and forecasts closely to assure that the schedule adjustments seem reasonable. Operators may override the schedule modifications as necessary.

At this moment, Buster is watching the remnants of Xavier, a tropical storm that dumped over 20 inches of rain across the metropolis. Radar and ground reports shown on the internal website indicate a few weak rain bands are still associated with the disappearing storm. Twenty percent of the routes in the bus network have been affected by local flooding. Some have been rerouted or actually terminated until the water recedes. Any additional rain makes the road closure process a dynamic situation and each route change tends to ripple through the entire system, so Buster is monitoring the progress closely. He has already talked to Jerry at the weather service office and has Tammy, his assistant, monitoring radio traffic amongst highway maintenance personnel within the city and surrounding communities to pick up reports of heavier rain squalls. If indications of another rain band develop, Buster will assess the impact of the projected rain and adjust the scheduling directly or coordinate with Jerry to update the area affected by the rain and have the updated information reissued to the scheduling program.

3.5.5.2 Transit Management Technical Description

Transit operations revolve around scheduling and it is essential that all components of the multi-modal transportation scheme reach each designated location at specified times. Transit system users depend upon this scheduling consistency. However, inclement weather affects different components of the multi-modal system in different ways. Therefore, it becomes important to know specifically what the type and intensity of weather is expected and how this weather scenario is likely to affect the performance of the fleet. Winter storm and heavy rain conditions tend to disrupt bus and ferry scheduling more significantly than rail performance, thus significant attention needs to be placed on pavement and wave conditions and their impacts on bus and ferry traffic flow.

Support for transit management functions by *Clarus* involves weather-, pavement-, and transit-related data collected from diverse sources owned and/or operated by surface transportation organizations. Some transit organizations own weather data collection systems and many rely on reports from their transit operators that may be captured in for use within the *Clarus System*. The data from these systems are transferred at routine intervals to one or more data fusion centers to form the *Clarus* database. Service providers and other users (e.g., transit authorities) extract data, as needed, from the *Clarus System*. They receive quality-controlled data and associated metadata for the specified data request. Service Providers then integrate the *Clarus* data with other pertinent weather and non-weather data to produce specific products and services.

The information that follows provides a step-by-step flow of activities that depicts a general scenario unique to a transit management function in conjunction with the *Clarus*

Framework scenario. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity responsible for each is noted on the line before each set of bullets.

AUTONOMOUS ENTITY

VEHICLE COLLECTION – TRANSIT AGENCY

- Transit Vehicle systems detect and store weather, pavement, and transit operations information as a function of time and location over their routes
- The Vehicle Data Collector uploads the data from the transit vehicle at specified intervals, or drop points, and stores the aggregated vehicle-based route and operations data in an operational database

CLARUS

See the *Clarus* Framework Scenario

PUBLIC AND PRIVATE SURFACE TRANSPORTATION WEATHER SERVICE PROVIDERS

TRANSIT MANAGEMENT DECISION SUPPORT

- The observed weather, pavement and water level conditions are coupled with reported maintenance actions to assess the current condition of the road surface for numerous representative points along a segment of highway
- For route-based transit operations (e.g., Ferries and Light Rail), the observed weather and route conditions are used to assess the current condition of the route
- Using the observed and forecasted weather conditions, Transit Management Decision Support System assesses the anticipated pavement and/or route conditions and recommends service adjustments including transit parking
- These observations and projections are composed into value-added deliverables which may be stored for distribution or sent directly to the end users
- Weather, water level, route and road condition data are processed and alerts are generated when specific operational thresholds are exceeded

PRODUCT CONSUMER

TRANSIT MANAGEMENT ACTIVITIES

- Weather, water level, route and road condition advisory information is acquired from Service Providers and NOAA
- Decisions are made on the impact of the projected conditions on the schedules of transit vehicles within the fleet
- Schedules and routes are adjusted to accommodate for the impact of the weather, route conditions, road conditions, wave height conditions, and traffic flow
- Revised schedules and routes are computed and made available to transit system users

3.5.6 Scenario E - EMERGENCY AND PUBLIC SAFETY FUNCTION

3.5.6.1 Emergency and Public Safety Representative Scenario Description

Jane is an emergency management coordinator for the City of Fertile, a small community in the midst of the Corn Belt. Her team maintains the 911 service plus interfaces with the local and regional police and fire departments, ambulance services, medical facilities, and other emergency management agencies. Because many of the incidents her group deals with are associated with inclement weather conditions, the city has equipped her emergency management operations center with a dedicated weather support console. The console has three monitors that the emergency management operator can connect to various information resources such as the city's network of video cameras, the state ESS network, websites containing free weather information, and a website provided under contract from a surface transportation weather service provider.

The surface transportation service provider and the State DOT allow Fertile to have access to the Maintenance Decision Support System (MDSS) the DOT has implemented in the DOT district in which Fertile resides. This program has been under development within the district for the last couple of years and became more robust when the nationwide **Clarus System** went operational to collect weather, pavement and hydrologic data from surface transportation monitoring sites around the country, including from the various sources surrounding Fertile. The *Clarus* data increased the density of the weather information available to analyze weather conditions and provided pavement temperature and surface conditions used to assess the impact of maintenance actions. Jane and her staff are not meteorologists by any means but because of their need to stay up on the weather, the emergency management team has become "the local weather experts" and assists with decision support information for school closures, county maintenance decisions, and other local activities where the team can help without jeopardizing their primary emergency management services.

On this particular January evening, Jane is on duty and the City of Fertile is in the midst of a winter storm. Looking out the window Jane estimates that there are 4 to 6 inches of snow on the ground so far and another 2 to 3 inches are expected. That amount fits with the reports that Jane has been hearing from the state maintenance drivers as they work the local highways in the area around Fertile. It also fits with the snowfall totals that the MDSS estimates for the road segments in the Fertile area. Jane has been watching the maintenance activities in the area by monitoring the MDSS display that shows the location of the maintenance trucks and the reported and estimated road conditions. The team knows that these trucks are instrumented with data logging equipment that telemeters the data back to a central computer at least once every ten minutes. This information is immediately processed and updated on their MDSS display. The team has gained confidence that the reports are current and reliable.

As Jane monitors the maintenance activity, she is watching the plowing and treatment progress knowing that two trucks are out of action from the Loam garage. Although the

Interstate that is just 10 miles east of Fertile is in good shape, US-49 is in marginal shape, and State Routes 10, 33, and 46 have not even been touched yet. So far, these conditions have not been a problem. The emergency calls have been a few vehicles off the road and a couple of fender benders in town. At 10:18 PM this all changes. A 911 medical emergency call comes in from a residence 2 miles northwest of Sandy City just off State Route 33.

Jane addresses the issue, conferences in the Centralia hospital, confirms that an ambulance needs to be dispatched immediately from Centralia, and contacts the ambulance service and confirms with all parties that the ambulance is on the way. She also calls the State Police and advises them of the emergency. However, Jane is aware that State Route 33 has not been plowed or treated yet. She immediately contacts Lenny, the supervisor for the Loam garage who is working with staff at the garage to get one or both of the inoperable trucks back on the road. Since Lenny is in the shop and not his office, he asks Jane to tell him where trucks 9984 and 3762 are currently and where the ambulance needs to go. She indicates the trucks last positions from the MDSS map and the spot of the emergency. Lenny indicates that since truck 3762 is near the US-52 intersection with State Route 10; he will have Dale jump onto route 33 just west of Centralia and clear the road in front of the ambulance.

Meanwhile, he will ask Roger in truck 9984 to take a short cut along county AB onto route 33 so he can pick up the plowing activity about half way between Centralia and Sandy City. Lenny then asks Jane if she will contact Dean in Sandy City and see if they can get a city truck to make sure the road is clear to the emergency site. Jane contacts Dean who initiates action to get a truck on the road to the residence. Jane then begins to monitor the progress of the maintenance vehicles, the ambulance, and the State Highway patrol car dispatched by the Highway Patrol to assist and calls back to the 911 contact to provide information on the emergency response activities. Once the Highway Patrol officer arrives on site, Jane passes responsibility to the officer. However, she continues to monitor the progress of the ambulance and updates the officer when he requests a position.

3.5.6.2 Emergency and Public Safety Technical Description

Responses to local or regional emergencies or general public safety functions may be significantly impacted by weather-related conditions. The aggregation of many local and regional support services rendered by members of the service provider community becomes an important part of the agency's decision process. Service providers acquire quality-controlled *Clarus* data and integrate it with data from other sources (e.g., observed hydro-meteorological data from other public and private sources, numerical weather prediction model data, road condition reports, and camera imagery) to produce consumer products.

Local emergency and public safety operations focus on quick mobilization of resources. Inclement weather affects the mobilization plan in different ways depending upon the character of the weather situation. Precipitation impacts road conditions and the subsequent effect on the mobilization plan is dependent upon traffic impacts and the

maintenance or flood control actions taken by local agencies. Wind speed and direction can affect the dispersion of plumes and emergency responses taken to protect public safety.

Regional emergency and disaster management operations also focus on quick mobilization of diverse resources. They may also require an immediate, highly localized assessment of the transport of hazardous materials within the atmosphere around and disseminating from a disaster site. Inclement weather affects the mobilization plan in different ways depending upon the character of the weather situation. In disaster situations, the airborne movement of noxious, lethal, or hazardous materials or gases is often dependent upon local weather conditions in the area of the disaster and the effect of the event on these meteorological factors. The determination of safety zones around the disaster needs to be defined as soon as possible after the event. In addition, the evacuation or movement of affected parties needs to be implemented quickly. The response scenario becomes a dynamic process if the source of hazardous materials persists and weather conditions change.

Support for emergency and public safety functions by *Clarus* is enhanced by weather, pavement, and hydrologic data collected from diverse sources owned and/or operated by surface transportation organizations. Although local emergency and public safety authorities are not typically owners of surface transportation weather data collection systems, they benefit from the data collected by other agencies within their area of operation. The process to provide support for these public safety agencies requires that data from these local and regional environmental information systems be transferred at routine intervals to one or more data fusion centers to form the *Clarus* database.

The information that follows provides a step-by-step flow of activities that depicts a general scenario unique to a local or regional emergency and public safety function in conjunction with the *Clarus* Framework scenario. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity responsible for each is noted on the line before each set of bullets.

AUTONOMOUS ENTITY

VEHICLE COLLECTION – PUBLIC SAFETY AGENCY

- Emergency Vehicle systems detect and store weather, pavement, and emergency operations information as a function of time and location
- Vehicle Data Collector uploads the data from the vehicle at specified intervals or drop points and stores the aggregated vehicle-based data in an operational database

CLARUS

See the *Clarus* Framework Scenario

PUBLIC AND PRIVATE SURFACE TRANSPORTATION WEATHER SERVICE PROVIDERS

EMERGENCY AND PUBLIC SAFETY DECISION SUPPORT

- The observed weather, pavement and hydrologic conditions are coupled with reported maintenance actions to assess the current condition of the road surface or route for numerous representative points along a segment of highway
- Observed and forecasted weather conditions serve as input into a dispersion model that simulates the flow of air and local environmental factors
- Observed and forecasted precipitation events and hydrologic conditions serve as input into a water level model that predicts the location and timing of roadway flooding
- Using the forecasted weather conditions, the Service Provider pavement condition model or DSS assesses the anticipated pavement conditions assuming no maintenance actions
- The DSS also assesses the anticipated pavement and route conditions based upon input from highway crews and their expected route timing.
- These observations and projections are composed into value-added deliverables that may be stored for distribution or sent directly to the end users.

PRODUCT CONSUMER

LOCAL EMERGENCY AND PUBLIC SAFETY ACTIVITIES

- Weather and road condition advisory information are acquired from Service Providers and NOAA
- Decisions are made on the impact of the projected weather and pavement conditions on the response timing of emergency vehicles within the local area
- Response times and routes are adjusted to accommodate for the impact of the weather, road conditions, and traffic flow and integrated into an emergency management deployment system
- Information regarding weather, road conditions, traffic flow, and emergency management logistics is displayed on in-vehicle devices and PDAs to facilitate coordinated emergency and public safety activities
- Output from the dispersion model feed into the emergency management deployment system which provides guidance on the appropriate deployment of available resources and possible evacuation and response plans associated with the disaster event
- Emergency management and law enforcement personnel coordinate with traffic managers to evacuate residents from hazardous areas

3.5.7 Scenario F - RAIL OPERATIONS MANAGEMENT FUNCTION

3.5.7.1 Rail Operations Management Representative Scenario Description

As a dispatcher for Rogers Railroad, Jimmie is always on the watch for changing weather conditions that could jeopardize his schedule and the safety of the trains currently in the rail network. Knowing that trains are susceptible to 'blow-overs' when strong winds or wind gusts hit the train from the side, Jimmie is especially careful to monitor for thunderstorm complexes or weather patterns that create a potential for high winds. On this Thursday in mid-April, Jimmie is watching a thunderstorm complex develop over the Texas Panhandle. He is aware that this area may become a potential concern based upon Weather Watches issued by the National Weather Service, advisory notices posted on a couple of websites that he has checked in the last hour, and the notification he received from the weather service provider a little over an hour ago. Rogers Railroad uses this weather service provider as its primary source of information but confirms their forecasts by checking products from the NWS and other sources.

