Clarus Weather System Design

DETAILED SYSTEM REQUIREMENTS SPECIFICATION

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Table of Contents

Table of Figures

Table of Tables

Revision History

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1 INTRODUCTION

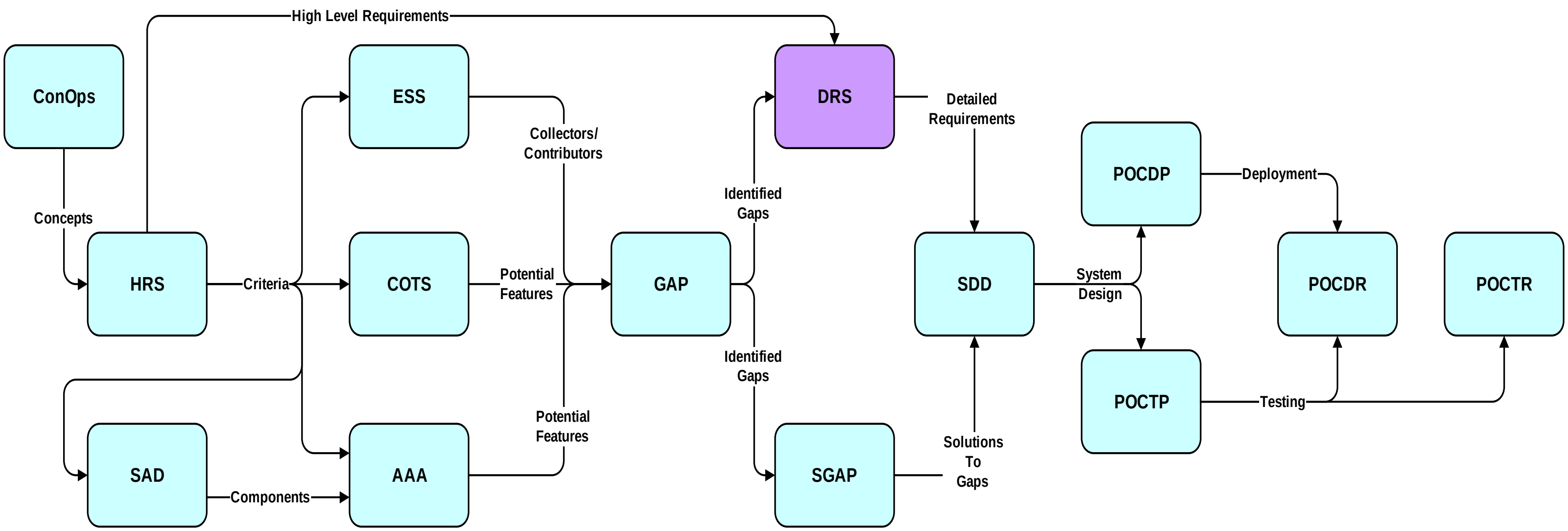
1.1 Purpose

The purpose of this requirements specification is to provide a repository for the high-level and detailed requirements governing the design of the *Clarus* system. These requirements capture the expression of general needs in the *Clarus* Concept of Operations (ConOps), in meetings with potential users and participants, and in subsequent documents identified below. These requirements will form the basis for the design verification and validation of the system. The intended audience for this document includes decision makers, stakeholders, designers, and testers.

This document may be updated periodically to reflect changes in the system requirements, including changes reflected in subsequent versions of the system.

As indicated in the highlighted box in Figure 1, the Detailed Systems Requirements Specification (DRS) is an intermediate deliverable in the larger context of the *Clarus* Weather System Design project, using criteria documented in the Concept of Operations, High-Level Requirements Specification, Survey of Environmental Sensor Stations, Analysis of COTS Systems, Analysis Architectural Alternatives Analysis, and the Design Gaps Analysis as input to the DRS.

Clarus System Design Deliverables



AAA – Architectural Alternatives Analysis
ConOps – Concept of Operations
COTS – Systems Engineering Analysis of *Clarus*-Related Systems
DRS – Detailed Requirements Specification
ESS – *Clarus* ESS Survey
GAP – Design Gaps Analysis
HRS – High-Level Requirements Specification

POCDP – Proof-of-Concept Deployment Plan
POCDR – Proof-of-Concept Demonstration Report
POCTP – Proof-of-Concept Test Plan
POCTR – Proof-of-Concept Test Results
SAD – System Architectural Description
SDD – System Design Document
SGAP – Solution to Fill Design Gaps

Figure 1 – *Clarus* System Documentation

1.2 Scope

Clarus is an initiative sponsored by the U.S. Department of Transportation (U.S. DOT) 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 check, and make available surface transportation weather and road condition observations so that State Departments of Transportation (DOTs) and other transportation agencies can be more productive in maintaining safety and mobility on all roads and surface transportation platforms. In addition to increasing productivity, it will maximize their RWIS/ESS investments.
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 data[1], and hydrologic (water level) data.

The *Clarus* Initiative consists of two development components.

- The first component is the development of the *Clarus* system – a network for sharing, quality checking, 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 *Clarus* system.

[1] "Pavement data" in this context includes surface and subsurface data specified in NTCIP 1204 (Ref. 8).

The addition of *Clarus* system data to national weather observations will further enhance general purpose weather forecasting, providing a wider range of benefits to the protection of life and property.

Data from the *Clarus* system will have a wide variety of direct and indirect uses. Users having the most immediate contact with the *Clarus* system will include the owners and operators of the observing systems that are providing information to the *Clarus* system, as well as the users directly accessing the data contained within the *Clarus* system. The following is an initial list — which will likely grow as the initiative progresses — of these stakeholders:

- 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 (which may include the observation system owners – e.g., state DOTs);
- The National Oceanic and Atmospheric Administration (NOAA);
- General weather service providers;
- Research and engineering community; and
- Climate data warehouse and other non-surface weather interests.

The deployed *Clarus* system is envisioned to include:

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

1.3 Definitions, Acronyms, and Abbreviations

This document may contain terms, acronyms, and abbreviations that are unfamiliar to the reader. A dictionary of these terms, acronyms, and abbreviations can be found in Appendix A.

1.4 References

The following documents contain additional information pertaining to this project or have been referenced within this document:

1. *Clarus – The Nationwide Surface Transportation Weather Observing and Forecast System*; Pisano, Pol, Stern, and Goodwin; TRB 2005.
2. *National ITS Architecture, Version 5.0*; FHWA, U.S. DOT; October 2003.
3. *Weather Information in the National ITS Architecture Version* 5.0; Meridian Environmental Technology, Inc.; August 2004.
4. *Clarus Initiative Coordinating Committee (ICC) Management Plan* (Revision 1); James Pol, U.S. DOT; September 2004.
5. *Surface Transportation Decision Support Requirements*, *Version 1.0*; Mitretek Systems, Inc.; January 2000.
6. *Weather Information for Surface Transportation: National Needs Assessment Report*; Office of the Federal Coordinator for Meteorology; FCM-R18-2002; December 2002.
7. *Weather and Environmental Content on 511® Services*; 511 Deployment Coalition; June 2003.
8. *NTCIP 1204 v02.23b NTCIP Environmental Sensor Station Interface Standard – Version 02*; National Electrical Manufacturers' Association, American Association of State Highway and Transportation Officials, and Institute of Transportation Engineers; 2005.
9. *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather*; The National Academies; BASC-U-02-06-A; 2004.
10. *Road Weather Information Systems (RWIS) Data Integration Guidelines*; Castle Rock Consultants; October 2002.
11. *Draft Report: Joint TMC/TOC System Integration Study for Emergency Transportation Operations and Weather: Baseline Conditions*; Battelle; 2004 (in review).
12. *Clarus Final Draft Concept of Operations;* Iteris and Meridian Environmental Technology, Inc.; June 24, 2005.
13. *IEEE Recommended Practice for Software Requirements Specifications*; Software Engineering Standards Committee of the IEEE Computer Society; IEEE Standard 830-1998, June 25, 1998.
14. *Security of Federal Automated Information Resources*; Appendix III to OMB Circular No. A-130; Office of Management and Budget; February 8, 1996.
15. *Clarus Weather System Design – High-level System Requirements Specification*; Mixon/Hill, Inc.; July 2005.

16. *Clarus Weather System Design – System Architectural Description;* Mixon/Hill, Inc.; October 2005.

17. *Clarus Weather System Design – Clarus ESS Survey*; Cambridge Systematics, Inc.; September 2005.

18. *Clarus Weather System Design – Systems Engineering Analysis of Clarus-Related Systems;* Mixon/Hill, Inc. and Oklahoma Climatological Survey; September 2005.

19. *Clarus Weather System Design –Architectural Alternatives Analysis*; Mixon/Hill, Inc.; September 2005.

20. *Clarus Weather System Design – Design Gaps Analysis*; Mixon/Hill, Inc.; October 2005.

Some portions of the *Clarus* Concept of Operations (Ref. 12) have been incorporated in this document, both for continuity of concept, and to help identify the basis for the high-level and detailed requirements. Specific attributions of this content are only included where they enhance the context of the requirements.

1.5 Overview

The organization and content of this document is generally based on the IEEE standards for System Requirements Specifications (Ref. 13). The requirements presented in this document represent the high-level and detailed objectives, constraints, and desires for the *Clarus* system.

Each requirement is identified by a unique *Clarus*-specific identifier to allow the requirement to be referenced in future documents, providing traceability throughout the development process. Each detailed requirement is traced to its parent through its identification number followed by a unique identifier.

A requirements document states what must be accomplished to fulfill the vision described in a concept of operations. It does not state how it is to be accomplished. This document describes each requirement and the basis for inclusion of that requirement.

The remaining sections of the document contain the requirements for the system. The sections and their content are as follows:

Section 2 – General Description provides a general overview of the entire system. This section describes the general factors that affect the system and its requirements.

Section 3 – System Architecture provides an overview of the *Clarus* system's components and their functions. Specific requirements in the next section are allocated to and organized according to these components.

Section 4 – Specific Requirements contains the requirements developed from reference documentation and stakeholder communications. This section organizes the requirements into categories that facilitate the system development process. The categories in this document are: Configuration & Administration Service (CAS), Configuration & Administration User Interface (CAUI), Collector Services (CS), Watchdog (DOG), Environmental Metadata Cache (EMC), Environmental Metadata Services (EMS), Qualified Environmental Data (QEDC), Qualified Environmental Data Services (QEDS), Quality Checking Services (QChS), Schedule Service (SS), and program requirements.

2 GENERAL DESCRIPTION

This section provides an overview of the entire system and describes the general factors that affect the system and its requirements. This section does not state specific requirements, but instead is intended to make the requirements easier to understand by giving them context. That context and the overall intent of the *Clarus* program are described in detail in the *Clarus* Concept of Operations (Ref. 12), from which much of the description in this section was derived.

2.1 System Perspective

The *Clarus* Initiative is essentially a plan to create a “network of networks” — much like the Internet — for surface transportation environmental data. While the Internet is an interconnection of computer networks, *Clarus* will be an interconnection of environmental (weather, pavement, and water level condition) data collection networks. Each of the weather networks will function autonomously; they will collect information and disseminate it internally without direction or dependence on *Clarus*.

Each participating weather network’s connection to *Clarus* will add two new possible modes of functionality. First, the participants will be able to *share collected environmental data* with *Clarus*. Second, participants will be able to *receive environmental data* collected by *Clarus*. The primary recipients of this data will be weather service providers, but any *Clarus* participants would be able to receive data if they so chose. This concept of autonomous data sharing is comparable to the World Wide Web layer of the Internet, where organizations can publish information on web pages, or browse and download information published by other organizations on the web. Ownership of the data is retained by the organization that provided the data to *Clarus*, and the provider organization can restrict the dissemination of the data through data sharing agreements with the *Clarus* program.

The *Clarus* system will add a third mode of functionality, which might be called “meta-librarian.” The *Clarus* system will collect, organize, and quality check the environmental data to be published by the system. The data will be collected from the participants, organized by location and type of data, and quality flags will be added. When this is done, the data will be published to the Service Providers and other participant/consumers in *Clarus*. Figure 2 shows the general process as data progresses from collection through publication to service providers.

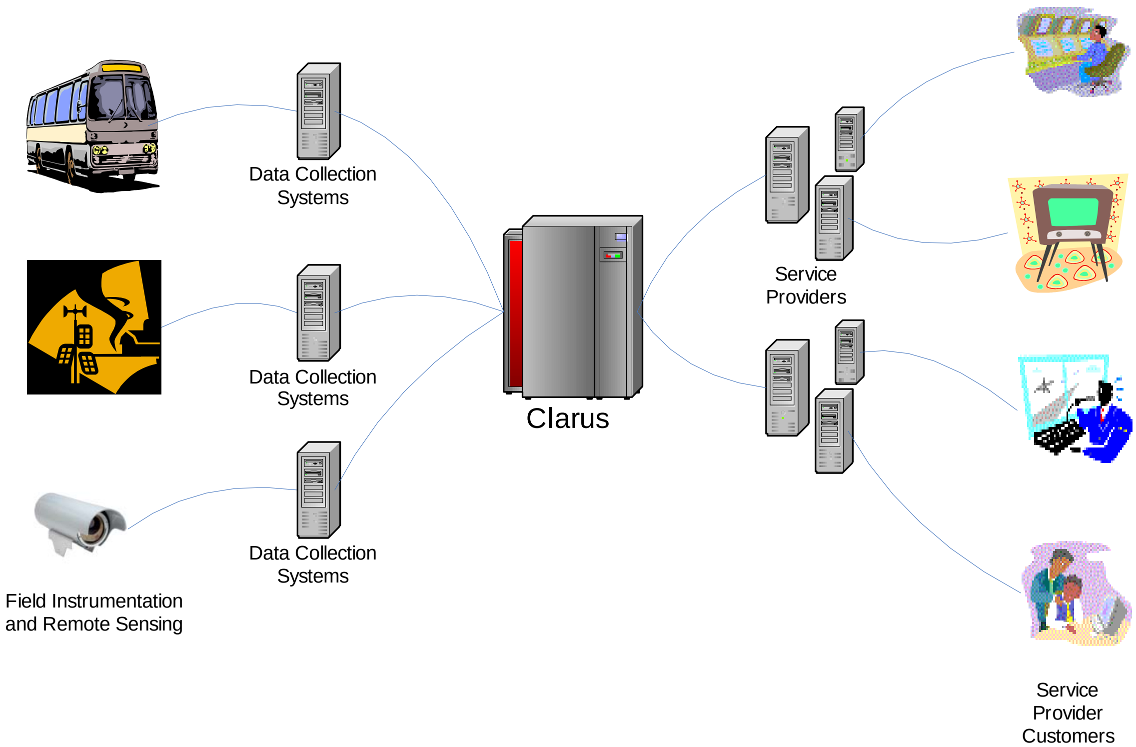


Figure 2 – *Clarus* Data Acquisition, Processing, and Publication

The principal interfaces that will be critical to *Clarus* are the interface between *Clarus* and the participating collectors, and the interface between *Clarus* and the participating service providers. MADIS, for example, uses NetCDF files as a standard interchange format. While the service provider interface is completely within the control of the *Clarus* Initiative, the interface(s) to the collectors may be influenced by what interfaces these systems can support.

