MTConnect® Standard

Part 1.0 – Overview and Fundamentals

Version 1.7.0

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1 Overview of MTConnect

MTConnect is a data and information exchange standard that is based on a *data dictionary* of terms describing information associated with manufacturing operations. The standard also defines a series of *semantic data models* that provide a clear and unambiguous representation of how that information relates to a manufacturing operation. The MTConnect Standard has been designed to enhance the data acquisition capabilities from equipment in manufacturing facilities, to expand the use of data driven decision making in manufacturing operations, and to enable software applications and manufacturing equipment to move toward a plug-and-play environment to reduce the cost of integration of manufacturing software systems.

The MTConnect standard supports two primary communications methods – *Request/Response* and *Publish/Subscribe* type of communications. The *Request/Response* communications structure is used throughout this document to describe the functionality provided by MTConnect. See *Section 8.3.6 - Streaming Data* for details describing the functionality of the *Publish/Subscribe* communications structure available from an *Agent*.

Although the MTConnect Standard has been defined to specifically meet the requirements of the manufacturing industry, it can also be readily applied to other application areas as well.

The MTConnect Standard is an open, royalty free standard – meaning that it is available for anyone to download, implement, and utilize in software systems at no cost to the implementer.

The *semantic data models* defined in the MTConnect Standard provide the information required to fully characterize data with both a clear and unambiguous meaning and a mechanism to directly relate that data to the manufacturing operation where the data originated. Without a *semantic data model*, client software applications must apply an additional layer of logic to raw data to convey this same level of meaning and relationship to manufacturing operations. The approach provided in the MTConnect Standard for modeling and organizing data allows software applications to easily interpret data from a wide variety of data sources which reduces the complexity and effort to develop applications.

The data and information from a broad range of manufacturing equipment and systems are addressed by the MTConnect Standard. Where the *data dictionary* and *semantic data models* are insufficient to define some information within an implementation, an implementer may extend the *data dictionary* and *semantic data models* to address their specific requirements. See *Section 6.7 - Extensibility* for guidelines related to extensibility of the MTConnect Standard.

To assist in implementation, the MTConnect Standard is built upon the most prevalent standards in the manufacturing and software industries. This maximizes the number of software tools available for implementation and provides the highest level of interoperability with other standards, software applications, and equipment used throughout manufacturing operations.

Current MTConnect implementations are based on HTTP as a transport protocol and XML as a language for encoding each of the *semantic data models* into electronic documents. All software examples provided in the various MTConnect Standard documents are based on these two core technologies.

The base functionality defined in the MTConnect Standard is the *data dictionary* describing manufacturing information and the *semantic data models*. The transport protocol and the programming language used to represent or transfer the information provided by the *semantic data models* are not restricted in the standard to HTTP and XML. Therefore, other protocols and programming languages may be used to represent the semantic models and/or transport the information provided by these data models between an *Agent* (server) and a client software application as may be required by a specific implementation.

Note: The term "document" is used with different meanings in the MTConnect Standard:

- Meaning 1: The MTConnect Standard itself is comprised of multiple documents each addressing different aspects of the Standard. Each document is referred to as a Part of the Standard.

- Meaning 2: In an MTConnect implementation, the electronic documents that are published from a data source and stored by an *Agent*.

- Meaning 3: In an MTConnect implementation, the electronic documents generated by an *Agent* for transmission to a client software application.

The following will be used throughout the MTConnect Standard to distinguish between these different meanings for the term "document":

- MTConnect Document(s) or Document(s) shall be used to refer to printed or electronic document(s) that represent a Part(s) of the MTConnect Standard.

- All reference to electronic documents that are received from a data source and stored in an *Agent* shall be referred to as "*Document*(s)" and are typically provided with a prefix identifier; e.g. *Asset Document*.

- All references to electronic documents generated by an *Agent* and sent to a client software application shall be referred to as a "*Response Document*".

When used with no additional descriptor, the form "document" shall be used to refer to any printed or electronic document.

Manufacturing software systems implemented utilizing MTConnect can be represented by a very simple structure as shown in *Figure 1* .

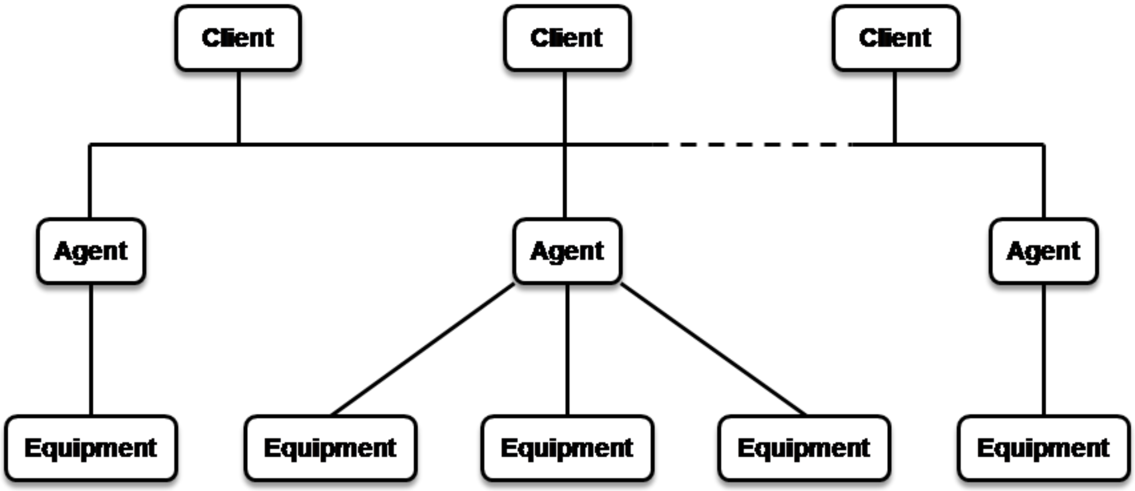


Figure 1: Basic MTConnect Implementation Structure

The three basic modules that comprise a software system implemented using MTConnect are:

Equipment: Any data source. In the MTConnect Standard, equipment is defined as any tangible property that is used to equip the operations of a manufacturing facility. Examples of equipment are machine tools, ovens, sensor units, workstations, software applications, and bar feeders.

Agent: Software that collects data published from one or more piece(s) of equipment, organizes that data in a structured manner, and responds to requests for data from client software systems by providing a structured response in the form of a *Response Document* that is constructed using the *semantic data models* defined in the Standard.

Note: The *Agent* may be fully integrated into the piece of equipment or the *Agent* may be independent of the piece of equipment. Implementation of an *Agent* is the responsibility of the supplier of the piece of equipment and/or the implementer of the *Agent*.

Client Software Application: Software that requests data from *Agents* and processes that data in support of manufacturing operations.

Based on *Figure 1* , it is important to understand that the MTConnect Standard only addresses the following functionality and behavior of an *Agent*:

- the method used by a client software application to request information from an *Agent*.
- the response that an *Agent* provides to a client software application.
- a *data dictionary* used to provide consistency in understanding the meaning of data reported by a data source.
- the description of the *semantic data models* used to structure *Response Documents* provided by an *Agent* to a client software application.

These functions are the primary building blocks that define the *Base Functional Structure* of the MTConnect Standard.

There are a wide variety of data sources (equipment) and data consumption systems (client software systems) used in manufacturing operations. There are also many different uses for the data associated with a manufacturing operation. No single approach to implementing a data communication system can address all data exchange and data management functions typically required in the data driven manufacturing environment. MTConnect has been uniquely designed to address this diversity of data types and data usages by providing different *semantic data models* for different data application requirements:

Data Collection: The most common use of data in manufacturing is the collection of data associated with the production of products and the operation of equipment that produces those products. The MTConnect Standard provides comprehensive *semantic data models* that represent data collected from manufacturing operations. These *semantic data models* are detailed in *MTConnect Standard: Part 2.0 - Devices Information Model* and *MTConnect Standard: Part 3.0 - Streams Information Model* of the MTConnect Standard.

Inter-operations Between Pieces of Equipment: The MTConnect Standard provides an *Interaction Model* that structures the information required to allow multiple pieces of equipment to coordinate actions required to implement manufacturing activities. This *Interaction Model* is an implementation of a *Request/Response* messaging structure. This *Interaction Model* is called `Interfaces` which is detailed in *MTConnect Standard: Part 5.0 - Interfaces* of the MTConnect Standard.

Shared Data: Certain information used in a manufacturing operation is commonly shared amongst multiple pieces of equipment and/or software applications. This information is not typically "owned" by any one manufacturing resource. The MTConnect

Standard represents this information through a series of *semantic data models* – each describing different types of information used in the manufacturing environment. Each type of information is called an *MTConnect Asset*. *MTConnect Assets* are detailed in *MTConnect Standard: Part 4.0 - Assets Information Model*, and its sub-Parts, of the MTConnect Standard.

2 Purpose of This Document

This document, *MTConnect Standard Part 1.0 - Overview and Fundamentals* of the *MTConnect* Standard, addresses two major topics relating to the MTConnect Standard. The first sections of the document define the organization of the documents used to describe the MTConnect Standard; including the terms and terminology used throughout the Standard. The balance of the document defines the following:

- Operational concepts describing how an *Agent* should organize and structure data that has been collected from a data source.
- Definition and structure of the *Response Documents* supplied by an *Agent*.
- The protocol used by a client software application to communicate with an *Agent*.

3 Terminology and Conventions

3.1 Glossary

CDATA

General meaning:

An abbreviation for Character Data.

CDATA is used to describe a value (text or data) published as part of an XML element.

For example, `"This is some text"` is the CDATA in the XML element:

```
<Message ...>This is some text</Message>
```

Appears in the documents in the following form: CDATA

HTTP

Hyper-Text Transport Protocol. The protocol used by all web browsers and web applications.

Note: HTTP is an IETF standard and is defined in RFC 7230.
See https://tools.ietf.org/html/rfc7230 for more information.

NMTOKEN

The data type for XML identifiers.

Note: The identifier must start with a letter, an underscore "_" or a colon. The next character must be a letter, a number, or one of the following ".", "-", "_", ":". The identifier must not have any spaces or special characters.

Appears in the documents in the following form: NMTOKEN.

REST

Stands for REpresentational State Transfer: A software architecture where a client software application and server move through a series of state transitions based solely on the request from the client and the response from the server.

Appears in the documents in the following form: REST.

URI

Stands for Universal Resource Identifier.

See http://www.w3.org/TR/uri-clarification/#RFC3986

URL

Stands for Uniform Resource Locator.

See http://www.w3.org/TR/uri-clarification/#RFC3986

URN

Stands for Uniform Resource Name.

See http://www.w3.org/TR/uri-clarification/#RFC3986

UTC/GMT

Stands for Coordinated Universal Time/Greenwich Mean Time.

UTC/GMT is the primary time standard by which the world regulates clocks and time.

The time stamp for all information reported in an *MTConnect Response Document* is provided in UTC/GMT format.

UUID

General meaning:

Stands for Universally Unique Identifier. (Can also be referred to as a GUID in some literature Globally Unique Identifier).

Note: Defined in RFC 4122 of the IETF. See https://www.ietf.org/rfc/rfc4122.txt for more information.

Appears in the documents in the following form: UUID.

Used as an attribute for an XML element:

Used as an attribute that provides a unique identity for a piece of information reported by an *Agent*.

Appears in the documents in the following form: `uuid`.

W3C

The World Wide Web Consortium (W3C) is an international community that develops open standards to ensure the long-term growth of the Web.

See *https://www.w3.org/*.

XML

Stands for eXtensible Markup Language.

XML defines a set of rules for encoding documents that both a human-readable and machine-readable.

XML is the language used for all code examples in the MTConnect Standard.

Refer to http://www.w3.org/XML for more information about XML.

XPath

General meaning:

XPath is a command structure that describes a way for a software system to locate information in an XML document.

XPath uses an addressing syntax based on a path through the document's logical structure.

See http://www.w3.org/TR/xpath for more information on XPath.

Appears in the documents in the following form: XPath.

Abstract Element

An element that defines a set of common characteristics that are shared by a group of elements.

An abstract element cannot appear in a document. In a specific implementation of a schema, an abstract element is replaced by a derived element that is itself not an abstract element. The characteristics for the derived element are inherited from the abstract element.

Appears in the documents in the following form: abstract.

Adapter

An optional piece of hardware or software that transforms information provided by a piece of equipment into a form that can be received by an *Agent*.

Appears in the documents in the following form: adapter.

Agent

Refers to an MTConnect Agent.

Software that collects data published from one or more piece(s) of equipment, organizes that data in a structured manner, and responds to requests for data from client software systems by providing a structured response in the form of a *Response Document* that is constructed using the *semantic data models* defined in the Standard.

Appears in the documents in the following form: *Agent*.

alarm limits

A set of limits used to trigger warning or alarm indicators.

Application Programming Interface

A set of methods to provide communications between software applications.

The API defined in the MTConnect Standard describes the methods for providing the *Request/Response* Information Exchange between an *Agent* and client software applications.

Appears in the documents in the following forms: Application Programming Interface or API.

Archetype

General Description of an *MTConnect Asset*:

Archetype is a class of *MTConnect Assets* that provides the requirements, constraints, and common properties for a type of *MTConnect Asset*.

Appears in the documents in the following form: Archetype.

Used as an XML term describing an *MTConnect Asset*:

In an XML representation of the *Asset Information Models*, `Archetype` is an abstract element that is replaced by a specific type of *Asset* Archetype.

Appears in the documents in the following form: `Archetype`

Asset

item, thing or entity that has potential or actual value to an organization *Ref:ISO 55000:2014(en)*

Note 1 to entry: Value can be tangible or intangible, financial or non-financial, and includes consideration of risks and liabilities. It can be positive or negative at different stages of the asset life.

Note 2 to entry: Physical assets usually refer to equipment, inventory and properties owned by the organization. Physical assets are the opposite of intangible assets, which are non-physical assets such as leases, brands, digital assets, use rights, licences, intellectual property rights, reputation or agreements.

Note 3 to entry: A grouping of assets referred to as an asset system could also be considered as an asset.

Asset Document

An electronic document published by an *Agent* in response to a *Request* for information from a client software application relating to Assets.

Attachment

The connection by which one thing is associated with another.

Attribute

A term that is used to provide additional information or properties for an element.

Appears in the documents in the following form: attribute.

Base Functional Structure

A consistent set of functionalities defined by the MTConnect Standard. This functionality includes the protocol(s) used to communicate data to a client software application, the *semantic data models* defining how that data is organized into *Response Documents*, and the encoding of those *Response Documents*.

Appears in the documents in the following form: *Base Functional Structure*.

buffer

General meaning:

A section of an *Agent* that provides storage for information published from pieces of equipment.

Used relative to *Streaming Data*:

A section of an *Agent* that provides storage for information relating to individual pieces of *Streaming Data*.

Appears in the documents in the following form: *buffer*.

Used relative to *MTConnect Assets*:

A section of an *Agent* that provides storage for *Asset Documents*.

Appears in the documents in the following form: *assets buffer*.

Child Element

A portion of a data modeling structure that illustrates the relationship between an element and the higher-level *Parent Element* within which it is contained.

Appears in the documents in the following form: *Child Element*.

Client

A process or set of processes that send *Requests* for information to an *Agent*; e.g. software applications or a function that implements the *Request* portion of an *Interface Interaction Model*.

Appears in the documents in the following form: client.

Component

General meaning:

A *Structural Element* that represents a physical or logical part or subpart of a piece of equipment.