Jimmie particularly likes the geo-referenced RailNet display that the provider developed jointly with Rogers. The entire Rogers Railroad network is the primary display and each train in the system appears in its current position on the display. Jimmie has the ability to add or delete state and county boundaries, rivers, lakes, highways, cities, and other geographic reference parameters. On top of this background, Jimmie can add one or more weather or rail-related parameters to create a composite display of the rail system and weather conditions. In addition, he can zoom the display area to create regional or local areas of the Rogers network. Once he has a display combination and an area he likes and can use in the future, he saves both the view areas and parameter combinations for future use.

Jimmie finds the display of weather information improved over the weather overlay system from two years ago due to the additional data that is available from the surface transportation sector via the **Clarus System**. Even though this additional data is not directly rail related, it filled a number of weather data voids where neither NOAA nor Rogers Railroad had weather observation sites. Jimmie has also found the added water depth information from HiFAS (Highway Flooding Analysis System) that is communicated through the *Clarus System* has proven helpful in augmenting the flood potential display previously derived from just the hydrological data derived from NOAA sources.

The Texas Panhandle storms are developing quickly. Jimmie is monitoring the progress of a freight train bound from Nashville to Albuquerque that is currently 70 miles east of Amarillo. It is carrying mostly of benign commercial goods but does have 10 cars containing a toxic commercial solvent. Jimmie is keeping an eye on the radar overlay of the storms on the rail configuration in the northern Panhandle as he manages the movement of trains throughout the southwestern quadrant of the United States. While he is sending a message to a train west of Salt Lake City, the WeatherWatch

system initiates an alert indicating a strong thunderstorm south of Amarillo moving northeast is projected to cross the rail line somewhere along a segment roughly 10 to 30 miles east of Amarillo in approximately 45 minutes.

The WeatherWatch program has derived this path from the attribute data provided by the NexRAD radar and has placed a flashing display of the potential path of the storm on the RailNet display of the northern Panhandle of Texas. The display indicates there is a potential for brief high winds, hail, and heavy rain. Jimmie finishes his note to the Utah train and immediately edits an advisory note with the specifics of the storm that had been auto-generated by WeatherWatch system for transmission to the Nashville to Albuquerque train. Jimmie now focuses his attention on this train. Jimmie has the ability to perform “what-if” analyses using the combined capabilities of the RailNet/WeatherWatch system. Based upon the current speed of the train, the train and the storm will be in the same vicinity at roughly the same time.

Jimmie decides to test some modifications to the train’s speed and see if he can slow the train to avoid the timing of this well organized thunderstorm cell. As he tests a couple of scenarios, the WeatherWatch system updates the storm track information. The update indicates that the storm is intensifying and now the segment is better defined in a range of 15 to 25 miles east of Amarillo. In addition, Jimmie now notices the highlighted 54 mph wind gust entry taken from surface observations near the current thunderstorm position. Because of the toxic material on this particular train, Jimmie decides to slow the train to 25 mph to try to avoid the thunderstorm. He sends notification to the engineer to reduce the speed to 25 mph and be prepared to bring the train to a complete stop if this thunderstorm or additional storms along the line of cells will pass the rail line near the position of the train.

3.5.7.2 Rail Operations Management Technical Description

For the railroad industry, value-added products created by members of the service provider community become an essential part of decision support for planning and daily operations. Railroad operation decision-making relies upon the availability of timely current and forecasted weather information along thousands of miles of rail line across the nation that experience extreme weather conditions ranging from violent thunderstorms to bitter cold air temperatures. Safeguarding the movement of freight and passengers requires knowledge of weather events that can result in derailment due to high winds, the buckling of track due to extreme temperatures or rail washout due to flooding. The preparation of the appropriate weather information requires the use of a broad range of weather information to formulate how weather conditions will evolve over an entire rail network along with site-specific information relating transient weather conditions that result in isolated, yet severe, weather conditions along the railroad right of way. Likewise, military rail operations need rail network weather information in order to plan and manage shipment of sensitive military assets.

The information that follows provides a step-by-step flow of activities that depicts a general scenario unique to a railroad operations management function in conjunction with the *Clarus* Framework scenario. Each successive heading and set of bullets

constitutes the next stage of activities with a general flow of time increasing as the list progresses. The entity responsible for each is noted on the line before each set of bullets.

AUTONOMOUS ENTITY

VEHICLE COLLECTION – RAIL VEHICLES

- Railroad Vehicle (e.g., train cars, rail maintenance vehicles) systems detect and store weather and route operations information as a function of time and location
- Vehicle Data Collector uploads the data from the railroad vehicle at specified intervals or drop points and stores the aggregated vehicle-based data in an operational database

CLARUS

See the *Clarus* Framework Scenario

PUBLIC AND PRIVATE SURFACE TRANSPORTATION WEATHER SERVICE PROVIDERS

DATA INTEGRATION

- The Service Providers collect, store, and consolidate the *Clarus* data with observed meteorological, hydrologic and rail data from various other sources
- The Service Providers acquire forecast guidance products to complement the observed data
- Observed data are consolidated and composed into presentations showing the data from various sites displayed on a geo referenced background
- The observed and forecasted data are composed into route-specific weather forecast and rail condition products
- The forecasts are organized into textual and geographical presentations

DATA TRANSFORMATION

- Weather condition, hydrologic conditions and forecast data for specific railroad segments and routes are stored in a database on information delivery systems ready for access.
- Rail conditions are computed for segments of a given geographical region and are stored along with the weather condition, hydrologic condition and forecast information

RAILROAD OPERATIONS DECISION SUPPORT

- The observed weather, hydrologic, route and rail conditions are coupled with railroad operations data to assess the current condition of the railroad network.
- Using the forecasted weather conditions, the DSS assesses the anticipated impacts to rail traffic and recommends routing guidance and/or actions to mitigate short-term threats.
- These observations and projections are composed into value-added deliverables that may be stored for distribution or sent directly to the end users.

PRODUCT CONSUMER

RAIL OPERATIONS MANAGEMENT ACTIVITIES

- Weather and rail condition advisory information is acquired from Service Providers and NOAA
- Decisions are made on the impact of the projected conditions on heavy rail train routing and rail carrier schedules
- Schedules are adjusted to accommodate for the impact of the weather, rail conditions, and train traffic
- Revised schedules are computed and made available to rail system users
- Decision support advisories are followed to maintain effective right-of-way control

3.5.8 Scenario G - COMMERCIAL VEHICLE OPERATIONS FUNCTION

3.5.8.1 Commercial Vehicle Operations Representative Scenario Description

Commercial Express, a trucking firm with over 3500 trucks operating throughout the United States, recently decided to take aggressive action to counter the effect the cost of fuel was having on their profit margin. Commercial was aware that fuel usage on a given route was significantly impacted by factors such as wind resistance, rolling friction, engine efficiency, vehicle speed, speed consistency (minimal starting and stopping), distance traveled, elevation changes, the type of vehicle, and the operational state of the vehicle (level of maintenance). Barry, the director of research at Commercial Express had done a literature review of all of these factors and had developed a set of algorithms to estimate the effect of each parameter on fuel efficiency. What Barry found was that many of the factors were greatly impacted by the weather and pavement conditions along the route.

Barry discussed his weather requirement with Route Decisions, a surface transportation weather service provider, and the two firms agreed to develop a decision support system to assess scheduling and operational techniques to minimize the total cost of operating a truck between two locations. Route Decisions would provide a high-resolution analysis and forecast of weather and pavement conditions for the entire highway network that Commercial Express uses. This forecast would cover a 72-hour period and would be replaced every 12 hours and updated more frequently, if adjustments were needed. Commercial Express would then define a “shipment” – that is, the truck and its operating characteristics, the type of trailer, the gross weight of the shipment, and the operational status of the truck and trailer.

The decision support model would simulate the movement of the truck along its route and compute the operational costs associated with the forecasted weather and pavement conditions in each 10 km segment along the entire route. The mock shipment would then be recomputed over the potential routes at sequentially later start times (the typical evaluation was done for start times one hour apart out to a maximum departure delay of 24 hours). At the end of the simulation, the dispatcher would receive a listing of the estimated operational costs for each potential route and departure time. If specific departure times indicated that significant reductions in cost would occur, the dispatcher would assign that shipment with a specified departure time and itinerary. Commercial Express completed the decision support program two years ago and is now nearing the end of the second year of the test. The evaluation has been performed on a set of test routes representing 5% of their total operation over the two-year period.

Barry has worked closely with the dispatchers and Route Decisions through the first two years verifying the cost estimates against actual costs and documenting the performance of the forecasts provided by Route Decisions. Results indicate a substantial improvement in the short haul costs during this second year of the program and Theodore, the research technician at Route Decisions, has documented that this improvement is largely associated with the improved data set that became available last

summer when the **Clarus System** became operational this last summer. Detailed weather and pavement condition reports are now available from one source and these reports fill major gaps in their previous weather and pavement database. Route Decisions has archived the data from the first two years and Barry is presently rerunning the “shipments” using actual observed data in place of the forecasted data for the second year of operations.

Results for the first year and initial indications from the second indicate that shifts in the scheduling produce significant reductions in operational costs and that the scheduling recommended from the operational forecasts tend to capture reasonable route start-time adjustments. Theodore has also told Barry that several of the states are instrumenting their maintenance vehicles with maintenance data collection systems and the data will be telemetered from the trucks to the central collection point on a nearly continual basis. This information will be carried over the **Clarus System** and will considerably aid in the assessment of current road conditions and subsequently improve route forecasts. Barry feels the first two years of the route planning decision support system has proven successful and with the data support enhancements offered by **Clarus** Barry is ready to implement the program throughout the entire Commercial Express network.

3.5.8.2 Commercial Vehicle Operations Technical Description

The management of commercial vehicle fleets may be significantly impacted by weather-related conditions. Fleet management of commercial vehicles revolves around scheduling and routing, and it is essential that all components of the inter-modal transportation scheme reach each designated location at specified times. Commercial vehicle operators depend upon this scheduling consistency. However, inclement weather affects different components of the inter-modal system in different ways, thus it becomes important to know specifically what the type and intensity of weather is expected and how this weather scenario is likely to impact the performance of the fleet. High wind conditions and precipitation events causing vehicle instability and slick pavement tend to disrupt commercial vehicles the most because of their wind profile and weight, thus significant attention needs to be placed on these conditions and their impact on commercial vehicles.

Support for commercial vehicle fleet management functions by *Clarus* involves weather, pavement, and commercial vehicle-related data collected from diverse sources owned and/or operated by surface transportation organizations. Commercial vehicle fleet management can provide vehicle-based environment data collection systems or provide services within jurisdictions that maintain collection systems for other transportation requirements. The data from these systems are transferred at routine intervals to one or more data fusion centers to form the *Clarus* database.

The information that follows provides a step-by-step flow of activities that depicts a general scenario as to how a commercial vehicle operations function in conjunction with the *Clarus* Framework scenario would occur. Each successive heading and set of bullets constitutes the next stage of activities with a general flow of time increasing as

the list progresses. The entity responsible for each is noted on the line before each set of bullets.

AUTONOMOUS ENTITY

VEHICLE COLLECTION – COMMERCIAL VEHICLE OPERATIONS

- Commercial Vehicle systems detect and store weather, pavement, hydrologic and commercial vehicle operations information as a function of time and location
- The Vehicle Data Collector uploads the data from the commercial vehicle at specified intervals, or drop points, and stores the aggregated vehicle-based data in an operational database

CLARUS

See the *Clarus* Framework Scenario

PUBLIC AND PRIVATE SURFACE TRANSPORTATION WEATHER SERVICE PROVIDERS

COMMERCIAL VEHICLE DECISION SUPPORT

- The observed weather, pavement, and hydrologic conditions are coupled with reported maintenance actions to assess the current condition of the road surface for numerous representative points along a segment of highway
- Using the forecasted weather conditions, the Decision Support System (DSS) assesses the anticipated pavement conditions
- The DSS also assesses the anticipated pavement conditions based upon input from highway crews and their expected route timing.
- Commercial Vehicle Rollover potential and fuel economy predictions are calculated based on current and forecasted wind speed and direction along specified routes
- These observations and projections are composed into value-added deliverables that may be stored for distribution or sent to the end users.

PRODUCT CONSUMER

COMMERCIAL VEHICLE OPERATIONS MANAGEMENT ACTIVITIES

- Weather and road condition advisory information is acquired from Service Providers
- Decisions are made on impact of the projected conditions on the routing and schedules of commercial vehicles within the fleet
- Schedules and routing are adjusted to accommodate for the impact of the weather, road conditions, and traffic flow
- Revised schedules and routes are computed and made available to commercial vehicle operators

3.6 Comparison of the Clarus System to Other Federal Systems

The development of the *Clarus System* relative to present and future federal weather observation systems is important in order to preserve complementary systems rather than competing systems. This is particularly important given the present efforts within

the National Oceanic and Atmospheric Administration (NOAA) to develop a next generation weather observation system known as the Integrated Surface Observing System (ISOS). ISOS will be designed to gather data from the National Weather Service's Automated Surface Observing System (ASOS), the Climate Reference Network, Integrated Flood Observing and Warning System (IFLOWS), and Hydrometeorological Automated Data System (HADS), as well as from all non-NOAA surface environmental monitoring networks that provide complementary data (e.g., surface transportation weather networks and other private networks) NOAA's Environmental Real-time Observation Network (NERON) will provide the data gathering and processing infrastructure. When fully operational the ISOS will provide the data to NWS forecast offices as well as to the academic and private sectors to improve forecasts and warnings, to improve water management, and to improve the detection of changes in climate. Given the direction of the NOAA ISOS to provide a national support mechanism for weather data access, it is important for the *Clarus System* design to consider elements found within these existing federal systems in the United States and similar systems in Canada.