While the participants may want to access the network through "a one-stop Internet portal for all surface transportation weather and pavement related observations" (Ref. 12), there is no requirement that the system be a single centralized system. Designers are free to explore centralized and de-centralized architectures so long as the interfaces with participants give the appearance of a "one-stop" portal.

The issues of data retention and archive are also not explicitly addressed. While some data retention is likely to be necessary to support the quality checking function and the publication function, there is a clear recognition that as the data age, they lose value to all but climatological investigators and other researchers. This phase of development does not include directly archiving the large volume of environmental data in *Clarus*. Considering the technical scope of such an effort, archiving may be externalized or be deferred until the *Clarus* network is operational and proven.

2.2 System Functions

The *Clarus* system will collect data from contributing members, organize and quality check the data, and then publish the data for use by service providers and other members of the network. These basic processes are shown in Figure 3 in terms of *Clarus* system objects and their interactions. The ellipses represent specific types of data, user roles, or equipment, and the arrows represent the interactions between them[2]. For example, a "Collector" administers a "Sensor," collects "Observation Data," provides "Sensor Metadata," and receives "Quality Feedback".

[2] The arrows in Figure 3 do *not* indicate data flows; they show the subject-object orientation of the relationship.

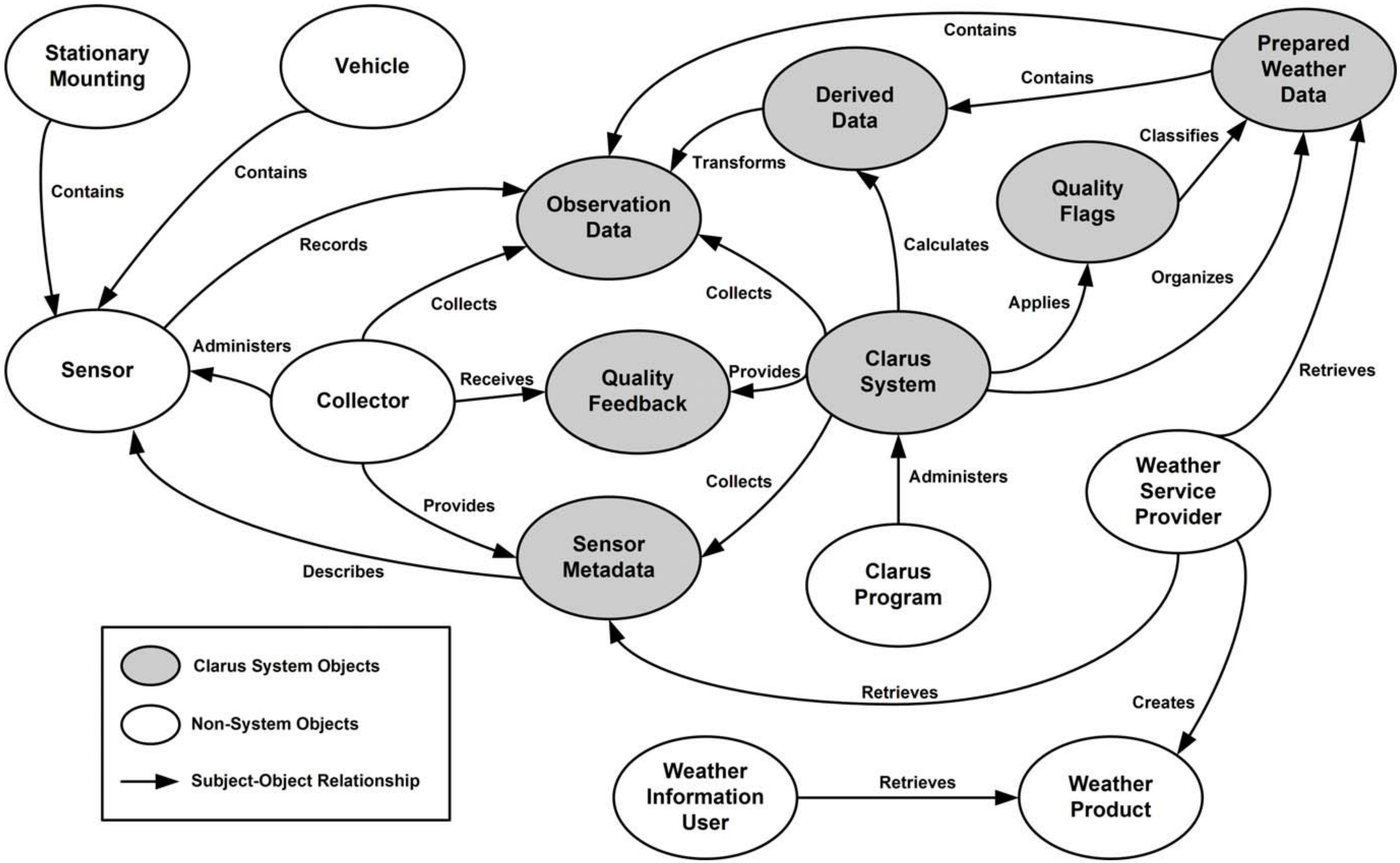


Figure 3 – Basic *Clarus* System Objects and Functions

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, organize, quality check, 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.

Determining data types will be a significant challenge. 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.

While there are many types of environmental data that could be collected, the *Clarus* emphasis on surface weather and transportation puts the focus on those weather elements that have a direct bearing on surface transportation systems. These environmental data elements are described in the NTCIP 1204 standard for Environmental Sensor Station (ESS) interfaces (Ref. 8) and summarized in Table 1 as potential environmental data elements to include in the *Clarus* system.

Table 1 – Potential *Clarus* Environmental Data Elements

Identification Objects Station Category Site Description	Snapshot Filename Image	Visibility Data Objects Visibility Visibility Situation
Data Instrumentation Objects Type of Station Door Status Battery Status Line Volts Station Meta Data Block Weather Block Mobile Block	Air Quality Parameters Carbon Monoxide Parameter Carbon Dioxide Parameter Nitrous Oxide Parameter Nitrogen Dioxide Parameter Sulfur Dioxide Parameter Ozone Parameter Particulate Matter Parameter Air Quality Block Object	Radiation Objects Solar Radiation Total Sun Cloud Cover Situation Terrestrial Radiation Solar Radiation v2 Total Radiation Total Radiation Period
Location Objects Latitude Longitude Vehicle Speed Vehicle Bearing Odometer	Temperature Data Objects Number of Temperature Sensors Temperature Sensor Table Temperature Sensor Wetbulb Temperature Dewpoint Temperature Maximum Temperature Minimum Temperature	Pavement Sensor Objects Number of Pavement Sensors Pavement Sensor Table Pavement Sensor Number of Sub-Surface Sensors Sub-Surface Sensor Table Sub-Surface Sensor Pavement Block Sub-Surface Block Object
Station Elevation Objects Reference Height Pressure Height Wind Sensor Height Atmospheric Pressure	Snapshot Parameters Number of Snapshot Cameras Snapshot Camera Table Snapshot Camera	Mobile Platform Objects Detected Friction Observed Ground State Observed Pavement State
Wind Data Section Average Wind Direction Average Wind Speed Spot Wind Direction Spot Wind Speed Wind Situation Wind Gust Speed Wind Gust Direction Number of Wind Sensors Wind Sensor Table Wind Sensor	Humidity and Precipitation Data Objects Relative Humidity Water Depth Adjacent Snow Depth Roadway Snow Depth Roadway Snow Pack Depth Precipitation Indicator Rainfall or Water Equivalent of Snow Snowfall Accumulation Rate Precipitation Situation Ice Deposit (Thickness) Precipitation Start Time Precipitation End Time Total Precipitation Past One Hour Total Precipitation Past Three Hours Total Precipitation Past Six Hours Total Precipitation Past Twelve Hours Total Precipitation Past Twenty-Four Hours Precipitation Sensor Model Information Number of Water Level Sensors Water Level Sensor Table Water Level Sensor	Pavement Treatment Objects Number of Treatments Pavement Treatment Table Pavement Treatment Treatment Amount Treatment Width Pavement Treatment Block Operational Mode Command State Sprayer State Signal Duration Signal Event Count Last Signal Event Active Event Count Inactive Event Count Last Active Event Last Inactive Event PTS Error Code Monitoring Detectors
Water Quality Parameters		

There are basic temporal limits for the data collection, quality checking, processing, and publication of the environmental data. There is also a period for which the Service Provider Customers have temporal-driven requirements. The design of *Clarus* will need to consider these time horizons when planning the technical limitations of the system architecture. These data time horizons are illustrated in Figure 4.

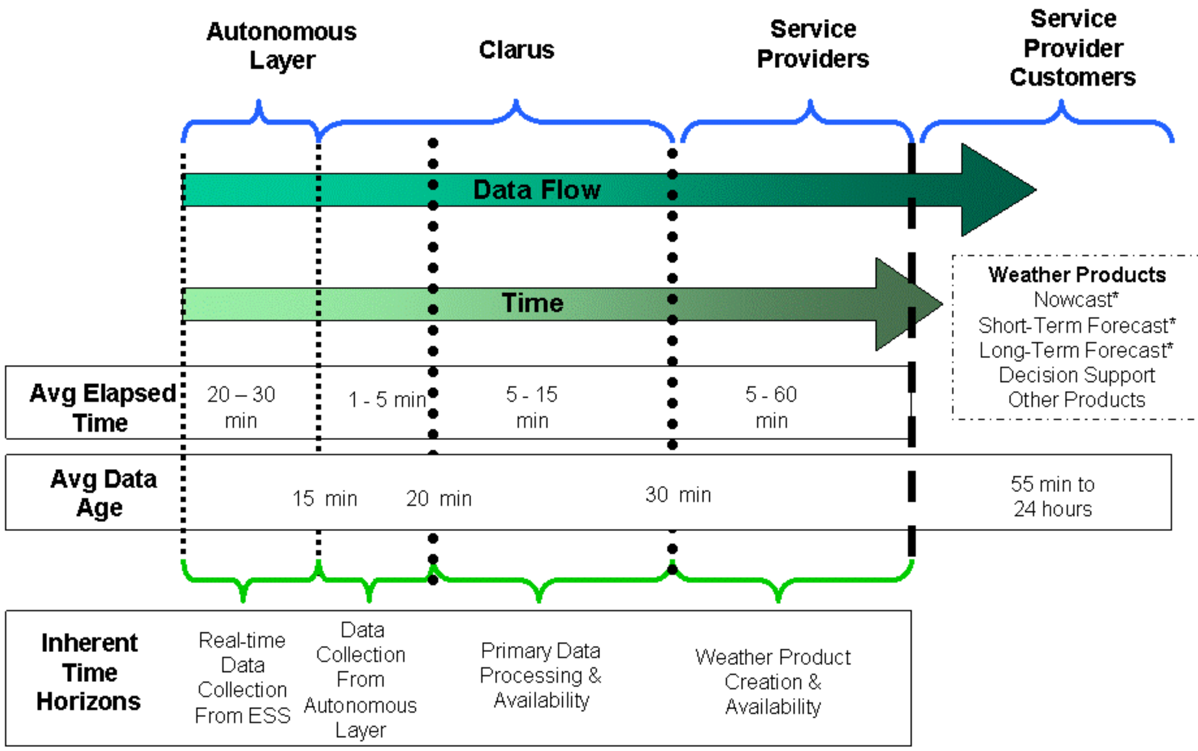


Figure 4 – Time Horizons for Weather Data

The average elapsed time for the Autonomous Layer varies as a result of configuration and communications latencies that are inherent within the operation of the system to collect the data. The *Clarus* component includes the time required to communicate data from the Autonomous Layer to the *Clarus* system import process as well as the time required to process the input data into storage structures. Further, the variation in the Service Provider component includes the time required to add other data to the *Clarus* data and to perform the human- and machine-based product generation. The average data age grows as a result 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.

For the purposes of defining the boundaries of these time horizons, the following definitions apply:

- **Average Elapsed Time** is the estimated time for the process within a given layer or layer subdivision to take place. The age of observed and recorded values can vary widely within these bands.
- **Average Data Age** is the estimated average age of an ESS observation as it is transferred from the ESS to the end user.

2.3 User Characteristics

Direct and indirect use of the *Clarus* system can be applied to a wide audience. Because a variety of users can derive benefit from the *Clarus* system, it is necessary to focus upon those users who have the most immediate contact with the system components.

The primary user classes include the owners and operators of the observing systems collecting and sending information to *Clarus*, and the users directly accessing the data published by 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 institutions;
- Instrument and observation platform suppliers;
- Direct data users including system owners and their contractors;
- Surface transportation weather service providers (which may include the observation system owners);
- NOAA;
- General weather service providers;
- Research and engineering community; and
- 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 requirements 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) (Ref. 5), *Weather Information for Surface Transportation* (WIST) (Ref. 6), and 511 Deployment Coalition (Ref. 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 data from raw field observations to various levels of data use. This is illustrated in Figure 5.

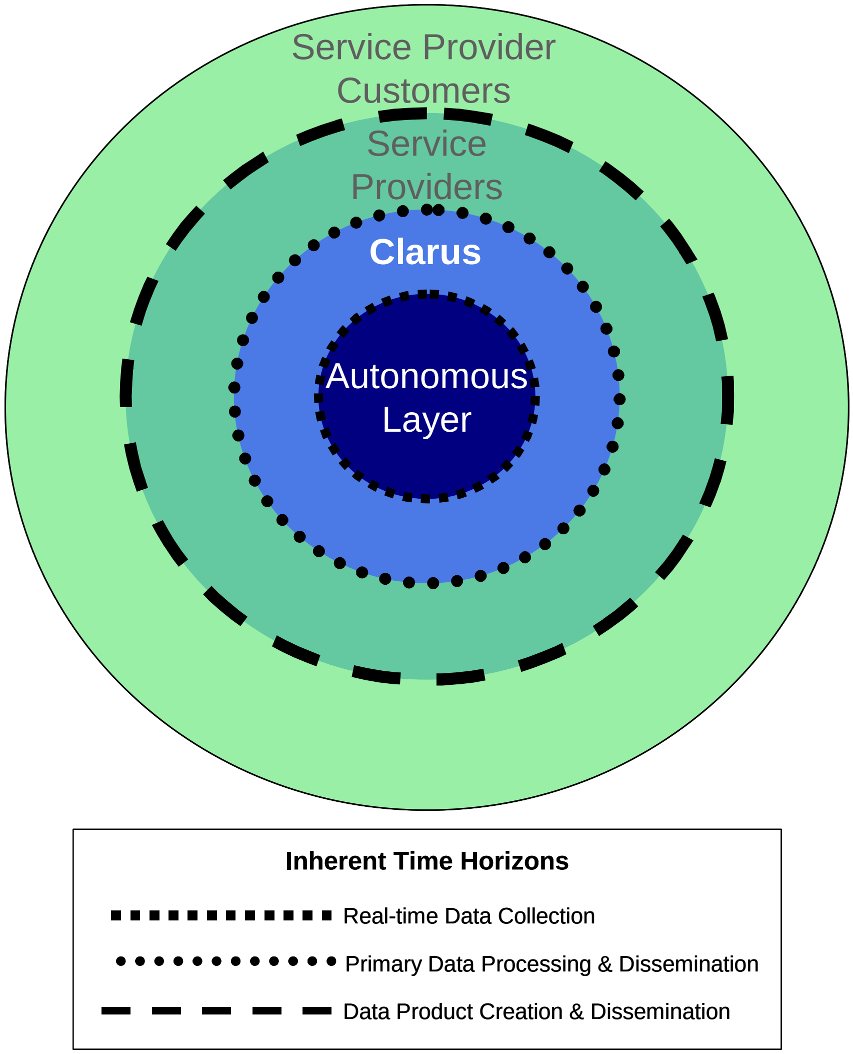


Figure 5 – *Clarus* User Layers and Time Horizon Relationships

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 Autonomous Layer data comprises the vast majority of the raw input data to the *Clarus* system.

