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This publication was prepared by the NTCIP Environmental Sensor Station (ESS) Working Group, which is a subdivision of the Joint Committee on the NTCIP. The Joint Committee is organized under a Memorandum of Understanding among the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and the National Electrical Manufacturers Association (NEMA). The Joint Committee on the NTCIP consists of six representatives from each of the standards organizations, and provides guidance for NTCIP development.

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- Environment Canada
- Ice and Snow Technologies
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- Ministry of Ontario
- Mitretek
- Qualimetrics
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- Trevilon Corporation
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- Virginia DOT
- Washington State DOT

FOREWORD

NTCIP 1204 v02 identifies and defines how a management station may wish to interface with a field device to control and monitor pavement sensors, weather stations, air quality monitors, and other equipment related to the monitoring of and response to environmental conditions in an NTCIP-compliant fashion.

This NTCIP standards publication was developed, maintained, and approved in accordance with the Joint AASHTO, ITE, and NEMA NTCIP policies and procedures. This NTCIP standards publication has been Jointly Approved and published, and shall be cited as the major version NTCIP 1204 v02. This major version is the last and final revision in a series of major-plus-minor version numbers. The major-plus-minor version number is in the header on each page to identify this major version.

NTCIP 1204 v02 is an NTCIP Data Dictionary Standard. Data Dictionary Standards provide definitions of data elements for use within NTCIP systems. A Joint NTCIP Data Dictionary Standard is equivalent to these document types at the standards organizations:

AASHTO – Standard Specification
ITE – Software Standard
NEMA – Standard

There are 3 normative and 3 informative annexes in NTCIP 1204 v02:

- (a) Annex A is normative and contains a Requirements Traceability Matrix (RTM) that traces requirements to the dialogs and data elements used to fulfill it.
- (b) Annex B is informative and provides a graphical representation of the major nodes of the ISO tree as defined by this standard.
- (c) Annex C is normative and is a placeholder for test procedures that may be added to this standard at a later date.
- (d) Annex D is informative and identifies the significant revisions in NTCIP 1204 v02 that have been made since NTCIP 1204 v01.
- (e) Annex E is informative and responds to user requests by providing an explanation as to how certain complex features can be supported by the standard and why certain other features are not supported by this version of the standard.
- (f) Annex F is normative and serves as a placeholder to define certain details that are likely to be moved to other standards at a future date.

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Approvals

This standards publication was separately balloted and approved by AASHTO, ITE, and NEMA after recommendation by the Joint Committee on the NTCIP. Each organization has approved this standard as the following standard type, as of the date:

AASHTO – Standard Specification; April 2006
ITE – Software Standard; October 2005
NEMA – Standard; October 2005

History

The development history of NTCIP 1204 is:

TS 3.7 version 97.01.11. Approved by AASHTO, ITE, and NEMA in 1998.

TS 3.7 Amendment 1, version 98.01.02. Approved by AASHTO and NEMA in 1999 and approved by ITE in 2001.

NTCIP 1204:1998 v01.12. Combined TS 3.7 version 01.11 and Amendment 1 version 02, converted to the 1204 numbering scheme, and made changes in sections: 3.2.2, 3.3.1, 3.8.11, 3.8.12, 3.11.2.10, 3.11.2.11, 3.11.2.12, 3.11.4.3, 3.11.4.4, 3.14.1 through 3.14.7, and 4.2.1.

NTCIP 1204:1998 v01.13. November 2001 edition – Reformatted for printing: incremented version number, updated document to NTCIP 8002 v04 Template format, added approvals and history to Foreword, and converted references to TS 3 Standards to renumbered NTCIP Standards. The underline and strikethrough format used to indicate the amendment changes was removed. The normative reference to WMO BUFR was corrected and References were updated.

NTCIP 1204 v02. Starting in 2001, version 02 was developed to reflect lessons learned, to update to new document formats, and to add new features such as the control of automated de-icing equipment. In May 2004, the Joint Committee on the NTCIP accepted v02.18 as a User Comment Draft. Standards Bulletin B0098 sent v02.19b out for comment.

NTCIP 1204 v02.22 – In March 2005, the Joint Committee on the NTCIP accepted v02.22 as a Recommended Standard. In April 2005, User Comment UC0354 was considered and disposed to produce v02.23b.

NTCIP 1204 v02.23b was approved by AASHTO in April 2006, approved by ITE in October 2005, and approved by NEMA in October 2005. NTCIP 1204 v02 was Jointly Approved in 2006.

NTCIP 1204 v02.24. In November 2007, errata were approved to revise NTCIP 1204 v02 for: section 4.2.1 Capture Snapshot Image and the UML diagram in Figure 4-1; section 5.11.6.6 Sub-Surface Moisture OID; section 5.11.6.7 Sub-Surface Sensor Error OID; and section 5.16.3.4 Snapshot Camera Command ACCESS field. The approved errata are included in v02.24. See Annex D for the Documentation of Revisions. In May 2008, the standard was edited and formatted for publication.

INTRODUCTION

NTCIP 1204 v02 provides definitions of data elements for environmental sensor data, including weather data, pavement condition data, water level data, and air-quality data. The data is defined using the Simple Network Management Protocol (SNMP) object-type format as defined in RFC 1212 and the defined NTCIP format defined in NTCIP 8004. This data would typically be exchanged between a management station and a field device using one of the NTCIP 1103 recognized Application Layers (e.g., SNMP). The data may also be exchanged among management stations using other protocols.

This standard defines requirements that are applicable to all NTCIP environments and it also contains optional and conditional clauses that are applicable to specific environments for which they are intended.

The following keywords apply to this document: AASHTO, ITE, NEMA, NTCIP, ESS, data, data dictionary, object.

In 1992, the NEMA 3-TS Transportation Management Systems and Associated Control Devices Section began development of the NTCIP. The Transportation Section's purpose was in response to user needs to include standardized systems communication in the NEMA TS 2 standard, *Traffic Controller Assemblies*. Under the guidance of the Federal Highway Administration's NTCIP Steering Group, the NEMA effort was expanded to include the development of communications standards for all transportation field devices that could be used in an Intelligent Transportation Systems (ITS) network.

In September 1996, an agreement was executed among AASHTO, ITE, and NEMA to jointly develop, approve, and maintain the NTCIP standards. Under the guidance of a Joint AASHTO/ITE/NEMA Committee on the NTCIP, a Working Group was created in order to develop the object definitions Environmental Sensor Stations. The first meeting of this working group was in November 1996, and the 1204 version 01 was produced in 1998. In 2001, efforts began to update and enhance the standard, which resulted in this version 02.

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Section 1 GENERAL [Informative]

1.1 SCOPE

Environmental sensors include a wide array of sensors, including those which monitor weather, roadway surface, water level, and air quality conditions. These sensors are typically connected to a nearby microprocessor termed a Remote Processor Unit (RPU). An Environmental Sensor Station (ESS) consists of the RPU plus its suite of sensors.

Typically, this equipment is permanently located at a site along a travel corridor. In some cases, the "stations" may be portable, or even mobile. For the purpose of this standard, all three types of stations are called ESS. In the transportation community, these devices are frequently used in order to improve roadway maintenance and traffic operations.

Environmental sensors are also frequently co-located with pavement treatment systems (PTS) and, in fact, may use the same controller. Thus, for the purpose of this standard, the term ESS may also include a PTS.

NOTE: The PTS portion of this standard may be placed in a separate standard in the future.

Unfortunately, there have not been standards defining how these devices communicate with management systems. As a result, each manufacturer has developed its own protocol to meet its own particular needs. This approach has resulted in systems that are not interchangeable or interoperable. If an agency wishes to use either a central management system or additional ESS from a different vendor, the agency encounters significant systems integration costs. This additional cost inhibits information sharing within and between various potential users of the data and prevents vendor independence. Without vendor independence, costs further increase due to a lack of a competitive market.

These problems have not been limited to weather and environmental monitoring. Many other devices also need to exchange information. In surface transportation, examples include traffic signal controllers, dynamic message signs, bus priority sensors, etc. To address these problems, the NTCIP is developing a family of open standards for communications between field devices and central management systems.

This standard is a part of that larger family and is designed to define an interoperable and interchangeable interface between a transportation management system and an ESS while still allowing for extensions beyond this standard to allow for new functions as they may be needed. It is expected that this will support the deployment of ESS from one or more vendors in a consistent and cost-efficient way.

This standard only addresses a subset of the requirements required for procurement. It does not address requirements related to the performance of the sensors (e.g., accuracy, the supported detection range, the time it takes to detect conditions, etc.), hardware components, mounting details, etc.

This standard standardizes the communications interface by identifying the various operational needs of the users (Section 2) and subsequently identifying the requirements (Section 3) that must be supported for each need. The standard then defines the NTCIP standardized communications interface used to fulfill these requirements by identifying the dialogs (section 4) and related data concepts (Section 5) that must be supported for each requirement.

The traceability among the various sections is defined by the Protocol Requirements List (section 3.3) and the Requirements Traceability Matrix (Annex A). Conformance requirements for this standard are provided in section 3.3.

An implementation of this standard requires lower level services to structure, encode, and exchange the data concepts defined by this standard. This standard assumes that the data concepts will be exchanged by one of the protocols defined in NTCIP 2301.