The *Clarus System* continues the efforts begun with past national weather data collection initiatives to expand the volume and coverage of remote and direct observations of the atmosphere and environment. In fact, the growth of atmospheric science and operational weather forecasting in the United States was facilitated by the expansion of weather data collections beyond surface observations in the 1930's with the growth of commercial aviation and the acquisition of observed pilot reports. Since then, NOAA, the Department of Defense (DoD), the National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA) have dramatically expanded weather observations to include a national network of Doppler weather radars, a constellation of advanced weather satellites, networks of surface-based atmospheric profilers and sounders, and a network of over 4,200 federally operated surface observation sites including nearly 1,000 Automated Surface Observation System (ASOS) stations. More recently the contributions of the private and academic sectors to expand routine weather observations has resulted in a sophisticated network of weather observations that is unsurpassed at any other location in the world. The next generation data system comprised of the integration of the above data system will constitute the NOAA ISOS of which the *Clarus System* will be a valuable contributor and data source.

The integration of surface transportation-based weather information into the existing national observing infrastructure through *Clarus* will serve three primary purposes:

- 1) Surface transportation-based weather observations will enhance and extend the existing national observation database, supporting general improvements to weather forecasting capabilities, and enhancing the protection of life and property,
- 2) A national collection of real-time surface transportation-based weather observations will provide for much broader access to this valuable dataset in support of real-time responses to observed weather conditions, and

- 3) Integration of surface transportation-based weather observations with existing observed data would permit broader support for surface transportation-specific models, which predict the impacts of weather on maintenance and traffic-related concerns.

As the national observing infrastructure is comprised of many national-scale weather observation systems, the weather data collection facilitates support a broad set of applications generally geared toward a particular end use (e.g. aviation, fire, agriculture, radar, satellite, upper air, water supply, etc.). Although the *Clarus System* will be a component of ISOS, the organizational structure in itself provides logic applicable to the problem of bringing together all the surface transportation weather observations under a single nationwide system.

The national observational network, which serves as the model for central points of data collection within the national weather venue, has proven valuable and reliable. The *Clarus System* will provide a central collection point for surface transportation-based weather observations that can be incorporated into ISOS through accepted existing operational methods. Similar central collection points presently exist within the national observational network including those of the National Environmental Satellite Data Information Service (NESDIS) for managing collection and quality control of information from the constellation of earth observing satellites, the National Climatic Data Center for managing collection and quality control of data from NOAA's national network of Doppler weather radars, and the FAA AWOS (Automated Weather Observation System) Data Acquisition System (ADAS) that is maintained in each of the 22 Air Route Traffic Control Centers nationwide. The purpose of these central collection points is to manage the high volume of observational traffic and to provide for coordinated entry of data into the national observational database. This concept is consistent with the anticipated operation of the *Clarus System*, which will have the responsibility of collecting, storing, quality controlling, and distributing surface transportation weather observations, traffic data, and roadway characteristics, providing the coordinated entry of this data into the NSWOS, and making the information available for stakeholder data users.

However, the *Clarus System* is different from previous weather observation data collection initiatives in that it is specifically associated with the measurement of weather and environmental conditions with respect to the surface transportation infrastructure (e.g. roadway, railway, etc.). The method of this data collection is further distinct from most of the existing observation networks in that the collection of the observations is performed not by federal agencies. Rather, the data collected within the *Clarus System* is primarily collected by state and local transportation agencies (referred to within the *Clarus Concept of Operations* as the 'autonomous layer' to identify the independence of these agencies from the *Clarus System* operations). This single element is the greatest differentiator between the *Clarus System* data collection and those of existing federal elements within the national observing framework. Beyond this difference the contrasts between the *Clarus System* and other data collection systems becomes less distinct.

For example, all data collection systems must consider data management, data distribution, quality control, and data archive. A unique challenge of the *Clarus System* over those of existing surface observation collection efforts will be the added challenge of proper handling and quality control of the non-atmospheric data elements (e.g. pavement temperature, pavement chemical concentration, water depth). In general, the quality of the ESS data, based on varied calibration, maintenance practices and sensor siting, is not uniform. There needs to be quality control of the data to ensure that spurious or incorrect data are properly identified to outside systems and users. Methods must be designed for the data as it is collected to be tagged with metadata and filtered as part of the data fusion process. This is especially true for identifying ESS observations that may be pertinent to localized road maintenance applications, but not properly located to provide acceptable representation of atmospheric conditions useful for broader meteorological analysis and forecasting. Effective methods of maintaining quality control from observations that invite non-homogeneity with adjacent observations present particular challenges.

Some systems have begun to investigate methods to incorporate ESS data into the broader database of weather observations from different data collection networks. The NOAA Forecast Systems Laboratory (FSL) has an established research effort to develop methods to broaden the collection of federal and non-federal observation data, including proprietary public and private data, into the national collective through a program known as the Meteorological Assimilation Data Ingest System (MADIS). Although considered to be experimental and primarily for support of research endeavors, MADIS provides collection of surface mesoscale network (mesonet) data from locales not previously supported in the national framework including a limited amount of ESS data provided to MADIS by State DOTs.

Currently, MADIS is the gateway representing the only routine federal incorporation of surface transportation weather information into the NSWOS. MADIS provides data to end-users in netCDF flat file format that includes quality control statistics for the observed data. MADIS addresses methods for handling restricted access data. These data may be restricted by public and private data providers (e.g. State DOTs desiring not to release non-atmospheric data or private sector data providers who maintain agreements to only provide data to the NWS). As the *Clarus System* will incorporate similar data restriction issues, MADIS efforts afford the opportunity to *Clarus System* designers to evaluate the effectiveness of maintaining these important distinctions between proprietary and non-proprietary data.

Recently, NOAA has indicated that MADIS will be transformed from a research effort into an operational system. As such, given the present incorporation of ESS data into MADIS, the NOAA effort must be strongly considered as a model for the *Clarus System* and will require close inspection during the *Clarus System* Design.

Another existing system that holds promise as a template from which the *Clarus System* can emulate is the Road Weather Information Network (RWIN) established through funding from Transport Canada and operated by the Meteorological Service of Canada

(MSC). RWIN started as a side project in Canada for weather information integration and it soon became a focus project. The RWIN is similar to MADIS in that it integrates data from various weather sources into one database. RWIN relies on geo-spatial and information management technologies for real-time data acquisition, quality assurance and control, spatial data storage and real-time delivery of quality assured data to clients.

The RWIN is based on a client/server, distributed computing architecture and makes use of the GIS, spatial data browsing and visualization, and spatial data management technologies. The RWIN data architecture is scalable and is capable of handling text, snap shots, video, image, GIS and raster data sets. The web dissemination architecture supports spatial data browsing, data views in a map form, and data exchange in an interactive and batch mode using various web services. A Metadata catalogue for ESS and for non-ESS datasets enables a user to view data spatially and temporally and to view an ESS performance, status and maintenance history. The plug and play, and reusable software components architecture provides the flexibility of adding new applications or new data sources easily.

A prototype for RWIN is currently undergoing acceptance testing in Ontario and will soon start to accept test data from Quebec. The RWIN orientation session is set for May 2005, with a revised and enhanced version available by June 2005. By 2006-2007, metadata files are to be populated and by 2007-2008, a functional, tested system will be deployed. Participating jurisdictions sign a Road Weather Information System (RWIS) Agreement that requires them to share weather information with the MSC for at least the first two years following acceptance of the agreement. This provision could serve as an important example for the *Clarus System* to promote the adoption of the *Clarus System*. As data becomes shared with the MSC, the MSC is able to control how this data is further shared.

Additional benefits of RWIN to the *Clarus System* will result from the present efforts of RWIN to overcome deployment challenges in Canada and to utilize these solutions within the *Clarus System* Design. Further, teamwork between the Canadian RWIN and the U.S. *Clarus System* would promote sharing of weather information across boundaries and could stimulate better operations and research within surface transportation.

4 Conceptual System Architecture

The National Academy of Sciences report, *Where the Weather Meets the Road*, found that system robustness must be a major objective of an integrated road weather observation and data management system. For *Clarus* to achieve this capability the system must thoroughly address the broad range of technical issues it will face. These technical issues frame the system architecture and include:

- data acquisition,
- data integration and management,
- validation / quality control, and
- data availability / distribution.

This Concept of Operations has addressed each of these categories relative to the various core *Clarus* Use Case Functions. A *Clarus* system design will be required that permits the functional requirements of each Use Case to be comprehensively addressed with respect to the detailed user needs of the weather service and surface transportation weather service provider communities. This includes, but is not limited to:

- consideration of the specific technical issues associated with providing the convenient and consistent flow of ESS data from the Autonomous Layer into the *Clarus System*,
- the effective accessibility of *Clarus* data to the transportation related user community via the private surface transportation weather service providers, and
- the support for public weather service providers (e.g., NOAA) to provide for public safety and protection of property.

The following sections briefly discuss the challenges associated with each of these broad technical issues.

4.1 Data Acquisition

One challenge of data acquisition and integration will be to overcome the disparate, and in some cases proprietary, data formats and database protocols. Standards for data exchange need to be supported in the weather and transportation communities. Adherence to these standards will help to eliminate unnecessary complexities within the *Clarus System*. Until these standards are more widely adopted, the *Clarus System* will also likely need to communicate with the Environmental Sensor Station (ESS) network databases and/or their individual ESS through application programming interfaces (API) special to those systems. However, a successful *Clarus System* has the potential of fostering a much more rapid adoption of standards within the industry. Regardless of how it is accomplished, the *Clarus System* must include diverse and innovative ways of collecting data from these systems without unduly inconveniencing the data providers or increasing their cost of operations.

Data collected and distributed by *Clarus* will span both traditional fixed sensors along the roadway and those collected from mobile platforms. The fixed sensors along the

roadway are a predominant part of the existing 2,500+ ESS deployments nationwide. Mobile ESS platforms are increasing in popularity, and over time will likely become more predominant than fixed sensors for collection of road weather data. These mobile platforms will provide an additional level of complexity in data collection and will present challenges associated with quality control and database design, since the location metadata becomes highly time dependent. In addition, new sensor design and deployment for both fixed and mobile platforms will continue as emphasis on surface transportation weather increases in the coming decades. This will influence sensor configurations and will require the *Clarus System* to be adaptive to storage and dissemination of information from emerging sensor technologies. One such technology that is presently growing in use without a clear method of incorporation within either a data management and/or weather utilization schema is video capture from ESS locations via NTCIP standards. The *Clarus System* should also be able to support the inclusion of non-automated road and route condition observations. The ITS architecture for the inclusion of traffic and weather information is well defined and provides a strong basis for the *Clarus System* to build upon.

As stated above, the lack of a standard for reporting of ESS data is a critical problem. Each vendor has its own method for storing and communicating data, and in many cases, different methods even for different models from the same vendor. More critically, in cases where the data format is reasonably clear, metadata are not easily attainable, and in some cases, not accurate, greatly diminishing the utility of the data. These issues can only be remedied with the application of a detailed but flexible standard to the data reporting formats for ESS data. Such a standard must include both mandatory information (such as location), and sensor-dependent information (the data available by virtue of the sensors at that location). The *Clarus System* must also address missing data, since some current systems do not differentiate between nominal and missing data. Once the data are collected by the *Clarus System*, they will need to be converted to a standard format. This standard format should have the same data element definitions that are used by the standardized weather message set.

4.2 Data Integration and Management

The architectural framework found within the National Intelligent Transportation Systems (ITS) Architecture is a valuable guide on integration of information from ESS networks. Although more research on the needs of the user community will be required as the *Clarus System* evolves, the pros and cons of database architectures and concepts as they apply to the *Clarus Initiative* must be considered. One of the biggest issues for the *Clarus System* may simply be the volume of data involved (not so much the number of bytes, but more the number of observations). ESS data may include data from a variety of sensors (including video cameras) and the frequency of observations can be as high as once per minute. The VII Initiative's vehicular data will present a much bigger data storage problem, as these vehicles may report data at intervals of one second or less. Regardless of the chosen database format, the *Clarus System* should be abstracted and modularized to the point that any new data stream can be handled with minimal effort and without disruption to the streams that are already present within the system.

Several types of database concepts may be applied in the *Clarus System*. One option is a *hierarchical database*. As implied by its name, data in a hierarchical database is stored in a hierarchy, usually utilizing a directory structure on a file system. This is a very straightforward means of organizing data. The subdirectories of the hierarchy are used to group the data with other data with similar attributes (such as sensor, time, source, etc.).