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.

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 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 group could be anyone using weather information, but are largely found within the surface transportation community. The weather products received by these end users are built from 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 checking information on the data they originally provided to *Clarus*.

Figure 5 can also be viewed as a depiction of the time horizons that separate the stakeholder groups. There is an inherent time scale, similar to Figure 4, emanating from the center of the diagram outward, representing the flow and processing of data through the *Clarus* system and between the layers.

The context diagram in Figure 6 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 maintain data collection systems. These organizations make up the Autonomous Layer — the primary contributors of surface transportation data to the *Clarus* system. These stakeholders can benefit from *Clarus* by receiving quality-controlled data from the *Clarus* system. The quality-controlled data are not value-added data, but data with flags indicating that elements do not meet quality checking thresholds.

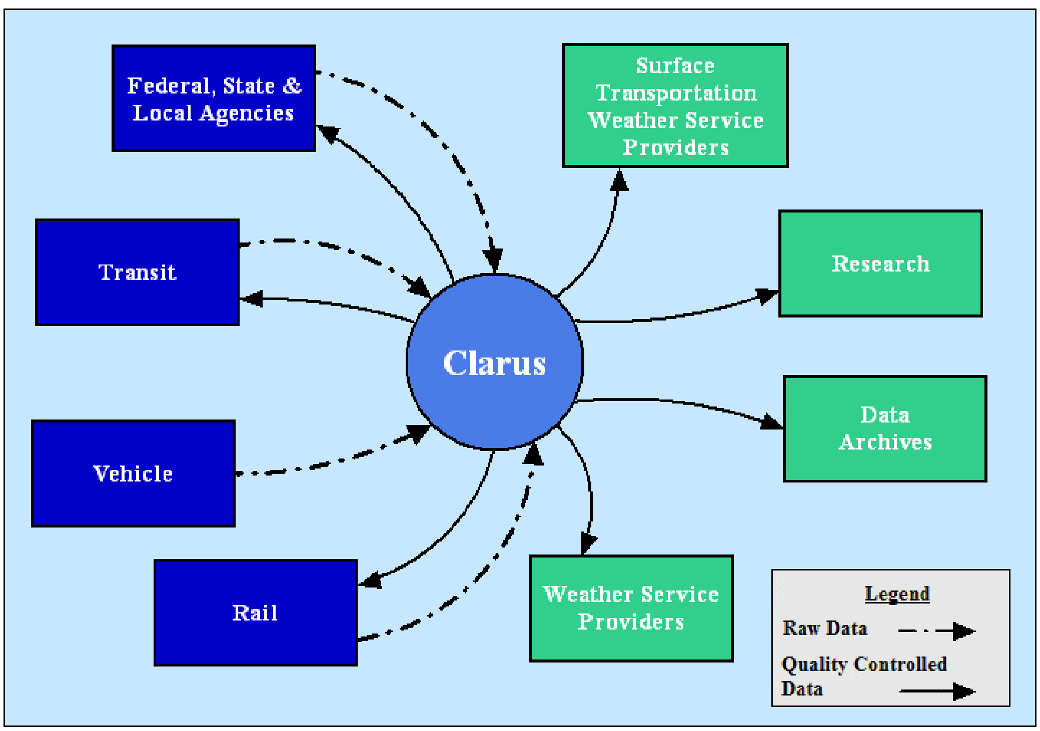


Figure 6 – Context Diagram of *Clarus* User Needs

The private and public sector Service Providers are the principal *Clarus* users. These Service Providers generate value-added road and rail weather information services for the transportation community. Additional Service Providers having direct access to *Clarus* data resources include research organizations, external agencies that may choose to archive *Clarus* data, and other related weather service providers.

Within the context of Figure 6, the following roles can be assigned to each group of users:

- **Federal, State, and Local Agencies –** These are the transportation system and road weather information system (RWIS) 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. These users, primarily maintenance and operations personnel, are the principal consumers of information provided by surface transportation weather service providers. Additional data from this group may include closed circuit television (CCTV) images, road condition information, and records of treatment activities such as plowing and chemical application.
- **Transit –** These are the owners and operators of transit 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.
- **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 specifics such as rail temperatures, frozen switches, icing on electrical power distribution systems, 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 –** 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 National Weather Service (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.
- **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.

2.4 General Constraints

Timeliness of information and reliability of the system are major constraints on the design. Both of these factors can be addressed through appropriate system architecture and implementation.

To address the timeliness factor, the system should be designed such that it can both retrieve and disseminate large volumes of data from a variety of sources and at potentially high rates. An architecture that spreads its data collection and dissemination processes across multiple servers and communication channels may address this issue. The inherent scalability of such a design may also enable the system to expand and add new data sources and end-users.

Reliability can be achieved through a variety of design and deployment considerations. Hardware, operating system, and development environment have significant impacts on the inherent reliability of the system. To maximize system uptime, redundancies may be required at both the hardware and software levels of the system. The primary challenge here will be the trade-off between the desire for reliability and the cost of redundancies.

While the availability of the system is covered in the Concept of Operations, the criticality of the system is not explicitly addressed. Since *Clarus* is not replacing any existing application, the system is not currently critical to any operation or transportation function; neither is it intended to support any "critical national security missions."[3] Nonetheless, once the *Clarus* system is operational, many DOTs will use the environmental data from the *Clarus* system in their normal management and operations of their infrastructure. If the *Clarus* system fails, requestors will need to use their legacy systems.

The system will be "open," using architecture and communications interfaces that are non-proprietary and broadly supported within the information technology industry. The system should be standards based, where national standards are applicable. Special consideration should be given to the national intelligent transportation system (ITS) standards.

[3] Security considerations for the *Clarus* system fall under the guidance of Reference 14, OMB Circular No. A-130, which, by its own definition, does not apply to "critical national security missions." Future applications of *Clarus* may necessitate revisiting this classification.

2.5 Assumptions and Dependencies

The usefulness of the *Clarus* system is dependent on participation by multiple environmental data providers and multiple environmental data consumers. While the system could be placed in operation with data from only a single contributing network, there is no added value without the participation of other weather data sources. Likewise, participation by a small number of data consumers would not justify the cost of operating the system.

Several assumptions have been made as to how long it will take environmental data contributors to collect, process, and publish their data. Data not collected in a timely manner may be of limited use to the data consumers. Assumptions have also been made about the accuracy of the data, and the ability of the contributing systems to provide adequate location, time/date, and data qualification tags. Accepting data from contributors who cannot provide these tags with the data could seriously complicate the design of the data acquisition interfaces.

Even though the system will check the data and apply quality flags, consumers of *Clarus*-provided data will need to understand that neither FHWA nor the contributing data providers will accept responsibility for the accuracy of any of the data. The particular limitations and conditions will be defined in data sharing agreements to be established with data providers, and disclaimer information will be made available to data consumers by whatever means the data are published.

Several requirements deal with "regional" needs, without specifying regional boundaries. It is unlikely that the regional boundaries from contributing systems will correspond with the regional boundaries defined within data consumer systems. It is even likely that participating data contributors will have different (though possibly overlapping) coverage areas for their networks. Data consumers will need to understand that data will be presented by geographic coordinates, not by regional boundaries. Consumers will also need to understand that coverage will not be uniform and will depend on sensor placement by the contributing organizations.

The availability, format, and precision of geo-reference coordinates for data collection points could present unusual problems for the data acquisition system. Data in the system database and in published data sets will likely include geo-reference coordinates in decimal longitude, latitude, and elevation.

The availability, format, and precision of time/date stamps could also present unusual problems for the data acquisition system, particularly if contributing systems cannot manage Daylight Savings Time (DST), span time zones, or span areas that do and do not participate in DST. *Clarus* timestamps for data in the database and in published data sets need to be referenced to a standard time reference such as Coordinated Universal Time (UTC).

The base assumption regarding "database tools" is that the selected data storage software will include appropriate programming interfaces, query tools, and configuration and management tools. No special database tools will be developed as a part of the *Clarus* system. Some tools may developed in the future as part of ongoing *Clarus* Initiative activities.

3 SYSTEM ARCHITECTURE

The process of generating detailed system requirements has two major parts: allocating the high-level requirements to specific system components, and elaborating the requirements on the function and interchange between those components. The functional components of the *Clarus* system have been detailed in the *Clarus* System Architectural Description and are summarized in this section. **Figure 7**, taken from that document, represents the general structure and flow of information within the *Clarus* system.

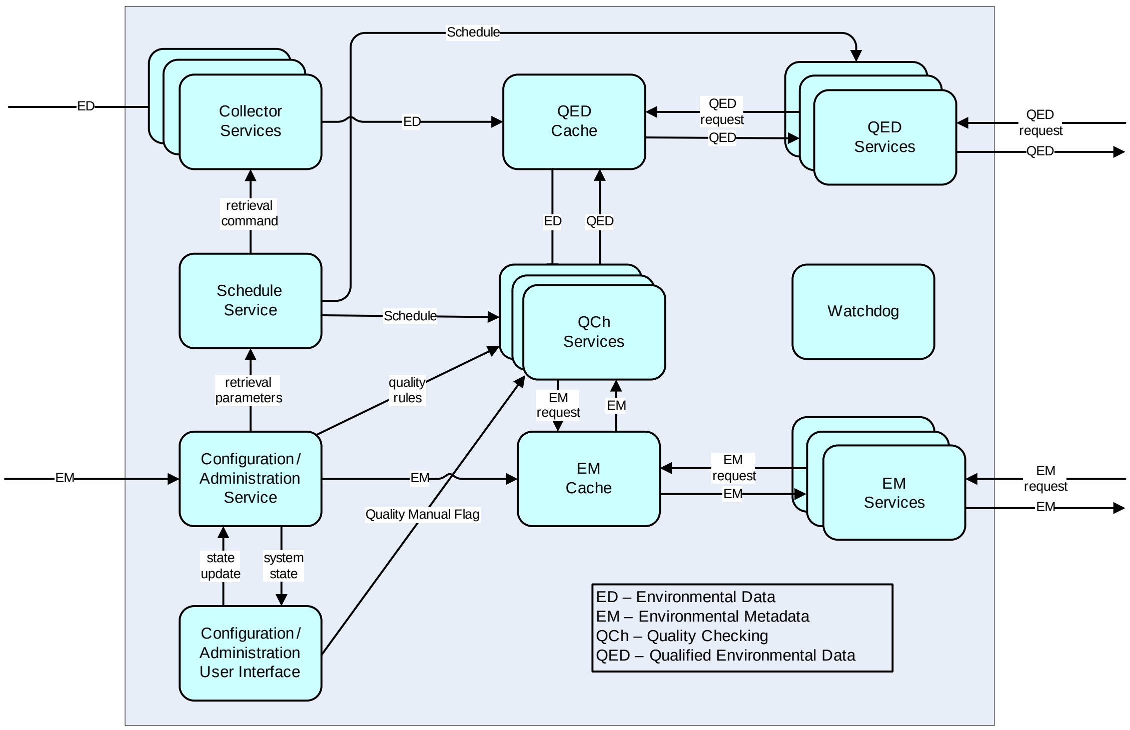


Figure 7 – Data Flows within the *Clarus* System

Four of the components in **Figure 7** are modeled as sets of services: the collector, quality checking (QCh), qualified environmental data, and environmental metadata services. The collector, QED, and EM services are sets of services because each individual service represents a particular data format interface. A set of services is required to properly interpret and transform all the incoming and outgoing environmental information. The particular collector, QED, or EM service performing a transformation depends on the origin and destination of the environmental data.

The fourth component modeled as a set is the quality checking service. It is a set of services because it represents in one component all the QCh algorithms that can be applied to environmental data collected by *Clarus*. The specific algorithms and sequence in which they are applied are determined by quality rules established through the configuration & administration service. This arrangement supports flexibility in adding and removing QCh algorithms to produce the best possible qualified environmental data in the *Clarus* system.

There are two services that keep the *Clarus* system operating: the watchdog and schedule services. The watchdog service monitors the overall system state and restarts unresponsive services as needed, thus preventing long-term service disruption. The schedule service prioritizes requests to receive environmental data from collectors and contributors. The schedule service will also prioritize and respond to subscription requests for environmental data (not depicted in **Figure 7**).

The set of collector services in the *Clarus* system receives environmental data from ED collectors and contributors through both push and pull methods. Each collector service is capable of understanding a particular data format and is responsible for extracting the environmental data and placing it into the qualified environmental data cache flagged as unqualified environmental data.

Quality rules set up by the configuration & administration service are executed by the quality checking services to apply sets of computations on the environmental data stored in the qualified environmental data cache. Flagging out-of-range values is one example of a quality rule. Other quality rules could be created to derive environmental conditions from existing information such as dew point. Multiple passes by the quality checking services on the QEDC information could apply grid algorithms sequentially to further quality check the environmental data. This allows constant access to qualified environmental data in-process. The QEDC is still valuable to end-users since it will always identify its level of quality and can be continuously delivered.

The QED services format the qualified environmental data to fulfill requests from and information subscriptions for environmental service providers and end-users. Similarly, the EM services format the metadata to meet requests from and metadata subscriptions for environmental service providers. Each of these components is a set of services, with each individual service supporting a particular data format.

The configuration and administration service supports both the *Clarus* system and program. It maintains information about data provider redistribution restrictions and controls who has access to modify the system state, quality rules, and set ED retrieval schedules. The configuration & administration service manages environmental metadata, formatting it for internal storage. Data transactions and system operational statistics are logged in the configuration and administration user interface as well. The configuration and administration user interface allows administrative users to interact with these functions and supports the manual quality review processes.

4 SPECIFIC REQUIREMENTS

This section presents the high-level and detailed requirements for the *Clarus* system and the associated institutional program necessary to achieve the needs and goals described by the Concept of Operations. These requirements describe the expected attributes and capabilities of the system and allocate capabilities to specific components within the *Clarus* system. The high-level requirements in this document are limited to those that can be derived from a context diagram (Figure 8) that pictures the *Clarus* system as a single functional block with its interfaces. The types of high-level requirements described in this section correspond roughly to these functions and interfaces. Functional requirements describe what happens inside the *Clarus* system itself: quality checking, development, and packaging of environmental data. Each interface to the *Clarus* system has its own requirements with regard to the collection of data from providers as input; the dissemination of data for output; the controlling rules and constraints under which the system operates; and the means (primarily data management) by which it works.