1.2 REFERENCES

For approved amendments, contact:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1752
Rosslyn, VA 22209-3801
e-mail: ntcip@nema.org

Draft amendments, which are under discussion by the relevant NTCIP Working Group, and amendments recommended by the NTCIP Joint Committee are available at www.ntcip.org.

1.2.1 NORMATIVE REFERENCES

The following standards contain provisions, which, through references in this text, constitute provisions of this Standard. By reference herein, these standards are adopted, in whole or in part as indicated, in this publication. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

Identifier	Title	Summary
Glossary of Meteorology	<i>Glossary of Meteorology, Second Edition; American Meteorological Society, 2000.</i>	This document defines common meteorological terms.
AASHTO / ITE / NEMA NTCIP 1201:2005 v02.32	<i>NTCIP Global Object Definitions – version 02</i>	NTCIP 1201 v02 defines data elements that are used by multiple types of devices (e.g., signs, sensor stations, signals, etc.). Many of these objects, such as time and scheduling objects, are referenced by this standard in order to fulfill user needs.
AASHTO / ITE / NEMA NTCIP 2301:2001 v01.08	<i>NTCIP – Simple Transportation Management Framework (STMF) Application Profile</i>	The STMF Application Profile as restricted by this standard, defines the mechanisms by which the data defined in this standard is exchanged.

WMO No. 306:1995	<i>Technical Regulations; Manual on Codes, International Codes, Volume 1.2, Annex II, FM 94-X Ext. BUFR – Binary Universal Form for the Representation of Meteorological Data.</i>	BUFR is a major standard of the meteorological community that provides standardized definitions of various pieces of data as well as encoding forms. The NTCIP ESS standard uses common data definitions where appropriate; however, the NTCIP uses different encoding (as defined in NTCIP 2301) and customizes many terms in order to reflect the unique needs of the transportation community.
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1.2.2 OTHER REFERENCES

The following documents and standards may provide the reader with a more complete understanding of the entire protocol and the relations between all parts of the protocol. However, these documents do not contain direct provisions that are required by this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standard listed below.

Identifier	Title	Summary
IAB STD 16	(RFC 1155) <i>Structure and Identification of Management Information for TCP/IP based Internets</i> , M. Rose, K. McCloghrie, May 1990, (RFC 1212) <i>Concise MIB Definitions</i> , M. Rose and K. McCloghrie, March 1991	This standard defines the generic format for defining an SNMP Management Information Base (MIB). The NTCIP standards have further refined this in NTCIP 8004.
National ITS Architecture, Version 5.0	<i>National ITS Architecture, FHWA, 2003</i>	The National ITS Architecture is used to define the how the contents of this standard relate to the overall scope of ITS.
AASHTO / ITE / NEMA NTCIP 1103 v01.26 (Recommended Std, June 2005)	<i>Transportation Management Protocols</i>	This standard defines the protocols used to exchange information between management systems and most field devices. It is a normative reference of NTCIP 2301, which is a normative reference to this standard.
AASHTO / ITE / NEMA NTCIP 2201:2003 v01.15	<i>Transportation Transport Profile (T2)</i>	This standard defines a specialized, low-bandwidth transport mechanism for exchanging data.
AASHTO / ITE / NEMA NTCIP 2202:2001 v01.05	<i>Transport Profile for Internet (TCP/IP and UDP/IP)</i>	This standard defines how the NTCIP community uses the TCP/IP and UDP/IP standards.

AASHTO / ITE / NEMA NTCIP 8004 v01.38 Jointly Approved December 2005	<i>Structure and Identification of Management Information</i>	This standard defines and explains the structure used by the NTCIP effort to document data definitions.
OMG Unified Modeling Language Specification, Version 1.5	OMG Unified Modeling Language Specification, Object Management Group, 2003	The standard that formally defines the meaning of each symbol used in the UML diagrams contained in this standard. However, as these diagrams are informational, this standard is not normative.
Publication No. FHWA-SA-98-008	<i>Assessing the Results of the Strategic Highway Research Program, FHWA, 1998</i> http://www.fhwa.dot.gov/winter/roadsvr/sumrept.pdf	This document describes how ESS can be used within transportation management systems in order to improve operations.
Weather-Responsive Traffic Management	<i>Weather-Responsive Traffic Management – Concept of Operations. FHWA, 2003.</i> http://ops.fhwa.dot.gov/weather/best_practices/WeatherConOps0103.pdf	An overview of how weather data can be used in traffic management applications.

1.2.3 CONTACT INFORMATION

1.2.3.1 American Meteorological Society and World Meteorological Organization Documents

Prepayment is required prior to shipment of these documents. Printed copies are available from:

American Meteorological Society
45 Beacon Street
Boston, MA 02108
(617) 227-2425

1.2.3.2 Internet Documents

Obtain Request for Comment (RFC) electronic documents from several repositories on the World Wide Web, or by “anonymous” File Transfer Protocol (FTP) with several hosts. Browse or FTP to:

www.rfc-editor.org
www.rfc-editor.org/repositories.html
for FTP sites, read <ftp://ftp.isi.edu/in-notes/rfc-retrieval.txt>

1.2.3.3 National ITS Architecture

The National ITS Architecture may be viewed on-line at <http://itsarch.iteris.com/itsarch/>

1.2.3.4 NTCIP Standards

Copies of NTCIP standards may be obtained from:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1752
Rosslyn, Virginia 22209-3801
www.ntcip.org, or
e-mail: ntcip@nema.org

1.2.3.5 Object Management Group Documents

Copies of OMG standards may be obtained electronically from:

Object Management Group
www.omg.org

1.2.3.6 OFCM Documents

Office of the Federal Coordinator for Meteorology
8455 Colesville Rd., Suite 1500
Silver Spring, MD 20910
(301) 427-2002

1.3 GENERAL STATEMENTS

< In the opinion of the ESS WG, this clause does not apply in the context of NTCIP 1204 v02. >

1.4 TERMS

For the purposes of this standard, the following terms, definitions, acronyms, and abbreviations apply. Meteorological terms not defined in this section are in accordance with their definitions in the *Glossary of Meteorology*. Electrical and electronic terms not defined in this section are used in accordance with their definitions in IEEE Std 100-2000. English words not defined in this section or in IEEE Std 100-2000 are used in accordance with their definitions in *Webster's New Collegiate Dictionary*.

TERM	DEFINITION
Binary Universal Form for the Representation of Meteorological Data (BUFR)	The name of the WMO standard binary code for the exchange and storage of non-gridded meteorological data.
Compatible	The ability of two or more systems or components to exchange information (IEEE Std. 610.12-1990: IEEE Standard Glossary of Software Engineering Terminology).
Consistent	The ability of two or more systems or components to exchange information and use the supported information that has been exchanged and gracefully reject any unsupported information according to defined rules.
Current	Reflecting the conditions at the present time (or at the time at which the data is time stamped) as determined by the Controller.

Deprecated	[To be revised in 1204 v03 to refer to NTCIP 8004 v02] The 'deprecated' value in the STATUS field of an 'OBJECT-TYPE' macro (see Section 5) indicates that the subject object was included in a previous version of the standard but no longer represents the preferred design.
Environmental Monitoring Equipment Package	The component within a management subsystem which performs advanced processing of the collected environmental data. This would include the analysis, forecasting and packaging of weather and road condition information for resource management.
Environmental Sensor Station	A location that includes a remote processor unit (RPU) connected to one or more sensors for the collection of environmental or meteorological data. It may also include a Pavement Treatment System.
Feature	A behavior of the device.
Interchangeable	A condition which exists when two or more items possess such functional and physical characteristics as to be equivalent in performance and durability, and are capable of being exchanged one for the other without alteration of the items themselves, or adjoining items, except for adjustment, and without selection for fit and performance. (National Telecommunications and Information Administration, U.S. Department of Commerce)
Interoperable	[To be revised in 1204 v03 to refer to NTCIP 8004 v02] The ability of two or more systems or components to exchange information and use the information that has been exchanged (IEEE Std. 610.12-1990: IEEE Standard Glossary of Software Engineering Terminology).
Management Information Base (MIB)	Management information of object definitions so that devices on a network can be remotely monitored, configured and controlled. The information is provided in a format called Abstract Syntax Notation.1 (ASN.1), which is an international standard for defining objects.
Management Station	The computer system with which the device communicates. Typically, the management station commands and monitors the device.
National Transportation Communications for ITS Protocol	The NTCIP is a family of protocols that provide common control and data collection services as well as accommodating various system topologies and data routing duties. The NTCIP will support not only currently deployed systems, but new systems and technologies as they become available.