A second database concept that could be adopted within the *Clarus System* is a *relational database*. A relational database would collect data items organized as a set of formally described tables from which data would be accessed or reassembled in many different ways without having to reorganize the database tables. One of the largest advantages of utilizing a relational database is the power of being able to easily use high-level languages such as the structured query language (SQL) to query and access the data. Further, scripting languages such as Perl, Tcl, Python, Ruby, and PHP greatly facilitate the quick development of high-level abstractions of the data. Although careful thought must be given to the layout of the tables in a relational database in order to optimize performance, they are generally easy to create and have another important advantage of being easy to extend. After the original database creation, a new data category can be added without requiring that all existing applications be modified.

A critical aspect of the *Clarus System* will be the speed of data throughput. Whatever database structure is utilized, the usefulness of the *Clarus System* will likely depend upon the ability of the end user to extract desired data with minimal latency. It is therefore essential that the *Clarus System* database system anticipate the common current and future applications of a surface transportation weather database. *Clarus*, fundamentally, is a system to collect, store, and disseminate near-real-time data. Thus, the priority must be on the rapid storage and retrieval of data. Although *Clarus* does not directly address the needs associated with archived data, inclusion of *Clarus* data within long-term data holdings is critical for application of the data in future research and analysis efforts. At present, no such national historical archive exists for surface transportation weather data at any federal, state, university or private sector location within the United States. In order to ensure that the real-time system operates at peak efficiency and with minimum latency the *Clarus* archives would likely need to reside on a separate server. However, the conceptual design of such an archive system is intertwined with the *Clarus* design and should be a consideration in the *Clarus* system design and development process.

The efficiency and reliability of the *Clarus System* may depend upon whether it is a centralized National system or a series of regional databases. Regional databases have the advantage of breaking the quantity of data down into a size that is easier to manage, and can possibly reduce latencies in retrieving data for regional users. Since many users will likely seek the data only from small regions, this method could work well. More compelling reasons, however, exist for a National database. First, users may need access to data from multiple regions, and accessing multiple databases to acquire the data defeats one of the fundamental purposes for developing *Clarus*. Second, the quality control (QC) modules will need to make use of data over a continuous plane. Thus, arbitrary divisions into regions could hamper QC efforts,

unless there is an overlap of regions, which would further complicate the scenario and increase overhead.

Finally, the operation of several regional database centers would undoubtedly cost more in the long run than one efficient center. Despite the scope of the challenge, it does appear likely that a National database would be best for the project. The few apparent advantages of regional servers can likely be overcome with redundant centralized systems and an allowance for major stakeholders to host *Clarus* mirror servers on a regional basis or even on their internal networks. This latter configuration could be used by a State DOT to make *Clarus* data available to its personnel without the problems associated with Internet access while having the additional benefit of reducing bandwidth loads on the *Clarus System*.

4.3 Data Validation and Quality Control

Quality control (QC) of surface transportation weather and road/route observations presents special challenges not faced with many observing networks. In general, the quality of ESS data is not uniform due to varied calibration and maintenance practices, sensor quality, and sensor siting issues. A rigorous data QC and data qualification process is therefore necessary to ensure that suspect or otherwise unrepresentative data are not disseminated to outside systems and users without appropriate quality assurance and metadata information.

Quality control of ESS and other road weather observations presents some unique challenges. For example, a faulty road condition sensor that is reporting, “Dry” may be difficult to catch until a significant precipitation event occurs. The QC flagging process would need to be robust enough to remember that the sensor was flagged as bad and not get tricked into unflagging the sensor simply because it gets exposed to an extended period of dry weather again. Likewise, the QC needs to be multivariate in that spatial or temporal consistency checks on any given variable must take into account the whole situation at each site. For example, a midsummer pavement temperature observation of 65° F may appear incorrect when compared to surrounding observations of well over 120° F in a spatial consistency check, but this situation occurs frequently in the real world when isolated thunderstorms occur. This is a relatively simple situation for a human to recognize, but is much more difficult to handle with a software program. As described in all of the Use Case Scenarios it will be necessary to draw upon observational datasets external to the *Clarus System* for QC processes.

The ability of users to accept and utilize ESS information with additional quality control measures will serve to vastly enhance the applicability of the data. However, metadata information associated with each observation is equally as important. Since the locations of ESS and other surface transportation weather observations are often dictated by the location of troublesome stretches of roadway, many of these observations come from unrepresentative areas by design. The metadata that reveals this situation to the data user therefore becomes very important to the user community in deciding how that data might be reasonably applied.

4.4 Data Availability and Distribution

Data availability, data distribution and the user-friendliness of these processes are vital to the success of *Clarus*. The *Clarus System* must support the common modes of access of the various user communities and should support on-the-fly reformatting of exported data to meet the user's needs. In many cases, the data will be imported into other software applications that can enhance the usefulness of that data. The *Clarus System Design* should provide methods of multiple data delivery formats to support the user's ability to receive data in formats that facilitate effective utilization of the *Clarus* data. Scheduled, request-based, publish/subscribe and data-driven data distribution methodologies must all be supported. Use of evolving methods such as the Canadian Meteorological Markup Language (CMML) and the Japanese Road Web Markup Language (RWML) to communicate data across platforms must be considered in achieving effective availability. Both user-friendly and system-friendly access to *Clarus* is critical for the usability and long-term success of the system.

As of 2004, approximately 2,500 ESS were taking point-specific measurements and observations of meteorological, hydrologic and pavement conditions. This figure will continue to grow over the next decade, perhaps exponentially as mobile observing platforms become more common. The frequency of observation within this network varies widely based upon the operational needs of the managing agency. Although observations are generally taken at least once every 10 to 15 minutes, the cost of communications between the collection points and the remote processing units (RPU) often dictates that the data is actually retrieved at less frequent intervals.

Since the value of this data generally decreases quickly after the time of observation, especially in critical situations where conditions are changing quickly, processing and redistributing the data with a minimum latency is a primary operational concern of the *Clarus Initiative*. The variable observation times of ESS networks coupled with the internal processing functions of the *Clarus System* (communications techniques, data consolidation for quality control, collection of site reports for regional report lists) considerably impact the potential data latency. The *Clarus* design must carefully weigh the requirements for a structured delivery format against the need for minimal data latency.

ESS data have the potential to fill significant holes within the surface weather observation network. Many sensors are placed far from other sources of weather information specifically to address data voids, and in these situations, provide a vital link to conditions in a generally isolated area. Even in locations where they are nearly co-located with stations from other networks, the addition of more sensors can lend increased confidence in meteorological data QC processes.

The envisioned relationship between *Clarus* and ISOS is illustrated in Figure 17. ISOS is comprised of many National-scale weather observation systems, each a product of automated weather data collection and generally geared toward a particular end use (e.g. aviation, fire, agriculture, radar, satellite, upper air, water supply, etc.). Each of the systems has its own particular sensor siting and operational characteristics. Although the *Clarus System* is envisioned to become a component of ISOS, its organizational structure itself provides logic applicable to the problem of bringing together all the surface transportation weather observations under a single nationwide system.

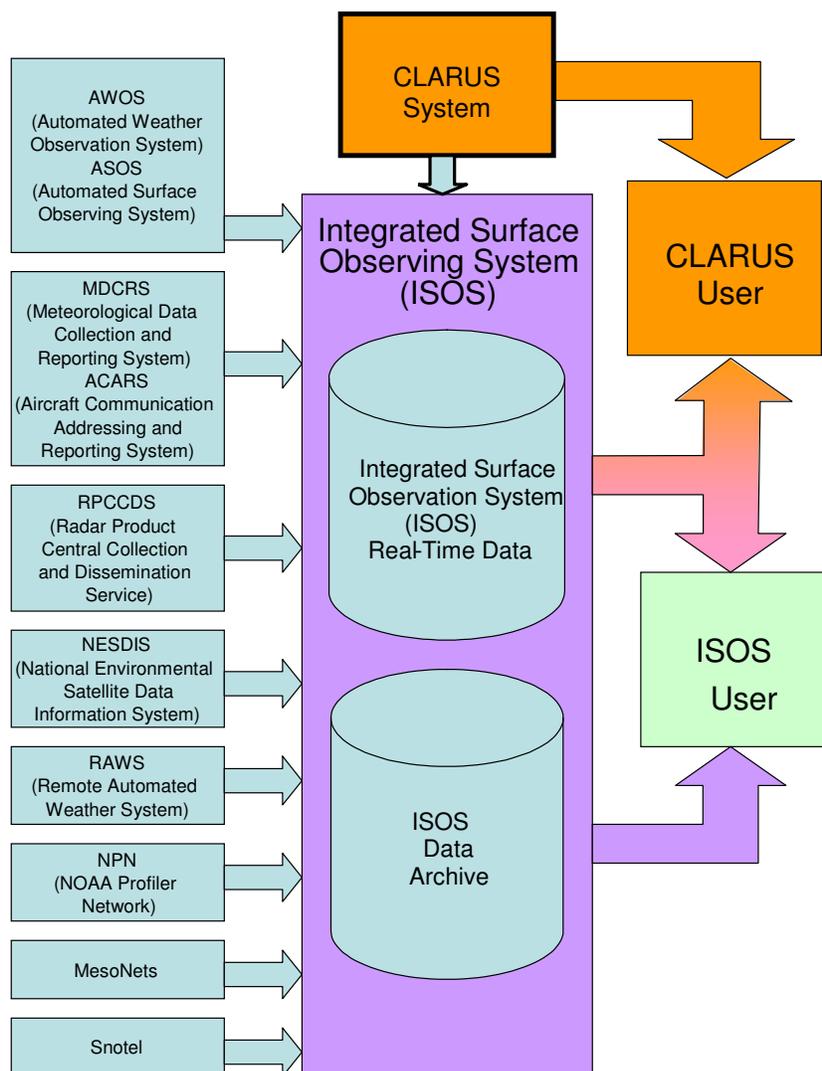


Figure 17. The Relationship Between *Clarus* and the Integrated Surface Observing System (ISOS) Infrastructure.

The model for central points of data collection within the National weather venue has proven valuable and reliable. The *Clarus System* will provide a central collection point for surface transportation-based weather observations that can be incorporated into the national observational infrastructure through accepted existing operational methods. Similar central collection points presently exist within the national observing framework including those of the National Environmental Satellite Data Information Service (NESDIS) for managing collection and quality control of information from the constellation of earth observing satellites, the National Climatic Data Center for managing collection and quality control of data from the national network of Doppler weather radars, and the FAA AWOS Data Acquisition System (ADAS) that is maintained in each of the 22 Air Route Traffic Control Centers nationwide.

The purpose of these central collection points is to manage the high volume of observational traffic and to provide for coordinated entry of data into ISOS. This concept is consistent with the anticipated operation of *Clarus*, which will have the responsibility of collecting, storing, quality controlling, and distributing surface transportation weather observations, providing the coordinated entry of this data into the NSWOS, and making the information available for stakeholder data users.

The fragmented physical architecture of existing ESS networks has been identified as one of the major obstacles that must be overcome with *Clarus*. At a most fundamental level, existing systems may be integrated into the *Clarus System* in a data flow approach. This is the model presently used by MesoWest, a research collaborative housed at the University of Utah that integrates information from many dissimilar automated weather observation systems. This tiered model of data integration can provide an intermediary step in the deployment of *Clarus*. In this case, it is envisioned that the existing weather observation systems maintained by the individual surface transportation system operators deliver data in a standardized format to *Clarus*. This configuration has historically limited the time horizon of data at a National tier to a longer period than at the local, e.g. hourly versus fifteen minute, due to parsing, quality assurance, and processing time requirements. A challenge and design opportunity of *Clarus* is to place all three tiers in real time on a nationwide scale.

4.5 *Clarus Subsystem Components and the Relationships between Components*

The operation of the *Clarus System* will involve five major components (Figure 18):

- 1) collection of ESS and related data from the Autonomous Layer into a Clarus central and/or regional spatial database server;
- 2) the Clarus database systems;
- 3) quality control of data within the Clarus database(s);
- 4) maintaining and storing special metadata information associated with the data; and
- 5) dissemination of Clarus data to the stakeholder community.