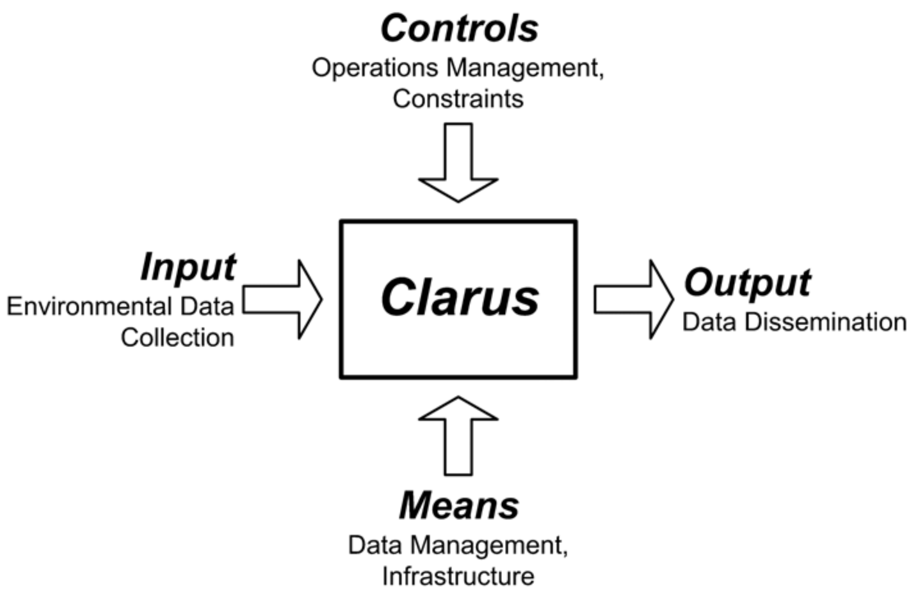


Figure 8 – High-Level Requirements Context

The high-level perspective assumed for these requirements has implications for downstream development activities. The high-level requirements provide a basis for components in system elaboration, and detailed requirements are subsequently tied to specific components. Conformance to high-level requirements is shown through testing based on plans derived from the detailed requirements. The entire development process is tied together by lines of traceability anchored in the high-level requirements.

In this section, the requirements are classified by the first letter in the requirement identification as described in Table 2 and shown in Table 3.

- Functional Requirements – Lists the characteristics that the system must support for each interface. Identifies what is to be done by the system, what inputs should be transformed to what outputs, and what specific operations are required. The functional requirements further include:

- Functional Data Requirements, which describe requirements specific to the definition and management of data used and provided by the system; and
- Functional Interface Requirements, which describe the functional interfaces to the *Clarus* system from information providers and consumers.

- Performance Requirements – Specifies static and dynamic capacity for the number of users, connections, and other performance related factors. Performance requirements further include:
  - Design Constraints, which identify constraints imposed by standards, regulations, software or hardware limitations; and
  - Quality Requirements, which provide requirements which address the general quality, usability, extensibility, flexibility, and maintainability of the system.
- Organizational Requirements – Includes requirements for policies and procedures to support the implementation, operations, training, and institutional requirements to support the system. This category also:
  - Details logical characteristics between the system and external data sources;
  - Specifies level of integration with external systems and defines the interfaces with each user class; and
  - Specifies any communications interfaces and protocols that should be supported.

Table 2 shows the general layout of the requirements tables, and explains the purpose or content of each column of the requirements table. The requirements in this document are a subset of the requirements information that will be tracked in the system “Requirements Matrix.” While this document is intended to record the requirements that apply to a particular implementation of the system, the Requirements Matrix tracks all proposed requirements for the system. The matrix includes requirements that may apply to future versions of the system or which have been deferred due to cost or complexity.

Table 3 provides an explanation of the requirement identification numbering system. The high-level requirements are identified as A-NNN, where A is the classification and NNN is a unique number. The detailed requirements are identified as A-NNNUU, where A-NNN is the parent or high-level requirement and UU is a unique identifier.

This section lists the functional characteristics that the system must support. It also identifies what is to be done by the system, what inputs should be transformed to what outputs, and what specific operations are required. The functional requirements are broken into subsections by each allocation to specific modules listed in Table 4.

Detailed requirements are associated with a parent or high-level requirement. They are used by developers in creating the design for the *Clarus* system, by testers to ensure all requirements are implemented during the build of the *Clarus* system, and by the client for documenting their expectations.

Many of the high-level requirements are allocated to more than one module or component of the *Clarus* system. Within each table, the high-level requirements show their allocations to particular modules. If the high-level requirement is allocated to more than one module, then the high-level requirement will be repeated in the corresponding allocation's module.

Following the high-level requirement, detailed requirement(s) are shown to create more refined requirements specific to the associated module. Figure 7 may be referenced while reviewing the detailed requirements to maintain context of the *Clarus* system's architecture.

Table 2 - Explanation of the Requirements Tables

ID	Requirement	Source	Allocation	Comment	Criticality
A unique identifier used to trace requirements from beginning to end in a system development process.	The text of the actual requirement. Requirements formulated with "… shall…" are direct requirements; those using "… shall be able to…" are conditioned on other requirements being fulfilled or on factors outside the control of the requirement's subject.	Source(s) for the requirement; could be a reference document or a "parent" requirement.	Identifies the module(s) for the high-level requirement as shown in Table 4.	Supporting text that may help explain the requirement, its priority, or the risks associated with implementing the requirement.	H = High M = Medium L = Low

Table 3 – Requirement ID Format

Requirement ID Format	Explanation of Format
High-level Requirement A-NNN Detailed Requirement A-NNNUU	A — Represents the classification of the requirements within the requirements document. The following classifications have been used in this requirements specification: D — Design Constraints F — General Functional Requirements H — Functional Data Requirements I — Functional Interface Requirements P — System Performance Requirements Q — Quality Requirements X — Organizational Requirements NNN — Provides unique identification. Numbering is not necessarily sequential; gaps in the sequence leave room to add additional related requirements when they are discovered. UU — Provides unique identification.

Table 4 – Allocation Format

Allocation	Name of Allocation Module
CAS	Configuration and Administration Service
CAUI	Configuration and Administration User Interface
CS	Collector Services
DOG	Watchdog
EMC	Environmental Metadata Cache
EMS	Environmental Metadata Services
QEDC	Qualified Environmental Data
QEDS	Qualified Environmental Data Services
QChS	Quality Checking Services
SS	Schedule Service

4.1 Configuration & Administration Service (CAS)

The requirements in this section specify the service to configure and administer the system. The CAS supports the *Clarus* system and program, manages information about data provider redistribution restrictions, controls access for modifying the system state and quality rules, applies manual quality flags, establishes environmental data retrieval schedules, and manages environmental metadata.

ID	Requirement	Source	Allocation - CAS	Comment	Criticality
F-101	The *Clarus* system shall implement quality checking processes as soon as data become available.	ConOps §2.4	QChS, SS, CAS		H
F-101B1	The CAS shall be able to configure schedules for executing QChS.				
F-151	The *Clarus* system shall record the methods applied when deriving quality checking information.	MHI	QChS, CAS		H
F-151B1	The CAS shall record the quality checking methods used.				
F-155	The *Clarus* system shall be able to implement quality checking rules for each environmental parameter.	ConOps §3.5.1.4	QChS, CAS, CAUI		H
F-155B1	The CAS shall be able to configure the quality checking rules for each environmental parameter.				
F-155B2	The CAS shall enable administrators to manage quality checking rules.				

ID	Requirement	Source	Allocation - CAS	Comment	Criticality
F-161	The *Clarus* system shall be able to implement quality checking rules for specific environmental situations.	ConOps §3.5.1.4	QChS, CAS	The rules for setting quality flags on environmental data elements may themselves depend on other environmental data. For example, stormy conditions may allow more spatial and temporal variability in wind speed observations than under fair weather conditions.	H
F-161B1	The CAS shall be able to configure quality checking rules for specific environmental situations.				
F-163	The *Clarus* system shall be able to implement quality checking rules specific to observation locations.	Task Force review	QChS, CAS	Quality checking rules may vary from region to region.	H
F-163B1	The CAS shall be able to configure quality checking rules specific to observation locations.				
F-171	The *Clarus* system shall be able to base its quality checking process on historical environmental data.	Inferred from ConOps §3.5.1.4	QChS, CAS		H
F-171B1	The CAS shall be able to configure historical environmental data to be used by quality checking processes.				

ID	Requirement	Source	Allocation - CAS	Comment	Criticality
F-175	The *Clarus* system shall be able to use multiple algorithms for its quality checking process.	Inferred from ConOps §4.3	QChS, CAS	Multiple methods or comparisons may be needed for a given observation.	M
F-175B1	The CAS shall be able to configure multiple algorithms to be used in the quality checking process.				
F-213	The *Clarus* system shall allow access to new surface transportation-related environmental data.	ConOps §1, 2.4, 3.1	CS, QChS, QEDC, QEDS, CAS, EMC, EMS, DOG	Access could only be provided when new data sources are established and available.	L
F-213B1	The CAS shall be configurable to allow new observation types to be implemented as they become available.				
F-806	The *Clarus* system shall enable administrators to manage security groups.	MHI	CAS, CAUI	Manage means create, read, update, and delete.	H
F-806B1	The CAS system shall enable administrators to manage security group members.				
F-806B2	The CAS shall have an administrator security group.				
F-806B3	The CAS shall have a quality manager security group.				

ID	Requirement	Source	Allocation - CAS	Comment	Criticality
F-811	The *Clarus* system shall be able to restrict environmental data publication based on source.	MHI & ConOps §4.5	QEDS, CAS	Use MADIS as a template (ConOps §3.6).	H
F-811B1	The CAS shall be able to record data sharing restrictions.				
F-901	The *Clarus* system shall record statistics about its operation.	OCS	CAS		H
F-901B1	The CAS shall record statistics about the system operation.				
F-905	The *Clarus* system shall log data transactions.	MHI	CS, QEDS, EMS, QChS, CAS, SS, DOG		H
F-905B1	The CAS shall log data transactions.				
H-120	The *Clarus* system shall acquire, process, and disseminate environmental metadata.	ConOps §3.3	CAS, EMC, EMS, CAUI	Roll up of H-121, H-122, H-123, H-201, which were deprecated.	
H-120B1	The CAS shall manage contributor metadata.			For example, ESS & VII contributor metadata.	
H-120B2	The CAS shall manage collector metadata.			For example, ESS & VII collector metadata.	
H-120B3	The CAS shall manage quality checking schedules.				

ID	Requirement	Source	Allocation - CAS	Comment	Criticality
H-120B4	The CAS shall manage environmental data collection schedules.				
H-120B5	The CAS shall manage ESS metadata.	Task Force			
I-032	The *Clarus* system shall manage environmental data and metadata according to the *Clarus* data sharing agreements.	MHI	CAS, CAUI	Changed from "The *Clarus* system shall manage system user privileges according to the *Clarus* data sharing agreements."	H
I-032B1	The CAS shall manage data sharing rules based on contributor data sharing agreements.				

4.2 Configuration & Administration User Interface (CAUI)

The requirements in this section specify the interface for administering the system and applying manual quality flags.

ID	Requirement	Source	Allocation - CAUI	Comment	Criticality
F-100	The *Clarus* system shall collect, quality check, and disseminate environmental data.	ConOps §1	CS, QChS, QEDS, CAUI	Environmental data includes all NTCIP 1204 data (summarized in Table 1).	H
F-100C1	The CAUI shall be able to initiate CS on demand.				
F-111	The *Clarus* system shall provide environmental data quality flags.	OCS	QChS, CAUI, QEDC		H
F-111C1	The CAUI shall enable a quality manager to apply manual flags to a set of observations from an individual ESS.			This requirement allows all observations from an ESS to have manual flags applied. Example, the ESS was destroyed by a car.	
F-111C2	The CAUI shall enable a quality manager to apply manual flags to a set of observations.			This requirement allows only some of the observations from an ESS to have manual flags applied. Example, a particular sensor is out of service.	
F-111C3	The CAUI shall enable a quality manager to apply manual flags to a set of observations over a fixed time range.				
F-111C4	The CAUI shall enable a quality manager to apply manual flags to a set of observations over a time range with an open ended future time.				
F-141	The *Clarus* system shall allow human quality checks of environmental data.	OCS	CAUI, QChS	Changed from "The *Clarus* system shall allow human intervention to override automatically applied quality assessment."	M

ID	Requirement	Source	Allocation - CAUI	Comment	Criticality
F-141C1	The CAUI shall allow a quality manager to apply a manual quality flag to environmental data.				
F-141C3	The CAUI shall allow manual quality flags to be entered.				
F-155	The *Clarus* system shall be able to implement quality checking rules specific to each environmental parameter.	ConOps §3.5.1.4	QChS, CAS, CAUI		H
F-155C1	The CAUI shall enable quality checking rules to be configured specific to each environmental parameter.				
F-806	The *Clarus* system shall enable administrators to manage security groups.	MHI	CAS, CAUI		H
F-806C1	The CAUI shall enable administrators to manage security group members.				
H-120	The *Clarus* system shall acquire, process, and disseminate environmental metadata.	ConOps §3.3	CAS, EMC, EMS, CAUI	Roll up of H-121, H-122, H-123, H-201, which were deprecated.	
H-120C1	The CAUI shall enable administrators to acquire environmental metadata.				
H-120C2	The CAUI shall enable administrators to manage environmental metadata.				

ID	Requirement	Source	Allocation - CAUI	Comment	Criticality
I-031	The *Clarus* system shall provide a user interface for administration.	MHI	CAUI		H
I-031C1	The CAUI shall enable administrators to manage contributor metadata.				
I-031C2	The CAUI shall enable administrators to manage collector metadata.				
I-031C3	The CAUI shall enable administrators to manage quality checking schedules.				
I-031C4	The CAUI shall enable administrators to manage environmental data collection schedules.				
I-032	The *Clarus* system shall manage environmental data and metadata according to the *Clarus* data sharing agreements.	MHI	CAS, CAUI	Changed from "The *Clarus* system shall manage system user privileges according to the *Clarus* data sharing agreements."	H
I-032C1	The CAUI shall enable administrators to manage contributor data sharing agreements.				
I-032C2	The CAUI shall enable administrators to assign system privileges.				

4.3 Collector Services (CS)

The requirements in this section specify the collection of environmental data. The Collector Services shall receive environmental data, convert the environmental data into a standard format, and store the environmental data in the Qualified Environmental Data Cache.

ID	**Requirement**	**Source**	**Allocation - CS**	**Comment**	**Criticality**
F-100	The *Clarus* system shall collect, quality check, and disseminate environmental data.	ConOps §1	CS, QChS, QEDS, CAUI	Environmental data includes all NTCIP 1204 data (summarized in Table 1).	H
F-100D1	CS shall collect environmental data based on its configured schedule.				
F-100D2	CS shall be able to transform extracted environmental data into the internal storage format.				
F-100D3	CS shall be able to store transformed environmental data in the QEDC.				
F-100D4	CS shall be able to convert observation units into the *Clarus* standard unit specification.				
F-100D5	CS shall be able to be initiated on a schedule.				
F-100D6	CS shall be able to be initiated on demand.				
F-200	The *Clarus* system shall be able to detect data submission errors.	MHI	CS		H
F-200D1	CS shall log when a data submission error occurs.				