Obsolete	[To be revised in 1204 v03 to refer to NTCIP 8004 v02] The 'obsolete' value in the STATUS field of an 'OBJECT-TYPE' macro (see Section 5) indicates that the object was included in a previous version of the standard but is no longer in significant use within the industry.
Operator	The person who interfaces with the management station software, typically located at a control center.
Protocol	A specific set of rules, procedures and conventions defining the format and timing of data transmissions between devices that must be accepted and used to understand each other.
Remote Processor Unit	A field processor which collects data from sensors and can communicate the collected data to other computers; the processor may also process the collected data and/or control equipment.
Requirement	A requirement describes a condition or capability to which a system must conform; either derived directly from user needs, or stated in a contract, standard, specification, or other formally imposed document. A desired feature, property, or behavior of a system.
Requirements Traceability	The ability to follow or study the logical progression among the needs, requirements and design details in a step-by-step fashion.
Return	When discussing device requirements for providing data when an external system requests it, the term 'return' shall be understood that the data is sent to the requester.
Road Weather Data Collection Market Package	A set of components which perform all operations related to sensing, collecting, processing, and exchanging environmental related information, including the exchange of data among the dispersedly located equipment.
Road/Weather Information System	The collection of RPU's and sensors connected to a central system for analysis and use by maintenance personnel and transportation system managers.
Sensor	A device which is capable of detecting a condition and reporting the result to an RPU.
Simple Network Management Protocol	A communications protocol developed by the IETF, used for configuration and monitoring of network devices.
Simple Transportation Management Framework	Describes the organization of the information within devices and the methods of retrieving or modifying any information within the device. STMF also explains how to generate and utilize computer readable information organization descriptions.

Sub-Feature	A specialization of a more generic feature.
Upload	To transfer information from the referenced device to the central computer or an attached portable computer.
User	A person who will use the system that is developed.
User Need	The business or operational problem (opportunity) that must be fulfilled in order to justify purchase or use. While this is termed a 'user need' within the NTCIP community, it reflects needs of all stakeholders.

1.5 ABBREVIATIONS AND ACRONYMS

The abbreviations and acronyms used in NTCIP 1204 v02 are defined as follows:

IAB STD	Internet Architecture Board Standard
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISO	International Organization for Standardization
MIB	Management Information Base
NTCIP	National Transportation Communications for Intelligent Transportation Systems (ITS) Protocol
OID	OBJECT IDENTIFIER
PRL	Profile Requirements List
RFC	Request for Comments
SNMP	Simple Network Management Protocol
STMF	Simple Transportation Management Framework
T2	Transportation Transport Profile
TCP	Transmission Control Protocol
TMC	Traffic Management Center
TMP	Transportation Management Protocol
UDP	User Datagram Protocol
WG	Working Group
WMO	World Meteorological Organization

Section 2

CONCEPT OF OPERATIONS

[Normative]

This section defines the user needs that subsequent sections within this standard will address. Accepted system engineering processes detail that requirements should only be developed to fulfill well-defined user needs. The first stage in this process is to identify the ways in which the system will be used. In the case of this standard, this entails identifying the various ways in which transportation operations personnel may use ESS information in order to fulfill their duties.

This concept of operations provides the reader with:

- a. A detailed description of the scope of this standard;
- b. An explanation of how an ESS is expected to fit into the larger context of an ITS network;
- c. A starting point in the procurement process; and
- d. An understanding of the perspective of the designers of the standard.

This section is intended for all readers of the document, including:

- a. Transportation operations managers
- b. Transportation operations personnel
- c. Transportation engineers
- d. System integrators
- e. Device manufacturers

The first three categories of readers will find this section useful in order to understand how ESS equipment can be used in their system. For this audience, this section serves as the starting point in the procurement process. They will be able to become familiar with each feature covered by the standard and determine whether that feature is appropriate for their implementation. If it is, then their procurement specification will need to require support for the feature and all of the mandatory requirements related to that feature.

The last two categories of readers will find this section useful in order to gain a more thorough understanding as to why the more detailed requirements (as specified in later sections of this standard) exist.

2.1 TUTORIAL [INFORMATIVE]

A concept of operations describes a proposed system from the users' perspective. Typically, a concept of operations is used on a project to ensure that the system developers understand the users' needs. Within the context of NTCIP standards it is used to document the intent of each feature for which the standard supports a communications interface. It also serves as the starting point for users to select which features may be appropriate for their project.

The concept of operations starts with a discussion of the current situation and problems that have led to the need to deploy systems covered by the scope of the standard and to the development of the standard itself. This discussion is presented in layman's terms such that both the potential users of the system and the system developers can understand and appreciate the situation.

The concept of operations then documents key aspects about the proposed system, including the:

- a. Reference physical architecture – The reference physical architecture defines the overall context of the proposed system and defines which specific interface is addressed by this standard. The reference physical architecture may be supplemented with one or more samples that describe how the reference physical architecture may be realized in an actual deployment.
- b. Architectural Needs – The architectural needs section discusses the issues and needs relative to the system architecture that have a direct impact on this standard.
- c. Features – The features identify and describe the various functions that users may want the device to perform. These features are derived from the high level user needs identified in the problem statement but are refined and organized into a more manageable structure that form the basis of the traceability tables contained in Section 3 and Annex A.

The architectural needs and features are collectively called the *user needs*. Section 3 uses these user needs in the analysis of the system in order to define the various functional requirements of an ESS. Each user need must be traced to one or more functional requirements and each functional requirement must be derived from at least one user need. This traceability is shown in the Protocol Requirements List (PRL) as provided in Section 3.3.

While the standard is intended to standardize communications across a wide range of deployments, it is not intended to mandate support for every feature for every deployment. Therefore, the PRL also defines each user need and requirement as mandatory, optional, or conditional. The only items marked mandatory are those that relate to the most basic functionality of the device. In order to obtain a device that meets specific needs, the user will need to first identify which optional needs are necessary for the specific project.

Each requirement identified is then presented in the Requirements Traceability Matrix (RTM) in Annex A, which defines how the requirement is fulfilled through the standardized dialogs and data element definitions provided in Sections 4 and 5.

A conformant device may support other user needs, as long as they are conformant with the requirements of this standard and the standards it references (i.e., NTCIP 2301 and NTCIP 8004). For example, a device may support data that has not been defined by this standard; however, when exchanged via one of the NTCIP 2301 protocols, the data must be properly registered with a valid OBJECT IDENTIFIER under the Global ISO Naming Tree.

NOTE: Off-the-shelf interoperability and interchangeability can only be obtained by using well documented user needs, along with their corresponding requirements and design, that are broadly supported by the industry as a whole. Designing a system that uses environments or features not defined in a standard or not typically deployed in combination with one another will inhibit the goals of interoperability and interchangeability, especially if the documentation of these user needs is not available for distribution to system integrators. The standards allow implementations to support additional user needs in order to support innovation, which is constantly needed within the industry; but users should be aware of the risks involved with using such environments or features.

The concept of operations concludes by describing the degree to which security issues have been addressed by the standard and by providing a description of how this standard relates to the National ITS Architecture.

2.2 CURRENT SITUATION AND PROBLEM STATEMENT [INFORMATIVE]

Transportation system managers use ESS in a variety of ways to improve transportation system

operations. The primary uses of ESS data support the following:¹

- a. Sharing the data with the broader weather community contributes to better weather forecasts
- b. Improved highway maintenance operations through supporting timely, accurate, and relevant weather forecasting and knowledge of existing road weather conditions
- c. More accurate traveler information, which can result in better route planning by travelers and more effective, safer transportation system use
- d. Improved management of facilities maintenance resources, leading to more timely facilities clearance and improved traveler safety
- e. More effective use of advisory and regulatory mechanisms to ensure public safety
- f. Enhanced monitoring of potential hazardous conditions, to improve transportation system security and traveler safety

One of the most common ESS deployed by transportation system managers is the road/weather ESS. These ESS are used to collect information about road and weather conditions, such as precipitation and air and surface temperatures. With the data returned by these ESS, transportation system managers can determine when there are incipient hazardous travel conditions due to precipitation, fog, high winds, snow, ice and/or flooding. When travel is becoming hazardous due to snow and/or ice, transportation system managers can dispatch road maintenance crews to treat the roads and remove snow and ice if possible. Transportation system managers can also use ESS in conjunction with other Intelligent Transportation System (ITS) devices, such as Dynamic Message Signs (DMS), to advise travelers of poor travel conditions or to notify travelers of travel policy changes due to bad weather. For example, foggy conditions could trigger a DMS to display a lowered speed limit in a high-speed area. Snow and ice conditions could trigger a DMS to display a requirement for travelers to use chains on their tires. Icy conditions on bridges or roadways can also lead to the triggering of a spraying device that sprays anti-icing or de-icing chemicals on bridge or roadway surfaces to improve driving conditions. High water or high wind conditions could trigger a DMS to display a message either recommending that travelers choose a different route or that they reduce their speed to protect themselves against the potential hazard.

Although the normal use of ESS is by transportation system managers, the data from these ESS is sometimes used by emergency management personnel. For example, when flood conditions occur, regardless of their extent, emergency management personnel use data on the depth of water in areas covered by ESS to determine how and when to respond to flooding. Emergency management personnel will re-route travelers from flooded areas, in some cases by deploying (in conjunction with transportation system personnel) signs indicating that sections of road are closed due to flooding.

A transportation system manager may also be interested in using an ESS to measure air quality. This data can be used to monitor concentrations of certain chemicals to ensure that they do not exceed toxic levels. For example, tunnel systems frequently use sensors to ensure that carbon monoxide levels stay within safe levels. The data can also provide a valuable resource to air quality management systems in order to determine the accuracy of predictions. Finally, some research has suggested that air-quality hot-spots could be monitored in order to encourage traffic to avoid these areas during problematic periods.