Appears in the documents in the following form: *Component*.

Used in *Information Models*:

A data modeling element used to organize the data being retrieved from a piece of equipment.

- When used as an XML container to organize *Lower Level* `Component` elements.

  Appears in the documents in the following form: `Components`.

- When used as an abstract XML element. `Component` is replaced in a data model by a type of *Component* element. `Component` is also an XML container used to organize *Lower Level* `Component` elements, *Data Entities*, or both.

  Appears in the documents in the following form: `Component`.

Composition

General meaning:

Data modeling elements that describe the lowest level basic structural or functional building blocks contained within a `Component` element.

Appears in the documents in the following form: *Composition*

Used in *Information Models*:

A data modeling element used to organize the data being retrieved from a piece of equipment.

- When used as an XML container to organize `Composition` elements.

  Appears in the documents in the following form: `Compositions`

- When used as an abstract XML element. `Composition` is replaced in a data model by a type of *Composition* element.

  Appears in the documents in the following form: `Composition`.

Condition

An indicator of the ability of a piece of equipment or *Component* to function to specification.

control limits

A set of limits used to indicate whether a process variable is stable and in control.

Controlled Vocabulary

A restricted set of values that may be published as the *Valid Data Value* for a *Data Entity*.

Appears in the documents in the following form: *Controlled Vocabulary*.

current

occurring in or existing at the present time.

Current Request

A *Current Request* is a *Request* to an *Agent* to produce an *MTConnectStreams Response Document* containing the *Observations Information Model* for a snapshot of the latest *observations* at the moment of the *Request* or at a given *sequence number*.

data dictionary

Listing of standardized terms and definitions used in *MTConnect Information Models*.

Appears in the documents in the following form: *data dictionary*.

Data Entity

A primary data modeling element that represents all elements that either describe data items that may be reported by an *Agent* or the data items that contain the actual data published by an *Agent*.

Appears in the documents in the following form: *Data Entity*.

Data Item

General meaning:

Descriptive information or properties and characteristics associated with a *Data Entity*.

Appears in the documents in the following form: data item.

Used in an XML representation of a *Data Entity*:

- When used as an XML container to organize `DataItem` elements.
  Appears in the documents in the following form: `DataItems`.
- When used to represent a specific *Data Entity*, the form `DataItem` is an XML element.
  Appears in the documents in the following form: `DataItem`.

Data Set

A set of *key-value pairs* where each entry is uniquely identified by the *key*.

Data Source

Any piece of equipment that can produce data that is published to an *Agent*.

Appears in the documents in the following form: data source.

Data Streaming

A method for an *Agent* to provide a continuous stream of information in response to a single *Request* from a client software application.

Appears in the documents in the following form: *Data Streaming*.

Deprecated

An indication that specific content in an *MTConnect Document* is currently usable but is regarded as being obsolete or superseded. It is recommended that deprecated content should be avoided.

Appears in the documents in the following form: **DEPRECATED** .

Deprecation Warning

An indicator that specific content in an *MTConnect Document* may be changed to **DEPRECATED** in a future release of the standard.

Appears in the documents in the following form: **DEPRECATION WARNING** .

Devices Information Model

A set of rules and terms that describes the physical and logical configuration for a piece of equipment and the data that may be reported by that equipment.

Appears in the documents in the following form: *Devices Information Model*.

Document

A piece of written, printed, or electronic matter that provides information or evidence that serves as an official record.

Document Body

The portion of the content of an *MTConnect Response Document* that is defined by the relative *MTConnect Information Model*. The *Document Body* contains the *Structural Elements* and *Data Entities* reported in a *Response Document*.

Appears in the documents in the following form: *Document Body*.

Document Header

The portion of the content of an *MTConnect Response Document* that provides information from an *Agent* defining version information, storage capacity, protocol, and other information associated with the management of the data stored in or retrieved from the *Agent*.

Appears in the documents in the following form: *Document Header*.

electric current

The rate of flow of electric charge.

Element

Refers to an XML element.

An XML element is a logical portion of an XML document or schema that begins with a `start-tag` and ends with a corresponding `end-tag`.

The information provided between the `start-tag` and `end-tag` may contain attributes, other elements (sub-elements), and/or CDATA.

Note: Also, an XML element may consist of an `empty-element tag`. Refer to *Appendix B* for more information on element tags.

Appears in the documents in the following form: element.

Element Name

A descriptive identifier contained in both the `start-tag` and `end-tag` of an XML element that provides the name of the element.

Appears in the documents in the following form: element name.

Used to describe the name for a specific XML element:

Reference to the name provided in the `start-tag`, `end-tag`, or `empty-element tag` for an XML element.

Appears in the documents in the following form: *Element Name*.

engineering units

A quantity, dimension, or magnitude used in engineering adopted as a standard in terms of which the magnitude of other quantities of the same kind can be expressed or calculated.

Equipment

Represents anything that can publish information and is used in the operations of a manufacturing facility shop floor. Examples of equipment are machine tools, ovens, sensor units, workstations, software applications, and bar feeders.

Appears in the documents in the following form: equipment or piece of equipment.

Equipment Metadata

See *Metadata*

Error Information Model

The rules and terminology that describes the *Response Document* returned by an *Agent* when it encounters an error while interpreting a *Request* for information from a client software application or when an *Agent* experiences an error while publishing the *Response* to a *Request* for information.

Appears in the documents in the following form: *Error Information Model*.

Extensible

The ability for an implementer to extend *MTConnect Information Models* by adding content not currently addressed in the MTConnect Standard.

Fault State

In the MTConnect Standard, a term that indicates the reported status of a *Condition* category *Data Entity*.

Appears in the documents in the following form: *Fault State*.

Force

A push or pull on a mass which results in an acceleration.

heartbeat

General meaning:

A function that indicates to a client application that the communications connection to an *Agent* is still viable during times when there is no new data available to report often referred to as a "keep alive" message.

Appears in the documents in the following form: *heartbeat*.

When used as part of an *HTTP Request*:

The form `heartbeat` is used as a parameter in the query portion of an *HTTP Request Line*.

Appears in the documents in the following form: `heartbeat`.

Higher Level

A nested element that is above a lower level element.

HTTP Error Message

In the MTConnect Standard, a response provided by an *Agent* indicating that an *HTTP Request* is incorrectly formatted or identifies that the requested data is not available from the *Agent*.

Appears in the documents in the following form: *HTTP Error Message*.

HTTP Header

In the MTConnect Standard, the content of the *Header* portion of either an *HTTP Request* from a client software application or an *HTTP Response* from an *Agent*.

Appears in the documents in the following form: *HTTP Header*.

HTTP Message

An *HTTP Message* consists of requests from client to server and responses from server to client. *Ref:IETF:RFC-2616*

HTTP Method

In the MTConnect Standard, a portion of a command in an *HTTP Request* that indicates the desired action to be performed on the identified resource; often referred to as verbs.

HTTP Request

In the MTConnect Standard, a communications command issued by a client software application to an *Agent* requesting information defined in the *HTTP Request Line*.

Appears in the documents in the following form: *HTTP Request*.

HTTP Request Line

In the MTConnect Standard, the first line of an *HTTP Request* describing a specific *Response Document* to be published by an *Agent*.

Appears in the documents in the following form: *HTTP Request Line*.

HTTP Response

In the MTConnect Standard, the information published from an *Agent* in reply to an *HTTP Request*. An *HTTP Response* may be either a *Response Document* or an *HTTP Error Message*.

Appears in the documents in the following form: *HTTP Response*.

HTTP Server

In the MTConnect Standard, a software program that accepts *HTTP Requests* from client software applications and publishes *HTTP Responses* as a reply to those *Requests*.

Appears in the documents in the following form: *HTTP Server*.

HTTP Status Code

In the MTConnect Standard, a numeric code contained in an *HTTP Response* that defines a status category associated with the *Response* either as a success status or a category of an HTTP error.

Appears in the documents in the following form: *HTTP Status Code*.

id

General meaning:

An identifier used to distinguish a piece of information.

Appears in the documents in the following form: id.

Used as an XML attribute:

When used as an attribute for an XML element - *Structural Element*, *Data Entity*, or *Asset*. `id` provides a unique identity for the element within an XML document.

Appears in the documents in the following form: `id`.

Implementation

A specific instantiation of the MTConnect Standard.

Information Model

The rules, relationships, and terminology that are used to define how information is structured.

For example, an information model is used to define the structure for each *MTConnect Response Document*; the definition of each piece of information within those documents and the relationship between pieces of information.

Appears in the documents in the following form: *Information Model*.

instance

Describes a set of *Streaming Data* in an *Agent*. Each time an *Agent* is restarted with an empty *buffer*, data placed in the *buffer* represents a new *instance* of the *Agent*.

Appears in the documents in the following form: *instance*.

Interaction Model

Defines how information is exchanged across an *Interface* between independent systems.

Interface

The means by which communication is achieved between independent systems.

key

A unique identifier in a *key-value pair* association.

key-value pair

An association between an identifier referred to as the *key* and a value which taken together create a *key-value pair*. When used in a set of *key-value pairs* each *key* is unique and will only have one value associated with it at any point in time.

Lower Level

A nested element that is below a higher level element.

lower limit

The lower conformance boundary for a variable.

Note: immediate concern or action may be required.

lower warning

The lower boundary indicating increased concern and supervision may be required.

maximum

A numeric upper constraint.

Message

A communication in writing, in speech, or by signals.

Metadata

Data that provides information about other data.

For example, *Equipment Metadata* defines both the *Structural Elements* that represent the physical and logical parts and sub-parts of each piece of equipment, the relationships between those parts and sub-parts, and the definitions of the *Data Entities* associated with that piece of equipment.

Appears in the documents in the following form: *Metadata* or *Equipment Metadata*.

minimum

A numeric lower constraint.

MTConnect Agent

See definition for *Agent*.

MTConnect Asset

An *MTConnect Asset* is an *Asset* used by the manufacturing process to perform tasks.

Note 1 to entry: An *MTConnect Asset* relies upon an *MTConnect Device* to provide *observations* and information about itself and the *MTConnect Device* revises the information to reflect changes to the *MTConnect Asset* during their interaction. Examples of *MTConnect Assets* are Cutting Tools, Part Information, Manufacturing Processes, Fixtures, and Files.

Note 2 to entry: A singular `assetId` uniquely identifies an *MTConnect Asset* throughout its lifecycle and is used to track and relate the *MTConnect Asset* to other *MTConnect Devices* and entities.

Note 3 to entry: *MTConnect Assets* are temporally associated with a device and can be removed from the device without damage or alteration to its primary functions.

MTConnect Device

An *MTConnect Device* is a piece of equipment or a manufacturing system that produces *observations* about itself and/or publishes data using the *MTConnect Information Model*.

MTConnect Document

Printed or electronic document(s) that represent a Part(s) of the MTConnect Standard.

MTConnect Event

An *MTConnect Event* is an *observation* of either a state or discrete value of the *Component*. *Component* states **SHOULD** have a controlled vocabulary.

MTConnect Information Model

See *Information Model*

MTConnect Interface

An *Interaction Model* for interoperability between pieces of equipment.

MTConnect Request

A communication request for information issued from a client software application to an *Agent*.

Appears in the documents in the following form: *MTConnect Request*.

MTConnect XML Document

See *Response Document*.

MTConnectAssets Response Document

A *Response Document* published by an *MTConnect Agent* in response to an *Asset Request*.

MTConnectDevices Response Document

A *Response Document* published by an *MTConnect Agent* in response to a *Probe Request*.

MTConnectErrors Response Document

An electronic document published by an *Agent* whenever it encounters an error while interpreting a *Request* for information from a client software application or when an *Agent* experiences an error while publishing the *Response* to a *Request* for information.

Appears in the documents in the following form: *MTConnectErrors Response Document*.

MTConnectStreams Response Document

A *Response Document* published by an *MTConnect Agent* in response to a *Current Request* or a *Sample Request*.

nominal

The ideal or desired value for a variable.

observable

A quality, property, or characteristic that can be observed.

observation

The observed value of a property at a point in time.

Observations Information Model

An *Information Model* that describes the *Streaming Data* reported by a piece of equipment.

observe

The act of measuring or determining the value of a property at a point in time.

organize

The act of containing and owning one or more elements.

organizer

An element that contains and owns one or more elements.

parameter

General Meaning:

A variable that must be given a value during the execution of a program or a communications command.

When used as part of an *HTTP Request*:

Represents the content (keys and associated values) provided in the *Query* portion of an *HTTP Request Line* that identifies specific information to be returned in a *Response Document*.

Appears in the documents in the following form: parameter.

Parent Element

An XML element used to organize *Lower Level* child elements that share a common relationship to the *Parent Element*.

Appears in the documents in the following form: *Parent Element*.

Part

Part is defined as a discrete item that has both defined and measurable physical characteristics including mass, material and features and is created by applying one or more manufacturing process steps to a workpiece.

Persistence

A method for retaining or restoring information.

Probe

An instrument commonly used for measuring the physical geometrical characteristics of an object.

Probe Request

A *Probe Request* is a *Request* to an *Agent* to produce an *MTConnectDevices Response Document* containing the *Devices Information Model*.

Protocol

A set of rules that allow two or more entities to transmit information from one to the other.

Publish/Subscribe

In the MTConnect Standard, a communications messaging pattern that may be used to publish *Streaming Data* from an *Agent*. When a *Publish/Subscribe* communication method is established between a client software application and an *Agent*, the *Agent* will repeatedly publish a specific `MTConnectStreams` document at a defined period.

Appears in the documents in the following form: *Publish/Subscribe*.

Query

General Meaning:

A portion of a request for information that more precisely defines the specific information to be published in response to the request.

Appears in the documents in the following form: *Query*.

Used in an *HTTP Request Line*:

The form `query` includes a string of parameters that define filters used to refine the content of a *Response Document* published in response to an *HTTP Request*.

Appears in the documents in the following form: `query`.

Reference

Reference is a pointer to information that is associated with another *Structural Element*.

Request

A communications method where a client software application transmits a message to an *Agent*. That message instructs the *Agent* to respond with specific information.

Appears in the documents in the following form: *Request*.

Request/Response

A communications pattern that supports the transfer of information between an *Agent* and a client software application. In a *Request/Response* information exchange, a client software application requests specific information from an *Agent*. An *Agent* responds to the *Request* by publishing a *Response Document*.

Appears in the documents in the following form: *Request/Response*.

Requester

An entity that initiates a *Request* for information in a communications exchange.

Appears in the documents in the following form: *Requester*.

reset

A reset is associated with an occurrence of a *Data Entity* indicated by the `resetTriggered` attribute. When a reset occurs, the accumulated value or statistic are reverted back to their initial value. A *Data Entity* with a *Data Set* representation removes all *key-value pairs*, setting the *Data Set* to an empty set.

Responder

An entity that responds to a *Request* for information in a communications exchange.

Appears in the documents in the following form: *Responder*.

Response Document

An electronic document published by an *MTConnect Agent* in response to a *Probe Request*, *Current Request*, *Sample Request* or *Asset Request*.

Root Element

The first *Structural Element* provided in a *Response Document* encoded using XML. The *Root Element* is an XML container and is the *Parent Element* for all other XML elements in the document. The *Root Element* appears immediately following the XML Declaration.

Appears in the documents in the following form: *Root Element*.

Sample

General meaning:

The collection of one or more pieces of information.

Used when referring to the collection of information:

When referring to the collection of a piece of information from a data source.

Appears in the documents in the following form: sample.