ID	Requirement	Source	Allocation - CS	Comment	Criticality
F-201	The *Clarus* system shall be able to access in-situ environmental observations from data collectors.	OCS	CS	Access to data may be conditional based on data sharing agreements to be reached with individual data collector organizations.	H
F-201D1	CS shall be able to collect in-situ environmental observations from data collectors.				
F-205	The *Clarus* system shall be able to access remotely sensed environmental observations from data collectors.	OCS	CS		M
F-205D1	CS shall be able to retrieve remotely sensed environmental observations from data collectors.				
F-211	The *Clarus* system shall be able to receive roadway weather measurements derived from VII data.	OCS	CS		M
F-211D1	CS shall be able to retrieve roadway weather measurements derived from VII data.				
F-213	The *Clarus* system shall allow access to new surface transportation-related observed environmental data.	ConOps §1, 2.4, 3.1	CS, QChS, QEDC, QEDS, CAS, EMC, EMS, DOG	Access could only be provided when new data sources are established and available.	L
F-213D1	CS shall be able to be implemented to collect new observation types as they become available.				

ID	Requirement	Source	Allocation - CS	Comment	Criticality
F-214	The *Clarus* system shall accept environmental data derived from images.	MHI	CS	Images would include CCTV and still images.	H
F-214D1	CS shall accept surface condition data derived from surface images.	Task Force review		Surface condition data may include, for example, "dry", "wet", "icy", "snow-covered", or "flooded". Used to be F-216.	H
F-214D2	CS shall accept atmospheric condition data derived from atmospheric images.	Task Force review		Used to be F-217.	H
F-221	The *Clarus* system shall be able to retrieve environmental data directly from environmental sensor station collectors.	Task Force review	CS	Changed from "The *Clarus* system shall be able to retrieve environmental data directly from environmental sensor stations."	L
F-221D1	CS shall be able to retrieve environmental data directly from environmental sensor station collectors.				
F-222	The *Clarus* system shall minimize the time for data acquisition.	OCS			H
F-222D1	CS shall be able to dynamically adjust its retrieval schedules when environmental data is expected to be ready but is temporarily delayed.				
F-223	The *Clarus* system shall process data as they are received.	ConOps §3.4.3	CS, QChS		H
F-223D1	CS shall process environmental data as they are received.				

ID	Requirement	Source	Allocation - CS	Comment	Criticality
F-231	The *Clarus* system shall collect pavement-related observations.	ConOps §2.5	CS	Pavement-related observations could include precipitation accumulation, flooding or treatments.	H
F-231D1	CS shall be able to collect pavement-related observations.				
F-241	The *Clarus* system shall accept environmental data from railway systems or in-situ ESS along tracks.	ConOps §2.5.7	CS		H
F-241D1	CS shall be able to collect environmental data from railway systems from railway collectors.				
F-241D2	CS shall be able to collect environmental data from in-situ ESS along tracks from railway collectors.				
F-245	The *Clarus* system shall accept environmental data from railroad vehicles.	ConOps §2.5.7	CS		H
F-245D1	CS shall accept environmental data derived from railroad vehicle data.				
F-251	The *Clarus* system shall accept environmental data from (roadway) vehicles.	Inferred from ConOps §2.5.x	CS		H
F-251D1	CS shall accept environmental data collected from (roadway) vehicles.				

ID	Requirement	Source	Allocation - CS	Comment	Criticality
F-255	The *Clarus* system shall accept environmental data from maintenance and construction vehicles.	ConOps §2.5.2	CS		H
F-255D1	CS shall accept environmental data collected from maintenance and construction vehicles.				
F-261	The *Clarus* system shall accept environmental data from service patrol vehicles.	ConOps §2.5.3	CS		H
F-261D1	CS shall accept environmental data collected from service patrol vehicles.				
F-271	The *Clarus* system shall accept environmental data from transit vehicles.	ConOps §2.5.5	CS	Transit vehicles include watercraft (ferries) and buses.	H
F-271D1	CS shall accept environmental data collected from transit vehicles.				
F-275	The *Clarus* system shall accept environmental data from emergency vehicles.	ConOps §2.5.6	CS		H
F-275D1	CS shall accept environmental data collected from emergency vehicles.				
F-281	The *Clarus* system shall be able to receive weather data from weather service providers.	ConOps §3.5.1.4	CS		H

ID	Requirement	Source	Allocation - CS	Comment	Criticality
F-281D1	CS shall be able to receive weather data from weather service providers.			For example, ASOS/AWOS.	
F-905	The *Clarus* system shall log data transactions.	MHI	CS, QEDS, EMS, QChS, CAS, SS, DOG		H
F-905D1	CS shall create a log entry when a data set is invalid.			An "invalid" data set is one that cannot be understood as received.	
H-011	The *Clarus* system baseline data types shall be defined by the NTCIP ESS 1204 standard.	ConOps §3.3 (Table 2)	CS, QEDC, QEDS	Version 02.20 was accepted as a recommended standard by the NTCIP Joint Committee in March 2005. See www.ntcip.org/library/documents.	H
H-011D1	CS shall accept data types defined by NTCIP 1204.				
H-012	The *Clarus* system data definitions shall be consistent with the ITE TM 1.03 standard, Functional Level Traffic Management Data Dictionary (TMDD).	Task Force review	CS, QEDS		H
H-012D1	CS shall accept environmental data described by definitions defined by the TMDD.				
H-012D2	CS shall accept environmental data described by definitions defined by CMML version 2.				
H-020	The *Clarus* system shall acquire, process, and disseminate environmental data.	ConOps §2.1	CS, QChS, QEDS	Roll up of H-021, H-022, H-023, which were deprecated.	H

ID	Requirement	Source	Allocation - CS	Comment	Criticality
H-151	The *Clarus* system shall accept only observations that include location, timestamp, and source metadata.	Implied throughout ConOps	CS	Appendix A includes a discussion of "metadata" in this context.	H
H-151D1	CS shall accept only observations that include location, timestamp, and source metadata.				
H-155	The *Clarus* system shall accept only observations of identified measurement types and units.	OCS	CS		H
H-155D1	CS shall accept only observation of identified measurement types and units.			Incoming units will be converted to NTCIP 1204 units.	
H-301	The *Clarus* system shall be able to acquire, process, and disseminate environmental data from across North America.	ConOps §3.4.2, amended in Task Force review	CS, QChS, QEDS	North America in this context includes the United States, it territories, Canada, and Mexico	H
H-301D1	CS shall be able to acquire environmental data from across North America.				
I-011	The *Clarus* system shall accept data through a *Clarus* standard interface.	OCS	CS	Standard to be determined during design phase of this project.	H
I-011D1	CS shall implement the *Clarus* standard interface.				

ID	Requirement	Source	Allocation - CS	Comment	Criticality
I-012	The *Clarus* system shall be able to communicate with environmental sensor stations through its collector using the NTCIP ESS 1204.	ConOps §3.3	CS	Version 02.20 was accepted as a recommended standard by the NTCIP Joint Committee in March 2005. See www.ntcip.org/library/documents. The ending phrase "for data collection" was removed.	L
I-012D1	CS shall be able to process NTCIP ESS 1204 data.				
I-013	The *Clarus* system shall be able to communicate with RWIS databases through their native interfaces.	ConOps §3.4.2	CS		L
I-013D1	CS shall be able to accept data from an RWIS database in its native output format.			At such time as this requirement may be implemented RWIS databases will be treated as a collector.	
I-014	The *Clarus* system shall be able to communicate with an individual ESS through its native interface.	ConOps §3.4.2	CS	Deprecated. F-221 covers this.	L
I-016	The *Clarus* system shall transfer data as efficiently as possible.	Inferred from ConOps §3.2	CS, EMS, QEDS, SS	Related to F-501, F-222.	H
I-016D1	CS shall transfer data concurrently.				
I-016D2	CS shall be able to request collector environmental data on demand.				
I-016D3	CS shall be able to accept environmental data pushed from collectors.				

ID	Requirement	Source	Allocation - CS	Comment	Criticality
I-017	The *Clarus* system shall employ industry standards to minimize implementation impact to users and providers.	Inferred from ConOps §4.1	CS, QEDS, EMC, EMS	Standards in this context refer to the environmental data standards in common use among *Clarus* stakeholders.	H
I-017D1	CS shall be able to extract environmental data from an XML message that conforms to the *Clarus* standard XML message specification.				
I-017D2	CS shall be able to extract environmental data from comma separated value messages.				
I-017D3	CS that process comma separated value ASCII text shall be able to dynamically parse environmental data that includes a descriptive header row conforming to the *Clarus* collector standard message specification.				
I-017D4	CS that process comma separated value ASCII text shall be able to dynamically parse environmental data described by a stored collector configuration.				
I-017D5	CS shall be able to extract environmental data from CMML version 2 messages.				
I-017D6	CS shall be able to extract environmental data from netCDF version 3.6 messages.				

4.4 Watchdog (DOG)

The requirements in this section specify the operation of the watchdog to keep the system running. The watchdog is an automated system management service that will monitor the overall *Clarus* system, restart unresponsive services, notify the CAS of failures, and log data transactions.

ID	Requirement	Source	Allocation - DOG	Comment	Criticality
F-213	The *Clarus* system shall allow access to new surface transportation related observed environmental data.	ConOps §1, 2.4, 3.1	CS, QChS, QEDC, QEDS, CAS, EMC, EMS, DOG	Access could only be provided when new data sources are established and available.	L
F-213G1	The DOG shall be able to monitor new environmental data services as they are added.				
F-905	The *Clarus* system shall log data transactions.	MHI	CS, QEDS, EMS, QChS, CAS, SS, DOG		H
F-905G1	The DOG shall be able to record its activities.				
Q-012	The *Clarus* system shall be able to automatically recover from an unexpected shutdown.	MHI	DOG		H
Q-012G1	The watchdog service shall monitor the overall *Clarus* system state.				
Q-012G2	The watchdog service shall be able to restart unresponsive *Clarus* system services.				

4.5 Environmental Metadata Cache (EMC)

The requirements in this section specify the storage of environmental metadata. The EMC will store environmental metadata about the contributors and collectors from the Configuration & Administration Services and send environmental metadata to the Environmental Metadata Services upon request.

ID	Requirement	Source	Allocation - EMC	Comment	Criticality
F-213	The *Clarus* system shall allow access to new surface transportation related observed environmental data.	ConOps §1, 2.4, 3.1	CS, QChS, QEDC, QEDS, CAS, EMC, EMS, DOG	Access could only be provided when new data sources are established and available.	L
F-213E1	The EMC shall be configurable to allow new observation types to be implemented as they become available.				
H-120	The *Clarus* system shall acquire, process, and disseminate environmental metadata.	ConOps §3.3	CAS, EMC, EMS, CAUI	Roll up of H-121, H-122, H-123, H-201, which have been deprecated.	
H-120E1	The EMC shall be able to process environmental metadata.				
H-120E2	The EMC shall be able to uniquely identify each contributor, collector, and station sensor.				

ID	Requirement	Source	Allocation - EMC	Comment	Criticality
H-120E3	The EMC shall be able to maintain contact info for each contributor, collector, and station sensor.				
H-120E4	The EMC shall be able to maintain backup contact info for each contributor, collector, and station sensor.				
H-120E5	The EMC shall be able to maintain owner names for each contributor, collector, and station sensor.				
H-120E6	The EMC shall be able to maintain an equipment list for each station.				
H-120E7	The EMC shall be able to maintain pavement types for stations with corresponding instrumentation.				
H-120E8	The EMC shall be able to maintain latitude, longitude, and elevation for stations.				
H-120E9	The EMC shall be able to maintain a reference to additional metadata.	Task Force		An example would be a URL to a picture of the ESS.	
I-017	The *Clarus* system shall employ industry standards to minimize implementation impact to users and providers.	Inferred from ConOps §4.1	CS, QEDS, EMC, EMS	Standards in this context refer to the environmental data standards in common use among *Clarus* stakeholders.	H

ID	Requirement	Source	Allocation - EMC	Comment	Criticality
I-017E1	The EMC shall store collector metadata that consists of information based on TMDD & MS/ETMCC.				

4.6 Environmental Metadata Services (EMS)

The requirements in this section specify the services for the retrieval of environmental metadata. The EMS receives request, gets environmental metadata from cache, formats environmental metadata to fulfill requests and subscriptions, and sends formatted metadata back to requester.

ID	Requirement	Source	Allocation - EMS	Comment	Criticality
D-062	The *Clarus* system shall disseminate environmental metadata in response to polling.	OCS	EMS		H
D-062F1	EMS shall disseminate metadata in response to polling.				
D-091	The *Clarus* system shall disseminate data using standard Internet protocols.	OCS	QEDS, EMS		H
D-091F1	EMS shall disseminate metadata using standard Internet protocols.				
F-213	The *Clarus* system shall allow access to new surface transportation related observed environmental data.	ConOps §1, 2.4, 3.1	CS, QChS, QEDC, QEDS, CAS, EMC, EMS, DOG	Access could only be provided when new data sources are established and available.	L
F-213F1	The *Clarus* system shall allow new EMS to be implemented that disseminate new observation types to be implemented as they become available.				

ID	Requirement	Source	Allocation - EMS	Comment	Criticality
F-401	The *Clarus* system shall be able to provide sensor equipment metadata in response to a request.	OCS	EMS	Subject to data sharing agreements.	H
F-401F1	EMS shall be able to provide sensor equipment metadata in response to a request.				
F-501	The *Clarus* system shall minimize the time for data dissemination.	MHI	QEDS, EMS		H
F-501F1	EMS shall respond to queries for metadata within five minutes.			Related to I-016, F-222.	
F-905	The *Clarus* system shall log data transactions.	MHI	CS, QEDS, EMS, QChS, CAS, SS, DOG		H
F-905F1	EMS shall log metadata transactions.				
H-120	The *Clarus* system shall acquire, process, and disseminate environmental metadata.	ConOps §3.3	CAS, EMC, EMS, CAUI	Roll up of H-121, H-122, H-123, H-201, which have been deprecated.	
H-120F1	The EMS shall accept source queries that consist of a list of *Clarus* contributors.				
H-120F2	The EMS shall accept source queries that consist of a list of *Clarus* contributors including station identifier.				

ID	Requirement	Source	Allocation - EMS	Comment	Criticality
H-120F3	The EMS shall accept location queries based on a bounding latitude/longitude coordinate pair.				
H-120F4	The EMS shall accept location queries based on latitude/longitude location and radius.	Task Force			
I-016	The *Clarus* system shall transfer data as efficiently as possible.	Inferred from ConOps §3.2	CS, EMS, QEDS, SS	Related to F-501, F-222.	H
I-016F1	EMS shall transfer data concurrently.				
I-017	The *Clarus* system shall employ industry standards to minimize implementation impact to users and providers.	Inferred from ConOps §4.1	CS, QEDS, EMS	"Standards" in this context refer to the environmental data standards in common use among *Clarus* stakeholders.	H
I-017F1	EMS shall be able to distribute metadata in a comma separated value ASCII format.				
I-023	The *Clarus* system shall respond to queries for environmental metadata from the available metadata.	MHI			H
I-023F1	EMS responses shall include metadata that meets the requested metadata query filtering specifications.				

ID	Requirement	Source	Allocation - EMS	Comment	Criticality
I-023F2	EMS shall respond to queries returning no results with a message stating that no results matching that query are available.	Task Force			
P-025	The *Clarus* system shall respond to a request for information within five minutes.	MHI	QEDS, EMS	Related to F-501.	H
P-025F1	The EMS shall respond to a request for metadata within five minutes.				