ESS are typically deployed along the roadside as part of a network of sensors that report their findings to a central management system. The ESS data received at the central system is processed to provide the transportation system manager with intelligence about road weather conditions that can trigger operator action. For example, high wind conditions might trigger a warning to travelers; if the high wind conditions are severe or in an area where they constitute a high risk, they might trigger the closing of a bridge or a

¹ Additional information about how this data can be used is provided in *Weather-Responsive Traffic Management – Concept of Operations*.

section of roadway. Likewise, a network of ESS may also be used to provide the transit system operator information about conditions that affect the health or safety of transit riders. The processing logic could be rather simple (e.g., monitoring high winds) or very complex (e.g., predictions of weather conditions on or near the road). In the latter case, the ESS data would likely serve as one of many inputs, others might include data from the national weather service and other sources.

However, ESS can also be deployed on a vehicle. Usually these ESS are atmospheric sensors or pavement sensors, gathering information about snow and ice conditions, pavement conditions, and similar data designed to provide the transportation system manager with information about conditions along a particular section of roadway. The data from mobile ESS are used to complement those from stationary ESS also deployed along the transportation network.

2.3 REFERENCE PHYSICAL ARCHITECTURE [INFORMATIVE]

This standard addresses the communications interface between a management station and a controller. The relationship between these and other logical components is depicted in Figure 2-1. However, one should realize that the actual physical arrangement of these components may vary from deployment to deployment; Sections 2.3.1 through 2.3.3 provide sample physical architectures that are supported by this reference architecture.

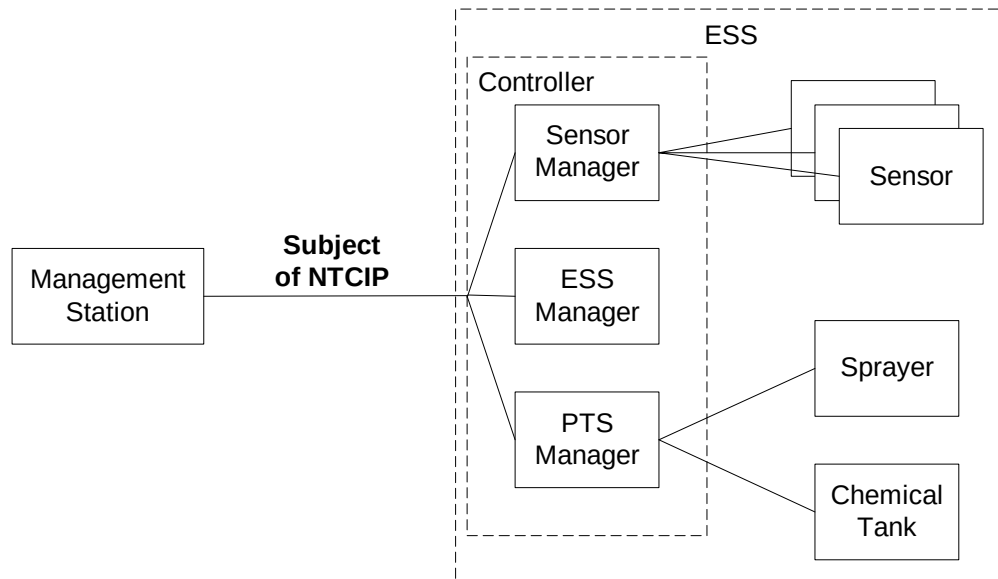


**Figure 2-1
Reference Architecture**

The major components of the system are as follows:

- a. **Management Station** – One or more host computing platforms that manage one or more NTCIP field devices, such as an ESS. Management stations are typically located in some type of management center (e.g., a Traffic Management Center) and may be a considerable distance from the ESS. Other types of management stations include maintenance laptops that a field technician may use on a trip to visit the device or a field processor that may monitor the data reported from the ESS and automatically activate signs or other equipment under certain conditions. There may be multiple management stations for a given ESS. Within the ESS community, a management station is sometimes called a central processing unit or "CPU". The management station is responsible for configuring, monitoring and controlling the ESS.

- b. **ESS** – A Controller and its connected equipment, such as environmental Sensors and/or pavement treatment equipment, including Sprayer(s) and a Chemical Tank. Each of its sub-components is defined further below.
- c. **Controller** – A host computing platform that is used to manage the collection and reporting of sensor data and/or to manage the treatment of pavement for icing conditions. It includes an ESS Manager and may include a Sensor Manager and/or a PTS Manager. Within the ESS community, a controller is sometimes called a remote processing unit or "RPU". The controller is responsible for continually monitoring conditions. When a controller receives a request from a management station, it shall immediately respond with its most recent reading for that data. A system operator should be aware that the nature of some information may require significant time to collect (e.g., average wind speed), or may be dated (e.g., information stored in a log); thus the information contained in the response may have been collected some time prior to the request being sent.
- d. **Sensor Manager** – The portion of the controller that manages the collection and reporting of sensor data.
- e. **ESS Manager** – The portion of the controller that deals with general functionality that applies to both sensor management and PTS management.
- f. **PTS Manager** – The portion of the controller that manages the treatment of pavement for icing conditions.
- g. **Sensor** – A device that responds to a physical stimulus and transmits a resulting impulse. (*Merriam-Webster On-Line Dictionary, 2004*)
- h. **Sprayer** – A device that dispenses the chemical from the storage tank as a fine mist.
- i. **Chemical Tank** – A vessel used to store a chemical mixture for later application to the roadway.

The following subsections describe sample physical architectures that are supported by this reference architecture.

2.3.1 Remote Weather Station

Figure 2-2 depicts a wind sensor on a bridge that is connected by a low-speed wireless radio link due to its remote location.

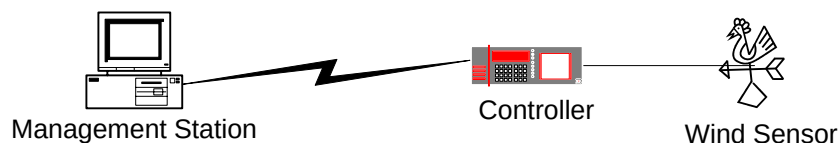


Figure 2-2
Remote Weather Station

2.3.2 Sprayer Combined with a Pavement Sensor

Figure 2-3 depicts an ESS consisting of a controller, a pavement sensor, and a sprayer. The controller is connected to the management station through a separate connection, perhaps a dial-up link.

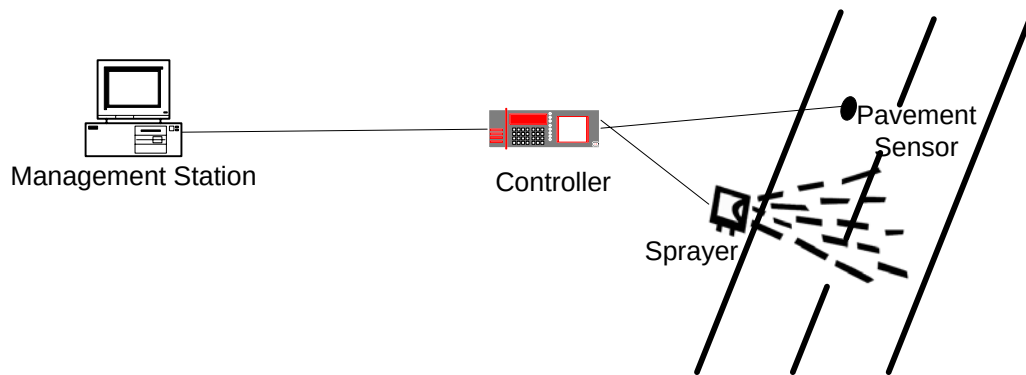


Figure 2-3

Sprayer Combined with a Pavement Sensor

2.3.3 Pavement Treatment Station

Figure 2-4 depicts an ESS that only consists of sprayers for pavement treatment.

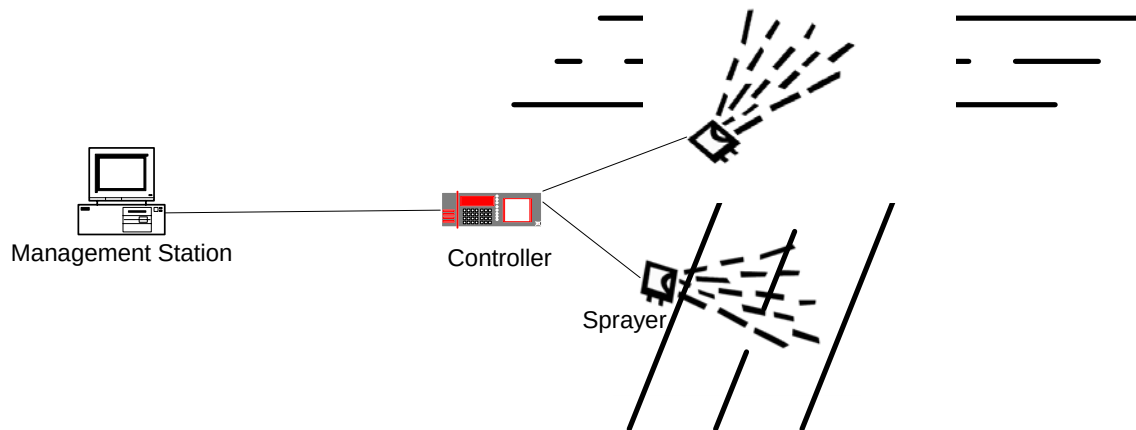


Figure 2-4

Pavement Treatment Station

2.4 ARCHITECTURAL NEEDS

The following subsections define the communications environment within which an ESS is expected to operate.