Used as an *MTConnect Request*:

When representing a specific type of communications request between a client software application and an *Agent* regarding *Streaming Data*.

Appears in the documents in the following form: *Sample Request*.

Used as part of an *HTTP Request*:

Used in the `path` portion of an *HTTP Request Line*, by a client software application, to initiate a *Sample Request* to an *Agent* to publish an `MTConnectStreams` document.

Appears in the documents in the following form: `sample`.

Used to describe a *Data Entity*:

Used to define a specific type of *Data Entity*. A *Sample* type *Data Entity* reports the value for a continuously variable or analog piece of information.

Appears in the documents in the following form: *Sample* or *Samples*.

Used as an XML container or element:

- When used as an XML container that consists of one or more types of Sample XML elements.

  Appears in the documents in the following form: `Samples`.

- When used as an abstract XML element. It is replaced in the XML document by types of `Sample` elements representing individual *Sample* type of *Data Entity*.

  Appears in the documents in the following form: `Sample`.

Sample Request

A *Sample Request* is a *Request* to an *Agent* to produce an *MTConnectStreams Response Document* containing the *Observations Information Model* for a set of timestamped *observations* made by *Components*.

schema

General meaning:

The definition of the structure, rules, and vocabularies used to define the information published in an electronic document.

Appears in the documents in the following form: schema.

Used in association with an *MTConnect Response Document*:

Identifies a specific schema defined for an *MTConnect Response Document*.

Appears in the documents in the following form: *schema*.

semantic data model

A methodology for defining the structure and meaning for data in a specific logical way.

It provides the rules for encoding electronic information such that it can be interpreted by a software system.

Appears in the documents in the following form: *semantic data model*.

sensing element

A mechanism that provides a signal or measured value.

Sensor

A *sensing element* that responds to a physical stimulus and transmits a resulting signal.

Sensor Configuration

Data in the *MTConnectDevices Response Document* that provides the information required for maintenance and support of the *sensor unit*.

Sensor Data

The value of a physical quantity reported by a measuring instrument or controller as an *observation*.

sensor element

A *sensor element* provides a signal or measured value.

sensor unit

An intelligent piece of equipment that manages the signals of one or more *sensing elements* and provides the measured values.

sequence number

The primary key identifier used to manage and locate a specific piece of *Streaming Data* in an *Agent*.

sequence number is a monotonically increasing number within an instance of an *Agent*.

Appears in the documents in the following form: *sequence number*.

specification limits

A set of limits defining a range of values designating acceptable performance for a variable.

Spindle

A mechanism that provides rotational capabilities to a piece of equipment.

Typically used for either work holding, materials or cutting tools.

Standard

General meaning:

A document established by consensus that provides rules, guidelines, or characteristics for activities or their results (as defined in ISO/IEC Guide 2:2004).

Used when referring to the MTConnect Standard:

The MTConnect Standard is a standard that provides the definition and semantic data structure for information published by pieces of equipment.

Appears in the documents in the following form: Standard or MTConnect Standard.

Streaming Data

The values published by a piece of equipment for the *Data Entities* defined by the *Equipment Metadata*.

Appears in the documents in the following form: *Streaming Data*.

Streams Information Model

The rules and terminology (*semantic data model*) that describes the *Streaming Data* returned by an *Agent* from a piece of equipment in response to a *Sample Request* or a *Current Request*.

Appears in the documents in the following form: *Streams Information Model*.

Structural Element

General meaning:

An XML element that organizes information that represents the physical and logical parts and sub-parts of a piece of equipment.

Appears in the documents in the following form: *Structural Element*.

Used to indicate hierarchy of Components:

When used to describe a primary physical or logical construct within a piece of equipment.

Appears in the documents in the following form: *Top Level Structural Element*.

When used to indicate a *Child Element* which provides additional detail describing the physical or logical structure of a *Top Level Structural Element*.

Appears in the documents in the following form: *Lower Level Structural Element*.

subtype

General meaning:

A secondary or subordinate type of categorization or classification of information.

In software and data modeling, a subtype is a type of data that is related to another higher-level type of data.

Appears in the documents in the following form: subtype.

Used as an attribute for a *Data Entity*:

Used as an attribute that provides a sub-categorization for the `type` attribute for a piece of information.

Appears in the documents in the following form: `subType`.

Table

A two dimensional set of values given by a set of *key-value pairs Table Entries*. Each *Table Entry* contains a set of *key-value pairs* of *Table Cells*. The `Entry` and `Cell` elements comprise a tabular representation of the information.

Table Cell

A subdivision of a *Table Entry* representing a singular value.

Table Entry

A subdivision of a *Table* containing a set of *key-value pairs* representing *Table Cells*.

time stamp

General meaning:

The best available estimate of the time that the value(s) for published or recorded information was measured or determined.

Appears in the documents as "time stamp".

Used as an attribute for recorded or published data:

An attribute that identifies the time associated with a *Data Entity* as stored in an *Agent*.

Appears in the documents in the following form: `timestamp`.

Top Level

Structural Elements that represent the most significant physical or logical functions of a piece of equipment.

type

General meaning:

A classification or categorization of information.

In software and data modeling, a type is a grouping function to identify pieces of information that share common characteristics.

Appears in the documents in the following form: type.

Used as an attribute for a *Data Entity*:

Used as an attribute that provides a categorization for piece of information that share common characteristics.

Appears in the documents in the following form: `type`.

upper limit

The upper conformance boundary for a variable.

Note: immediate concern or action may be required.

upper warning

The upper boundary indicating increased concern and supervision may be required.

Valid Data Value

One or more acceptable values or constrained values that can be reported for a *Data Entity*.

Appears in the documents in the following form: *Valid Data Value*(s).

WARNING

General Meaning:

A statement or action that indicates a possible danger, problem, or other unexpected situation.

Used relative to changes in an *MTConnect Document*:

Used to indicate that specific content in an *MTConnect Document* may be changed in a future release of the standard.

Appears in the documents in the following form: **WARNING** .

Used as a *Valid Data Value* for a *Condition*:

Used as a *Valid Data Value* for a *Condition* type *Data Entity*.

Appears in the documents in the following form: `WARNING`.

Used as an *Element Name* for a *Data Entity*:

Used as the *Element Name* for a *Condition* type *Data Entity* in an *MTConnect-Streams Response Document*.

Appears in the documents in the following form: `Warning`.

XML Container

In the MTConnect Standard, a type of XML element.

An XML container is used to organize other XML elements that are logically related to each other. A container may have either *Data Entities* or other *Structural Elements* as *Child Elements*.

XML Document

An XML document is a structured text file encoded using XML.

An XML document is an instantiation of an XML schema. It has a single root XML element, conforms to the XML specification, and is structured based upon a specific schema.

MTConnect Response Documents may be encoded as an XML document.

XML Schema

In the MTConnect Standard, an instantiation of a schema defining a specific document encoded in XML.

3.2 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.7.0.

[MTConnect Part 2.0] *MTConnect Standard: Part 2.0 - Devices Information Model*. Version 1.7.0.

[MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Streams Information Model*. Version 1.7.0.

[MTConnect Part 4.0] *MTConnect Standard: Part 4.0 - Assets Information Model*. Version 1.7.0.

[MTConnect Part 5.0] *MTConnect Standard: Part 5.0 - Interfaces*. Version 1.7.0.

4 MTConnect Standard

The MTConnect Standard is organized in a series of documents (also referred to as MTConnect Documents) that each address a specific set of requirements defined by the Standard. Each MTConnect Document will be referred to as a Part of the Standard; e.g., *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Together, these documents describe the *Base Functional Structure* specified in the MTConnect Standard.

Implementation of any manufacturing data management system may utilize information from any number of these documents. However, it is not necessary to realize all information contained in these documents for any one specific implementation.

4.1 MTConnect Documents Organization

The MTConnect specification is organized into the following documents:

MTConnect Standard Part 1.0 - Overview and Fundamentals: Provides an overview of the MTConnect Standard and defines the terminology and structure used throughout all documents associated with the Standard. Additionally, [MTConnect Part 1.0] describes the functions provided by an *Agent* and the protocol used to communicate with an *Agent*.

MTConnect Standard: Part 2.0 - Devices Information Model: Defines the *semantic data model* that describes the data that can be supplied by a piece of equipment. This model details the XML elements used to describe the structural and logical configuration for a piece of equipment. It also describes each type of data that may be supplied by a piece of equipment in a manufacturing operation.

MTConnect Standard: Part 3.0 - Streams Information Model: Defines the *semantic data model* that organizes the data that is collected from a piece of equipment and transferred to a client software application from an *Agent*.

MTConnect Standard: Part 4.0 - Assets Information Model: Provides an overview of *MTConnect Assets* and the functions provided by an *Agent* to communicate information relating to *Assets*. The various *semantic data models* describing each type of *MTConnect Asset* are defined in sub-Part documents (Part 4.x) of the MTConnect Standard.

MTConnect Standard: Part 5.0 - Interfaces: Defines the MTConnect implementation of the *Interaction Model* used to coordinate actions between pieces of equipment used in manufacturing systems.

4.2 MTConnect Document Versioning

The MTConnect Standard will be periodically updated with new and expanded functionality. Each new release of the Standard will include additional content adding new functionality and/or extensions to the *semantic data models* defined in the Standard.

The MTConnect Standard uses a three-digit version numbering system to identify each release of the Standard that indicates the progression of enhancements to the Standard. The format used to identify the documents in a specific version of the MTConnect Standard is:

major.minor.revision

major – Identifier representing a consistent set of functionalities defined by the MTConnect Standard. This functionality includes the protocol(s) used to communicate data to a client software application, the *semantic data models* defining how that data is organized into *Response Documents*, and the encoding of those *Response Documents*. This set of functionalities is referred to as the *Base Functional Structure*.

When a release of the MTConnect Standard removes or modifies any of the protocol(s), *semantic data models*, or encoding of the *Response Documents* included in the *Base Functional Structure* in such a way that it breaks backward compatibility and a client software application can no longer communicate with an *Agent* or cannot interpret the information provided by an *Agent*, the *major* version identifier for the Documents in the release is revised to a successively higher number.

See *Section 4.5 - Backwards Compatibility* for details regarding the interaction between a client software application and versions of the MTConnect Standard.

minor – Identifier representing a specific set of functionalities defined by the MTConnect Standard. Each release of the Standard (with a common *major* version identifier) includes new and/or expanded functionality – protocol extensions, new or extended *semantic data models*, and/or new programming languages. Each of these releases of the Standard is indicated by a successively higher *minor* version identifier.

If a new *major* version of the MTConnect Standard is released, the *minor* version identifier will be reset to 0.

revision – A supplemental identifier representing only organizational or editorial changes to a *minor* version document with no changes in the functionality described in that document.

New releases of a specific document are indicated by a successively higher revision version identifier.

If a new *minor* version of a document is released, the *revision* identifier will be reset to 0.

An example of the version identifier for a specific document would be:

Version M.N.R

4.2.1 Document Releases

A *major* revision change represents a substantial change to the MTConnect Standard. At the time of a *major* revision change, all documents representing the MTConnect Standard will be updated and released together.

A *minor* revision change represents some level of extended functionality supported by the MTConnect Standard. At the time of a *minor* version release, MTConnect Documents representing the changes or enhancements to the Standard will be updated as required. However, all documents, whether updated or not, will be released together with a new *minor* version number. Providing all documents at a common *major* and *minor* version makes it easier for implementers to manage the compatibility and upgrade of the different software tools incorporated into a manufacturing software system.

Since a *revision* represents no functional changes to the MTConnect Standard and includes only editorial or descriptive changes that enhance the understanding of the functionality supported by the Standard, individual documents within the Standard may be released at any time with a new *revision* and that release does not impact any other documents associated with the MTConnect Standard.

The latest released version of each document provided for the MTConnect Standard, and historical releases of those documents, are provided at http://www.mtconnect.org.

4.3 MTConnect Document Naming Conventions

MTConnect Documents are identified as follows:

4.3.1 Document Title

Each MTConnect Document **MUST** be identified as follows:

MTConnect® Standard

Part #.# - *Title*

Version M.N.R.

The following keys are used to distinguish different Parts of the MTConnect Standard and the version of the MTConnect Document:

#.# – Identifier of the specific Part and sub-Part of the MTConnect Standard

Title – Description of the type of information contained in the MTConnect Document

M – Indicator of the *major* version of the MTConnect Document

N– Indicator of the *minor* version of the MTConnect Document

R – Indicator of the revision of the MTConnect Document

For example, a release of *MTConnect Standard: Part 2.0 - Devices Information Model* would be:

MTConnect® Standard

Part 2.0 - *Devices Information Model*

Version 1.2.0

4.3.2 Electronic Document File Naming

Electronic versions of the MTConnect Documents will be provided in PDF format and follow this naming convention:

MTC_Part#-#_Title_M-N-R.pdf

The electronic version of the same release of *MTConnect Standard: Part 2.0 - Devices Information Model* would be:

MTC_Part_2-0_Devices_Information_Model_1-2-0.pdf

4.4 Document Conventions

Additional information regarding specific content in the MTConnect Standard is provided in the sections below.

4.4.1 Use of MUST, SHOULD, and MAY

These words convey specific meaning in the MTConnect Standard when presented in capital letters, Times New Roman font, and a Bold font style.

- The word **MUST** indicates content that is mandatory to be provided in an implementation where indicated.
- The word **SHOULD** indicates content that is recommended, but the exclusion of which will not invalidate an implementation.
- The word **MAY** indicates content that is optional. It is up to the implementer to decide if the content is relevant to an implementation.
- The word **NOT** may be added to the words **MUST** or **SHOULD** to negate the requirement.

4.4.2 Text Conventions

The following conventions will be used throughout the MTConnect Documents to provide a clear and consistent understanding of the use of each type of information used to define the MTConnect Standard.

These conventions are:

- Standard text is provided in Times New Roman font.

- References to documents, sections or sub-sections of a document, or figures within a document are *italicized*; e.g., *MTConnect Standard: Part 2.0 - Devices Information Model*.

- Terms with a specific meaning in the MTConnect Standard will be *italicized*; e.g., *major* indicating a version of the Standard.

- When these same terms are used within the text without specific reference to their function within the MTConnect Standard, they will be provided as non-italicized font; e.g., major indicating a descriptor of another term.

- Terms representing content of an MTConnect *semantic data model* or the protocol used in MTConnect will be provided in fixed size, Courier New font; e.g., `component`, `probe`, `current`.

  When these same terms are used within the text without specific reference to their function within the MTConnect Standard, they will be provided as Times New Roman font.

- All *Valid Data Values* that are restricted to a limited or controlled vocabulary will be provided in upper case Courier New font with an _(underscore) separating words. For example: `ON`, `OFF`, `ACTUAL`, `COUNTER_CLOCKWISE`, etc.

- All descriptive attributes associated with each piece of data defined in a *Response Document* will be provided in Courier New font and camel case font style. For example: `nativeUnits`.

4.4.3 Code Line Syntax and Conventions

The following conventions will be used throughout the MTConnect Documents to describe examples of software code produced by an *Agent* or commands provided to an *Agent* from a client software application.

All examples are provided in fixed size Courier New font with line numbers.

These conventions are:

- XML Code examples:

Example 1: XML Code Examples

```
<MTConnectStreams xmlns:m="urn:mtconnect.com:
    MTConnectStreams:1.1" xmlns:xsi=
    "http://www.w3.org/2001/XMLSchema-instance"
    xmlns="urn:mtconnect.com:MTConnectStreams:1.1"
```

- HTTP URL examples:
  - http://<authority>/<path>[?<query>]When a portion of a URL is enclosed in angle brackets ("<" and ">"), that section of the URL is a place holder for specific information that will replace the term between the angle brackets.