4.7 Qualified Environmental Data (QEDC)

The requirements in this section specify the storage of qualified environmental data. The QEDC receives environmental data from the Collector Services (CS), stores qualified environmental data, sends environmental data to Quality Checking Services (QCS), receives quality checked environmental data from QCS, receives requests from the Qualified Environmental Data Services (QEDS), and sends qualified environmental data in response to Qualified Environmental Data Services' request.

ID	Requirement	Source	Allocation - QEDC	Comment	Criticality
F-111	The *Clarus* system shall provide environmental data quality flags.	OCS	QChS, CAUI, QEDC		H
F-111I1	The QEDC shall keep the results of each quality test for each observation for the life of the observation.				
F-213	The *Clarus* system shall allow access to new surface transportation related observed environmental data.	ConOps §1, 2.4, 3.1	CS, QChS, QEDC, QEDS, CAS, EMC, EMS, DOG	Access could only be provided when new data sources are established and available.	L
F-213I1	The QEDC shall be configurable to allow new observation types to be implemented as they become available.				
F-521	The *Clarus* system shall maintain a dynamic library of data for at least seven days.	Task Force review	QEDC		H

ID	Requirement	Source	Allocation - QEDC	Comment	Criticality
F-521I1	The QEDC shall maintain observations and their associated quality flags for seven days.				
H-011	The *Clarus* system baseline data types shall be defined by the NTCIP ESS 1204 standard.	ConOps §3.3 (Table 2)	CS, QEDC, QEDS	Version 02.20 was accepted as a recommended standard by the NTCIP Joint Committee in March 2005. See www.ntcip.org/library/documents.	H
H-011I1	The QEDC observation types shall be defined by NTCIP ESS 1204.				
I-021	The *Clarus* system shall allow service providers to select specific desired data sets.	ConOps §3.5.1.4	QEDS, QEDC		H
I-021I1	The QEDC shall support queries for its observations.				
I-022	The *Clarus* system shall respond to queries for environmental data from the available data.	MHI	QEDS, QEDC		H
I-022I1	The QEDC shall support queries against all of its available observation datasets.				
P-013	The *Clarus* system shall support 470 million current observations.	MHI	QEDC	4.7 million road miles in North America; approximately 100 environmental parameters for a reporting location (based on NTCIP 1204).	M

ID	Requirement	Source	Allocation - QEDC	Comment	Criticality
P-013I1	The QEDC combined from all available *Clarus* hosts shall support 470 million current observations.				

4.8 Qualified Environmental Data Services (QEDS)

The requirements in this section specify the means of disseminating qualified environmental data. In all requirements where it applies, data is to be disseminated only in accordance with the data sharing agreements. The QEDS receive requests, get quality checked environmental data from cache, format quality checked environmental data to fulfill requests and subscriptions, and sends formatted environmental data back to requester.

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
D-051	The *Clarus* system shall disseminate data in response to a scheduled request.	OCS	QEDS, SS		H
D-051J1	QEDS shall disseminate data in response to a scheduled environmental data request.				
D-061	The *Clarus* system shall disseminate environmental data in response to polling.	OCS	QEDS		H
D-061J1	QEDS shall disseminate data in response to an immediate environmental data request.				
D-071	The *Clarus* system shall disseminate data in response to a change notification request.	OCS	QEDS		H
D-071J1	QEDS shall disseminate data in response to a change notification request.				
D-081	The *Clarus* system shall be able to notify subscribers when data sets become available.	OCS	QEDS		H

ID	**Requirement**	**Source**	**Allocation - QEDS**	**Comment**	**Criticality**
D-081J1	QEDS shall disseminate environmental data to subscribers when datasets fulfilling a subscription query become available.				
D-081J2	QEDS shall be able to disseminate environmental data to contributor subscribers when datasets fulfilling a subscription query applying threshold filters become available.				
D-091	The *Clarus* system shall disseminate data using standard Internet protocols.	OCS	QEDS, EMS		H
D-091J1	QEDS system shall disseminate environmental data using standard Internet protocols.				
F-100	The *Clarus* system shall collect, quality check, and disseminate environmental data.	ConOps §1	CS, QChS, QEDS, CAUI	"Environmental data" includes all NTCIP 1204 data (summarized in Table 1).	H
F-100J1	QEDS shall disseminate environmental data.				
F-100J2	QEDS shall be able to disseminate environmental data in English units.				

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
F-115	The *Clarus* system shall provide notification of data quality conditions to data contributors.	ConOps §2.4	QChS, QEDS	A "data contributor" in this context could ultimately be a State DOT maintenance engineer or traffic manager.	H
F-115J1	The observation quality flags shall be used to determine data quality condition notifications.				
F-115J2	QEDS shall provide quality checking statistics to data contributors.	Task Force		Functionality may be similar to that provided by MADIS and MesoWest.	
F-140	The *Clarus* system shall enable quality managers to review which quality checks passed or failed.	OCS		New high-level requirement.	H
F-140J1	QEDS shall enable quality managers to review which quality checks passed or failed.				
F-213	The *Clarus* system shall allow access to new surface transportation related observed environmental data.	ConOps §1, 2.4, 3.1	CS, QChS, QEDC, QEDS, CAS, EMC, EMS, DOG	Access could only be provided when new data sources are established and available.	L
F-213J1	QEDS shall be able to disseminate new observation types as they become available.				
F-219	The *Clarus* system shall disseminate NWS watches, warnings, and advisories.	Task Force review	QEDS	New. Split from F-218.	M

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
F-219J1	QEDS shall be able to disseminate NWS watches, warnings, and advisories.				
F-501	The *Clarus* system shall minimize the time for data dissemination.	MHI	QEDS, EMS		H
F-501J1	QEDS shall respond to environmental data queries within one minute.			Related to I-016, F-222.	
F-505	The *Clarus* system shall be able to disseminate data based on spatial queries.	ConOps §3.4.2	QEDS	Defining this as "spatial" allows coverage of custom regions.	H
F-505J1	QEDS shall be able to disseminate data based on spatial queries.				
F-811	The *Clarus* system shall be able to restrict environmental data publication based on source.	MHI & ConOps §4.5	QEDS, CAS	Use MADIS as a template (ConOps §3.6).	H
F-811J1	QEDS shall be able to determine if an observation can be disseminated.				
F-905	The *Clarus* system shall log data transactions.	MHI	CS, QEDS, EMS, QChS, CAS, SS, DOG		H
F-905J1	QEDS shall log their activities.				

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
H-011	The *Clarus* system baseline data types shall be defined by the NTCIP ESS 1204 standard.	ConOps §3.3 (Table 2)	CS, QEDC, QEDS	Version 02.20 was accepted as a recommended standard by the NTCIP Joint Committee in March 2005. See www.ntcip.org/library/documents.	H
H-011J1	QEDS shall disseminate environmental data types defined by NTCIP 1204.				
H-012	The *Clarus* system data definitions shall be consistent with the ITE TM 1.03 standard, Functional Level Traffic Management Data Dictionary (TMDD).	Task Force review	CS, QEDS		H
H-012J1	QEDS shall disseminate data with descriptions that conform to the TMDD.				
H-020	The *Clarus* system shall acquire, process, and disseminate environmental data.	ConOps §2.1	CS, QChS, QEDS	Roll up of H-021, H-022, H-023, which were deprecated.	H
H-301	The *Clarus* system shall be able to acquire, process, and disseminate environmental data from across North America.	ConOps §3.4.2, amended in Task Force review	CS, QChS, QEDS	North America in this context includes the United States, it territories, Canada, and Mexico	H
H-301J1	QEDS shall be able to disseminate environmental data collected from across North America.				
I-016	The *Clarus* system shall transfer data as efficiently as possible.	Inferred from ConOps §3.2	CS, EMS, QEDS, SS	Related to F-501, F-222.	H

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
I-016J1	QEDS shall transfer data concurrently.				
I-017	The *Clarus* system shall employ industry standards to minimize implementation impact to users and providers.	Inferred from ConOps §4.1	CS, QEDS, EMS	"Standards" in this context refer to the environmental data standards in common use among *Clarus* stakeholders.	H
I-017J1	QEDS shall be able to disseminate environmental data in netCDF version 3.6 format.				
I-017J2	QEDS shall be able to disseminate environmental data in HDF version 5 format.				
I-017J3	QEDS shall be able to disseminate environmental data in CMML version 2 format.				
I-017J4	QEDS shall be able to disseminate environmental data in comma separated value ASCII format.				
I-021	The *Clarus* system shall allow service providers to select specific desired datasets.	ConOps §3.5.1.4	QEDS, QEDC		H

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
I-021J1	QEDS shall respond to environmental data queries selecting specific desired datasets.				
I-022	The *Clarus* system shall respond to queries for environmental data from the available data.	MHI	QEDS, QEDC		H
I-022J1	QEDS shall enable users to request environmental data from among the available output formats.				
I-022J2	QEDS shall respond to queries returning no results with a message stating that no results matching that query are available.	Task Force			
I-025	The *Clarus* system shall enable environmental data queries by timestamp.	ConOps §3.5.1.4			H
I-025J1	QEDS shall accept timestamp queries based on a single timestamp range.				
I-026	The *Clarus* system shall enable environmental data queries by location reference.	ConOps §3.5.1.4			H
I-026J1	QEDS shall accept location queries based on a bounding latitude/longitude coordinate pair.				

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
I-026J2	QEDS shall accept location queries based on a latitude/longitude location and radius.				
I-027	The *Clarus* system shall enable environmental data queries by quality.	ConOps §3.5.1.4			H
I-027J1	QEDS shall accept quality flag queries based on a range of quality flag values.				
I-028	The *Clarus* system shall enable environmental data queries by source.	MHI			H
I-028J1	QEDS shall accept source queries that consist of a list of *Clarus* contributors.				
I-028J2	QEDS shall accept source queries that are a list of *Clarus* contributors combined with a station identifier.				
I-033	The *Clarus* system shall allow users to create a data subscription request.	ConOps §4.5			H
I-033J1	QEDS shall be able to accept a subscription request.				

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
I-033J2	QEDS shall accept data subscriptions that include an environmental data request and the publishing trigger.				
I-033J3	QEDS shall be able to accept subscription requests with triggers based on a schedule.				
I-033J4	QEDS shall be able to accept subscription requests with triggers based on quality flag state changes.				
I-033J5	QEDS shall disseminate subscription responses to the originating request address by default.				
I-033J6	QEDS shall disseminate subscription responses to a specified return address.				
I-033J7	QEDS shall uniquely identify environmental data subscriptions.				
I-033J8	QEDS shall automatically delete a subscription when the triggering event will not occur again and no more responses are possible.				
P-024	The *Clarus* system shall be able to publish new data within twenty minutes of data receipt.	ConOps §3.2 (Fig. 7)	QChS, QEDS		H

ID	Requirement	Source	Allocation - QEDS	Comment	Criticality
P-024J1	QEDS shall disseminate subscription responses within twenty minutes of new data becoming available.				
P-025	The *Clarus* system shall respond to a request for information within one minute.	MHI	QEDS, EMS	Related to F-501.	H
P-025J1	QEDS shall respond to an environmental data request within one minute.				
P-031	The *Clarus* system shall be able to handle three hundred simultaneous requests for environmental data.	MHI	QEDS	Estimated that half of the concurrent users may be requesting data at any one time.	H
P-031J1	QEDS shall be able to respond to three hundred simultaneous queries.				

4.9 Quality Checking Services (QChS)

The requirements in this section specify the services needed for quality checking. The QChS receive environmental data from qualified environmental data cache, execute multiple methods to quality check the environmental data, apply quality flags, and send quality checked environmental data to the Qualified Environmental Data Cache (QEDC) with its associated quality flags.

ID	Requirement	Source	Allocation - QChS	Comment	Criticality
F-100	The *Clarus* system shall collect, quality check, and disseminate environmental data.	ConOps §1	CS, QChS, QEDS, CAUI	"Environmental data" includes all NTCIP 1204 data (summarized in Table 1).	H
F-100H1	The QChS shall quality check environmental data.				
F-101	The *Clarus* system shall implement quality checking processes as soon as data become available.	ConOps §2.4	QChS, SS, CAS		H
F-101H1	QChS shall be able to be configured individually.				
F-101H2	QChS processing order shall be able to be configured.				
F-101H3	QChS processing shall commence when new data arrives but no less frequently than the scheduled interval.				
F-111	The *Clarus* system shall provide environmental data quality flags.	OCS	QChS, CAUI, QEDC		H
F-111H1	Each QChS shall produce a unique quality flag value.				

ID	Requirement	Source	Allocation - QChS	Comment	Criticality
F-111H2	The QChS shall be able to indicate a numeric confidence value.				
F-115	The *Clarus* system shall provide notification of data quality conditions to data contributors.	ConOps §2.4	QChS, QEDS	A "data contributor" could be a State DOT maintenance engineer or traffic manager.	H
F-115H1	A QChS shall evaluate data quality conditions.				
F-121	The *Clarus* system shall detect out of range values.	ConOps §3.5.1.4	QChS	Examples – sensor range tests and climates tests.	H
F-121H1	QChS algorithms shall use sensor range metadata for range checking bounds.				
F-121H2	QChS algorithms shall use climate records for range checking bounds.				
F-121H3	QChS algorithms shall be able to use monthly climate extremes for range checking bounds.				
F-125	The *Clarus* system shall not modify original observations.	OCS	QChS		H
F-125H1	QChS shall apply separate, independent quality flags that do not modify the observation.				
F-141	The *Clarus* system shall allow human quality checks of observations.	OCS	CAUI, QChS	Changed from "The *Clarus* system shall allow human intervention to override automatically applied quality assessment." Example – manual quality test.	M

ID	Requirement	Source	Allocation - QChS	Comment	Criticality
F-141H1	QChS shall implement a manual override to set quality flags.				
F-151	The *Clarus* system shall record the methods applied when deriving quality checking information.	MHI	QChS, CAS		H
F-151H1	QChS shall indicate when a quality check has been performed.				
F-155	The *Clarus* system shall be able to implement quality checking rules for each environmental parameter.	ConOps §3.5.1.4	QChS, CAS, CAUI	Example – variable-specific tests.	H
F-155H1	QChS shall be able to implement quality checking rules for a specific environmental parameter.				
F-161	The *Clarus* system shall be able to implement quality checking rules for specific environmental situations.	ConOps §3.5.1.4	QChS, CAS	The rules for setting quality flags on environmental data elements may themselves depend on other environmental data. For example, stormy conditions may allow more spatial and temporal variability in wind speed observations than under fair weather conditions.	H
F-161H1	QChS shall be able to implement quality checking rules for specific environmental situations.				