2.4.1 Generic Architectural Needs

The features defined in Section F.1.1 of Annex F shall be incorporated into this standard by reference.

NOTE: Some user needs apply to a wide range of different types of NTCIP devices. It is expected that these user needs will eventually be documented in a separate standard. However, at this time, the separate standard does not exist. Instead these user needs are defined in Annex F as an interim step to the creation of this separate document.

2.5 FEATURES

The following subsections identify and describe the various features that may be offered by the ESS. It is divided into the following major subsections:

- a. ESS Manager Features
- b. Sensor Manager Features

c. Pavement Treatment System Manager Features

2.5.1 ESS Manager Features

The following subsections identify and describe the various features that may be offered by the ESS Manager, which is the part of the controller that performs the functionality that may apply to both a Sensor Manager and a PTS Manager. It consists of the following features:

- a. Generic Features
- b. Monitor Door Status
- c. Monitor Power
- d. Monitor Mobile Station Data

2.5.1.1 Generic Features

The features defined in Section F.1.2 of Annex F shall be incorporated into this standard by reference.

NOTE: Some user needs apply to a wide range of different types of NTCIP devices. It is expected that these user needs will eventually be documented in a separate standard. However, at this time, the separate standard does not exist. Instead these user needs are defined in Annex F as an interim step to the creation of this separate document.

2.5.1.2 Monitor Door Status

A transportation system operator may wish to determine if any doors on the ESS equipment are open; this may assist the operator in determining whether maintenance crews have properly secured the controller after maintenance and/or may act as an indication to the system to treat any data as suspect.

2.5.1.3 Monitor Power

A transportation system operator may wish to monitor the power for the ESS to ensure proper operation.

2.5.1.4 Monitor Mobile Station Data

A transportation system operator may wish to monitor the movements of a mobile ESS and, if it is part of a mobile pavement treatment system, monitor the chemicals being dispersed.

2.5.2 Sensor Manager Features

The following subsections identify and describe the various features that may be offered by the Sensor Manager. It consists of the following features:

- a. Monitor weather conditions
- b. Monitor pavement
- c. Monitor subsurface conditions
- d. Monitor human readings
- e. Monitor water levels
- f. Monitor air quality and bio-hazards
- g. Monitor mobile weather profile

2.5.2.1 Monitor Weather Conditions

This feature focuses on weather conditions that can directly or indirectly affect the transportation system. It contains the following sub-features:

2.5.2.1.1 Monitor Atmospheric Pressure

A transportation system operator may need to monitor the atmospheric pressure in the vicinity of the ESS.

2.5.2.1.2 Monitor Winds

A transportation system operator may need to monitor the current wind conditions in the vicinity of the ESS.

2.5.2.1.3 Monitor Temperature

A transportation system operator may need to monitor the temperature at the ESS's location.

2.5.2.1.4 Monitor Humidity

A transportation system operator may need to monitor the humidity at the ESS's location.

2.5.2.1.5 Monitor Precipitation

A transportation system operator may need to monitor the amount, intensity, and type of precipitation in the vicinity of the ESS.

2.5.2.1.6 Monitor Solar Radiation

A transportation system operator may need to monitor the amount of solar radiation in the vicinity of the ESS.

2.5.2.1.7 Monitor Visibility

A transportation system operator may need to monitor the visibility in the vicinity of the ESS.

2.5.2.1.8 View Weather Image

A transportation system operator may need to visually inspect weather conditions and/or verify the reported weather conditions.

2.5.2.2 Monitor Pavement

This feature focuses on monitoring road conditions that may adversely affect transportation operations immediately or in the near future. It supports the transportation system operator's ability to dispatch equipment to address the condition or to provide appropriate warnings. It includes the following sub-features:

2.5.2.2.1 Monitor Pavement Surface Condition

A transportation system operator may need to monitor the pavement surface temperature and moisture condition (e.g., dry, wet, snowy, icy, chemical concentration, etc.).

2.5.2.2.2 Monitor Icing Conditions

A transportation system operator may need to monitor whether pavement conditions are likely for ice formation on the pavement. This includes the ability to monitor pavement temperature (i.e., as opposed to surface temperature), the depth of any water film on the surface, and the predicted freeze point of the surface. Further, if passive sensor technologies are used, the operator will need to configure and monitor the parameters defining the current treatments being applied in order to validate the configuration.

2.5.2.2.3 View Pavement Image

A transportation system operator may need to visually inspect pavement conditions and/or verify the reported pavement conditions.

2.5.2.3 Monitor Subsurface Conditions

A transportation system operator may need to retrieve the conditions below the road surface, such that s/he may monitor conditions that could damage roads and/or affect the onset of icing conditions.

2.5.2.4 Monitor Human Readings

A transportation system operator may need to retrieve data that was manually observed and entered by field personnel.

2.5.2.5 Monitor Water Level

A transportation system operator may need to monitor the depth of water at one or more locations (e.g., over a roadway, in a stream, of a reservoir, etc.).

2.5.2.6 Monitor Air Quality and Bio-hazards

A transportation system operator may need to monitor the current air quality in the vicinity of the ESS and determine whether there are airborne bio-hazards in the vicinity of the ESS.

2.5.2.7 Monitor Mobile Weather Profile

A transportation system operator may need to monitor information that is specific to a mobile station such as speed, direction of travel, miles traveled, and detected state of the roadway which includes friction.

2.5.3 Pavement Treatment System Manager Features

The following subsections identify and describe the various features that may be offered by a Pavement Treatment System Manager. It consists of the following features:

- a. Manage Stationary Spray System
- b. Manage Mobile Spray System

2.5.3.1 Manage Stationary Spray System

A transportation system operator may need to manage the application of anti-icing or de-icing chemicals through the use of a sprayer connected to the ESS (e.g., a bridge sprayer). The management of this device includes the configuration, monitoring, and activation of this device.

2.5.3.2 Manage Mobile Spray System

A transportation system operator may need to manage the application of anti-icing or de-icing chemicals from a mobile pavement treatment system (e.g., a salt truck).

2.6 SECURITY

This standard does not address any security issues. Any security pertaining to protecting the communications with an ESS should be implemented either physically by protecting the communications access points, or logically by enabling security features associated with the underlying communications protocols.

2.7 RELATIONSHIP OF USER NEEDS TO NATIONAL ITS ARCHITECTURE FLOWS [INFORMATIVE]

There are seven National ITS Architecture Flows associated with the operation of an ESS. These are:

- a. Environmental Sensors Control
- b. Environmental Conditions Data
- c. Environmental Probe Data
- d. Emissions Sensor Control
- e. Area Pollution Data
- f. Roadway Treatment System Control
- g. Roadway Treatment System Data

The main user need groups (features), as identified above, are related to the National ITS Architecture Flows in the following manner:

User Need Group	Source	Architecture Flow	Destination
Manage ESS	MCMS	environmental sensors control	RS
	TMS	environmental sensors control	RS
	STWS	environmental sensors control	RS
	WS	environmental sensors control	RS
	EMMS	emissions sensor control	RS
Monitor weather conditions	RS	environmental conditions data	MCMS
	RS	environmental conditions data	TMS
	RS	environmental conditions data	STWS
	RS	environmental conditions data	WS
	RS	environmental probe data	TMS
Monitor pavement	RS	environmental conditions data	MCMS
	RS	environmental conditions data	TMS
	RS	environmental conditions data	STWS
	RS	environmental conditions data	WS
	RS	environmental probe data	TMS
Monitor subsurface conditions	RS	environmental conditions data	MCMS
	RS	environmental conditions data	TMS
	RS	environmental conditions data	STWS
	RS	environmental conditions data	WS
	RS	environmental probe data	TMS
Monitor human readings	RS	environmental conditions data	MCMS
	RS	environmental conditions data	TMS
	RS	environmental conditions data	STWS
	RS	environmental conditions data	WS
	RS	environmental probe data	TMS
Monitor flood levels	RS	environmental conditions data	MCMS
	RS	environmental conditions data	TMS
	RS	environmental conditions data	STWS
	RS	environmental conditions data	WS
	RS	environmental probe data	TMS
Monitor air quality	RS	area pollution data	EMMS
Control Pavement Treatment	MCMS	roadway treatment system control	RS
	RS	roadway treatment system status	MCMS

Section 3

FUNCTIONAL REQUIREMENTS

[Normative]

This section defines the Functional Requirements based on the user needs identified in the Concept of Operations (see Section 2). This section provides the reader with:

- a. A tutorial
- b. Architectural Requirements – These are requirements related to the architectural needs defined in Section 2.4.
- c. Data Exchange Requirements – These are requirements related to the features identified in Section 2.5 that can be realized through a data exchange. For example, this includes the requirement to be able to retrieve weather information.
- d. Supplemental Requirements – These are additional requirements derived from the Concept of Operations that do not fall into one of the above two categories. For example, they include requirements related to the number of pavement sensor inputs that an ESS may require, which may be a supplemental requirement to providing pavement sensor data.

This section is intended for all readers of the document, including:

- a. Transportation operations managers
- b. Transportation operations personnel
- c. Transportation engineers
- d. System integrators
- e. Device manufacturers

The first three categories of readers will find this section useful in order to understand the details of what the standard requires of an ESS. This audience will find Section 3.3 to be particularly useful in preparing procurement specifications and will be able to map the various rows of this table to the more detailed text contained within the other sections.