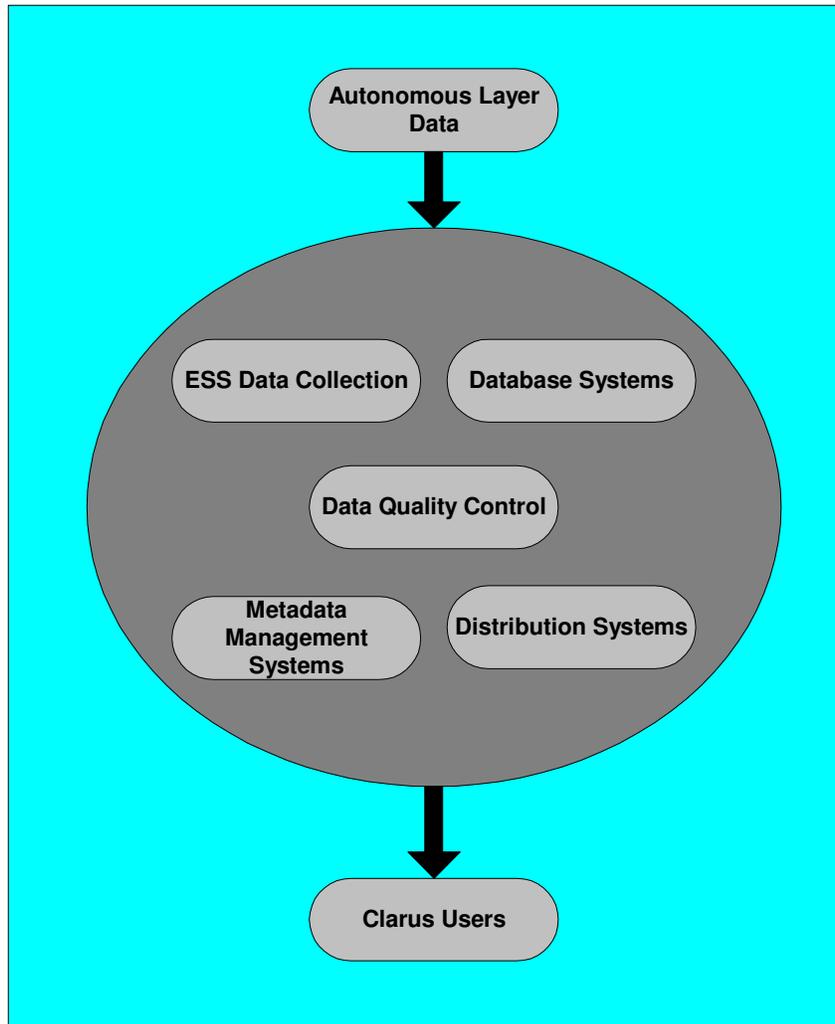


Figure 18. Components Central to the *Clarus* System Design.

These components are in addition to the elements outside of *Clarus* that will be required to support the *Clarus Initiative*. These include the sensors that collect environmental data (either fixed or mobile), the communications systems, and the software utilized by the User to acquire and turn *Clarus* data into applications and information for the User Client (e.g., the traveling public, maintenance operations, etc.).

One significant component not within the *Clarus System*, but central to the success of *Clarus*, is the collection of the data by indigenous statewide or regional networks that will subsequently be collected by *Clarus*. This includes fixed and mobile ESS data, road and route condition observations, and perhaps even winter maintenance data as automated maintenance activities data collection becomes more commonplace. A significant portion of this data collection is already in place and will require limited design effort aside from identification of existing deployments. These data collection networks represent the one area that is almost entirely out of the direct control of the *Clarus System* management. Issues associated with this non-*Clarus* component will require the understanding of data distribution restrictions, proprietary data formats and

data, real and perceived liability issues pertaining to ESS data redistribution, and the definition of ownership of the observed data.

The first *Clarus* subsystem component provides a significant challenge since *Clarus* must establish interfaces that permit off-loading of data from primarily vendor-specific equipment and databases onto the *Clarus System*. Many of these vendor databases and their communications interfaces are, at least initially, non-NTCIP compliant and/or proprietary. Often, these databases reside behind firewalls that may require considerable negotiation with information technology personnel to penetrate. These two issues pose significant obstacles to *Clarus*' development. Data may either be pushed or pulled into the *Clarus System* depending upon the agreements negotiated with data providers. Some data providers may be able to provide File Transfer Protocol (FTP) access for *Clarus* to retrieve data from their existing servers. In other situations, the data provider may maintain a server that contains the data but which does not support FTP or similar access to that data. Special procedures may need to be developed in order to allow the *Clarus System* to access data from these systems. In still other cases, *Clarus* may need to communicate directly with an ESS in order to retrieve data, possibly even resorting to the use of a dial-up modem. Once the data enters the *Clarus System*, some entry-level QC checks can be made (e.g., bounds checking).

The potential designs and obstacles for the *Clarus* database component were discussed earlier. Among those issues were the database design (hierarchical vs. relational) and the concepts of regional databases vs. a central redundant database. This second subsystem is the heart of the *Clarus System* and will require considerable forethought. The database must serve both present and anticipated user needs, must be kept flexible to acceptance of new types of data that are not presently available, must balance utility and user-friendliness with response time and system cost, and must possess a considerable degree of redundancy to prevent loss of service in the event of catastrophic equipment or communications failures. The *Clarus* database should be kept isolated from the varied and often proprietary data formats of much of the data available from present ESS networks.

Once data has been stored in a unified format within the *Clarus* database, the third *Clarus* subsystem will then be able to request recent and incoming data from the *Clarus* database(s), perform validity as well as internal and spatial consistency checks on the data as a whole, and return quality control flags pertaining to the data back to the *Clarus* database(s). These quality flags will then be made available to the *Clarus* user in a simple format alongside the *Clarus* data. If the *Clarus* database ends up being developed as a relational database users may even limit their queries to return data that has not been flagged as suspect through simple statements within the SQL requests. The *Clarus System* will not attempt to correct or remove suspect data.

The fourth *Clarus* subsystem can be considered a metadata management system. This is a sorely needed element of the ESS networks of today. Users often misuse or are hesitant to use ESS data because, unlike most meteorological observing networks, these systems are often placed in unrepresentative areas for very specific monitoring purposes. Blind application of this data can often cause the ESS data to be more of a detriment than an asset. The lack of data qualification with a consistent metadata format is probably second only to insufficient routine maintenance and calibration as the

leading cause of questionable data. Misunderstandings about the data source cause users to perceive the ESS network information as unreliable. The *Clarus* database must accommodate not only the data and associated quality control information, but also convenient ways for accessing and/or limiting information based on metadata attributes.

The final (and most visible) *Clarus* subsystem component is the delivery system. This system is comprised of the user interfaces, servers, and communications mechanisms used to retrieve data from the *Clarus System*. Since this is the only part of the *Clarus System* that will be a concern to most users, it is essential that it be user and system friendly and reliable. The delivery system needs to support both push and pull data distributions. Data pushing will permit scheduled delivery, possibly through a publish and subscription mechanism, of *Clarus* data to end users needing a steady supply of information for their applications, including routine delivery to the NSWOS for integration with other weather data types. Once within the NSWOS, the data is also available for distribution through established dissemination methods such as the National Weather Service Telecommunications Gateway.

Data-driven push methods can also help to reduce latencies for users needing near real-time access to data, as the system can automatically distribute data to waiting parties as soon as it becomes available rather than waiting for the user to query or poll for it. Data pull methods of access should include the use of web portals for display and/or download of user-selected data as well as support of FTP or similar access to the data. This subsystem should have a prioritized data caching capability for data that is time critical. Since many users will have a desire to import *Clarus* data into other applications as a decision aid, it is envisioned that the *Clarus System* will have a primary standardized interface with some flexibility to translate different formats in which these users wish to retrieve or receive the data. This capability will lessen the need for middleware obstacles to perform data conversion and thus promote much broader application of *Clarus* data.

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Appendix A – *Clarus* Use Case Actor Descriptions

A.1 Clarus Manually Entered Data Collector

The *Clarus* Manually Entered Data Collector actor allows for the collection of data pertinent to *Clarus* through a Human-Machine Interface (HMI). This capability allows *Clarus* users to supplement weather-related information received via other systems through a manual entry mechanism.

A.2 Clarus Operator

The *Clarus* Operator actor manages the collection, integration and dissemination of all data within the *Clarus* System.

A.3 Commercial Vehicle

The Commercial Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support safe and efficient commercial vehicle operations. Commercial Vehicles could provide vehicle identification, location, wiper system state, exterior temperature, rain sensor status, sun sensor status, fog lamp status, and traction control state.

A.4 Commercial Vehicle Fleet Operations

The Commercial Vehicle Fleet Operations actor provides the capability for commercial drivers and fleet managers to receive weather information and to monitor the safety and security of their commercial vehicle drivers and fleet.

A.5 Emergency Management Operations

The Emergency Management Operations actor represents the humans and systems that monitor all emergency requests, (including those from the E911 Operator) and sets up pre-defined responses to be executed by an emergency management system. Based on received weather information, Emergency Management Personnel may also override predefined responses where it is observed that they are not achieving the desired result. This actor includes dispatchers who manage an emergency fleet (police, fire, ambulance, HAZMAT, etc.) or higher order emergency managers who provide response coordination during emergencies.

A.6 Emergency Vehicle

The Emergency Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support safe and efficient incident response. Emergency Vehicles could provide vehicle identification, location, wiper system state, exterior temperature, rain sensor status, sun sensor status, fog lamp status, and traction control state.

A.7 ESS Data Collector

The ESS Data Collector actor collects ESS measurement data from the ESS Equipment actor.

A.8 ESS Equipment

The ESS Equipment actor represents the Environmental Sensor Stations collecting environmental data as well as Railroad ESS monitoring the wayside.

A.9 Information Service Provider

The Information Service Provider (ISP) actor collects, processes, stores, and disseminates transportation information to system operators and the traveling public. The ISP delivers traveler information to subscribers and the public at large. Information provided includes weather information, basic advisories, traffic and road/route conditions, transit schedule information, yellow pages information, ride matching information, and parking information. The ISP can utilize both basic one-way (broadcast) and personalized two-way information communication. The ISP provides the capability for an informational infrastructure to connect providers and consumers.

A.10 Maintenance and Construction Vehicle

The Maintenance and Construction Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support highway maintenance and construction. All types of maintenance and construction vehicles are covered, including heavy equipment and supervisory vehicles. A wide range of operational status is monitored, measured, and made available, depending on the specific type of vehicle or equipment. For example, for a snowplow, the information would include whether the plow is up or down and material usage information. The actor may also contain capabilities to monitor vehicle systems to support maintenance of the vehicle itself and other sensors that monitor environmental conditions including the road condition and surface weather information. This actor can represent a diverse set of mobile environmental sensing platforms, including wheeled vehicles and any other vehicle that collects and reports environmental information. Maintenance and Construction Vehicles could provide vehicle identification, location, wiper system state, exterior temperature, rain sensor status, sun sensor status, fog lamp status, and traction control state.

A.11 NOAA (ISOS)

This actor represents NOAA's Integrated Surface Observation System (ISOS), which is envisioned to be a National Mesonet.

A.12 NOAA (non-ISOS)

This actor represents NOAA's systems that do not include the Integrated Surface Observation System (ISOS), which is envisioned to be a National Mesonet.

A.13 NOAA Collector for Clarus Data

The National Oceanic and Atmospheric Administration, which runs the National Weather Service (NWS), that provides weather, hydrologic, and climate information and warnings of hazardous weather including thunderstorms, flooding, hurricanes, tornadoes, winter weather, tsunamis, and climate events. It provides atmospheric weather observations and forecasts. The interface provides formatted weather data products suitable for on-line processing and integration with other ITS data products as well as Doppler radar images, satellite images, severe storm warnings, and other products that are formatted for presentation to various ITS users. The NOAA Collector for *Clarus* represents the NOAA interface point that receives the weather information processed by the *Clarus System*.

A.14 NOAA Integrator

The NOAA Integrator actor represents the NOAA interface point where NOAA's processed data are disseminated to other systems including the *Clarus System* and other Weather Service Providers.

A.15 NOAA Research

The NOAA Research actor represents the NOAA research activities that utilize archived NOAA weather data.

A.16 Non-Surface Observations

The Non-Surface Observations actor represents the collection of atmospheric weather observation data by both International and U.S equipment.

A.17 Private Sector Weather Observation Equipment

The Private Sector Weather Observation Equipment actor represents environmental sensing equipment that provides weather observation data to Private Weather Service Providers.

A.18 Private Surface Transportation Weather Service Provider

The Private Surface Transportation Weather Service Provider actor receives data from the *Clarus System* and provides value-added weather and surface transportation data integration and interpretation to the Weather Information User Community.

A.19 Private Vehicle

The Private Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and convenient travel. Private Vehicles could provide anonymous vehicle identification, location, wiper system state, exterior temperature, rain sensor status, sun sensor status, fog lamp status, and traction control state.

A.20 Private Weather Data Collector

The Private Weather Data Collector actor collects data and provides it to the *Clarus System* based on its weather observation equipment. Together with the Private Weather Data Disseminator actor, the Private Weather Data Collector provides all of the general weather data interfaces for the Private Weather Service Provider.

A.21 Private Weather Data Disseminator

The Private Weather Data Disseminator actor receives data from the *Clarus System* and provides value-added general weather data integration and interpretation to the Weather Information User Community.

A.22 Private Weather Service Provider

The Private Weather Service Provider actor provides data to the *Clarus System* based on its weather observation equipment. The Private Weather Service Provider integrates, transforms and interprets general weather data including data from the *Clarus System* for dissemination to the Weather Information User Community.

A.23 Public Sector Weather Observation Equipment (non-NOAA)

The Public Sector Weather Observation Equipment (non-NOAA) actor represents other environmental sensing equipment besides ESS that provides weather observation data to Public Weather Data Collectors other than NOAA.

A.24 Public Surface Transportation Weather Service Provider

The Public Surface Transportation Weather Service Provider actor receives data from the *Clarus System* and provides value-added weather and surface transportation data integration and interpretation to the Weather Information User Community.

A.25 Public Weather Data Collector (non-NOAA)

The Public Weather Data Collector (non-NOAA) actor collects data and provides it to the *Clarus System* based on its weather observation equipment. Together with the Public Weather Data Disseminator actor, the Public Weather Data Collector provides all of the general weather data interfaces for the Public Weather Service Provider.