ID	Requirement	Source	Allocation - QChS	Comment	Criticality
F-162	The *Clarus* system shall be able to implement quality checking spatial tests using available data.	OCS		New requirement. Available data could be from adjacent environmental sensor stations and ASOS. Examples – Barnes spatial test and optimal interpolation spatial test.	H
F-162H1	QChS shall be able to implement quality checking spatial tests using available data.			Available data could be from adjacent environmental sensor stations and ASOS.	
F-163	The *Clarus* system shall be able to implement quality checking rules specific to observation locations.	Task Force review	QChS, CAS	Quality checking rules may vary from region to region.	H
F-163H1	QChS shall be able to implement different quality checking rules specific to regional weather.				
F-165	The *Clarus* system shall be able to base its quality checking process on values from multiple observations.	ConOps §3.5.1.4		Example – variable-specific and like instrument tests.	H
F-165H1	QChS shall be able to flag observations based on more than one observation type.				
F-166	The *Clarus* system shall be able to base its quality checking process on values distributed in time.	OCS		New high-level requirement. Example – step tests and persistence tests.	H
F-166H1	QChS shall be able to base its quality checking process on values distributed in time.				

ID	Requirement	Source	Allocation - QChS	Comment	Criticality
F-171	The *Clarus* system shall be able to base its quality checking process on historical environmental data.	Inferred from ConOps §3.5.1.4	QChS, CAS	See F-121.	H
F-171H1	QChS shall be able to use historical environmental data in their quality checking algorithms.				
F-175	The *Clarus* system shall be able to use multiple algorithms for its quality checking process.	Inferred from ConOps §4.3	QChS, CAS	Multiple methods or comparisons may be needed for a given observation.	M
F-175H1	QChS shall be implemented for each defined standard quality checking algorithm.				
F-213	The *Clarus* system shall allow access to new surface transportation related observed environmental data.	ConOps §1, 2.4, 3.1	CS, QChS, QEDC, QEDS, CAS, EMC, EMS, DOG	Access could only be provided when new data sources are established and available.	L
F-213H1	QChS shall be implemented to quality check new observation types as they become available.				
F-223	The *Clarus* system shall process data as they are received.	ConOps §3.4.3	CS,QChS		H

ID	Requirement	Source	Allocation - QChS	Comment	Criticality
F-223H1	QChS shall apply quality flags to data as they are received.				
F-905	The *Clarus* system shall log data transactions.	MHI	CS, QEDS, EMS, QChS, CAS, SS, DOG		H
F-905H1	QChS shall log quality checking activity.				
H-020	The *Clarus* system shall acquire, process, and disseminate environmental data.	ConOps §2.1	CS, QChS, QEDS	Roll up of H-021, H-022, H-023, which were deprecated.	H
H-301	The *Clarus* system shall be able to acquire, process, and disseminate environmental data from across North America.	ConOps §3.4.2, amended in Task Force review	CS, QChS, QEDS	North America in this context includes the United States, it territories, Canada, and Mexico	H
H-301H1	QChS shall process environmental data from across North America.				
P-023	The *Clarus* system shall be able to complete an automated quality checking check of environmental data within ten seconds of data receipt.	OCS	QChS		H

ID	Requirement	Source	Allocation - QChS	Comment	Criticality
P-023H1	A QChS shall be able to complete an automated quality check within ten seconds of when data is available for checking.				
P-024	The *Clarus* system shall be able to publish new data within twenty minutes of data receipt.	ConOps §3.2 (Fig. 7)	QChS, QEDS		H
P-024H1	All QChS shall be completed within twenty minutes of data being available for checking.			A goal of 5 minutes was established at the task force review.	

4.10 Schedule Service (SS)

The requirements in this section specify the scheduling of the collector services and quality checking services. The SS schedules input for environmental data from collectors and contributors, schedules Quality Checking Services (QCS), and schedules dissemination of qualified environmental data and metadata based on subscriptions.

ID	Requirement	Source	Allocation - SS	Comment	Criticality
D-051	The *Clarus* system shall disseminate data in response to a scheduled request.	OCS	QEDS, SS		H
D-051K1	The SS shall be able to initiate a QEDS response.				
F-101	The *Clarus* system shall implement quality checking processes as soon as data become available.	ConOps §2.4	QChS, SS, CAS		H
F-101K1	The SS shall be able to initiate QChS.				
F-905	The *Clarus* system shall log data transactions.	MHI	CS, QEDS, EMS, QChS, CAS, SS, DOG		H
F-905K1	The SS shall record when it initiates actions.				
I-016	The *Clarus* system shall transfer data as efficiently as possible.	Inferred from ConOps §3.2	CS, EMS, QEDS, SS	Related to F-501, F-222.	H
I-016K1	The SS shall be able to store event schedules.				
I-016K2	The SS shall be able to initiate CS.				

4.11 Program Requirements

The requirements in this section specify the distribution, performance, and organizational requirements.

ID	Requirement	Source	Allocation	Comment	Criticality
D-011	The *Clarus* system shall be able to be hosted at one or more physical locations.	MHI			H
D-011A1	The *Clarus* system shall track its constituent hosts.				
D-011A2	The *Clarus* system shall allocate each collector to a specific host.				
D-011A3	The *Clarus* system shall allocate each contributor to a specific host.				
D-011A4	*Clarus* hosts shall be able to aggregate environmental data from other *Clarus* hosts.				
D-011A5	*Clarus* hosts shall be able to distribute queries to other *Clarus* hosts.				
D-021	The *Clarus* system shall use hardware that implements industry accepted standard interfaces.	MHI			H
D-031	The *Clarus* system shall use software that implements industry accepted standard interfaces.	MHI			H
D-041	The *Clarus* system shall be able to operate on redundant hardware.	ConOps §3.4.2			H

ID	Requirement	Source	Allocation	Comment	Criticality
D-101	All HTML coding shall meet FHWA requirements for web sites.	Contract		FHWA requirements for HTML coding can be found at http://www.tfhrc.gov/qkref/qrg08.htm	H
D-111	The *Clarus* system shall support modular components.	OCS			H
D-121	The *Clarus* system shall be able to use latitude, longitude, and elevation coordinates to specify location to the nearest three feet.	MHI			H
D-126	The *Clarus* system shall use Coordinated Universal Time (UTC) for all timestamps.	OCS			H
X-801	The *Clarus* program shall alert users to system modifications.	OCS		Changed from F-801.	H
P-011	The *Clarus* system shall be able to publish environmental data at three times the volume rate that it collects it.	MHI			M
P-041	The *Clarus* system shall be able to support six hundred concurrent users.	MHI		An estimate of the number of concurrent potential users of the *Clarus* system: one tenth of the registered users at any one time.	H
P-042	The *Clarus* system shall be able to support six thousand registered users.	MHI		An estimate of the number of individual users: a pool of 250 weather service providers, ten per provider; 100 governmental agencies, 25 per agency; and 1000 other users.	H

ID	Requirement	Source	Allocation	Comment	Criticality
Q-011	The *Clarus* system shall be able to mitigate communication denial-of-service attacks.	MHI			H
Q-013	The *Clarus* system shall be able to respond to 95% of all requests for environmental data 95% of the time.	MHI			H
X-201	The *Clarus* program shall establish data sharing agreements with all participating sources of environmental data.	Task Force review			H
X-20110	The *Clarus* program shall identify categories of recipients for dissemination of data.	Task Force			
X-20111	The *Clarus* program shall determine the need for bilateral *Clarus* Data Sharing Agreements with countries, agencies, states, and regions.			The U.S. Department of State will facilitate the review of international agreements if it is determined that a Circular 175 process is required. [See Case-Zablocki Act of 1977]	
X-20112	The authorized representative(s) of the contributors shall be identified.			Both the signatories of the *Clarus* Data Sharing Agreement and the positions/organizations responsible for Quality Control (QC)/Quality Assurance (QA) shall be named.	

ID	Requirement	Source	Allocation	Comment	Criticality
X-20113	The contributors shall identify and define the types of data and information that will be included in the *Clarus* Data Sharing Agreement.			Examples of data and information include surface condition data, atmospheric condition data,weather hazards reports and associated metadata.	
X-20114	The contributors shall identify the intended use of their shared data and information.				
X-20115	The contributors shall identify the categories of recipients of their shared data and information.				
X-20116	The contributors shall define the units of measurements of their shared data and information.			Identification markers are needed for qualitative data and information.	
X-20118	The *Clarus* program shall determine how it will provide data and information to contributors.				
X-20119	The *Clarus* program shall provide data and information statistics on its operation to contributors.				
X-20120	The contributors shall inform the *Clarus* program of changes in authorized personnel/offices.	Task Force			

ID	Requirement	Source	Allocation	Comment	Criticality
X-20121	The *Clarus* program shall inform contributors of the "acceptance and use" of their data and information.				
X-20123	The *Clarus* Initiative Management Team shall undertake joint communications activities and products that will enhance public understanding and dissemination of contributions of the *Clarus* program.				
X-20124	The *Clarus* Initiative Management Team shall agree upon the activities and products that will enhance public understanding/ communication of the contribution of the *Clarus* program.				
X-20126	The contributors shall inform the *Clarus* program of known error(s) and modifications in its data and information.				
X-20127	The *Clarus* program shall determine its redistribution of shared data from contributors based upon *Clarus* Data Sharing Agreements.				

ID	Requirement	Source	Allocation	Comment	Criticality
X-20128	The *Clarus* program shall report successes and failures in data and information transmission to its contributors.				
X-20129	The contributors shall report periods of data and information outages to the *Clarus* program.				
X-20131	The *Clarus* program shall maintain information about requestors and their access to data and information.				
X-20132	The *Clarus* Initiative Management Team shall review and amend data and information sharing and use policies.			Define policy advisement structure.	
X-20133	The *Clarus* Initiative Management Team shall specify the general frequency of policy meetings.			Define policy advisement structure.	
X-20134	The *Clarus* Initiative Coordinating Committee shall nominate technical expert(s) to participate on technical working groups.			Define technical advisement structure.	

ID	Requirement	Source	Allocation	Comment	Criticality
X-20135	The requestors shall adhere to the intellectual property requirements of the *Clarus* User Agreement.	Task Force			
X-20136	The contributors shall adhere to the intellectual property requirements of the *Clarus* Data Sharing Agreement.				
X-20139	The contributors shall have the right to use the *Clarus* system data and information for purposes delineated within the *Clarus* Data Sharing Agreement.				
X-20140	The requestors shall have the right to use the *Clarus* system data and information for purposes delineated within the *Clarus* User Agreement.	Task Force			
X-20141	The *Clarus* program shall have the right to reject the use of data and information provided by the contributors when deemed appropriate.				
X-20142	The *Clarus* program shall inform contributors of the policies, processes and procedures employed to reject data and information provided by the contributors.				

ID	Requirement	Source	Allocation	Comment	Criticality
X-20149	The contributors shall provide the *Clarus* program with a timely notice of their intent to change, alter, replace, or eliminate any shared data and information as specified within this *Clarus* Data Sharing Agreement.				
X-20152	Any reference in the *Clarus* Data Sharing Agreement to statutes, regulations and rules shall be a reference to the amended, substituted, replaced or re-enacted statute, regulations and rules.				
X-20165	The *Clarus* program shall provide to contributors the limitation of liability for contributing environmental data and metadata.	Task Force			
X-20166	The *Clarus* program shall provide to requesters the limitation of liability for using environmental data and metadata.	Task Force			
X-205	The *Clarus* program shall maintain continuous 24x7 operations.	OCS			H

ID	Requirement	Source	Allocation	Comment	Criticality
X-207	The *Clarus* program shall provide an environment that has uninterruptible power for the *Clarus* system.	MHI			H
X-209	The *Clarus* program shall provide an environment that has redundant communication for the *Clarus* system.	MHI			H
X-211	The *Clarus* program shall provide network management tools.	OCS		Network management tools can be used to determine latency.	H
X-215	The *Clarus* program shall provide setup support.	ConOps §3.3.1 (Fig. 9)			H
X-221	The *Clarus* program shall provide for customer service.	OCS			H
X-225	The *Clarus* program shall provide a trained support staff.	ConOps §3.3.1			H
X-232	The *Clarus* program shall define quality checking rules for environmental observations.	MHI		Specifies the rules to be implemented according to F-155, F-161, F-165, F-171, and F-175.	H
X-233	The *Clarus* program shall define data retention standards.	MHI			H
X-235	The *Clarus* program shall provide documentation of *Clarus* standards.	OCS		That is, the *Clarus* program needs to provide documentation of whatever standards it creates for its own development, deployment, management, and operations.	H

ID	Requirement	Source	Allocation	Comment	Criticality
X-237	The *Clarus* program standards shall accommodate contributions of new sensor technologies to the *Clarus* system.	Inferred from ConOps §1			M
X-239	The *Clarus* program standards shall support multiple methods of data delivery to users.	Inferred from ConOps §4.3			M
X-305	The *Clarus* program shall maintain a comprehensive *Clarus* system test environment.	OCS			H
X-311	The *Clarus* program shall test all software changes in the designated test environment before deployment to production.	OCS			H
X-315	The *Clarus* program shall test all hardware changes in the designated test environment before deployment to production.	OCS			H
X-601	The *Clarus* program shall operate the *Clarus* system according to its published IT Security Plan.	Contract			H

ID	Requirement	Source	Allocation	Comment	Criticality
X-605	The *Clarus* program shall operate according to Government IT security requirements as outlined in OMB Circular A-130, Management of Federal Information Resources, Appendix III, Security of Federal Automated Information Resources.	Contract			H
X-611	The *Clarus* program shall operate according to Government IT security requirements as outlined in the National Institute of Standards and Technology (NIST) Guidelines, Departmental Information Resource Management Manual, and associated guidelines.	Contract			H
X-615	The *Clarus* program shall operate according to Government IT security requirements as outlined in U.S. DOT Order 1630.2B, Personnel Security Management.	Contract			H
X-805	Weather service providers shall be able to use *Clarus* data to provide localized special weather products.	ConOps §3.4.2			L

ID	Requirement	Source	Allocation	Comment	Criticality
X-811	Public agency maintenance and construction personnel shall be able to use the *Clarus* system to obtain environmental conditions.	ConOps §2.5.2			L
X-815	Rail system personnel shall be able to use the *Clarus* system to obtain environmental conditions.	Inferred from ConOps §2.5.7			L
X-821	Traffic management personnel shall be able to use the *Clarus* system to obtain environmental conditions.	Inferred from ConOps §2.5.3			L
X-823	Transit personnel shall be able to use the *Clarus* system to obtain environmental conditions.	Inferred from ConOps §2.5.5			L
X-825	The freight community shall be able to use the *Clarus* system to obtain environmental conditions.	Inferred from ConOps §2.5.8			L
X-827	Emergency management and public safety personnel shall be able to use the *Clarus* system to obtain environmental conditions.	Inferred from ConOps §2.5.6			L
X-905	The *Clarus* program shall maintain information about data providers.	OCS			H

ID	Requirement	Source	Allocation	Comment	Criticality
X-910	The *Clarus* program shall maintain metadata about each data provider's network.	OCS			H
X-915	The *Clarus* program shall maintain information about data provider redistribution restrictions.	OCS			H
X-921	The *Clarus* program shall maintain information about service providers.	OCS			H
X-925	The *Clarus* program shall maintain information about service provider communications.	OCS			M
X-931	The *Clarus* program shall maintain information about service provider access to data.	OCS			H
X-935	The *Clarus* program shall allow potential weather element data providers to request permission to submit weather information.	MHI			H
X-101	The *Clarus* system shall accept data only from sources which data sharing agreements have been established.	MHI	(The *Clarus* program shall approve sources.)	"Approved sources" are anticipated to be those with whom a data sharing agreement has been established.	H

APPENDIX A - DEFINITIONS, ACRONYMS, AND ABBREVIATIONS

The following table provides definitions of terms, acronyms, and abbreviations to assist interpretation of this document.