The last two categories of readers will find this section useful in order to fully understand what is required of equipment meeting this interface standard. They will also be able to use the table in Section 3.3 to document the capabilities of their implementations.

3.1 TUTORIAL [INFORMATIVE]

The Functional Requirements Section defines the formal requirements that are intended to fulfill the user needs identified in Section 2. This is achieved through the development of a Protocol Requirements List (PRL) that traces each user need to one or more requirements defined in this section. The details of each requirement are then presented following the PRL. The functional requirements are presented in three broad categories as follows:

- a. Architectural Requirements – These requirements define the required behavior of the system in exchanging data across the communications interface, including any restrictions to general architectural requirements, based upon the architectural needs identified in the Concept of Operations.

- b. Data Exchange Requirements – These requirements define the required behavior of the system in exchanging data across the communications interface based upon the features identified in the Concept of Operations.
- c. Supplemental Requirements – These requirements define additional requirements of the system that are derived from the architectural and/or data exchange requirements, but are not themselves architectural or data exchange requirements. A given supplemental requirement may relate to multiple architectural and/or data exchange requirements. Supplemental requirements frequently include range capabilities of the equipment (e.g., how many ____ are supported by the device).

3.2 SCOPE OF THE INTERFACE [INFORMATIVE]

<In the opinion of the responsible NTCIP working group, this section does not apply in the context of this standard publication.>

3.3 PROTOCOL REQUIREMENTS LIST

The PRL, provided in 3.3.7 and 3.3.8, maps the user needs defined in Section 2 to the requirements defined in Section 3. The table can be used by:

- a. A user or specification writer to indicate which requirements are to be implemented in a project-specific implementation.
- b. The protocol implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight.
- c. The supplier and user, as a detailed indication of the capabilities of the implementation.
- d. The user, as a basis for initially checking the potential interoperability with another implementation.

3.3.1 User Needs Column

The user needs are defined within Section 2 and the PRL is based upon the user need sections within that Section. The section identifier and section name are indicated within these columns.

3.3.2 Requirements Column

The requirements are defined within Section 3 and the PRL references the traces from user needs to these requirements. The section identifier and section name are indicated within these columns.

3.3.3 Conformance Column

The following notations and symbols are used to indicate status and conditional status in the PRL within all NTCIP standards. Not all of these notations and symbols may be used within this standard.

3.3.3.1 Status Symbols

The following symbols are used to indicate status:

M	Mandatory
M.#	Support of every item of the group labeled by the same numeral # required, but only one is active at time
O	Optional
O.# (range)	Part of an option group. Support of the number of items indicated by the '(range)' is required from all options labeled with the same numeral #

C	Conditional
N/A	Not-applicable (i.e. logically impossible in the scope of the standard)
X	Excluded or prohibited

The O.# (range) notation is used to show a set of selectable options (e.g., O.2 (1..*) would indicate that one or more of the option group 2 options must be implemented). Two character combinations are used for dynamic requirements. In this case, the first character refers to the static (implementation) status, and the second refers to the dynamic (use); thus "MO" means "mandatory to be implemented, optional to be used."

3.3.3.2 Conditional Status Notation

The following predicate notations may be used:

<predicate>:	This notation introduces a single item that is conditional on the <predicate>.
<predicate>::	This notation introduces a table or a group of tables, all of which are conditional on the <predicate>.

The <predicate>: notation means that the status following it applies only when the PRL states that the feature or features identified by the predicate are supported. In the simplest case, <predicate> is the identifying tag of a single PRL item. The <predicate>:: notation may precede a table or group of tables in a section or subsection. When the group predicate is true then the associated section shall be completed. The symbol <predicate> also may be a Boolean expression composed of several indices. "AND", "OR", and "NOT" shall be used to indicate the Boolean logical operations.

The predicates used in this standard map to the following clauses:

PREDICATE	CLAUSE
Active	3.6.9
Air	2.5.2.6
CO	3.5.2.3.6.1
CO2	3.5.2.3.6.2
Compressed	F.1.1.2
ESS	F.1.1.1
Icing	2.5.2.2.2
Mobile	The device must be able to operate while in motion.
N2O	3.5.2.3.6.3
NO2	3.5.2.3.6.4
O3	3.5.2.3.6.6
PM10	3.5.2.3.6.7
Passive	3.6.10
Pavement	2.5.2.2
Pressure	2.5.2.1.1
SO2	3.5.2.3.6.5
Subsurface	2.5.2.3
Temperature	2.5.2.1.3
Weather	2.5.2.1
Wind	2.5.2.1.2

3.3.4 Project Requirement Column

The support column can be used by a procurement specification to identify the required features for the given procurement or by an implementer to identify which features have been implemented. In either case, the user circles the appropriate answer (Yes, No, or N/A) in the support column:

Yes	Supported by the implementation.
No	Not supported by the implementation.
N/A	Not applicable

3.3.5 Additional Project Requirements Column

The "Additional Project Requirements" column may used by a procurement specification to provide additional notes and requirements for the product to be procured or may be used by an implementer to provide any additional details about the implementation. In some cases, default text already exists in this field, which the user should complete in order to fully specify the equipment. However, additional text can be added to this field as needed to fully specify a feature.

3.3.6 Instructions for Completing the PRL

In the 'project requirements' column, each response shall be selected either from the indicated set of responses (for example: Yes / No / NA), or it shall reference additional items that are to be attached.

If a conditional requirement is inapplicable, use the Not Applicable (NA) choice. If a mandatory requirement is not satisfied, exception information must be supplied by entering a reference Xi, where i is a unique identifier, to an accompanying rationale for the non-conformance. When the status is expressed as a two-character combination (as defined in A.3.1), the response shall address each element of the requirement; e.g., for the requirement "mo," the possible compliant responses are "yy" or "yn."

To claim conformance with this standard, an implementation shall satisfy the mandatory and selected optional requirements as identified in the PRL.

NOTE: A specification can allow for flexibility in a deliverable by leaving the selection in the Project Requirement column blank for a given row. For example, a specification could allow for either passive or active icing detectors by selecting 'Yes' on line 2.5.2.2.2, and leaving lines 3.6.9 and 3.6.10 blank.

3.3.7 Protocol Requirements List (PRL) Table

† Designates that this requirement is composed of several more detailed requirements as defined in the second half of the PRL contained in Section 3.3.8.

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
2.4	Architectural Needs			M	Yes	
2.4.1	Generic Architectural Needs			M	Yes	(See F.1.1)
2.5	Features			M	Yes	
2.5.1	ESS Manager Features			M	Yes	
2.5.1.1	Generic Features			M	Yes	(See F.1.2)
2.5.1.2	Monitor Door Status			O	Yes / No	
		3.5.1.2.1	Retrieve ESS Door Status	M	Yes / NA	
2.5.1.3	Monitor Power			O	Yes / No	
		3.5.1.2.2	Retrieve Battery Status	O.6 (1..*)	Yes / No / NA	
		3.5.1.2.3	Retrieve Line Volts	O.6 (1..*)	Yes / No / NA	
2.5.1.4	Monitor Mobile Station Data			Mobile:M	Yes / NA	
		3.5.1.3.1	Retrieve Mobile ESS Movement	M	Yes / NA	
		3.5.1.3.2	Retrieve Mobile Treatment Information	M	Yes / NA	
		3.5.1.3.3	Retrieve Compressed Mobile Station Data	M	Yes / NA	
2.5.2	Sensor Manager Features			O.1 (1..*)	Yes / No	
2.5.2.1 (Weather)	Monitor Weather Conditions			O.2 (1..*)	Yes / No / NA	
2.5.2.1.1 (Pressure)	Monitor Atmospheric Pressure			O.3 (1..*)	Yes / No / NA	
		3.5.2.3.2.1	Retrieve Atmospheric Pressure	M	Yes / NA	
		3.6.1	Required Number of Atmospheric Pressure	M	Yes / NA	The ESS shall support at least ____ atmospheric pressure sensors.