    Note: The angle brackets in a URL do not relate to the angle brackets used as the `tag` elements in an XML example.
  - A portion of a URL that is enclosed in square brackets "[" and "]" indicates that the enclosed content is optional.
  - All other characters in the URL are literal.

4.4.4 Semantic Data Model Content

For each of the *semantic data models* defined in the MTConnect Standard, there are tables describing pieces of information provided in the data models. Each table has a column labeled *Occurrence*. *Occurrence* defines the number of times the content defined in the tables **MAY** be provided in the usage case specified.

- If the *Occurrence* is 1, the content **MUST** be provided.
- If the *Occurrence* is 0..1, the content **MAY** be provided and if provided, at most, only one occurrence of the content **MUST** be provided.
- If the *Occurrence* is 0..*, the content **MAY** be provided and any number of occurrences of the content **MAY** be provided.
- If the *Occurrence* is 1..*, one or more occurrences of the content **MUST** be provided.
- If the *Occurrence* is a number, e.g., 2, exactly that number of occurrences of the content **MUST** be provided.

Note: "*" indicates multiple number of occurrences and is represented by ∞ in the figures.

4.4.5 Referenced Standards and Specifications

Other standards and specifications may be used to describe aspects of the protocol, *data dictionary*, or *semantic data models* defined in the MTConnect Standard. When a specific standard or specification is referenced in the MTConnect Standard, the name of the standard or specification will be provided in *italicized* font.

See *Section 3 - Terminology and Conventions*: Bibliography for a complete listing of standards and specifications used or referenced in the MTConnect Standard.

4.4.6 Deprecation and Deprecation Warnings

When the MTConnect Institute adds new functionality to the MTConnect Standard, the new content may supersede some of the functionality of existing content or significantly enhance one of the *semantic data models*. When this occurs, existing content may no longer be valid for use in the new version of the Standard.

4.4.6.1 Deprecation

In cases when new content supersedes the functionality of the existing content, the original content **MUST** no longer be included in future implementations – only the new content should be used.

The superseded content is identified by striking through the original content (~~original content~~) and marking the content with the words "**DEPRECATED** in *Version M.N*".

The deprecated content must remain in all future *minor* versions of the document. The content may be removed when a *major* version update is released. This provides implementers guidance on how to interpret data that may be provided from equipment utilizing an older version of the Standard. This content provides the information required for implementers to develop software applications that support backwards compatibility with older versions of the standard.

A software application may be designed to be compliant with any specific *minor* version of the standard. That software application may be collecting data from many different pieces of equipment. Each of these pieces of equipment may be providing data defined by the current version or any of the previous *minor* versions of the standard. To maintain compatibility with existing pieces of equipment, software applications should be implemented to interpret data defined in the current release of the MTConnect Standard, as well as all deprecated content associated with earlier versions of the Standard.

4.4.6.2 Deprecation Warning

When new content provides improved alternatives for defining the *semantic data mod-*

els, the MTConnect Institute may determine that the original content could possibly be deprecated in the future. When this occurs, a content will be marked with the words "**DEPRECATION WARNING** " to identify the content that may be deprecated in the future. This provides advanced notice to implementers that they should choose to utilize the improved alternatives when developing new products or software systems to avoid the possibility that the original content may be deprecated in a future version of the Standard.

4.5 Backwards Compatibility

MTConnect Documents with a different *major* version identifier represent a significant change in the *Base Functional Structure* of the MTConnect Standard. This means that the schema or protocol defined by the Standard may have changed in ways that will require software applications to change how they request and/or interpret data received from an *Agent*. Software applications should be fully version aware since no assumption of backwards compatibility should be assumed at the time of a *major* revision change to the MTConnect Standard.

The MTConnect Institute strives to maintain version compatibility through all *minor* revisions of the MTConnect Standard. New *minor* versions may introduce extensions to existing *semantic data models*, extend the protocol used to communicate to the *Agent*, and/or add new *semantic data models* to extend the functionality of the Standard. Client software applications may be designed to be compliant with any specific *minor* version of the MTConnect Standard. Additionally, software applications should be capable of interpreting information from an *Agent* providing data based upon a lower *minor* version identifier. It should also be capable of interpreting information from an *Agent* providing data based upon a higher *minor* version identifier of the MTConnect Standard than the version supported by the client, even though the client may ignore or not be capable of interpreting the extended content provided by the *Agent*.

A *revision* version of any MTConnect Document provides only editorial changes requiring no changes to an *Agent* or a client application.

5 MTConnect Fundamentals

The MTConnect Standard defines the functionality of an *Agent*. In an MTConnect installation, pieces of equipment publish information to an *Agent*. Client software applications request information from the *Agent* using a communications protocol. Based on the specific information that the client software application has requested from the *Agent*, the *Agent* forms a *Response Document* based upon one of the *semantic data models* defined in the MTConnect Standard and then transmits that document to the client software application.

Figure 2 illustrates the architecture of a typical MTConnect installation.

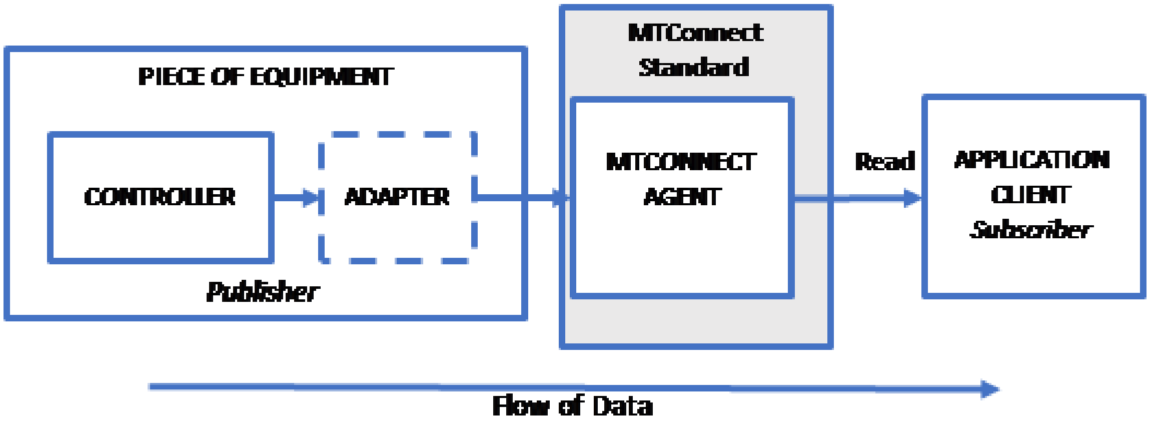


Figure 2: MTConnect Architecture Model

> Note: In each implementation of a communication system based on the MTConnect Standard, there **MUST** be a schema defined that encodes the rules and terminology defined for each of the *semantic data models*. These schemas **MAY** be used by client software applications to validate the content and structure of the *Response Documents* published by an *Agent*.

5.1 Agent

An *Agent* is the centerpiece of an MTConnect implementation. It provides two primary functions:

- Organizes and manages individual pieces of information published by one or more pieces of equipment.

- Publishes that information in the form of a *Response Document* to client software applications.

The MTConnect Standard addresses the behavior of an *Agent* and the structure and meaning of the data published by an *Agent*. It is the responsibility of the implementer of an *Agent* to determine the means by which the behavior is achieved for a specific *Agent*.

An *Agent* is software that may be installed as part of a piece of equipment or it may be installed separately. When installed separately, an *Agent* may receive information from one or more pieces of equipment.

Some pieces of equipment may be able to communicate directly to an *Agent*. Other pieces of equipment may require an *Adapter* to transform the information provided by the equipment into a form that can be sent to an *Agent*. In either case, the method of transmitting information from the piece of equipment to an *Agent* is implementation dependent and is not addressed as part of the MTConnect Standard.

One function of an *Agent* is to store information that it receives from a piece of equipment in an organized manner. A second function of an *Agent* is to receive *Requests* for information from one or many client software applications and then respond to those *Requests* by publishing a *Response Document* that contains the requested information.

There are three types of information stored by an *Agent* that **MAY** be published in a *Response Document*. These are:

- *Equipment Metadata* defines the *Structural Elements* that represent the physical and logical parts and sub-parts of each piece of equipment that can publish data to the *Agent*, the relationships between those parts and sub-parts, and the *Data Entities* associated with each of those *Structural Elements*. This *Equipment Metadata* is provided in an *MTConnectDevices Response Document*. See *MTConnect Standard: Part 2.0 - Devices Information Model* for more information on *Equipment Metadata*.

- *Streaming Data* provides the values published by pieces of equipment for the *Data Entities* defined by the *Equipment Metadata*. *Streaming Data* is provided in an *MTConnectStreams Response Document*. See *MTConnect Standard: Part 2.0 - Devices Information Model* for more information on *Streaming Data*.

- *MTConnect Assets* represent information used in a manufacturing operation that is commonly shared amongst multiple pieces of equipment and/or software applications. *MTConnect Assets* are provided in an *MTConnectAssets Response Document*. See *MTConnect Standard: Part 4.0 - Assets Information Model* for more information on *MTConnect Assets*.

The exchange between an *Agent* and a client software application is a *Request* and *Response* information exchange mechanism. See *Section 5.4 - Request/Response Information Exchange* for details on this *Request/Response* information exchange mechanism.

5.1.1 Instance of an Agent

As described above, an *Agent* collects and organizes values published by pieces of equipment. As with any piece of software, an *Agent* may be periodically restarted. When an *Agent* restarts, it **MUST** indicate to client software applications whether the information available in the *buffer* represents a completely new set of data or if the *buffer* includes data that had been collected prior to the restart of the *Agent*.

Any time an *Agent* is restarted and begins to collect a completely new set of *Streaming Data*, that set of data is referred to as an *instance* of the *Agent*. The *Agent* **MUST** maintain a piece of information called `instanceId` that represents the specific *instance* of the *Agent*.

`instanceId` is represented by a 64-bit integer. The `instanceId` **MAY** be implemented using any mechanism that will guarantee that the value for `instanceId` will be unique each time the *Agent* begins collecting a new set of data.

When an *Agent* is restarted and it provides a method to recover all, or some portion, of the data that was stored in the *buffer* before it stopped operating, the *Agent* **MUST** use the same `instanceId` that was defined prior to the restart.

5.1.2 Storage of Equipment Metadata for a Piece of Equipment

An *Agent* **MUST** be capable of publishing *Equipment Metadata* for each piece of equipment that publishes information through the *Agent*. *Equipment Metadata* is typically a static file defining the *Structural Elements* associated with each piece of equipment reporting information through the *Agent* and the *Data Entities* that can be associated with each of these *Structural Elements*. See details on *Structural Elements* and *Data Entities* in *MTConnect Standard: Part 2.0 - Devices Information Model*.

The MTConnect Standard does not define the mechanism to be used by an *Agent* to acquire, maintain, or store the *Equipment Metadata*. This mechanism **MUST** be defined as part of the implementation of a specific *Agent*.

5.1.3 Storage of Streaming Data

Streaming Data that is published from a piece(s) of equipment to an *Agent* is stored by the *Agent* based upon the sequence upon which each piece of data is received. As described below, the order in which data is stored by the *Agent* is one of the factors that determines the data that may be included in a specific *MTConnectStreams Response Document*.

5.1.3.1 Management of Streaming Data Storage

An *Agent* stores a fixed amount of data. The amount of data stored by an *Agent* is dependent upon the implementation of a specific *Agent*. The examples below demonstrate how discrete pieces of data received from pieces of equipment are stored.

The method for storing *Streaming Data* in an *Agent* can be thought of as a tube that can hold a finite set of balls. Each ball represents the occurrence of a *Data Entity* published by a piece of equipment. This data is pushed in one end of the tube until there is no more room for additional balls. At that point, any new data inserted will push the oldest data out the back of the tube. The data in the tube will continue to shift in this manner as new data is received.

This tube is referred to as a *buffer* in an *Agent*.

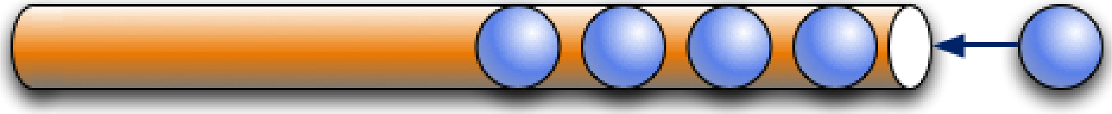


Figure 3: Data Storage in Buffer

In *Figure 4* , the maximum number of *Data Entities* that can be stored in the *buffer* of the *Agent* is 8. The maximum number of *Data Entities* that can be stored in the *buffer* is represented by a value called `bufferSize`. This example illustrates that when the *buffer* fills up, the oldest piece of data falls out the other end.

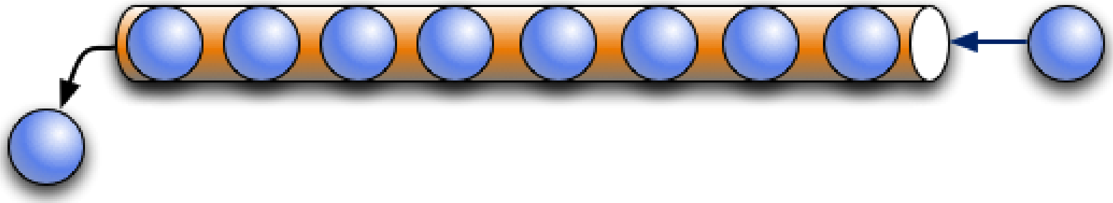


Figure 4: First In First Out Buffer Management

This process constrains the memory storage requirements for an *Agent* to a fixed maximum size since the MTConnect Standard only requires an *Agent* to store a finite number of pieces of data.

As an implementation guideline, the *buffer* **SHOULD** be sized large enough to provide storage for a reasonable amount of information received from all pieces of equipment that are publishing information to that *Agent*. The implementer should also consider the impact of a temporary loss of communications between a client software application and an *Agent* when determining the size for the *buffer*. A larger *buffer* will allow a client software application more time to reconnect to an *Agent* without losing data.

5.1.3.2 Sequence Numbers

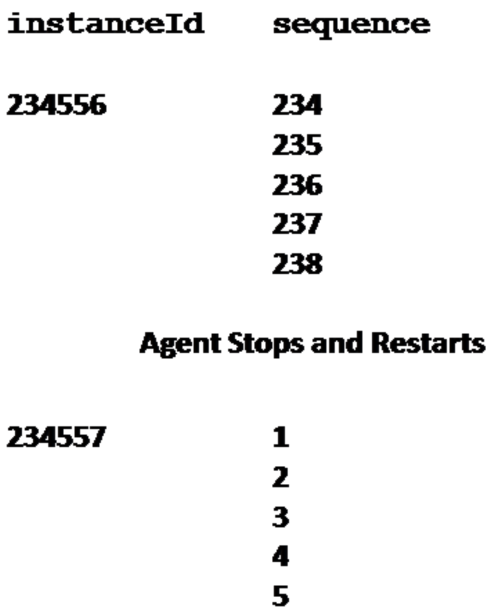
In an *Agent*, each occurrence of a *Data Entity* in the *buffer* will be assigned a monotonically increasing *sequence number* as it is inserted into the *buffer*. The *sequence number* is a 64-bit integer and the values assigned as *sequence numbers* will never wrap around or be exhausted; at least within the next 100,000 years based on the size of a 64-bit number.

sequence number is the primary key identifier used to manage and locate a specific piece of data in an *Agent*. The *sequence number* associated with each *Data Entity* reported by an *Agent* is identified with an attribute called `sequence`.