Term	Definition
ADAS	ARPS Data Analysis System
ARPS	Advanced Regional Prediction System
ASCII	A code that represents letters, numerals, punctuation marks and control signals as seven bit groups.
CAS	Configuration and Administration Service
CAUI	Configuration and Administration User Interface
CCTV	Closed Circuit Television
Clarus Initiative	• Development of tools, models, decision support that leverage the *Clarus* System • End-to-End processes spanning data gathering to road weather information products & services • Research activities that support creation of road weather information products & services
Clarus Program	Operations and maintenance functions and personnel needed to sustain the *Clarus* System
Clarus System	Tools for sharing surface weather observations and relevant surface transportation conditions
CMML	Canadian Meteorological Markup Language
Collector	An electronic device used to convert environmental sensor electrical signals into environmental condition measured values and store them for retrieval.
ConOps	Concept of Operations
Contributor	A managing agency or organization that owns and/or operates a set of environmental sensor collectors.
COTS	Commercial Off-the-Shelf
CS	Collector Services
DOG	Watchdog
DOT	Department of Transportation
DRS	Detailed Systems Requirements Specification
DSS	Decision Support System
DST	Daylight Savings Time
EMC	Environmental Metadata Cache
EMS	Environmental Metadata Services
Environmental data	In the *Clarus* context, includes atmospheric, surface, and hydrologic data; more specifically, it includes all data defined in NTCIP 1204 (Ref. 8).

Term	Definition
Environmental metadata	In the *Clarus* context, includes all contributor, collector, ESS, and sensor data relating to environmental data.
ESS	Environmental Sensor Station
External data	Weather data used to assist in quality checking such as ASOS and climate records
FHWA	Federal Highway Administration
GPS	Global Positioning System
HDF	Hierarchical Data Format; a data file format developed at the National Center for Supercomputing Applications (NCSA) (http://hdf.ncsa.uiuc.edu/)
hPa	hectopascal = 100 Pascals = 1 millibar
HTML	Hypertext Markup Language
ICC	(*Clarus*) Initiative Coordinating Committee
IEEE	Institute of Electrical and Electronic Engineers, Inc.
in-situ	From Latin, "in-situ" means "in place." As applied to meteorological data, it refers to data specific to a (fixed) point of observation.
IT	Information Technology
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITS America	Intelligent Transportation Society of America
MADIS	Meteorological Assimilation Data Ingest System
MDSS	Maintenance Decision Support System
metadata	In common information systems use, "metadata" is "data about data." Within the meteorological community, this use has been extended to include data about objects related to weather observations. For example, location data for an ESS becomes metadata for the observation data.
MHI	Mixon/Hill, Inc.
MS/ETMCC	Message Set for External Traffic Management Center Communication.
NCSA	National Cener for Supercomputing Applications
netCDF	Network Common Data Form is a binary data format standard for exchanging scientific data
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NTCIP	National Transportation Communications for ITS Protocol
NWS	National Weather Service
OCS	Oklahoma Climatological Survey
OMB	Office of Management and Budget
Open	Using interfaces that are non-proprietary and broadly supported within the information technology industry.
PMP	Project Management Plan

Term	Definition
Polling	Asking for information
QA	Quality Assurance
QC	Quality Control
QCh	Quality Check or Quality Checking
QChS	Quality Checking Services
QEDC	Qualified Environmental Data Cache
QEDS	Qualified Environmental Data Services
Quality checking	The operational activities and techniques required to ensure that quality requirements have been fulfilled.
Quality flag	An indicator of the degree to which quality requirements have been fulfilled; in the *Clarus* context, an indicator of the reliability or usefulness of a data element or dataset.
Quality manager	Personnel charged with reviewing the quality of the environmental data.
Requestor	The person or group requesting information from the Clarus system.
RUC	Rapid Update Cycle
RWIS	Road Weather Information System
Security groups	A method of grouping users and their privileges.
SHEF	Standard Hydrological Encoding Format
SS	Schedule Service
STWDSR	Surface Transportation Weather Decision Support Requirements
STWSP	Surface Transportation Weather Service Provider
TMC	Transportation Management Center
TMDD	Traffic Management Data Dictionary
TOC	Transportation (Traffic) Operations Center
TRB	Transportation Research Board
U.S. DOT	U.S. Department of Transportation
UTC	Coordinated Universal Time
VII	Vehicle Infrastructure Integration
WIST	Weather Information for Surface Transportation

APPENDIX B - SUPPLEMENTAL DESCRIPTION OF *CLARUS* QC TESTS

The *Clarus* detailed requirements describe QC tests to be implemented as *Clarus* standard tests. This appendix provides descriptions of these QC test methods as a means of clarifying the intended implementations. These descriptions should not be interpreted, however, as further elaborations of requirements or as design specifications. The *Clarus* system design descriptions will provide the final specifications and will be subject to formal design review.

Manual Quality Test

The *Clarus* manual quality test allows authorized *Clarus* personnel to flag particular observations as "passed" or "failed" independent of the automated analysis. For instance, if a network manager communicates to *Clarus* that one of its stations has a temperature bias, then that station's temperature data can be manually flagged as "failed" until the network corrects the problem. If a *Clarus* QA meteorologist determines that suspicious-looking snow depth data are from a real, meteorological event, that station's snow depth can be manually flagged as "passed" until the event ends. Observations that have received manual quality checks need not be run through the automated quality checks (Fiebrich and Crawford 2001).

Sensor Range Test

The *Clarus* range test will flag any observation that lies outside of the pre-determined range threshold values as "failed". The threshold values will usually be determined via sensor specifications or theoretical limits (Meek and Hatfield 1994). For instance, the range for relative humidity would likely be 0 to 100%. Observations that have received range filter flags of "failed" need not be run through the automated quality checks.

Climate Test

The *Clarus* climate test will flag any observation that exceeds defined, variable-specific climatological ranges as "failed" (Reek et al., 1992). Otherwise, the observation will be flagged as "passed". The *Clarus* climatological threshold values will be station-specific and will be based on either regional extremes or individual station extremes (if they are available).

Barnes Spatial Test

The *Clarus* Barnes spatial test will calculate an estimate for each observation using a one-pass Barnes objective analysis routine (Barnes 1964, Shafer et al. 2000). Neighboring observations will be weighted according to their distance from the station that is being estimated:

$$Z_e = \frac{\sum w(r_i) z_i}{\sum w(r_i)},$$

where Z_e is the estimated value, z_i are the neighboring observations, and w is the weighting, based on the neighboring site's distance to the site in question. The weighting decreases exponentially with distance from the station:

$$W(r_i) = e^{\frac{-r_i^2}{k_o}}.$$

The weight function, k_o, is determined by the Barnes analysis based upon the mean station spacing. The standard deviation, σ, of the observations within the radius of influence is calculated. The ratio of the difference between the observed (Z_o) and estimated (Z_e) values to the analysis' standard deviation is defined as:

$$\Delta = \frac{Z_e - Z_o}{\sigma}.$$

The *Clarus* Barnes spatial test will fail any observation whose value differs by more than three standard deviations from its estimated value (i.e., $\Delta > 3$). Otherwise, the *Clarus* Barnes spatial test will pass the observation, and list the Δ value with the QC flag to indicate the confidence in the observation. For instance, a Δ value of 1.5 would indicate that the observation was within 1.5 standard deviations of its expected value. Further analysis may indicate that the Barnes spatial test should have the ability to incorporate background fields (e.g., ADAS or RUC analysis from the previous hour) into the analysis to compensate for regions that have inadequate spatial or temporal coverage.

Optimal Interpolation Spatial Test

The *Clarus* Optimal Interpolation spatial test will calculate an estimate for each observation using a univariate optimal-interpolation technique (Belousov et al., 1968). Specifically, the test will use the nearest observation in each of eight directional sectors distributed around the observation (Miller and Benjamin, 1992). If the difference between the observation and estimate is "small", the observation is flagged as "passed", and the difference between the observation and the estimate is listed to indicate the confidence in the observation. The threshold for "small" is a function of the expected analysis error, which is dependent on location and density of the neighboring observations (Gandin, 1963, and Miller and Benjamin, 1991). If the difference is large, then neighboring observations are successively eliminated from the analysis to determine whether the discrepancy was caused by an erroneous observation from a neighboring site. If successively eliminating a neighboring station from the analysis results in a value that agrees with the observation, then the observation is flagged as "passed". The difference between the observation and the estimate indicates the confidence in the observation. In addition, the suspicious neighboring observation is not used in the analysis of other stations. If successive eliminations of neighboring stations does not result in an estimated value that agrees with the observation, the observation is flagged as "failed".

The *Clarus* Optimal Interpolation spatial check will incorporate a background field (e.g., ADAS or RUC analysis from the previous hour) into the analysis to compensate for regions that have inadequate spatial or temporal coverage. Miller and Benjamin (1992) found that subtracting the background field before performing the analysis improved error detection.

Step Test

The *Clarus* step test will flag all observations whose consecutive values in time exceed predefined variable-specific step threshold values as "failed" (Fiebrich and Crawford 2001). For instance, if a pressure observation changes by greater than 10 hPa in five minutes, the observation is flagged as "failed". As another example, if a temperature observation changes by greater than 10 °C in five minutes, the observation would be flagged as "failed".

Persistence Test

The *Clarus* persistence test will flag all observations whose consecutive values in time remain the same for a predefined variable-specific persistence threshold value during a defined time interval as "failed" (Oklahoma Climatological Survey). For instance, if a pressure observation remains unchanged (to the nearest pascal) for more than 30 minutes, the observation would be flagged as "failed". As another example, if a temperature observation remains unchanged (to the nearest tenth of a °C) for more than 120 minutes, the observation would be flagged as "failed".

Like Instrument Test

The *Clarus* like instrument test will flag all observations that differ from the corresponding like-instrument observations by more than a predefined variable-specific threshold value as "failed" (Fiebrich and Crawford 2001). For instance, if the wind speed at 10 m differs from the wind speed at 2 m by more than 5 ms^{-1}, then the observation would be flagged as "failed".

Potential Temperature Test

The *Clarus* potential temperature test will flag all temperature observations whose potential temperatures fail the *Clarus* Optimal Interpolation spatial test as "failed". Elevation differences will be incorporated to help model the horizontal correlation between mountain stations (Miller and Benjamin 1992).

Dew Point Temperature Test

The *Clarus* dew point temperature test will flag all temperature and relative humidity observations whose resulting dew point values fail the *Clarus* Barnes spatial test or the *Clarus* Optimal Interpolation spatial test as "failed" (Oklahoma Climatological Survey).

Sea Level Pressure Test

The *Clarus* sea level pressure test will flag all pressure observations whose computed sea level pressure values fail the *Clarus* Barnes spatial test or the *Clarus* Optimal Interpolation spatial test as "failed" (Oklahoma Climatological Survey).

Theoretical Solar Radiation Test

The *Clarus* theoretical solar radiation test will flag all downwelling short wave radiation observations whose values exceed the theoretical solar radiation for the site's latitude, longitude, and day of year as "failed" (Oklahoma Climatological Survey).

Precipitation Amount Test

The *Clarus* precipitation amount test would flag all precipitation amount observations whose values differ from the radar-estimated precipitation amount by more than a pre-determined threshold as "failed". The nearest or best radar to use for each location would be configurable. This technique is still being researched and is not recommended for *Clarus* proof-of-concept implementation (Oklahoma Climatological Survey).

Wind Direction Test

The *Clarus* wind direction test will function the same way as the Barnes and Optimal Interpolation spatial tests do, with the exception that wind direction estimates will be calculated from directional means (rather than arithmetic means). In addition, the wind direction observation will be subject to this test only if its associated wind speed observations are greater than 3 ms^{-1} (Oklahoma Climatological Survey). For instance, wind directions with associated wind speeds of 0-3 ms^{-1} will not be tested, because wind direction is highly variable during calm/light winds.

Soil Moisture Change Test

The *Clarus* soil moisture change test will function similarly to the step test except that different thresholds will be set for changes in moistening versus drying. For instance, the observations will be allowed to moisten more rapidly than they will be allowed to dry (Oklahoma Climatological Survey 2005).

Soil Moisture Freeze Test

The *Clarus* soil moisture freeze test will flag all observations whose associated subsurface temperatures are below freezing as "failed". Most soil moisture sensors do not operate correctly when the soil is frozen (Oklahoma Climatological Survey 2005).

Variable	Manual Flag	Sensor Range	Climate Check	Barnes Spatial	OI Spatial	Persistence	Step	Like Instrument	Variable Specific
Air Temperature	X	X	X	X	X	X	X	X	X
Atmospheric Pressure	X	X	X			X	X		X
Humidity	X	X	X	X	X	X	X		X
Long Wave Radiation	X	X	X	X		X	X		
Short Wave Radiation	X	X	X	X		X	X		X
Precipitation Occurrence	X	X				X		X	
Precipitation Type	X	X	X					X	
Precipitation Rate	X	X	X			X	X	X	
Precipitation Amount	X	X	X				X	X	
Visibility	X	X	X	X		X	X		
Wind Speed	X	X	X	X	X	X	X	X	
Wind Direction	X	X	X			X	X		X
Wind Gust	X	X	X	X		X	X	X	
Pavement Condition	X	X	X	X					
Pavement Temperature	X	X	X	X		X	X	X	
Pavement Chem Soln Freeze Pt	X	X	X	X					
Pavement Ice Thickness	X	X	X	X		X	X		
Snow Depth	X	X	X			X	X		
Water Depth, Road	X	X	X			X	X		
Water Depth, Stream	X	X	X			X	X		
Subsurface Temperature	X	X	X	X		X	X	X	
Subsurface Moisture	X	X	X						X
Air Quality Condition	X	X	X						
Bio-Hazards	X	X	X						
Camera Imagery	X	X							

Notes

Variable	Comments
Air Temperature	Like Instrument only if air temperature at another level is available. Variable specific tests include potential temperature and dew point tests.
Atmospheric Pressure	Variable specific test includes sea level pressure test.
Humidity	Variable specific test includes dew point test.
Long Wave Radiation	Spatial would be possible only for net and/or LW down
Short Wave Radiation	Variable specific test includes theoretical solar radiation test.
Precipitation Occurrence	Like instrument test with precipitation rate observations.
Precipitation Type	Like instrument test with precipitation occurrence observations.
Precipitation Rate	Like instrument test with precipitation occurrence observations.
Precipitation Amount	Like instrument test with precipitation occurrence observations.
Visibility	
Wind Speed	Like instrument only if wind speed at another level is available.
Wind Direction	Variable specific test includes the wind direction test.
Wind Gust	Like instrument with wind speed observations.
Pavement Condition	
Pavement Temperature	Like instrument tests with air temperature and subsurface temperature (if available)
Pavement Chem Soln Freeze Pt	
Pavement Ice Thickness	
Snow Depth	
Water Depth, Road	
Water Depth, Stream	
Subsurface Temperature	Intercomparison tests with air temperature and other subsurface temperatures (if available)
Subsurface Moisture	Variable specific tests include soil moisture change and soil moisture freeze tests.
Air Quality Condition	
Bio-Hazards	
Camera Imagery	

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