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
			Sensors			
2.5.2.1.2 (Wind)	Monitor Winds			O.3 (1..*)	Yes / No / NA	
		3.5.2.3.2.2	Retrieve Wind Data	M	Yes / NA	
		3.6.2	Required Number of Wind Sensors	M	Yes / NA	The ESS shall support at least ____ wind sensors.
2.5.2.1.3 (Temperature)	Monitor Temperature			O.3 (1..*)	Yes / No / NA	
		3.5.2.3.2.3	Retrieve Temperature	M	Yes / NA	
		3.5.2.3.2.4	Retrieve Daily Minimum and Maximum Temperature	M	Yes / NA	
		3.6.3	Required Number of Temperature Sensors	M	Yes / NA	The ESS shall support at least ____ temperature sensors (1..255).
2.5.2.1.4	Monitor Humidity			O.3 (1..*)	Yes / No / NA	
		3.5.2.3.2.5	Retrieve Humidity	M	Yes / NA	
		3.6.4	Required Number of Humidity Sensors	M	Yes / NA	The ESS shall support at least ____ humidity sensors.
2.5.2.1.5	Monitor Precipitation			O.3 (1..*)	Yes / No / NA	
		3.5.2.3.2.6.1	Retrieve Precipitation Presence	M	Yes / NA	
		3.5.2.3.2.6.2	Retrieve Precipitation Rates	O	Yes / No / NA	
		3.5.2.3.2.6.3	Retrieve Precipitation Totals	O	Yes / No / NA	
		3.5.2.3.5.2	Retrieve Precipitation Situation	M	Yes / NA	
		3.6.5	Required Number of Precipitation Sensors	M	Yes / NA	The ESS shall support at least ____ precipitation sensors.
2.5.2.1.6	Monitor Solar Radiation			O.3 (1..*)	Yes / No / NA	

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
		3.5.2.3.2.7	Retrieve Solar Radiation	M	Yes / NA	
		3.6.6	Required Number of Solar Radiation Sensors	M	Yes / NA	The ESS shall support at least ____ solar radiation sensors.
2.5.2.1.7	Monitor Visibility			O.3 (1..*)	Yes / No / NA	
		3.5.2.3.2.8	Retrieve Visibility	M	Yes / NA	
		3.6.7	Required Number of Visibility Sensors	M	Yes / NA	The ESS shall support at least ____ visibility sensors.
2.5.2.1.8	View Weather Image			O	Yes / No / NA	
		3.5.2.1.9	Configure Snapshot Camera	M	Yes / NA	
		3.5.2.3.8	Retrieve Snapshot	M	Yes / NA	Upon ESS delivery the FTP username shall be _____. Upon ESS delivery, the FTP password shall be _____.
		3.5.2.3.9	Retrieve Snapshot Camera Configuration	M	Yes / NA	
		3.5.2.4.1	Capture Snapshot Image	M	Yes / NA	
		3.5.2.4.2	Delete Snapshot	M	Yes / NA	
		3.5.2.4.3	Copy Snapshot	M	Yes / NA	
		3.6.20	Required Number of Snapshot Cameras	M	Yes / NA	The ESS shall support at least ____ snapshot cameras (1..255).
2.5.2.2 (Pavement)	Monitor Pavement			O.2 (1..*)	Yes / No / NA	
2.5.2.2.1	Monitor Pavement Surface Condition			M	Yes / NA	
		3.5.2.1.6	Configure Pavement Sensor	M	Yes / NA	
		3.5.2.3.3.1	Retrieve Pavement Surface Condition	M	Yes / NA	
		3.5.2.3.3.4	Retrieve Adjacent Snow Depth	O	Yes / No / NA	

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
		3.5.2.3.3.5	Retrieve Roadway Snow Depth	O	Yes / No / NA	
		3.5.2.3.3.6	Retrieve Roadway Ice Thickness	O	Yes / No / NA	
		3.6.8	Required Number of Pavement Sensors	M	Yes / NA	The ESS shall support at least ____ pavement sensors (1..255).
2.5.2.2.2 (Icing)	Monitor Icing Conditions			O	Yes / No / NA	
		3.5.2.1.8	Configure Passive Ice Detection Logic	Passive:M	Yes / NA	
		3.5.2.3.3.2	Retrieve Icing Conditions - Active	Active:M	Yes / NA	
		3.5.2.3.3.3	Retrieve Icing Conditions - Passive	Passive:M	Yes / NA	
		3.6.9 (Active)	Active Pavement Treatment Sensors	Icing:O.5 (1..2)	Yes / No / NA	
		3.6.10 (Passive)	Passive Pavement Treatment Sensors	Icing:O.5 (1..2)	Yes / No / NA	
2.5.2.2.3	View Pavement Image			O	Yes / No / NA	
		3.5.2.1.9	Configure Snapshot Camera	M	Yes / NA	
		3.5.2.3.8	Retrieve Snapshot	M	Yes / NA	Upon ESS delivery the FTP username shall be _____. Upon ESS delivery, the FTP password shall be _____.
		3.5.2.3.9	Retrieve Snapshot Camera Configuration	M	Yes / NA	
		3.5.2.4.1	Capture Snapshot Image	M	Yes / NA	
		3.5.2.4.2	Delete Snapshot	M	Yes / NA	
		3.5.2.4.3	Copy Snapshot	M	Yes / NA	
		3.6.20	Required Number of	M	Yes / NA	The ESS shall support at least ____

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
			Snapshot Cameras			snapshot cameras (1..255).
2.5.2.3 (Subsurface)	Monitor Subsurface Conditions			O.2 (1..*)	Yes / No / NA	
		3.5.2.1.7	Configure Sub-Surface Sensor	Subsurface:M	Yes / NA	
		3.5.2.3.4.1	Retrieve Basic Subsurface Conditions	M	Yes / NA	
		3.5.2.3.4.2	Retrieve Subsurface Moisture	O	Yes / No / NA	
		3.6.11	Required Number of Subsurface Sensors	M	Yes / NA	The ESS shall support at least ____ subsurface sensors (1..255).
2.5.2.4	Monitor Human Readings			O.2 (1..*)	Yes / No / NA	
		3.5.2.3.5.1	Retrieve Wind Situation	M	Yes / NA	
		3.5.2.3.5.2	Retrieve Precipitation Situation	M	Yes / NA	
		3.5.2.3.5.3	Retrieve Cloud Situation	M	Yes / NA	
		3.5.2.3.5.4	Retrieve Visibility Situation	M	Yes / NA	
		3.5.2.3.5.5	Retrieve Ground State	O	Yes / No / NA	
		3.5.2.3.5.6	Retrieve Pavement State	O	Yes / No / NA	
2.5.2.5	Monitor Water Level			O.2 (1..*)	Yes / No / NA	
		3.5.2.3.7	Retrieve Water Level	M	Yes / NA	
2.5.2.6 (Air)	Monitor Air Quality and Bio-hazards			O.2 (1..*)	Yes / No / NA	
		3.5.2.3.6.1 (CO)	Retrieve Carbon Monoxide Reading	O.4 (1..*)	Yes / No / NA	
		3.5.2.3.6.2 (CO2)	Retrieve Carbon Dioxide Reading	O.4 (1..*)	Yes / No / NA	
		3.5.2.3.6.3	Retrieve Nitrous Oxide	O.4 (1..*)	Yes / No /	

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
		(N2O)	Reading		NA	
		3.5.2.3.6.4 (NO2)	Retrieve Nitrogen Dioxide Reading	O.4 (1..*)	Yes / No / NA	
		3.5.2.3.6.5 (SO2)	Retrieve Sulfur Dioxide Reading	O.4 (1..*)	Yes / No / NA	
		3.5.2.3.6.6 (O3)	Retrieve Ozone Reading	O.4 (1..*)	Yes / No / NA	
		3.5.2.3.6.7 (PM10)	Retrieve Small Particulate Matter Reading	O.4 (1..*)	Yes / No / NA	
		3.6.13	Required Number of Carbon Monoxide Sensors	CO:M	Yes / NA	The ESS shall support at least ____ carbon monoxide sensors.
		3.6.14	Required Number of Carbon Dioxide Sensors	CO2:M	Yes / NA	The ESS shall support at least ____ carbon dioxide sensors.
		3.6.15	Required Number of Nitrous Oxide Sensors	N2O:M	Yes / NA	The ESS shall support at least ____ nitrous oxide sensors.
		3.6.16	Required Number of Nitrogen Dioxide Sensors	NO2:M	Yes / NA	The ESS shall support at least ____ nitrogen dioxide sensors.
		3.6.17	Required Number of Sulfur Dioxide Sensors	SO2:M	Yes / NA	The ESS shall support at least ____ sulfur dioxide sensors.
		3.6.18	Required Number of Ozone Sensors	O3:M	Yes / NA	The ESS shall support at least ____ ozone sensors.
		3.6.19	Required Number of Small Particulate Matter Sensors	PM10:M	Yes / NA	The ESS shall support at least ____ small particulate matter sensors.
2.5.2.7	Monitor Mobile Weather Profile			O	Yes / No / NA	
		3.5.2.3.1	Retrieve Weather Profile with Mobile Sources	M	Yes / NA	
		F.2.1.2.1	Retrieve Current Configuration of Logging Service	M	Yes / NA	
		F.2.1.2.2	Configure Logging Service	M	Yes / NA	
		F.2.1.2.3	Retrieve Logged Data	M	Yes / NA	

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
		F.2.1.2.4	Clear Log	M	Yes / NA	
		F.2.1.2.5	Retrieve Capabilities of Event Logging Service	M	Yes / NA	
		F.2.1.2.6	Retrieve Total Number of Logged Events	M	Yes / NA	
2.5.3	Pavement Treatment System Manager Features			O.1 (1..*)	Yes / No / NA	
2.5.3.1	Manage Stationary Spray System			Mobile:X; M	Yes / No / NA	
		3.5.3.1.1	Retrieve Stationary Pavement Treatment Configuration	M	Yes / NA	
		3.5.3.1.2	Configure Stationary Pavement Treatment System	M	Yes / NA	
		3.5.3.2.1	Retrieve Pavement Treatment Status	M	Yes / NA	
		3.5.3.4.1	Set PTS Operational Mode	M	Yes / NA	
		3.5.3.4.2	Manually Activate PTS Sprayer	M	Yes / NA	
		3.6.12	Required Number of Pavement Treatment Products	M	Yes / NA	The ESS shall support at least _____ pavement treatment products (1..255).
2.5.3.2	Manage Mobile Spray System			Mobile: M	Yes / No / NA	
		3.5.3.1.3	Retrieve Mobile Pavement Treatment Configuration	M	Yes / NA	
		3.5.3.1.4	Configure Mobile Pavement Treatment System	O	Yes / No / NA	
F.1.1	Generic Architectural Needs			M	Yes	
F.1.1.1 (ESS)	Provide Live Data			M	Yes	
		F.2.1.1.1	Retrieve Data	M	Yes	