The *sequence number* for each piece of data **MUST** be unique for an instance of an *Agent* (see *Section 5.1.1 - Instance of an Agent* for information on *instances* of an *Agent*). If data is received from more than one piece of equipment, the *sequence numbers* are based on the order in which the data is received regardless of which piece of equipment produced that data. The *sequence number* **MUST** be a monotonically increasing number that spans all pieces of equipment publishing data to an *Agent*. This allows for multiple pieces of equipment to publish data through a single *Agent* with no *sequence number* collisions and unnecessary protocol complexity.

The *sequence number* **MUST** be reset to one (1) each time an *Agent* is restarted and begins to collect a fresh set of data; i.e., each time `instanceId` is changed.

Figure 5 demonstrates the relationship between `instanceId` and sequence when an *Agent* stops and restarts and begins collecting a new set of data. In this case, the `instanceId` is changed to a new value and value for `sequence` resets to one (1):



instanceId	sequence
234556	234
	235
	236
	237
	238

Agent Stops and Restarts

instanceId	sequence
234557	1
	2
	3
	4
	5

Figure 5: instanceId and sequence

Figure 6 also shows two additional pieces of information defined for an *Agent*:

- `firstSequence` – the oldest piece of data contained in the *buffer*; i.e., the next piece of data to be moved out of the *buffer*
- `lastSequence` – the newest data added to the *buffer*

`firstSequence` and `lastSequence` provide guidance to a software application identifying the range of data available that may be requested from an *Agent*.

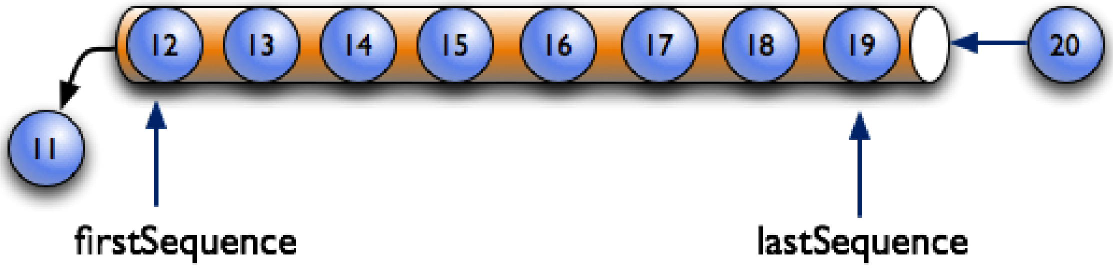


Figure 6: Indentifying the range of data with firstSequence and lastSequence

When a client software application requests data from an *Agent*, it can specify both the *sequence number* of the first piece of data (`from`) that **MUST** be included in the *Response*

Document and the total number (`count`) of pieces of data that **SHOULD** be included in that document.

In *Figure 7* , the request specifies that the data to be returned starts at *sequence number* 15 (`from`) and includes a total of three items (`count`).

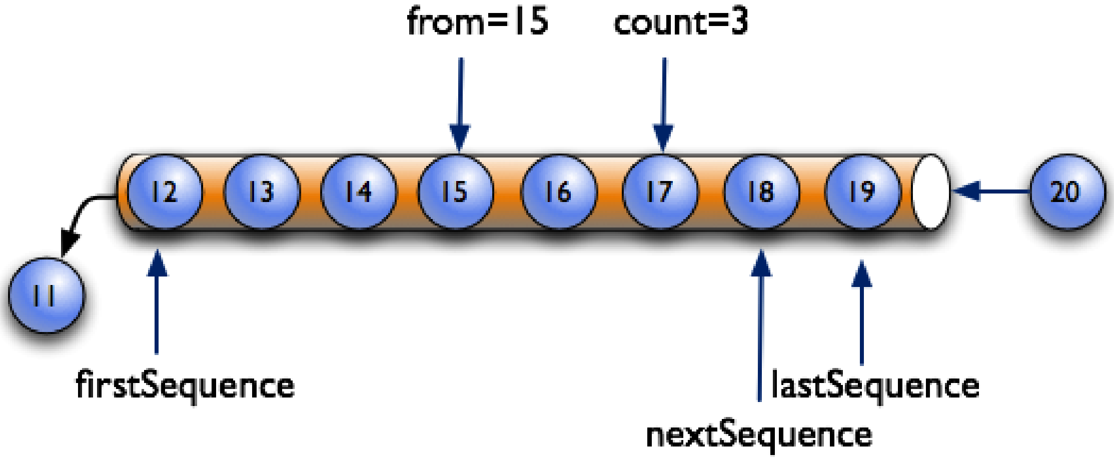


Figure 7: Identifying the range of data with from and count

Once a *Response* to a *Request* has been completed, the value of `nextSequence` will be established. `nextSequence` is the *sequence number* of the next piece of data available in the *buffer*. In the example in *Figure 7* , the next *sequence number* (`nextSequence`) will be 18.

As shown in *Figure 8* , the combination of `from` and `count` defined by the *Request* indicates a *sequence number* for data that is beyond that which is currently in the *buffer*. In this case, `nextSequence` is set to a value of `lastSequence` + 1.

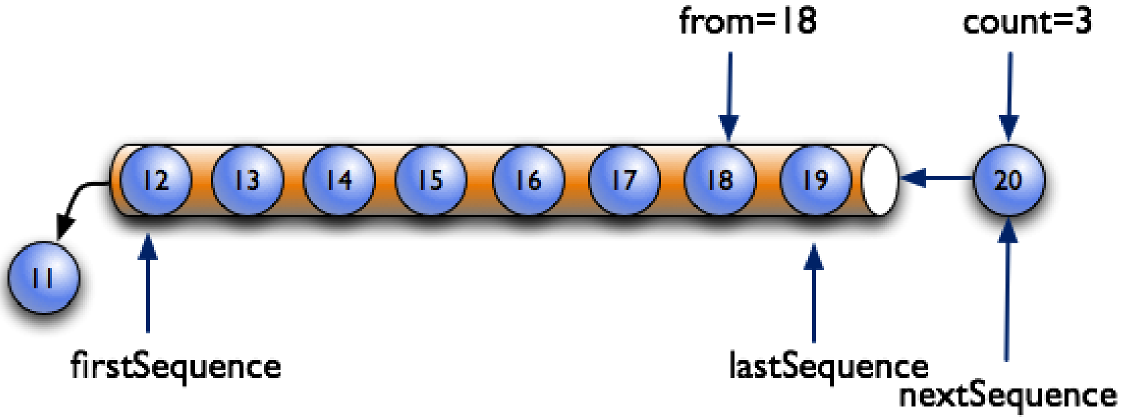


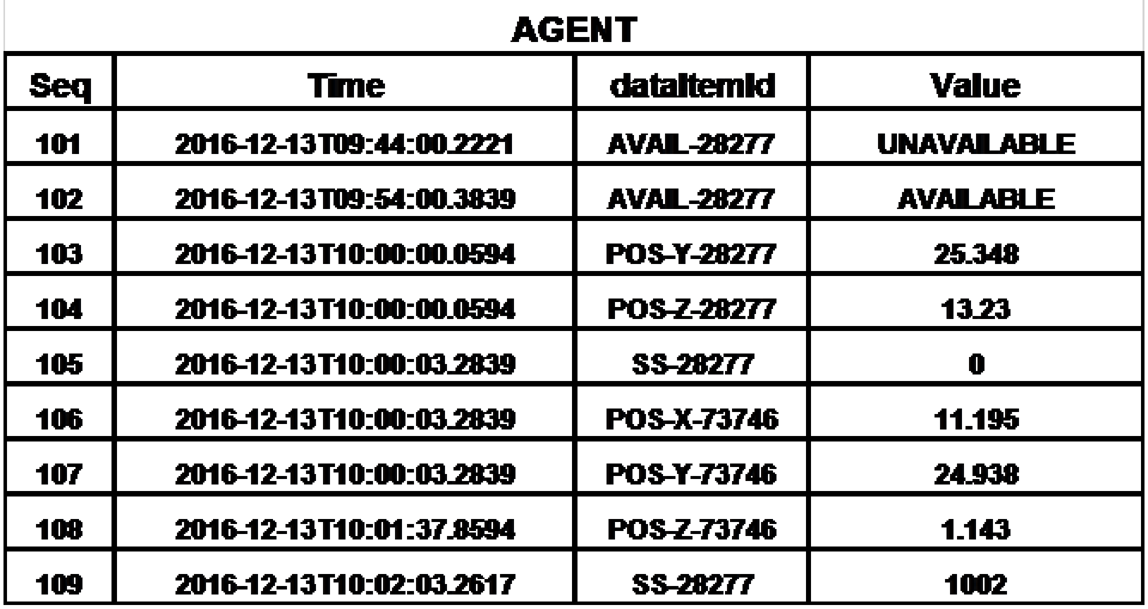
Figure 8: Indentifying the range of data with nextSequence and lastSequence

5.1.3.3 Buffer Data Structure

The information in the *buffer* of an *Agent* can be thought of as a four-column table of data. Each column in the table represents:

- The first column is the *sequence number* associated with each *Data Entity* - sequence.
- The second column is the time that the data was published by a piece of equipment. This time is defined as the timestamp associated with that *Data Entity*. See *Section 5.1.3.4 - Time Stamp* for details on timestamp.
- The third column, dataItemId, refers to the identity of *Data Entities* as they will appear in the *MTConnectStreams Response Document*. See *Section 5* of *MTConnect Standard: Part 3.0 - Streams Information Model* for details on dataItemId for a *Data Entity* and how that identify relates to the id attribute of the corresponding *Data Entity* in the *Devices Information Model*.
- The fourth column is the value associated with each *Data Entity*.

Figure 9 is an example demonstrating the concept of how data may be stored in an *Agent*:



AGENT

Seq	Time	dataItemId	Value
101	2016-12-13T09:44:00.2221	AVAIL-28277	UNAVAILABLE
102	2016-12-13T09:54:00.3839	AVAIL-28277	AVAILABLE
103	2016-12-13T10:00:00.0594	POS-Y-28277	25.348
104	2016-12-13T10:00:00.0594	POS-Z-28277	13.23
105	2016-12-13T10:00:03.2839	SS-28277	0
106	2016-12-13T10:00:03.2839	POS-X-73746	11.195
107	2016-12-13T10:00:03.2839	POS-Y-73746	24.938
108	2016-12-13T10:01:37.8594	POS-Z-73746	1.143
109	2016-12-13T10:02:03.2617	SS-28277	1002

Figure 9: Data Storage Concept

The storage mechanism for the data, the internal representation of the data, and the implementation of the *Agent* itself is not part of the MTConnect Standard. The implementer can choose both the amount of data to be stored in the *Agent* and the mechanism for how the data is stored. The only requirement is that an *Agent* publish the *Response Documents* in the required format.

5.1.3.4 Time Stamp

Each piece of equipment that publishes information to an *Agent* **SHOULD** provide a time stamp indicating when each piece of information was measured or determined. If no time stamp is provided, the *Agent* **MUST** provide a time stamp for the information based upon when that information was received at the *Agent*.

The `timestamp` associated with each piece of information is reported by an *Agent* as `timestamp`. `timestamp` **MUST** be reported in UTC (Coordinated Universal Time) format; e.g., "2010-04-01T21:22:43Z".

> Note: Z refers to UTC/GMT time, not local time.

Client software applications should use the value of `timestamp` reported for each piece of information as the means for ordering when pieces of information were generated as opposed to using `sequence` for this purpose.

> Note: It is assumed that `timestamp` provides the best available estimate of the time that the value(s) for the published information was measured or determined.

If two pieces of information are measured or determined at the exact same time, they **MUST** be reported with the same value for `timestamp`. Likewise, all information that is recorded in the *buffer* with the same value for `timestamp` should be interpreted as having been recorded at the same point in time; even if that data was published by more than one piece of equipment.

5.1.3.5 Recording Occurrences of Streaming Data

An *Agent* **MUST** record data in the *buffer* each time the value for that specific piece of data changes. If a piece of equipment publishes multiple occurrences of a piece of data with the same value, the *Agent* **MUST NOT** record multiple occurrence for that *Data Entity*.

> Note: There is one exception to this rule. Some *Data Entities* may be defined with a `representation` attribute value of `DISCRETE` (**DEPRECATED** in *Version 1.5*) (See *Section 7.2.2.12* of *MTConnect Standard: Part 2.0 - Devices Information Model* for details on `representation`.) In this case, each occurrence of the data represents a new and unique piece of information. The *Agent* **MUST** then record each occurrence of the *Data Entity* that is published by a piece of equipment.

The value for each piece of information reported by an *Agent* must be considered by a client software application to be valid until such a time that another occurrence of that piece of information is published by the *Agent*.

5.1.3.6 Maintaining Last Value for Data Entities

An *Agent* **MUST** retain a copy of the last available value associated with each *Data Entity* known to the *Agent*; even if an occurrence of that *Data Entity* is no longer in the *buffer*. This function allows an *Agent* to provide a software application a view of the last known value for each *Data Entity* associated with a piece of equipment.

The *Agent* **MUST** also retain a copy of the last value associated with each *Data Entity* that has flowed out of the *buffer*. This function allows an *Agent* to provide a software application a view of the last known value for each *Data Entity* associated with a *Current Request* with an `at` parameter in the `query` portion of its *HTTP Request Line* (See *Section 8.3.2 - Current Request Implemented Using HTTP* for details on *Current Request*).

5.1.3.7 Unavailability of Data

An *Agent* **MUST** maintain a list of *Data Entities* that **MAY** be published by each piece of equipment providing information to the *Agent*. This list of *Data Entities* is derived from the *Equipment Metadata* stored in the *Agent* for each piece of equipment.

Each time an *Agent* is restarted, the *Agent* **MUST** place an occurrence of every *Data Entity* in the *buffer*. The value reported for each of these *Data Entities* **MUST** be set to `UNAVAILABLE` and the `timestamp` for each **MUST** be set to the time that the last piece of data was collected by the *Agent* prior to the restart.

If at any time an *Agent* loses communications with a piece of equipment, or the *Agent* is unable to determine a valid value for all, or any portion, of the *Data Entities* published by a piece of equipment, the *Agent* **MUST** place an occurrence of each of these *Data Entities* in the *buffer* with its value set to `UNAVAILABLE`. This signifies that the value is currently indeterminate and no assumptions of a valid value for the data is possible.

Since an *Agent* may receive information from multiple pieces of equipment, it **MUST** consider the validity of the data from each of these pieces of equipment independently.

There is one exception to the rules above. Any *Data Entity* that is constrained to a constant data value **MUST** be reported with the constant value and the *Agent* **MUST NOT** set the value of that *Data Entity* to `UNAVAILABLE`.

> Note: The schema for the *Devices Information Model* (defined in *MTConnect Standard: Part 2.0 - Devices Information Model*) defines how the value reported for an individual piece of data may be constrained to one or more specific values.

5.1.3.8 Persistence and Recovery

The implementer of an *Agent* must decide on a strategy regarding the storage of *Streaming Data* in the *buffer* of the *Agent*.