A.26 Public Weather Data Disseminator

The Public Weather Data Disseminator actor receives data from the *Clarus System* and provides value-added general weather data integration and interpretation to the Weather Information User Community.

A.27 Railroad Management Operations

The Railroad Management Operations actor represents the management systems and people responsible for making decisions regarding rail operations based on received weather information.

A.28 Railroad Vehicle

The Railroad Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support rail operations. The Railroad Vehicle may be a train, locomotive, railroad maintenance vehicle or other vehicle that traverses the railway. Railroad Vehicles could provide vehicle identification, location, wiper system state, exterior temperature, rain sensor status, sun sensor status, fog lamp status, and traction control state.

A.29 Roadway Condition Collector

The Roadway Condition Collector actor represents the transportation agency collection of weather-related surface conditions, road/route conditions, CCTV images and radar derived data from the Roadway Condition Equipment.

A.30 Roadway Condition Equipment

The Roadway Condition Equipment actor represents transportation agency equipment that detects weather-related surface conditions and road/route conditions as well as CCTV images and flooding (e.g., stream gauges).

A.31 Roadway Construction Operations

The Roadway Construction Operations actor monitors and manages roadway infrastructure construction activities. Representing both public agencies and private contractors that provide these functions, this actor manages fleets of construction vehicles. This actor receives a wide range of status information from these vehicles and performs vehicle dispatch, routing, and resource management for the vehicle fleets and associated equipment. The actor manages equipment at the roadside, including environmental sensors and automated systems that monitor and mitigate adverse road and surface weather conditions. Additional interfaces to weather information providers (the weather service and surface transportation weather service providers) provide current and forecast weather information that can be fused with other data sources and used to support advanced decision support systems that increase the efficiency and effectiveness of construction operations.

A.32 Roadway Seasonal (non-Winter) Maintenance Provider

The Roadway Seasonal (non-Winter) Maintenance Provider actor monitors and manages roadway infrastructure for non-winter maintenance activities (e.g., road striping). Representing both public agencies and private contractors that provide these functions, this actor manages fleets of non-winter maintenance, or special service

vehicles (e.g., pot hole-filling equipment). The actor receives a wide range of status information from these vehicles and performs vehicle dispatch, routing, and resource management for the vehicle fleets and associated equipment. This actor manages equipment at the roadside, including environmental sensors and automated systems that monitor and mitigate adverse road and surface weather conditions. This actor manages the repair and maintenance of both non-ITS and ITS equipment including the traffic controllers, detectors, dynamic message signs, signals, and other equipment associated with the roadway infrastructure. Additional interfaces to weather information providers (the weather service and surface transportation weather service providers) provide current and forecast weather information that can be fused with other data sources and used to support advanced decision support systems that increase the efficiency and effectiveness of non-winter maintenance operations.

A.33 Roadway Winter Maintenance Operations

The Roadway Winter Maintenance Operations actor monitors and manages roadway infrastructure winter maintenance activities. Representing both public agencies and private contractors that provide these functions, this actor manages fleets of winter maintenance, or special service vehicles (e.g., snow and ice control equipment). The actor receives a wide range of status information from these vehicles and performs vehicle dispatch, routing, and resource management for the vehicle fleets and associated equipment. This actor manages equipment at the roadside, including environmental sensors and automated systems that monitor and mitigate adverse road and surface weather conditions. This actor manages the repair and maintenance of both non-ITS and ITS equipment including the traffic controllers, detectors, dynamic message signs, signals, and other equipment associated with the roadway infrastructure. Additional interfaces to weather information providers (the weather service and surface transportation weather service providers) provide current and forecast weather information that can be fused with other data sources and used to support advanced decision support systems that increase the efficiency and effectiveness of winter maintenance operations.

A.34 Roadway Service Patrol Vehicle

The Roadway Service Patrol Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support emergency assistance to vehicles on the freeway. Roadway Service Patrol Vehicles could provide vehicle identification, location, wiper system state, exterior temperature, rain sensor status, sun sensor status, fog lamp status, and traction control state.

A.35 Surface Observation Networks

The Surface Observation Networks actor represents all of the observations from the surface of the earth including both International and U.S equipment. These observations are fed into NOAA's ISOS.

A.36 Traffic Management Operations

The Traffic Management Operations actor monitors and controls traffic and the road network. It represents centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. This actor monitors and manages traffic flow and monitors the condition of the roadway, surrounding environmental conditions, and field equipment status.

A.37 Transit Management Operations

The Transit Management Operations actor manages transit vehicle fleets and coordinates with other modes and transportation services. It provides operations, maintenance, customer information, planning and management functions for the transit property. It spans distinct central dispatch and garage management systems and supports the spectrum of fixed route, flexible route, paratransit services, transit rail, and bus rapid transit (BRT) service. This actor takes into account current and forecasted weather conditions when deciding on current and future transit service levels.

A.38 Transit Vehicle

The Transit Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support safe and efficient movement of passengers. The types of transit vehicles contained in this actor include buses, paratransit vehicles, light rail vehicles, other vehicles designed to carry passengers, and supervisory vehicles. Transit Vehicles could provide vehicle identification, location, wiper system state, exterior temperature, rain sensor status, sun sensor status, fog lamp status, and traction control state.

A.39 Travelers

The Travelers actor collects, processes, stores, and disseminates transportation information to system operators and the traveling public. The actor can play several different roles in an integrated ITS. In one role, the Traveler actor provides a general data warehousing function, collecting information from transportation system operators and redistributing this information to other system operators in the region and other ISPs. In this information redistribution role, the Traveler actor provides a bridge between the various transportation systems that produce the information and the other ISPs and their subscribers that use the information. In a second role, a Traveler actor is focused on delivery of traveler information to subscribers and the public at large. Information provided includes basic advisories including weather, traffic and road/route conditions, transit schedule information, yellow pages information, ride matching information, and parking information. In a third role, the Traveler actor may be dedicated to, or even embedded within, the dispatch system.

A.40 Vehicle

The Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support safe vehicle travel on the roadway. Vehicles could

provide vehicle identification, location, wiper system state, exterior temperature, rain sensor status, sun sensor status, fog lamp status, and traction control state.

A.41 Vehicle Data Collector

The Vehicle Data Collector actor collects Vehicle measurement data from the various Vehicle actors. The Vehicle Data Collector could be the roadside collection units or a secondary aggregated collection unit that may be part of the US DOT VII Initiative.

A.42 Weather Information User Community

The Weather Information User Community actor represents the entire user community of *Clarus System* data including both public and private sector users.

Appendix B – Use Case Descriptions

B.1 Archive Weather Data Use Case

The Archive Weather Data use case is part of the NOAA processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case takes the environmental data collected from the NOAA ISOS and non-surface weather observation systems and combines it with the pertinent *Clarus* data for archival and use by NOAA's research community.

B.2 Check and Flag Collected ESS Data Use Case

The Check and Flag Collected ESS Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for checking and flagging the collected ESS data. This first phase of the *Clarus* quality control process will check for out-of-tolerance limits and other data characteristics that would require flagging of the data based on individual ESS measurements. The *Clarus* Operator will have the capability to fine-tune the algorithm parameters that does the checking and setting of flagging thresholds.

B.3 Check and Flag Manually Entered Data Use Case

The Check and Flag Manually Entered Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for checking and flagging manually entered data into the *Clarus System*. The manually entered data includes environmental conditions, roadway conditions and weather nowcasts and forecasts. This first phase of the *Clarus* quality control process will check for out-of-tolerance limits and other data characteristics that would require flagging of the data based on the manually entered data. The *Clarus* Operator will have the capability to fine-tune the algorithm parameters that does the checking and setting of flagging thresholds.

B.4 Check and Flag Non-Clarus External Environment Data Use Case

The Check and Flag Non-*Clarus* External Environment Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for checking and flagging the collected non-*Clarus* external environment data from NOAA and other service providers. This first phase of the *Clarus* quality control process will check for out-of-tolerance limits and other data characteristics that would require flagging of the data from NOAA or the Service Providers. It is preferred that raw sensor data be collected along with any standardized metadata. If the data has been pre-processed, *Clarus* would need to know what type of processing has been performed on the data in order to use it in further processing by the *Clarus System*. The *Clarus* Operator will have the capability to fine-tune the algorithm parameters that does the checking and setting of flagging thresholds and possible preprocessing constraints.

B.5 Check and Flag Road Condition Data Use Case

The Check and Flag Road Condition Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for checking and flagging the collected road condition data.

This first phase of the *Clarus* quality control process will check for out-of-tolerance limits and other data characteristics that would require flagging of the data based on individual road condition measurements. The *Clarus* Operator will have the capability to fine-tune the algorithm parameters that does the checking and setting of flagging thresholds.

B.6 Check and Flag Vehicle Data Use Case

The Check and Flag Vehicle Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for checking and flagging the collected vehicle data. This first phase of the *Clarus* quality control process will check for out-of-tolerance limits and other data characteristics that would require flagging of the data based on individual vehicle measurements. The *Clarus* Operator will have the capability to fine-tune the algorithm parameters that does the checking and setting of flagging thresholds.

B.7 Collect Non-Surface Observations Use Case

The Collect Non-Surface Observations use case is part of the NOAA processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for collecting non-surface (e.g., atmospheric) weather observations for NOAA.

B.8 Collect Surface Observations Use Case

The Collect Surface Observations use case is part of the NOAA processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for collecting surface (e.g., temperatures) weather observations for NOAA as part of the ISOS (Integrated Surface Observing System).

B.9 Compare ESS, Vehicle and Road Condition Data with External Weather Data Use Case

The Compare ESS, Vehicle and Road Condition Data with External Weather Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case takes the phase 1 quality controlled ESS, Roadway Condition, Vehicle, Manually Entered Weather Data and External Weather data and compares it by similar geographic location and type as part of the phase 2 quality control. The *Clarus* Operator will have the capability to fine-tune the algorithm parameters that does the comparing and setting of flagging thresholds.

B.10 Generate General Weather Nowcasts and Forecasts Use Case

The Generate General Weather Nowcasts and Forecasts use case is part of the NOAA processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case takes the environmental data collected from the NOAA ISOS and non-surface weather observation systems and combines it with the pertinent *Clarus* data to create general weather nowcasts and forecasts.

B.11 Generate NOAA Numerical Forecasts Use Case

The Generate NOAA Numerical Forecasts use case is part of the NOAA processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case takes the environmental data collected from the NOAA ISOS and non-surface

weather observation systems and combines it with the pertinent *Clarus* data to create numerical forecasts.

B.12 Generate Severe Weather Forecasts Use Case

The Generate Severe Weather Forecasts use case is part of the NOAA processing depicted on the *Clarus System Framework Use Case Diagram* (Figure 15). This use case takes the environmental data collected from the NOAA ISOS and non-surface weather observation systems and combines it with the pertinent *Clarus* data to create severe weather forecasts.

B.13 Integrate and Transform Service Provider Data Use Case

The Integrate and Transform Service Provider Data use case is part of the Service Provider processing depicted on the *Clarus System Framework Use Case Diagram* (Figure 15). This use case integrates the public (non-NOAA) and private weather data in preparation for the use by public and private general and surface transportation-specific weather service providers.

B.14 Integrate NOAA Data Use Case

The Integrate NOAA Data use case is part of the NOAA processing depicted on the *Clarus System Framework Use Case Diagram* (Figure 15). This use case integrates the ISOS and non-ISOS (non-surface weather observations) data in preparation for the generation of numerical forecasts, severe weather forecasts, general weather nowcasts and forecasts and data archival.

B.15 Provide ESS Measurements Use Case

The Provide ESS Measurements use case is outside of the *Clarus*, NOAA and Service Provider processing depicted on the *Clarus System Framework Use Case Diagram* (Figure 15). The purpose of this use case is solely to depict end-to-end functionality. This use case takes the ESS measurements from each ESS Equipment actor, which could be either publicly or privately owned, and sends the data to the ESS Data Collector actor.

B.16 Provide NOAA Weather Data Use Case

The Provide NOAA Weather Data use case is part of the NOAA processing depicted on the *Clarus System Framework Use Case Diagram* (Figure 15). This use case represents the transfer of NOAA data to the Traveler actor and the Weather Information User Community actor. The Weather Information User Community actor represents the following surface transportation users as depicted in Figure 13: Commercial Vehicle Fleet Operations, Emergency Management Operations, Railroad Management Operations, Roadway Construction Operations, Roadway Seasonal (Non-Winter) Maintenance Operations, Roadway Winter Maintenance Operations, Transit Management Operations and Traffic Management Operations.

B.17 Provide Private Weather Data Use Case

The Provide Private Weather Data use case is part of the Service Provider processing depicted on the *Clarus System Framework Use Case Diagram* (Figure 15). This use case processes data from Private Sector Weather Observation Equipment to Private Weather Data Collectors.

B.18 Provide Public Weather Data (non-NOAA) Use Case

The Provide Public Weather Data (non-NOAA) use case is part of the Service Provider processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case processes data from Public Weather Observation Equipment (non-NOAA) to Public Weather Data Collectors (non-NOAA).