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
		F.2.1.1.2	Deliver Data	M	Yes	
		F.2.1.1.3	Explore Data	M	Yes	
		3.6.21	Response Time for Requests	M	Yes	The Response Time for all requests shall be ____ milliseconds.
F.1.1.2 (Compressed)	Provide Compressed Data			Mobile:M; O	Yes / No	
		3.5.1.1.2	Retrieve Compressed Station Meta-Data	M	Yes	
		3.5.2.3.2.9	Retrieve Compressed Weather Data	Weather:M	Yes / NA	
		3.5.2.3.3.7	Retrieve Compressed Pavement Condition Data	Pavement:M	Yes / NA	
		3.5.2.3.4.3	Retrieve Compressed Subsurface Condition Data	Subsurface:M	Yes / NA	
		3.5.2.3.6.8	Retrieve Compressed Air Quality Data	Air:M	Yes / NA	
		3.6.21	Response Time for Requests	M	Yes	The Response Time for all requests shall be ____ milliseconds.
F.1.1.3	Provide Off-line Log Data			Mobile:M ; O	Yes / No	
		F.2.1.2.1	Retrieve Current Configuration of Logging Service	M	Yes / NA	
		F.2.1.2.2	Configure Logging Service	M	Yes / NA	
		F.2.1.2.3	Retrieve Logged Data	M	Yes / NA	
		F.2.1.2.4	Clear Log	M	Yes / NA	
		F.2.1.2.5	Retrieve Capabilities of Event Logging Service	M	Yes / NA	
		F.2.1.2.6	Retrieve Total Number of Logged Events	M	Yes / NA	
		F.2.2.1.5.1	Set Time	M	Yes / NA	
		F.2.2.1.5.2	Retrieve Current Time	M	Yes / NA	

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
		3.6.21	Response Time for Requests	M	Yes	The Response Time for all requests shall be ____ milliseconds.
		F.2.3.1†	Supplemental Requirements for Event Monitoring	M	Yes / NA	
F.1.2	Generic Features			M	Yes	
F.1.2.1	Retrieve the Device Identity			M	Yes	
		3.5.1.1.1	Retrieve ESS Characteristics	M	Yes	
		3.5.1.1.3	Configure ESS Manager	M	Yes	
		3.5.2.1.1	Retrieve Atmospheric Pressure Height	Pressure:M	Yes / NA	
		3.5.2.1.2	Retrieve Meta-Data for Each Wind Sensor	Wind:M	Yes / NA	
		3.5.2.1.3	Retrieve Temperature Sensor Meta-Data	Temperature:M	Yes / NA	
		3.5.2.1.4	Retrieve Pavement Sensor Meta-Data	Pavement:M	Yes / NA	
		3.5.2.1.5	Retrieve Sub-Surface Sensor Meta-Data	Subsurface:M	Yes / NA	
		F.2.2.1.1	Retrieve Device Component Information	M	Yes	
		F.2.2.1.2	Retrieve Device Configuration Identifier	M	Yes	
		F.2.2.1.3	Retrieve Supported Standards	M	Yes	
		F.2.2.1.4	Retrieve System Name	M	Yes	
F.1.2.2	Control External Devices			O	Yes / No	
		F.2.2.1.6	Retrieve External Port Information	M	Yes / NA	
		F.2.2.1.7	Configure Port Information	M	Yes / NA	
		F.2.2.2.1	Monitor Status of External	M	Yes / NA	

User Need ID	User Need	FR ID	Functional Requirement	Conformance	Project Requirement	Additional Project Requirements
			Device			
		F.2.2.4.1	Control External Device	M	Yes / NA	
		F.2.3.2	Required Number of Auxiliary Ports	M	Yes / NA	The ESS shall support at least ____ binary analog output ports (1..255).

3.3.8 Protocol Requirements List – Supplemental Table

Supplemental Requirement ID	Supplemental Requirement	Conformance	Project Requirement	Additional Project Requirements
F.2.3	Generic Supplemental Requirements			
F.2.3.1	Supplemental Requirements for Event Monitoring	M	Yes / NA	
F.2.3.1.1	Record and Timestamp Events	M	Yes / NA	
F.2.3.1.2	Support a Number of Event Classes	M	Yes / NA	The ESS shall support at least ____ event classes (1..255).
F.2.3.1.3	Support a Number of Event Types to Monitor	M	Yes / NA	The ESS shall support at least ____ event types (1..255).
F.2.3.1.4	Support Monitoring of Event Types	M	Yes / NA	
F.2.3.1.4.1	Support On-Change Events	M	Yes / NA	
F.2.3.1.4.2	Support Greater Than Events	M	Yes / NA	
F.2.3.1.4.3	Support Less Than Events	M	Yes / NA	
F.2.3.1.4.4	Support Hysteresis Events	M	Yes / NA	
F.2.3.1.4.5	Support Periodic Events	M	Yes / NA	
F.2.3.1.4.6	Support Bit-flag Events	M	Yes / NA	
F.2.3.1.5	Support Event Monitoring on Any Data	M	Yes / NA	
F.2.3.1.6	Support a Number of Events to Store in Log	M	Yes / NA	The ESS shall support storing at least ____ events in the log (1..65535).

3.4 ARCHITECTURAL REQUIREMENTS

There are no unique architectural requirements defined for this standard. The architectural needs are fully met through the generic architectural requirements defined in Annex F.

3.5 DATA EXCHANGE REQUIREMENTS

Data exchange requirements for ESS are provided in the following subsections.

3.5.1 ESS Manager Requirements

Requirements for managing an ESS Manager are provided in the following subsections.

3.5.1.1 ESS Configuration Requirements

Requirements for configuring an ESS Manager are provided in the following subsections.

3.5.1.1.1 Retrieve ESS Characteristics

Upon request, the ESS shall return information related to the station type, category, and location.

3.5.1.1.2 Retrieve Compressed Station Meta-Data

Upon request, the ESS shall return the following information about the station:

- a. Station Category
- b. Type of Station
- c. Location of ESS
- d. Location of sensors
- e. Pavement treatment information

3.5.1.1.3 Configure ESS Manager

Upon request, the ESS shall store the textual description of the ESS location, as provided within the request.

3.5.1.2 ESS Status Monitoring Requirements

Requirements for monitoring the status of an ESS Manager are provided in the following subsections.

3.5.1.2.1 Retrieve ESS Door Status

Upon request, the ESS shall return an indication as to whether any doors related to the ESS (e.g., cabinet doors, housing doors, etc.) are open.

3.5.1.2.2 Retrieve Battery Status

Upon request, the ESS shall return the charge status of the battery.

3.5.1.2.3 Retrieve Line Volts

Upon request, the ESS shall return the voltage on the incoming A/C power.

3.5.1.3 ESS Data Retrieval Requirements

Requirements for retrieving data from an ESS Manager are provided in the following subsections.

3.5.1.3.1 Retrieve Mobile ESS Movement

Upon request, the ESS shall return the speed, location, and direction of the mobile platform.

3.5.1.3.2 Retrieve Mobile Treatment Information

Upon request, the ESS shall return the pavement treatment that the mobile platform is dispersing.

3.5.1.3.3 Retrieve Compressed Mobile Station Data

Upon request, the ESS shall return the following information about the station in a compressed form:

- a. Location of ESS
- b. Speed of ESS
- c. Pavement treatment information

3.5.1.4 ESS Control Requirements

There are no control requirements for the ESS Manager.

3.5.2 Sensor Manager Requirements

Requirements for managing a Sensor Manager are provided in the following subsections.

3.5.2.1 Sensor Configuration Requirements

Requirements for configuring a Sensor Manager are provided in the following subsections.

NOTE: A Sensor Manager may also require a user to configure proprietary data during initial set-up.

3.5.2.1.1 Retrieve Atmospheric Pressure Height

Upon request, the ESS shall return the relative height of the atmospheric pressure sensor.

3.5.2.1.2 Retrieve Meta-Data for Each Wind Sensor

Upon request, the ESS shall return the location and relative height of each wind sensor connected to the ESS.

3.5.2.1.3 Retrieve Temperature Sensor Meta-Data

Upon request, the ESS shall return the number of temperature sensors and the relative height of each.

3.5.2.1.4 Retrieve Pavement Sensor Meta-Data

Upon request, the ESS shall return the number of pavement sensors and the following information for each sensor:

- a. A textual description of the location that the sensor is monitoring
- b. The type of pavement the sensor is monitoring
- c. The relative height of the pavement with respect to the station height
- d. An indication of the amount of sunlight to which the monitored pavement is subjected
- e. An indication of the sensor technology used.

3.5.2.1.5 Retrieve Sub-Surface Sensor Meta-Data

Upon request, the ESS shall return the number of subsurface sensors and the following information for each sensor:

- a. A textual description of the location that the sensor is monitoring
- b. The type of subsurface the sensor is monitoring
- c. The depth of the sensor location