In the simplest form, an *Agent* can hold the *buffer* information in volatile memory where no data is persisted when the *Agent* is stopped. In this case, the *Agent* **MUST** update the value for `instanceId` when the *Agent* restarts to indicate that the *Agent* has begun to collect a new set of data.

If the implementation of an *Agent* provides a method of persisting and restoring all or a portion of the information in the *buffer* of the *Agent* (*sequence numbers*, *time stamps*, identify, and values), the *Agent* **MUST NOT** change the value of the `instanceId` when the *Agent* restarts. This will indicate to a client software application that it does not need to reset the value for `nextSequence` when it requests the next set of data from the *Agent*.

When an implementer chooses to provide a method to persist the information in an *Agent*, they may choose to store as much data as is practical in a recoverable storage system. Such a method may also include the ability to store historical information that has previously been pushed out of the *buffer*.

5.1.3.9 Heartbeat

An *Agent* **MUST** provide a function that indicates to a client application that the HTTP connection is still viable during times when there is no new data available to report in a *Response Document*. This function is defined as *heartbeat*.

heartbeat represents the amount of time after a *Response Document* has been published until a new *Response Document* **MUST** be published, even when no new data is available.

See *Section 8.3.3.2 - Query Portion of the HTTP Request Line for a Sample Request* for more details on configuring the *heartbeat* function.

5.1.3.10 Data Sets

See *MTConnect Standard: Part 3.0 - Streams Information Model Section Part 3: DataItem with representation of DATA_SET* for management of *Data Sets*.

5.1.4 Storage of Documents for MTConnect Assets

An *Agent* also stores information associated with *MTConnect Assets*.

When a piece of equipment publishes a document that represents information associated with an *MTConnect Asset*, an *Agent* stores that document in a *buffer*. This *buffer* is called the *assets buffer*. The document is called an *Asset Document*.

The *assets buffer* **MUST** be a separate *buffer* from the one where the *Streaming Data* is stored.

The *Asset Document* that is published by the piece of equipment **MUST** be organized based upon one of the applicable *Asset Information Models* defined in one of the Parts 4.x of the MTConnect Standard.

An *Agent* will only retain a limited number of *Asset Documents* in the *assets buffer*. The *assets buffer* functions similar to the *buffer* for *Streaming Data*; i.e., when the *assets buffer* is full, the oldest *Asset Document* is pushed from the *buffer*.

Figure 10 demonstrates the oldest *Asset Document* being pushed from the *assets buffer* when a new *Asset Document* is added and the *assets buffer* is full:

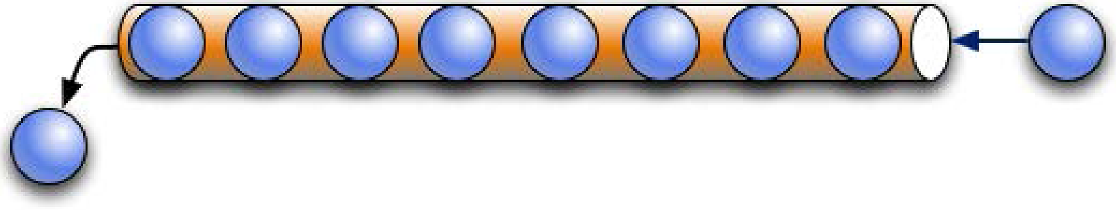


Figure 10: First In First Out Asset Buffer Management

Within an *Agent*, the management of *Asset Documents* behave like a key/value storage in a database. In the case of *MTConnect Assets*, the key is an identifier for an Asset (see details on `assetId` in *MTConnect Standard: Part 4.0 - Assets Information Model*) and the value is the *Asset Document* that was published by the piece of equipment.

Figure 11 demonstrates the relationship between the key (`assetId`) and the stored *Asset Documents*:

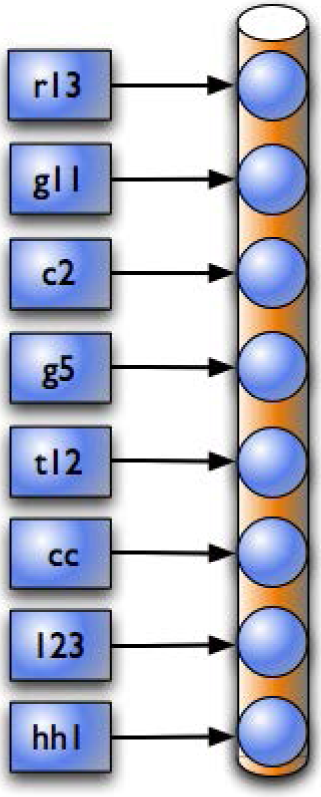


Figure 11: Relationship between assetId and stored Asset documents

Note: The key (assetId) is independent of the order of the *Asset Documents* stored in the *assets buffer*.

When an *Agent* receives a new *Asset Document* representing an *MTConnect Asset*, it must determine whether this document represents an *MTConnect Asset* that is not currently represented in the *assets buffer* or if the document represents new information for an *MTConnect Asset* that is already represented in the *assets buffer*. When a new *Asset Document* is received, one of the following **MUST** occur:

- If the *Asset Document* represents an *MTConnect Asset* that is not currently represented in the *assets buffer*, the *Agent* **MUST** add the new document to the front of the *assets buffer*. If the *assets buffer* is full, the oldest *Asset Document* will be removed from the *assets buffer*.

- If the *Asset Document* represents an *MTConnect Asset* that is already represented in the *assets buffer*, the *Agent* **MUST** remove the existing *Asset Document* representing that *MTConnect Asset* from the *assets buffer* and add the new *Asset Document* to the front of the *assets buffer*.

The MTConnect Standard does not specify the maximum number of *Asset Documents* that may be stored in the *assets buffer*; that limit is determined by the implementation of a specific *Agent*. The number of *Asset Documents* that may be stored in an *Agent* is defined by the value for `assetBufferSize` (See *Section 6.5 - Document Header* for more information on `assetBufferSize`.). A value of 4,294,967,296 or 2^{32} can be provided for `assetBufferSize` to indicate unlimited storage.

There is no requirement for an *Agent* to provide persistence for the *Asset Documents* stored in the *assets buffer*. If an *Agent* should fail, all *Asset Documents* stored in the *assets buffer* **MAY** be lost. It is the responsibility of the implementer to determine if *Asset Documents* stored in an *Agent* may be restored or if those *Asset Documents* are retained by some other software application.

Additional details on how an *Agent* organizes and manages information associated with *MTConnect Assets* are provided in *MTConnect Standard: Part 4.0 - Assets Information Model*.

5.2 Response Documents

Response Documents are electronic documents generated and published by an *Agent* in response to a *Request* for data.

The *Response Documents* defined in the MTConnect Standard are:

- *MTConnectDevices Response Document*: An electronic document that contains the information published by an *Agent* describing the data that can be published by one or more piece(s) of equipment. The structure of the *MTConnectDevices Response Document* document is based upon the requirements defined by the *Devices Information Model*. See *MTConnect Standard: Part 2.0 - Devices Information Model* for details on this information model.
- *MTConnectStreams Response Document*: An electronic document that contains the information published by an *Agent* that contains the data that is published by one or more piece(s) of equipment. The structure of the *MTConnectStreams Response Document* document is based upon the requirements defined by the *Streams Information Model*. See *MTConnect Standard: Part 3.0 - Streams Information Model* for details on this information model.
- *MTConnectAssets Response Document*: An electronic document that contains the information published by an *Agent* that **MAY** include one or more *Asset Documents*. The structure of the *MTConnectAssets Response Document* document is based upon the requirements defined by the *Asset Information Models*. See *MTConnect Standard: Part 4.0 - Assets Information Model* for details on this information model.
- *MTConnectErrors Response Document*: An electronic document that contains the information provided by an *Agent* when an error has occurred when trying to respond to a *Request* for data. The structure of the *MTConnectErrors Response Document* is based upon the requirements defined by the *Error Information Model*. See *Section 9 - Error Information Model* of this document for details on this information model.

Response Documents may be represented by any document format supported by an *Agent*. No matter what document format is used to structure these documents, the requirements for representing the data and other information contained in those documents **MUST** adhere to the requirements defined in the *Information Models* associated with each document.

5.2.1 XML Documents

XML is currently the only document format supported by the MTConnect Standard for encoding *Response Documents*. Other document formats may be supported in the future.

Since XML is the document format supported by the MTConnect Standard for encoding documents, all examples demonstrating the structure of the *Response Documents* provided throughout the MTConnect Standard are based on XML. These documents will be referred to as *MTConnect XML Documents* or *XML Documents*.

Section 6 - XML Representation of Response Documents defines how each document is structured as an *XML Document*.

5.3 Semantic Data Models

A *semantic data model* is a software engineering method for representing data where the context and the meaning of the data is constrained and fully defined.

Each of the *semantic data models* defined by the MTConnect Standard include:

- The types of information that may be published by a piece of equipment,
- The meaning of that information and units of measure, if applicable,
- Structural information that defines how different pieces of information relate to each other, and
- Structural information that defines how the information relates to where the information was measured or generated by the piece of equipment.

As described previously, the content of the *Response Documents* provided by an *Agent* are each defined by a specific *semantic data model*. The details for the *semantic data model* used to define each of the *Response Documents* are detail as follows:

- *MTConnectDevices Response Document*: *MTConnect Standard: Part 2.0 - Devices Information Model*.
- *MTConnectStreams Response Document*: *MTConnect Standard: Part 3.0 - Streams Information Model*.
- *MTConnectAssets Response Document*: *MTConnect Standard: Part 4.0 - Assets Information Model* and its sub-Parts.
- *MTConnectErrors Response Document*: *MTConnect Standard Part 1.0 - Overview and Fundamentals*, *Section 9 - Error Information Model*.

Without semantics, a single piece of data does not convey any relevant meaning to a person or a client software application. However, when that piece of data is paired with some semantic context, the data inherits significantly more meaning. The data can then be more completely interpreted by a client software application without human intervention.

The MTConnect *semantic data models* allows the information published by a piece of equipment to be transmitted to client software application with a full definition of the meaning of that information and in full context defining how that information relates to the piece of equipment that measured or generated the information.

5.4 Request/Response Information Exchange

The transfer of information between an *Agent* and a client software application is based on a *Request/Response* information exchange approach. A client software application requests specific information from an *Agent*. An *Agent* responds to the *Request* by publishing a *Response Document*.

In normal operation, there are four types of *MTConnect Requests* that can be issued by a client software application that will result in different *Responses* by an *Agent*. These *Requests* are:

- *Probe Request*– A client software application requests the *Equipment Metadata* for each piece of equipment that **MAY** publish information through an *Agent*. The *Agent* publishes a *MTConnectDevices Response Document* that contains the requested information. A *Probe Request* is represented by the term `probe` in a *Request* from a client software application.

- *Current Request* – A client software application requests the current value for each of the data types that have been published from a piece(s) of equipment to an *Agent*. The *Agent* publishes a *MTConnectStreams Response Document* that contains the requested information. A *Current Request* is represented by the term `current` in a *Request* from a client software application.

- *Sample Request* – A client software application requests a series of data values from the *buffer* in an *Agent* by specifying a range of *sequence numbers* representing that data. The *Agent* publishes a *MTConnectStreams Response Document* that contains the requested information. A *Sample Request* is represented by the term `sample` in a *Request* from a client software application.

- *Asset Request* – A client software application requests information related to *MTConnect Assets* that has been published to an *Agent*. The *Agent* publishes an *MTConnectAssets Response Document* that contains the requested information. An *Asset Request* is represented by the term `asset` in a *Request* from a client software application.

> Note: If an *Agent* is unable to respond to the request for information or the request includes invalid information, the *Agent* will publish an *MTConnectErrors Response Document*. See *Section 9 - Error Information Model* for information regarding *Error Information Model*

The specific format for the *Request* for information from an *Agent* will depend on the *Protocol* implemented as part of the *Request/Response* information exchange mechanism deployed in a specific implementation. See *Section 7 - Protocol and Messaging*, *Protocol* for details on implementing the *Request/Response* information exchange.

Also, the specific format for the *Response Documents* may also be implementation dependent. See *Section 6 - XML Representation of Response Documents* for details on the format for the *Response Documents* encoded with XML.

5.5 Accessing Information from an Agent

Each of the *Requests* defined for the *Request/Response* information exchange requires an *Agent* to respond with a specific view of the information stored by the *Agent*. The following describes the relationships between the information stored by an *Agent* and the contents of the *Response Documents*.

5.5.1 Accessing Equipment Metadata from an Agent

The *Equipment Metadata* associated with each piece of equipment that publishes information to an *Agent* is typically static information that is maintained by the *Agent*. The MTConnect Standard does not define how the *Agent* captures or maintains that information. The only requirement that the MTConnect Standard places on an *Agent* regarding this *Equipment Metadata* is that the *Agent* properly store this information and then configure and publish a *MTConnectDevices Response Document* in response to a *Probe Request*.

All issues associated with the capture and maintenance of the *Equipment Metadata* is the responsibility of the implementer of a specific *Agent*.

5.5.2 Accessing Streaming Data from the Buffer of an Agent

There are two *Requests* defined for the *Request/Response* information exchange that require an *Agent* to provide different views of the information stored in the *buffer* of the *Agent*. These *Requests* are `current` and `sample`.

The example in *Figure 12* demonstrates how an *Agent* interprets the information stored in the *buffer* to provide the content that is published in different versions of the *MTConnectStreams Response Document* based on the specific *Request* that is issued by a client software application.

In this example, an *Agent* with a *buffer* that can hold up to eight (8) *Data Entities*; i.e., the value for bufferSize is 8. This *Agent* is collecting information for two pieces of data – Pos representing a position and Line representing a line of logic or commands in a control program.

In this *buffer*, the value for firstSequence is 12 and the value for lastSequence is 19. There are five (5) different values for Pos and three (3) different values for Line.

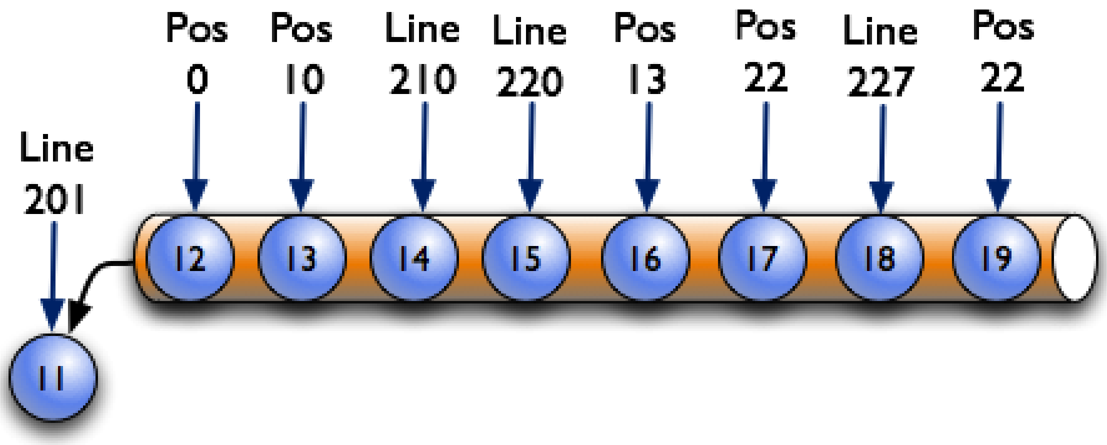


Figure 12: Example Buffer

If an *Agent* receives a *Sample Request* from a client software application, the *Agent* **MUST** publish an *MTConnectStreams Response Document* that contains a range of data values. The range of values are defined by the from and count parameters that must be included as part of the *Sample Request*. If the value of from is 14 and the value of count is 5, the *Agent* **MUST** publish an *MTConnectStreams Response Document* that includes five (5) pieces of data represented by *sequence numbers* 14, 15, 16, 17, and 18 – three (3) occurrences of Line and two (2) occurrences of Pos. In this case, nextSequence will also be returned with a value of 19.