B.19 Provide Roadway Conditions Use Case

The Provide Roadway Conditions use case is outside of the *Clarus*, NOAA and Service Provider processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). The purpose of this use case is solely to depict end-to-end functionality. This use case takes the roadway conditions (e.g., pavement, route) from each Roadway Condition Equipment actor, which could be either publicly or privately owned, and sends the data to the Roadway Condition Collector actor.

B.20 Provide Traveler Information Use Case

The Provide Traveler Information use case is part of the Service Provider processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is where the Information Service Provider disseminates their value-added weather information affecting travelers to the Travelers actor for no or minimal cost. It is expected that in the future 5-1-1 traveler information systems will contain weather information to assist travel planning and notification.

B.21 Provide Value-added Private Surface Transportation Weather Information Use Case

The Provide Value-added Private Surface Transportation Weather Information use case is part of the Service Provider processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is where the Private Surface Transportation Weather Service Provider disseminates their value-added weather information affecting the surface transportation network to the Weather Information User Community. The Weather Information User Community actor represents the following surface transportation users as depicted in Figure 13: Commercial Vehicle Fleet Operations, Emergency Management Operations, Railroad Management Operations, Roadway Construction Operations, Roadway Seasonal (Non-Winter) Maintenance Operations, Roadway Winter Maintenance Operations, Transit Management Operations and Traffic Management Operations.

B.22 Provide Value-added Private Weather Information Use Case

The Provide Value-added Private Weather Information use case is part of the Service Provider processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is where the general Private Weather Service Provider disseminates their value-added weather information to the Weather Information User Community. The Weather Information User Community actor represents the following surface transportation users as depicted in Figure 13: Commercial Vehicle Fleet Operations, Emergency Management Operations, Railroad Management Operations, Roadway Construction Operations, Roadway Seasonal (Non-Winter) Maintenance Operations, Roadway Winter Maintenance Operations, Transit Management Operations and Traffic Management Operations.

B.23 Provide Value-added Public Surface Transportation Weather Information Use Case

The Provide Value-added Public Surface Transportation Weather Information use case is part of the Service Provider processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is where the Public Surface Transportation Weather Service Provider disseminates their value-added weather information affecting the surface transportation network to the Weather Information User Community. The Weather Information User Community actor represents the following surface transportation users as depicted in Figure 13: Commercial Vehicle Fleet Operations, Emergency Management Operations, Railroad Management Operations, Roadway Construction Operations, Roadway Seasonal (Non-Winter) Maintenance Operations, Roadway Winter Maintenance Operations, Transit Management Operations and Traffic Management Operations.

B.24 Provide Value-added Public Weather Information Use Case

The Provide Value-added Public Weather Information use case is part of the Service Provider processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is where the general Public Weather Service Provider disseminates their value-added weather information to the Weather Information User Community. The Weather Information User Community actor represents the following surface transportation users as depicted in Figure 13: Commercial Vehicle Fleet Operations, Emergency Management Operations, Railroad Management Operations, Roadway Construction Operations, Roadway Seasonal (Non-Winter) Maintenance Operations, Roadway Winter Maintenance Operations, Transit Management Operations and Traffic Management Operations.

B.25 Provide Vehicle Measurements Use Case

The Provide Vehicle Measurements use case is outside of the *Clarus*, NOAA and Service Provider processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). The purpose of this use case is solely to depict end-to-end functionality. This use case takes the Vehicle measurements from each Vehicle actor, which could be either publicly or privately owned, and sends the data to the ESS Data Collector actor. The vehicles, as a minimum, fall into the following categories as depicted in Figure 14: Commercial Vehicle, Emergency Vehicle, Maintenance and Construction Vehicle, Private Vehicle, Railroad Vehicle, Roadway Service Patrol Vehicle or Transit Vehicle.

B.26 Send Flagged ESS Data Use Case

The Send Flagged ESS Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case takes the phase 1 quality control checked and flagged data and (1) forwards the information to the *Clarus* use case that compares ESS, Vehicle, and Road Condition Data with External Weather Data from NOAA and various types of service providers and (2) returns potential error metadata to the ESS Data Collector actor.

B.27 Send Flagged ESS, Road Condition and Vehicle QC'd Data to Collectors Use Case

The Send Flagged ESS, Road Condition and Vehicle QC'd Data to Collectors use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case takes the phase 2 quality control checked and flagged data and (1) forwards the information to the *Clarus* use case that transfers this data to NOAA and the various service providers and (2) returns potential error metadata to the appropriate collection actor.

B.28 Send Flagged Road Condition Data Use Case

The Send Flagged Road Condition Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case takes the phase 1 quality control checked and flagged data and (1) forwards the information to the *Clarus* use case that compares ESS, Vehicle, and Road Condition Data with External Weather Data from NOAA and various types of service providers, (2) forwards the information to the *Clarus* data repository and (3) returns potential error metadata to the Road Condition Collector actor.

B.29 Send Flagged Vehicle Data Use Case

The Send Flagged Vehicle Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case takes the phase 1 quality control checked and flagged data and (1) forwards the information to the *Clarus* use case that compares ESS, Vehicle, and Road Condition Data with External Weather Data from NOAA and various types of service providers and (2) returns potential error metadata to the Vehicle Data Collector actor.

B.30 Store and Index Quality Controlled Data Use Case

The Store and Index Quality Controlled Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case stores and indexes the data received by *Clarus* and its associated metadata to the extent needed for the *Clarus System* quality control process. The *Clarus* operator has the capability to specify what data should be stored and method of indexing as well as data storage compression mechanisms.

B.31 Transfer ESS Data Use Case

The Transfer ESS Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for transferring the collected ESS data from the ESS Data Collector actor to the *Clarus System*.

B.32 Transfer External Weather Data Use Case

The Transfer External Weather Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for collecting the external weather data from NOAA and various weather data service providers including nowcasts, forecasts, and public or private environmental sensor data from sensors not directly connected to *Clarus* via the ESS, Roadway and Vehicle Data Collector actors.

B.33 Transfer of Clarus ESS, Vehicle and Road Condition Data and Flags Use Case

The Transfer of *Clarus* ESS, Vehicle and Road Condition Data and Flags use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for taking the processed environmental data obtained from multiple sources and transferring it along with the pertinent metadata to NOAA and the various service providers. The *Clarus* operator has the capability to specify critical road/route environmental information processing priorities for the *Clarus System*.

B.34 Transfer Road Condition Data Use Case

The Transfer Road Condition Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for transferring the collected road condition data from the Roadway Condition Collector actor to the *Clarus System*.

B.35 Transfer Vehicle Data Use Case

The Transfer Vehicle Data use case is part of the *Clarus System* processing depicted on the *Clarus System* Framework Use Case Diagram (Figure 15). This use case is responsible for transferring the collected Vehicle data from the Vehicle Data Collector actor to the *Clarus System*.

Appendix C - Acronym List

AASHTO	American Association of State Highway and Transportation Officials
AMS	American Meteorological Society
ASOS	Automated Surface Observing System
CCTV	Closed-Circuit Television
DMS	Dynamic Message Signs
DoD	Department of Defense
DOT	Department of Transportation
DSS	Decision Support System
ESS	Environmental Sensor Station
FAA	Federal Aviation Administration
HAR	Highway Advisory Radio
ICC	Initiative Coordinating Committee
IMT	Initiative Management Team
ISP	Information Service Provider
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS America	Intelligent Transportation Society of America
FHWA	Federal Highway Administration
MADIS	Meteorological Assimilation Data Ingest System
MDSS	Maintenance Decision Support System
MDT	Mobile Data Terminal
NASA	National Aeronautics and Space Administration
NHI	National Highway Institute
NOAA	National Oceanic and Atmospheric Administration
NTCIP	National Transportation Communications for ITS Protocol
NSWOS	National Surface Weather Observing System
NWS	National Weather Service
PDA	Personal Digital Assistants
RWIS	Road Weather Information System
SEP	Systems Engineering Process
STWDSR	Surface Transportation Weather Decision Support Requirements
STWSP	Surface Transportation Weather Service Provider
TBDL	To Be Developed Later
TMC	Traffic Management Center
TRB	Transportation Research Board
UML	Unified Modeling Language
VII	Vehicle Infrastructure Integration
VSL	Variable Speed Limit
WIST	Weather Information for Surface Transportation

Appendix D - Alternative Text

Alternative text for Figure 1

This conceptual map diagram is enhanced by example photos of ESS, vehicle, and external weather data sources and shows the flow direction including brief descriptions of data management steps. Clarus is shown in the center with its key functions of collecting, checking, flagging, and sending of RWIS and vehicle data, collecting external weather data and comparing it with RWIS and vehicle data, transferring the quality controlled data on to users. The data sources are shown to the left of Clarus and the data users are shown to the right. ESS field equipment is shown providing ESS data to a state agency RWIS computer from which Clarus collects it. Patrol or maintenance vehicle data is shown being gathered by a roadside data collector that provides it to the local agency vehicle location computer from which Clarus collects it. External weather data sources such as radar is shown being provided to a Weather Information Service Provider such as NOAA from which it is collected by Clarus. Surface Transportation Weather Information Service Provider is the sole recipient of data from Clarus. The Surface Transportation Weather Information Service Provider is also shown receiving integrated and transformed data from the Weather Information Service Provider. The Surface Transportation Weather Information Service Provider is shown providing observation and forecast data and decision support information along two separate paths to an end user. A Traffic Operations Center is shown in that role in this figure.

[Back to Figure1](#)

Alternative text for Figure 2

Figure 2 is a high level diagram that depicts the principal interfaces that are included in the Road Weather Data Collection Market Package. It includes the following subsystems and associated equipment packages:

Subsystem	Equipment Package
Emergency Management	Emergency Environmental Monitoring
Information Service Provider	ISP Traveler Data Collection
Maintenance and Construction Management	MCM Environmental Information Processing
Traffic Management	TMC Environmental Monitoring
Transit Management	Transit Environmental Monitoring

Direction arrowed lines that are labeled with a data description in the figure show the architecture flow. This is described in the following table.

Source Subsystem / Terminator	Architecture Flow	Destination Subsystem / Terminator
Emergency Management	transportation weather information request	Surface Transportation Weather Service
Information Service Provider	transportation weather information request	Surface Transportation Weather Service

Source Subsystem / Terminator	Architecture Flow	Destination Subsystem / Terminator
Maintenance and Construction Center Personnel	maintenance and construction center personnel inputs	Maintenance and Construction Management
Maintenance and Construction Management	road weather information	Emergency Management
Maintenance and Construction Management	road weather information	Information Service Provider
Maintenance and Construction Management	maintenance and construction operations information presentation	Maintenance and Construction Center Personnel
Maintenance and Construction Management	road weather information	Media
Maintenance and Construction Management	road weather information	Other MCM
Maintenance and Construction Management	road weather information	Rail Operations
Maintenance and Construction Management	road data	Surface Transportation Weather Service
Maintenance and Construction Management	road weather information	Surface Transportation Weather Service
Maintenance and Construction Management	transportation weather information request	Surface Transportation Weather Service
Maintenance and Construction Management	road weather information	Traffic Management
Maintenance and Construction Management	road weather information	Transit Management
Maintenance and Construction Management	road weather information	Weather Service
Other MCM	road weather information	Maintenance and Construction Management
Surface Transportation Weather Service	transportation weather information	Emergency Management
Surface Transportation Weather Service	transportation weather information	Information Service Provider

Source Subsystem / Terminator	Architecture Flow	Destination Subsystem / Terminator
Surface Transportation Weather Service	transportation weather information	Maintenance and Construction Management
Surface Transportation Weather Service	transportation weather information	Traffic Management
Surface Transportation Weather Service	transportation weather information	Transit Management
Traffic Management	transportation weather information request	Surface Transportation Weather Service
Traffic Management	traffic operator data	Traffic Operations Personnel
Traffic Operations Personnel	traffic operator inputs	Traffic Management
Transit Management	transportation weather information request	Surface Transportation Weather Service
Weather Service	weather information	Emergency Management
Weather Service	weather information	Information Service Provider
Weather Service	weather information	Maintenance and Construction Management
Weather Service	weather information	Traffic Management
Weather Service	weather information	Transit Management

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Alternative text for Figure 3

Figure 3 is a high level diagram that depicts the principal interfaces that are included in the Weather Information Processing and Distribution market package. It includes the following subsystems and associated equipment packages:

Subsystem	Equipment Package
Emergency Management	Emergency Environmental Monitoring
Emergency Vehicle Subsystem	On-Board EV Environmental Monitoring
Information Service Provider	ISP Probe Information Collection
Maintenance and Construction Management	MCM Environmental Information Collection
Maintenance and Construction Vehicle	MCV Environmental Monitoring
Roadway Subsystem	Roadway Environmental Monitoring
Roadway Subsystem	Roadway Probe Beacons
Traffic Management	TMC Environmental Monitoring
Traffic Management	TMC Probe Information Collection
Transit Management	Transit Environmental Monitoring
Transit Vehicle Subsystem	On-Board Environmental Monitoring

Vehicle	Smart Probe
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Direction arrowed lines that are labeled with a data description in the figure show the architecture flow. This is described in the following table.