Likewise, if the same *Agent* receives a *Current Request* from a client software application, the *Agent* **MUST** publish an *MTConnectStreams Response Document* that contains the most current information available for each of the types of data that is being published to the *Agent*. In this case, the specific data that **MUST** be represented in the *MTConnectStreams Response Document* is Pos with a value of 22 and a *sequence number* of 19 and Line with a value of 227 and a *sequence number* of 18.

There is also a derivation of the *Current Request* that will cause an *Agent* to publish an *MTConnectStreams Response Document* that contains a set of data relative to a specific sequence number. The *Current Request* **MAY** include an additional parameter called `at`. When the `at` parameter, along with an `instanceId`, is included as part of a *Current Request*, an *Agent* **MUST** publish an *MTConnectStreams Response Document* that contains the most current information available for each of the types of *Data Entities* that are being published to the *Agent* that occur immediately at or before the *sequence number* specified with the `at` parameter.

For example, if the *Request* is `current?at=15`, an *Agent* **MUST** publish a *MTConnectStreams Response Document* that contains the most current information available for each of the *Data Entities* that are stored in the *buffer* of the *Agent* with a *sequence number* of 15 or lower. In this case, the specific data that **MUST** be represented in the *MTConnectStreams Response Document* is `Pos` with a value of 10 and a *sequence number* of 13 and `Line` with a value of 220 and a *sequence number* of 15.

If a `current` *Request* is received for a *sequence number* of 11 or lower, an *Agent* **MUST** return an `OUT_OF_RANGE` *MTConnectErrors Response Document*. The same *HTTP Error Message* **MUST** be given if a *sequence number* is requested that is greater than the end of the *buffer*. See *Section 9 - Error Information Model* for more information on *MTConnectErrors Response Document*.

5.5.3 Accessing MTConnect Assets Information from an Agent

When an *Agent* receives an *Asset Request*, the *Agent* **MUST** publish an `MTConnectAssets` document that contains information regarding the *Asset Documents* that are stored in the *Agent*.

See *MTConnect Standard: Part 4.0 - Assets Information Model* for details on *MTConnect Assets*, *Asset Requests*, and the *MTConnectAssets Response Document*.

6 XML Representation of Response Documents

As defined in *Section 5.2.1 - XML Documents*, XML is currently the only language supported by the MTConnect Standard for encoding *Response Documents*.

Response Documents must be valid and conform to the *schema* defined in the *semantic data model* defined for that document. The *schema* for each *Response Document* **MUST** be updated to correlate to a specific version of the MTConnect Standard. Versions, within a *major* version, of the MTConnect Standard will be defined in such a way to best maintain backwards compatibility of the *semantic data models* through all *minor* revisions of the Standard. However, new *minor* versions may introduce extensions or enhancements to existing *semantic data models*.

To be valid, a *Response Document* must be well-formed; meaning that, amongst other things, each element has the required XML *start-tag* and *end-tag* and that the document does not contain any illegal characters. The validation of the document may also include a determination that required elements and attributes are present, they only occur in the appropriate location in the document, and they appear only the correct number of times. If the document is not well-formed, it may be rejected by a client software application. The *semantic data model* defined for each *Response Document* also specifies the elements and *Child Elements* that may appear in a document. XML elements may contain *Child Elements*, CDATA, or both. The *semantic data model* also defines the number of times each element and *Child Element* may appear in the document.

Each *Response Document* encoded using XML consists of the following primary sections:

- XML Declaration
- Root Element
- Schema and Namespace Declaration
- Document Header
- Document Body

The following will provide details defining how each of the *Response Documents* are encoded using XML.

> Note: See *Section 3 - Terminology and Conventions* for the definition of XML related terms used in the MTConnect Standard.

6.1 Fundamentals of Using XML to Encode Response Documents

The MTConnect Standard follows industry conventions for formatting the elements and attributes included in an XML document. The general guidelines are as follows:

- All element names **MUST** be specified in Pascal case (first letter of each word is capitalized). For example: `<PowerSupply/>`.

- The name for an attribute **MUST** be Camel case; similar to Pascal case, but the first letter will be lower case. For example: `<MyElement nativeName="bob"/>` where `MyElement` is the *Element Name* and `nativeName` is an attribute.

- All CDATA values that are defined with a limited or controlled vocabulary **MUST** be in upper case with an _ (underscore) separating words. For example: `ON`, `OFF`, `ACTUAL`, and `COUNTER_CLOCKWISE`.

- The values provided for a date and/or a time **MUST** follow the W3C ISO 8601 format with an arbitrary number of decimals representing fractions of a second. Refer to the following specification for details on the format for dates and times: http://www.w3.org/TR/NOTE-datetime.

  The format for the value describing a date and a time will be YYYY-MM-DDThh:mm:ss.ffff. An example would be: 2017-01-13T13:01.213415Z.

  > Note: Z refers to UTC/GMT time, not local time.

  The accuracy and number of decimals representing fractions of a second for a `timestamp` **MUST** be determined by the capabilities of the piece of equipment publishing information to an *Agent*. All time values **MUST** be provided in UTC (GMT).

- XML element names **MUST** be spelled out and abbreviations are not permitted. See the exclusion below regarding the use of the suffix `Ref`.

- XML attribute names **SHOULD** be spelled out and abbreviations **SHOULD** be avoided. The exception to this rule is the use of `id` when associated with an identifier. See the exclusion below regarding the use of the suffix `Ref`.

- The abbreviation `Ref` for `Reference` is permitted as a suffix to element names of either a *Structural Element* or a *Data Entity* to provide an efficient method to associate information defined in another location in a *Data Model* without duplicating that original data or structure. See *Section 4.8* in *MTConnect Standard: Part 2.0 - Devices Information Model* for more information on `Reference`.

6.2 XML Declaration

The first section of a *Response Document* encoded with XML **SHOULD** be the *XML Declaration*. The declaration is a single element.

An example of an *XML Declaration* would be:

Example 2: Example of xml declaration

```
<?xml version="1.0" encoding="UTF-8"?>
```

This element provides information regarding how the XML document is encoded and the character type used for that encoding. See the W3C website for more details on the XML declaration.

6.3 Root Element

Every *Response Document* **MUST** contain only one root element. The MTConnect Standard defines `MTConnectDevices`, `MTConnectStreams`, `MTConnectAssets`, and `MTConnectError` as *Root Elements*.

The *Root Element* specifies a specific *Response Document* and appears at the top of the document immediately following the *XML Declaration*.

6.3.1 MTConnectDevices Root Element

`MTConnectDevices` is the *Root Element* for the *MTConnectDevices Response Document*.

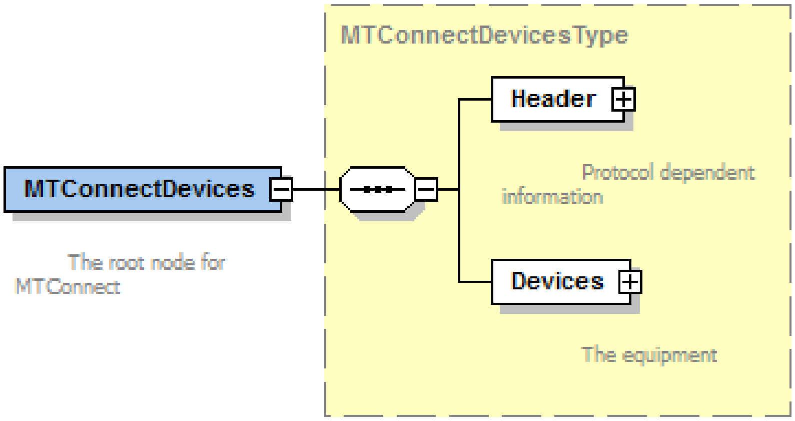


Figure 13: MTConnectDevices Structure

MTConnectDevices **MUST** contain two *Child Elements* - Header and Devices. Details for Header are defined in *Section 6.5 - Document Header*.

Devices is an XML container that represents the *Document Body* for an *MTConnectDevices Response Document* – see *Section 6.6 - Document Body*. Details for the *semantic data model* describing the contents for Devices are defined in *MTConnect Standard: Part 2.0 - Devices Information Model*.

MTConnectDevices also has a number of attributes. These attributes are defined in *Section 6.4 - Schema and Namespace Declaration*.

6.3.1.1 MTConnectDevices Elements

An MTConnectDevices element **MUST** contain a Header and a Devices element.

Table 1: Elements for MTConnectDevices

Element	Description	Occurrence
Header	An XML container in an *MTConnect Response Document* that provides information from an *Agent* defining version information, storage capacity, and parameters associated with the data management within the *Agent*.	1

Continuation of Table 1		
Element	Description	Occurrence
Devices	The XML container in an *MTConnect Response Document* that provides the *Equipment Metadata* for each of the pieces of equipment associated with an *Agent*.	1

6.3.2 MTConnectStreams Root Element

MTConnectStreams is the *Root Element* for the *MTConnectStreams Response Document*.

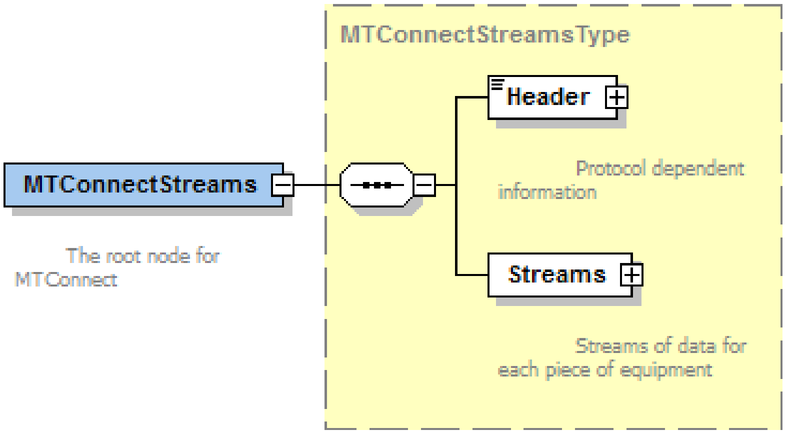

MTConnectStreamsType
Header
Protocol dependent information
MTConnectStreams
The root node for MTConnect
Streams
Streams of data for each piece of equipment

Figure 14: MTConnectStreams Structure

MTConnectStreams **MUST** contain two *Child Elements* - Header and Streams.

Details for Header are defined in *Section 6.5 - Document Header*.

Streams is an XML container that represents the *Document Body* for a *MTConnectStreams Response Document* – see *Section 6.6 - Document Body*. Details for the *semantic data model* describing the contents for Streams are defined in *MTConnect Standard: Part 3.0 - Streams Information Model*.

MTConnectStreams also has a number of attributes. These attributes are defined in *Section 6.4 - Schema and Namespace Declaration*.

6.3.2.1 MTConnectStreams Elements

An `MTConnectStreams` element **MUST** contain a `Header` and a `Streams` element.

Table 2: Elements for MTConnectStreams

Element	Description	Occurrence
`Header`	An XML container in an *MTConnect Response Document* that provides information from an *Agent* defining version information, storage capacity, and parameters associated with the data management within the *Agent*.	1
`Streams`	The XML container for the information published by an *Agent* in a *MTConnectStreams Response Document*.	1

6.3.3 MTConnectAssets Root Element

`MTConnectAssets` is the *Root Element* for the *MTConnectAssets Response Document*.

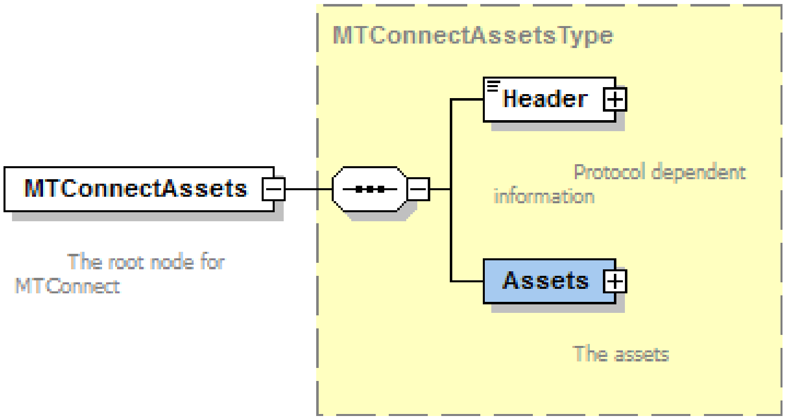


Figure 15: MTConnectAssets Structure

MTConnectAssets **MUST** contain two *Child Elements* - Header and Assets.

Details for Header are defined in *Section 6.5 - Document Header*.

Assets is an XML container that represents the *Document Body* for an *MTConnectAssets Response Document* – see *Section 6.6 - Document Body*. Details for the *semantic data model* describing the contents for Assets are defined in *MTConnect Standard: Part 4.0 - Assets Information Model*.

MTConnectAssets also has a number of attributes. These attributes are defined in *Section 6.4 - Schema and Namespace Declaration*.

6.3.3.1 MTConnectAssets Elements

An MTConnectAssets element **MUST** contain a Header and an Assets element.

Table 3: Elements for MTConnectAssets

Element	Description	Occurrence
Header	An XML container in an *MTConnect Response Document* that provides information from an *Agent* defining version information, storage capacity, and parameters associated with the data management within the *Agent*.	1
Assets	The XML container in an *MTConnectAssets Response Document* that provides information for *MTConnect Assets* associated with an *Agent*.	1

6.3.4 MTConnectError Root Element

MTConnectError is the *Root Element* for the *MTConnectErrors Response Document*.

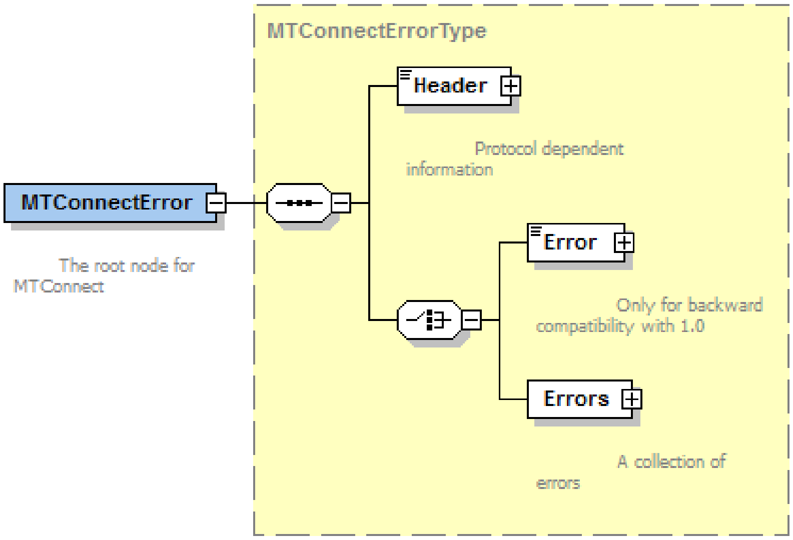

MTConnectErrorType
Header
Protocol dependent information
MTConnectError
The root node for MTConnect
Error
Only for backward compatibility with 1.0
Errors
A collection of errors

Figure 16: MTConnectError Structure

MTConnectError **MUST** contain two *Child Elements* - Header and Errors.