Source Subsystem / Terminator	Architecture Flow	Destination Subsystem / Terminator
Emergency Management	road network probe information	Maintenance and Construction Management
Emergency Management	road network probe information	Traffic Management
Emergency Vehicle Subsystem	environmental probe data	Emergency Management
Information Service Provider	road network probe information	Maintenance and Construction Management
Information Service Provider	road network probe information	Traffic Management
Maintenance and Construction Center Personnel	maintenance and construction center personnel inputs	Maintenance and Construction Management
Maintenance and Construction Field Personnel	maintenance and construction field personnel inputs	Maintenance and Construction Vehicle
Maintenance and Construction Management	maintenance and construction operations information presentation	Maintenance and Construction Center Personnel
Maintenance and Construction Management	environmental sensors control	Maintenance and Construction Vehicle
Maintenance and Construction Management	environmental sensors control	Roadway Subsystem
Maintenance and Construction Management	environmental conditions data	Surface Transportation Weather Service
Maintenance and Construction Management	road data	Surface Transportation Weather Service
Maintenance and Construction Management	environmental conditions data	Weather Service
Maintenance and Construction Vehicle	maintenance and construction field personnel information presentation	Maintenance and Construction Field Personnel
Maintenance and	environmental probe data	Maintenance and

Source Subsystem / Terminator	Architecture Flow	Destination Subsystem / Terminator
Construction Vehicle		Construction Management
Maintenance and Construction Vehicle	environmental conditions data	Roadway Subsystem
Maintenance and Construction Vehicle	environmental sensors control	Roadway Subsystem
Roadway Environment	environmental conditions	Emergency Vehicle Subsystem
Roadway Environment	environmental conditions	Maintenance and Construction Vehicle
Roadway Environment	environmental conditions	Roadway Subsystem
Roadway Environment	environmental conditions	Transit Vehicle Subsystem
Roadway Environment	environmental conditions	Vehicle
Roadway Subsystem	environmental conditions data	Maintenance and Construction Management
Roadway Subsystem	environmental conditions data	Maintenance and Construction Vehicle
Roadway Subsystem	environmental conditions data	Surface Transportation Weather Service
Roadway Subsystem	environmental conditions data	Traffic Management
Roadway Subsystem	environmental probe data	Traffic Management
Roadway Subsystem	environmental conditions data	Weather Service
Surface Transportation Weather Service	environmental conditions data	Maintenance and Construction Management
Surface Transportation Weather Service	environmental sensors control	Roadway Subsystem
Surface Transportation Weather Service	environmental conditions data	Traffic Management
Traffic Management	environmental sensors control	Roadway Subsystem
Traffic Management	environmental conditions data	Surface Transportation Weather Service
Traffic Management	environmental conditions data	Weather Service
Transit Management	road network probe information	Maintenance and Construction Management
Transit Management	road network probe information	Traffic Management
Transit Vehicle Subsystem	environmental probe data	Transit Management

Source Subsystem / Terminator	Architecture Flow	Destination Subsystem / Terminator
Vehicle	environmental probe data	Information Service Provider
Vehicle	environmental probe data	Roadway Subsystem
Weather Service	environmental conditions data	Maintenance and Construction Management
Weather Service	environmental sensors control	Roadway Subsystem
Weather Service	environmental conditions data	Traffic Management

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Alternative text for Table 1

Table 1 is a 3 x 3 matrix showing types of weather information products. They are cross-referenced to a type of product along the matrix headers and the weather data used to create them is shown down the left side.

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Alternative text for Table 2

Table 2 is a two column table showing the types of ESS data elements in the left column. In the right column are the elements assigned as sub categories for each of the data types.

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Alternative text for Figure 15

Figure 15 is a detailed and complex high level use case diagram illustrating the associations, use cases, and actors within the full framework of the Clarus system. It shows three large rectangles vertically stacked that represent from top to bottom of the diagram: NOAA, Clarus, and Service Providers. Inside each of these boxes are the actors, associations, and use cases that are specific to these groupings. Actors, associations, and use cases that are designated to the balance of the Autonomous and User Layers lie outside the boxes. Some associations cross between boxes and from outside the boxes to inside. The following descriptions of what is shown are organized by the box where it is located.

Outside all rectangles and left of the NOAA and Clarus rectangles are the following sets of actors and associations:

Non-Surface Observations (actor)

- Communicates with Use Case: 'Collect Non-Surface Observations'

Surface Observation Networks (actor)

- Communicates with Use Case: 'Collect Surface Observations'

ESS Equipment (actor)

- Communicates with Use Case: 'Provide ESS Measurements'

ESS Data Collector (actor)

- Communicates with Use Case: 'Collect Surface Observations'
- Communicates with Use Case: 'Send Flagged ESS, Road Condition and Vehicle QC'd Data to Collectors'
- Communicates with Use Case: 'Send Flagged ESS Data'
- Communicates with Use Case: 'Transfer ESS Data'
- Communicates with Use Case: 'Provide ESS Measurements'

Class Name: Roadway Condition Equipment (actor)

- Communicates with Use Case: 'Provide Roadway Conditions'

Roadway Condition Collector (actor)

- Communicates with Use Case: 'Send Flagged ESS, Road Condition and Vehicle QC'd Data to Collectors'
- Communicates with Use Case: 'Send Flagged Road Condition Data'
- Communicates with Use Case: 'Transfer Road Condition Data'
- Communicates with Use Case: 'Provide Roadway Conditions'

Vehicle (actor)

- Communicates with Use Case: 'Provide Vehicle Measurements'

Vehicle Data Collector (actor)

- Communicates with Use Case: 'Send Flagged ESS, Road Condition and Vehicle QC'd Data to Collectors'
- Communicates with Use Case: 'Provide Vehicle Measurements'
- Communicates with Use Case: 'Send Flagged Vehicle Data'
- Communicates with Use Case: 'Transfer Vehicle Data'

Outside of all rectangles and to the right of the Clarus rectangle are the following:

Travelers (actor)

- Communicates with Use Case: 'Provide NOAA Weather Data'
- Communicates with Use Case: 'Provide Traveler Information'

Weather Information User Community (actor)

- Communicates with Use Case: 'Provide Value-added Private Surface Transportation Weather Information'
- Communicates with Use Case: 'Provide Value-added Private Weather Information'
- Communicates with Use Case: 'Provide Value-added Public Weather Information'
- Communicates with Use Case: 'Provide Value-added Public Surface Transportation Weather Information'
- Communicates with Use Case: 'Provide NOAA Weather Data'

Within the NOAA rectangle are the following:

NOAA (ISOS) (actor)

- Communicates with Use Case: 'Integrate NOAA Data'
- Communicates with Use Case: 'Collect Surface Observations'

NOAA (non-ISOS) (actor)

- Communicates with Use Case: 'Integrate NOAA Data'
- Communicates with Use Case: 'Collect Non-Surface Observations'

NOAA Integrator (actor)

- Communicates with Use Case: 'Provide NOAA Weather Data'
- Communicates with Use Case: 'Transfer External Weather Data'
- Communicates with Use Case: 'Generate NOAA Numerical Forecasts'
- Communicates with Use Case: 'Generate Severe Weather Forecasts'
- Communicates with Use Case: 'Generate General Weather Nowcasts and Forecasts'
- Communicates with Use Case: 'Archive Weather Data'

NOAA Collector for Clarus Data (actor)

- Communicates with Use Case: 'Transfer of Clarus ESS, Vehicle and Road Condition Data and Flags'
- Communicates with Use Case: 'Integrate NOAA Data'

NOAA Research (actor)

- Communicates with Use Case: 'Archive Weather Data'

Within the Clarus rectangle are the following:

Clarus Manually Entered Data Collector (actor)

- Communicates with Use Case: 'Check and Flag Manually Entered Data'
- Communicates with Use Case: 'Send Flagged ESS, Road Condition and Vehicle QC'd Data to Collectors'

Clarus Operator (actor)

- Communicates with Use Case: 'Check and Flag Vehicle Data'
- Communicates with Use Case: 'Check and Flag Collected ESS Data'
- Communicates with Use Case: 'Check and Flag Non-Clarus External Environment Data'
- Communicates with Use Case: 'Store and Index Quality Controlled Data'
- Communicates with Use Case: 'Compare ESS, Vehicle and Road Condition Data with External Weather Data'
- Communicates with Use Case: 'Check and Flag Road Condition Data'
- Communicates with Use Case: 'Check and Flag Manually Entered Data'

Within the Service Provider rectangle are the following:

Public Weather Observation Equipment (non-NOAA) (actor)

- Communicates with Use Case: 'Provide Public Weather Data (non-NOAA)'

Public Weather Data Collector (non-NOAA) (actor)

- Communicates with Use Case: 'Provide Public Weather Data (non-NOAA)'
- Communicates with Use Case: 'Integrate and Transform Service Provider Data'
- Communicates with Use Case: 'Transfer External Weather Data'

Private Sector Weather Observation Equipment (actor)

- Communicates with Use Case: 'Provide Private Weather Data'

Private Weather Data Collector (actor)

- Communicates with Use Case: 'Integrate and Transform Service Provider Data'
- Communicates with Use Case: 'Provide Private Weather Data'
- Communicates with Use Case: 'Transfer External Weather Data'

Information Service Provider (actor)

- Communicates with Use Case: 'Provide Traveler Information'
- Communicates with Use Case: 'Transfer of Clarus ESS, Vehicle and Road Condition Data and Flags'

Private Surface Transportation Weather Service Provider (actor)

- Communicates with Use Case: 'Integrate and Transform Service Provider Data'
- Communicates with Use Case: 'Provide Value-added Private Surface Transportation Weather Information'
- Communicates with Use Case: 'Transfer of Clarus ESS, Vehicle and Road Condition Data and Flags'

Public Surface Transportation Weather Service Provider (actor)

- Communicates with Use Case: 'Provide Value-added Public Surface Transportation Weather Information'
- Communicates with Use Case: 'Transfer of Clarus ESS, Vehicle and Road Condition Data and Flags'
- Communicates with Use Case: 'Integrate and Transform Service Provider Data'

Private Weather Data Disseminator (actor)

- Communicates with Use Case: 'Transfer of Clarus ESS, Vehicle and Road Condition Data and Flags'
- Communicates with Use Case: 'Provide Value-added Private Weather Information'
- Communicates with Use Case: 'Integrate and Transform Service Provider Data'

Public Weather Data Disseminator (actor)

- Communicates with Use Case: 'Transfer of Clarus ESS, Vehicle and Road Condition Data and Flags'
- Communicates with Use Case: 'Provide Value-added Public Weather Information'
- Communicates with Use Case: 'Integrate and Transform Service Provider Data'

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Alternative text for Figure 16

Figure 16 is a UML sequence diagram that summarizes all the sequences described in the text. It is comprised of three vertically stacked rectangles, one each representing the three groupings: NOAA, Clarus, and Service Providers. The following tables organize the content of the figure into what the message of the sequence is, where it originates, and where it terminates. There are two “super” classes, NOAA and Clarus, which represent the entire NOAA entity or Clarus system.

NOAA Sequences

Message	From Class	To Class
Collect Surface Observations	Surface Observation Networks	NOAA
Collect Non-Surface Observations	Non-Surface Observations	NOAA
Transfer ESS Data	ESS Data Collector	NOAA
Provide NOAA Weather Data	NOAA Integrator	Travelers
Provide NOAA Weather Data	NOAA Integrator	Weather Information User Community
Transfer External NOAA Weather Data	NOAA Integrator	Clarus

Clarus Sequences

Message	From Class	To Class
Transfer ESS Data	ESS Data Collector	Clarus
Transfer Roadway Conditions Data	Roadway Conditions Collector	Clarus
Transfer Vehicle Data	Vehicle Data Collector	Clarus
Send ESS Data Error Report	Clarus	ESS Data Collector
Collect Clarus Manually Entered Data	Clarus Manually Entered Data Collector	Clarus
Collect Public Weather Data (non-NOAA)	Public Weather Data Collector (non-NOAA)	Clarus
Collect Private Weather Data	Private Weather Data Collector	Clarus
Transfer Clarus ESS, Vehicle and Road Condition Data and Flags	Clarus	NOAA Collector for Clarus Data
Transfer ESS, Vehicle and Road Condition Data and Flags	Clarus	Public Surface Transportation Weather Service Provider
Transfer ESS, Vehicle and Road Condition Data and Flags	Clarus	Private Surface Transportation Weather Service Provider
Transfer ESS, Vehicle and	Clarus	Information Service

Message	From Class	To Class
Road Condition Data and Flags		Provider
Transfer ESS, Vehicle and Road Condition Data and Flags	Clarus	Private Weather Data Disseminator
Transfer ESS, Vehicle and Road Condition Data and Flags	Clarus	Public Weather Data Disseminator

Service Provider Sequences

Message	From Class	To Class
Provide Value-Added Public Surface Transportation Weather Information	Public Surface Transportation Weather Service Provider	Weather Information User Community
Provide Value-Added Private Surface Transportation Weather Information	Private Surface Transportation Weather Service Provider	Weather Information User Community
Provide Traveler Information	Information Service Provider	Travelers
Provide Value-Added Private Weather Information	Private Weather Data Disseminator	Weather Information User Community
Provide Value-Added Public Weather Information	Public Weather Data Disseminator	Weather Information User Community

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