> Note: When compatibility with *Version 1.0.1* and earlier of the MTConnect Standard is required for an implementation, the *MTConnectErrors Response Document* contains only a single Error *Data Entity* and the Errors *Child Element* **MUST NOT** appear in the document.

Details for Header are defined in *Section 6.5 - Document Header*.

Errors is an XML container that represents the *Document Body* for an *MTConnectErrors Response Document* – See *Section 6.6 - Document Body*. Details for the *semantic data model* describing the contents for Errors are defined in *Section 9 - Error Information Model*.

MTConnectError also has a number of attributes. These attributes are defined in *Section 6.4 - Schema and Namespace Declaration*.

6.3.4.1 MTConnectError Elements

An MTConnectError element **MUST** contain a Header and an Errors element.

Table 4: Elements for MTConnectError

Element	Description	Occurrence
`Header`	An XML container in an *MTConnect Response Document* that provides information from an *Agent* defining version information, storage capacity, and parameters associated with the data management within the *Agent*.	1
`Errors`	The XML container in an *MTConnectErrors Response Document* that provides information associated with errors encountered by an *Agent*.	1

6.4 Schema and Namespace Declaration

XML provides standard methods for declaring the *schema* and *namespace* associated with a document encoded by XML. The declaration of the *schema* and *namespace* for MTConnect *Response Documents* **MUST** be structured as attributes in the *Root Element* of the document. XML defines these attributes as pseudo-attributes since they provide additional information for the entire document and not just specifically for the *Root Element* itself.

> Note: If a *Response Document* contains sections that utilize different *schemas* and/or *namespaces*, additional pseudo-attributes should appear in the document as declared using standard conventions as defined be W3C.

For further information on declarations refer to *Appendix C*.

6.5 Document Header

The *Document Header* is an XML container in an *MTConnect Response Document* that provides information from an *Agent* defining version information, storage capacity, and parameters associated with the data management within the *Agent*. This XML element is called `Header`.

`Header` **MUST** be the first XML element following the *Root Element* of any *Response Document*. The `Header` XML element **MUST NOT** contain any *Child Elements*.

The content of the `Header` element will be different for each type of *Response Document*.

6.5.1 Header for MTConnectDevices

The Header element for an *MTConnectDevices Response Document* defines information regarding the creation of the document and the data storage capability of the *Agent* that generated the document.

6.5.1.1 XML Schema Structure for Header for MTConnectDevices

The *XML Schema* in *Figure 17* represents the structure of the Header XML element that **MUST** be provided for an *MTConnectDevices Response Document*.

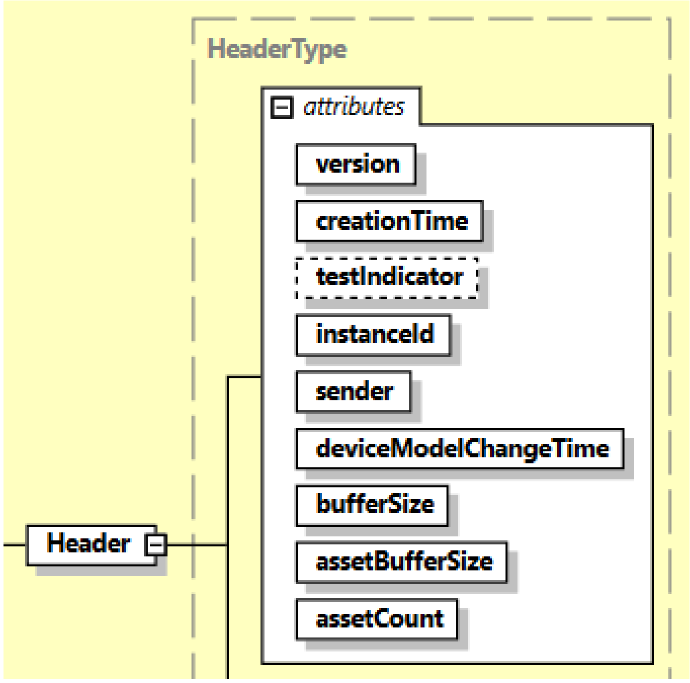


Figure 17: Header Schema Diagram for MTConnectDevices

6.5.1.2 Attributes for Header for MTConnectDevices

Table 5 defines the attributes that may be used to provide additional information in the Header element for an *MTConnectDevices Response Document*.

Table 5: MTConnectDevices Header

Attribute	Description	Occurrence
`version`	The *major*, *minor*, and *revision* number of the MTConnect Standard that defines the *semantic data model* that represents the content of the *Response Document*. It also includes the revision number of the *schema* associated with that specific *semantic data model*. The value reported for `version` **MUST** be a series of four numeric values, separated by a decimal point, representing a *major*, *minor*, and *revision* number of the MTConnect Standard and the revision number of a specific *schema*. As an example, the value reported for `version` for a *Response Document* that was structured based on *schema* revision 10 associated with Version 1.4.0 of the MTConnect Standard would be: 1.4.0.10 `version` is a required attribute.	1
`creationTime`	`creationTime` represents the time that an *Agent* published the *Response Document*. `creationTime` **MUST** be reported in UTC (Coordinated Universal Time) format; e.g., "2010-04-01T21:22:43Z". Note: Z refers to UTC/GMT time, not local time. `creationTime` is a required attribute.	1

Continuation of Table 5		
Attribute	Description	Occurrence
`testIndicator`	A flag indicating that the *Agent* that published the *Response Document* is operating in a test mode. The contents of the *Response Document* may not be valid and SHOULD be used for testing and simulation purposes only. The values reported for `testIndicator` are: - `true`: The *Agent* is functioning in a test mode. - `false`: The *Agent* is not functioning in a test mode. If `testIndicator` is not specified, the value for `testIndicator` **MUST** be interpreted to be `false`. `testIndicator` is an optional attribute.	0..1
`instanceId`	A number indicating a specific instantiation of the *buffer* associated with the *Agent* that published the *Response Document*. The value reported for `instanceId` **MUST** be a unique unsigned 64-bit integer. The value for `instanceId` **MUST** be changed to a different unique number each time the *buffer* is cleared and a new set of data begins to be collected. `instanceId` is a required attribute.	1

Continuation of Table 5

Attribute	Description	Occurrence
`sender`	An identification defining where the *Agent* that published the *Response Document* is installed or hosted. The value reported for `sender` **MUST** be either an IP Address or Hostname describing where the *Agent* is installed or the URL of the *Agent*; e.g., `http://<address>[:port]/`. Note: The port number need not be specified if it is the default HTTP port 80. `sender` is a required attribute.	1
`bufferSize`	A value representing the maximum number of *Data Entities* that **MAY** be retained in the *Agent* that published the *Response Document* at any point in time. The value reported for `bufferSize` **MUST** be a number representing an unsigned 32-bit integer. `bufferSize` is a required attribute. Note 1: `bufferSize` represents the maximum number of sequence numbers that **MAY** be stored in the *Agent*. Note 2: The implementer is responsible for allocating the appropriate amount of storage capacity required to accommodate the `bufferSize`.	1

Continuation of Table 5		
Attribute	Description	Occurrence
`assetBufferSize`	A value representing the maximum number of *Asset Documents* that can be stored in the *Agent* that published the *Response Document*. The value reported for `assetBufferSize` **MUST** be a number representing an unsigned 32-bit integer. `assetBufferSize` is a required attribute. Note: The implementer is responsible for allocating the appropriate amount of storage capacity required to accommodate the `assetBufferSize`.	1
`assetCount`	A number representing the current number of *Asset Documents* that are currently stored in the *Agent* as of the `creationTime` that the *Agent* published the *Response Document*. The value reported for `assetCount` **MUST** be a number representing an unsigned 32-bit integer and **MUST NOT** be larger than the value reported for `assetBufferSize`. `assetCount` is a required attribute.	1
`deviceModelChangeTime`	A timestamp in 8601 format of the last update of the `Device` information for any device.	1

Example 3 is an example of a `Header` XML element for an *MTConnectDevices Response Document*:

Example 3: Example of Header XML Element for MTConnectDevices

```
<Header creationTime="2017-02-16T16:44:27Z"
  sender="MyAgent" instanceId="1268463594"
```

```
    bufferSize="131072" version="1.4.0.10"
    assetCount="54" assetBufferSize="1024"/>
```

6.5.2 Header for MTConnectStreams

The `Header` element for an *MTConnectStreams Response Document* defines information regarding the creation of the document and additional information necessary for an application to interact and retrieve data from the *Agent*.

6.5.2.1 XML Schema Structure for Header for MTConnectStreams

The *XML Schema* in *Figure 18* represents the structure of the `Header` XML element that **MUST** be provided for an *MTConnectStreams Response Document*.

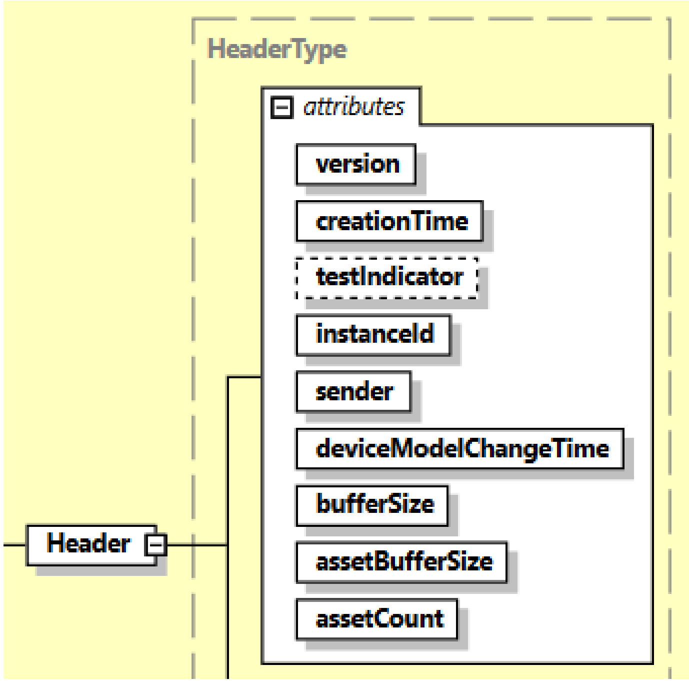


Figure 18: Header Schema Diagram for MTConnectStreams

6.5.2.2 Attributes for MTConnectStreams Header

Table 6 defines the attributes that may be used to provide additional information in the `Header` element for an *MTConnectStreams Response Document*.

Table 6: MTConnectStreams Header

Attribute	Description	Occurrence
`version`	The *major*, *minor*, and *revision* number of the MTConnect Standard that defines the *semantic data model* that represents the content of the *Response Document*. It also includes the revision number of the *schema* associated with that specific *semantic data model*. The value reported for `version` **MUST** be a series of four numeric values, separated by a decimal point, representing a *major*, *minor*, and *revision* number of the MTConnect Standard and the revision number of a specific *schema*. As an example, the value reported for `version` for a *Response Document* that was structured based on *schema* revision 10 associated with Version 1.4.0 of the MTConnect Standard would be: 1.4.0.10 `version` is a required attribute.	1
`creationTime`	`creationTime` represents the time that an *Agent* published the *Response Document*. `creationTime` **MUST** be reported in UTC (Coordinated Universal Time) format; e.g., "2010-04-01T21:22:43Z". Note: Z refers to UTC/GMT time, not local time. `creationTime` is a required attribute.	1

Continuation of Table 6		
Attribute	Description	Occurrence
`nextSequence`	A number representing the *sequence number* of the piece of *Streaming Data* that is the next piece of data to be retrieved from the *buffer* of the *Agent* that was not included in the Response Document published by the *Agent*. If the *Streaming Data* included in the Response Document includes the last piece of data stored in the *buffer* of the *Agent* at the time that the document was published, then the value reported for `nextSequence` **MUST** be equal to `lastSequence` + 1. The value reported for `nextSequence` **MUST** be a number representing an unsigned 64-bit integer. `nextSequence` is a required attribute.	1
`lastSequence`	A number representing the *sequence number* assigned to the last piece of *Streaming Data* that was added to the *buffer* of the *Agent* immediately prior to the time that the *Agent* published the Response Document. The value reported for `lastSequence` **MUST** be a number representing an unsigned 64-bit integer. `lastSequence` is a required attribute.	1

Continuation of Table 6		
Attribute	Description	Occurrence
firstSequence	A number representing the *sequence number* assigned to the oldest piece of *Streaming Data* stored in the *buffer* of the *Agent* immediately prior to the time that the *Agent* published the Response Document. The value reported for firstSequence **MUST** be a number representing an unsigned 64-bit integer. firstSequence is a required attribute.	1
testIndicator	A flag indicating that the *Agent* that published the *Response Document* is operating in a test mode. The contents of the *Response Document* may not be valid and **SHOULD** be used for testing and simulation purposes only. The values reported for testIndicator are: - true: The *Agent* is functioning in a test mode. - false: The *Agent* is not functioning in a test mode. If testIndicator is not specified, the value for testIndicator **MUST** be interpreted to be false. testIndicator is an optional attribute.	0..1

Continuation of Table 6

Attribute	Description	Occurrence
`instanceId`	A number indicating a specific instantiation of the *buffer* associated with the *Agent* that published the *Response Document*. The value reported for `instanceId` **MUST** be a unique unsigned 64-bit integer. The value for `instanceId` **MUST** be changed to a different unique number each time the *buffer* is cleared and a new set of data begins to be collected. `instanceId` is a required attribute.	1
`sender`	An identification defining where the *Agent* that published the *Response Document* is installed or hosted. The value reported for `sender` **MUST** be either an IP Address or Hostname describing where the *Agent* is installed or the URL of the *Agent*; e.g., `http://<address>[:port]/`. Note: The port number need not be specified if it is the default HTTP port 80. `sender` is a required attribute.	1

Continuation of Table 6

Attribute	Description	Occurrence
`bufferSize`	A value representing the maximum number of *Data Entities* that **MAY** be retained in the *Agent* that published the *Response Document* at any point in time. The value reported for `bufferSize` **MUST** be a number representing an unsigned 32-bit integer. `bufferSize` is a required attribute. Note 1: `bufferSize` represents the maximum number of *sequence numbers* that **MAY** be stored in the *Agent*. Note 2: The implementer is responsible for allocating the appropriate amount of storage capacity required to accommodate the `bufferSize`.	1
`deviceModelChangeTime`	A timestamp in 8601 format of the last update of the `Device` information for any device.	1

Example 4 is an example of a `Header` XML element for an *MTConnectStreams Response Document*:

Example 4: Example of Header XML Element for MTConnectStreams

```
<Header lastSequence="5430495" firstSequence="5299424"
  nextSequence="5430496" bufferSize="131072"
  version="1.4.0.12" instanceId="1579788747"
  sender="myagent" creationTime="2020-03-24T13:23:32Z"/>
```

6.5.3 Header for MTConnectAssets

The `Header` element for an *MTConnectAssets Response Document* defines information regarding the creation of the document and the storage of *Asset Documents* in the *Agent* that generated the document.

6.5.3.1 XML Schema Structure for Header for MTConnectAssets

The *XML Schema* in *Figure 19* represents the structure of the `Header` XML element that **MUST** be provided for an *MTConnectAssets Response Document*.

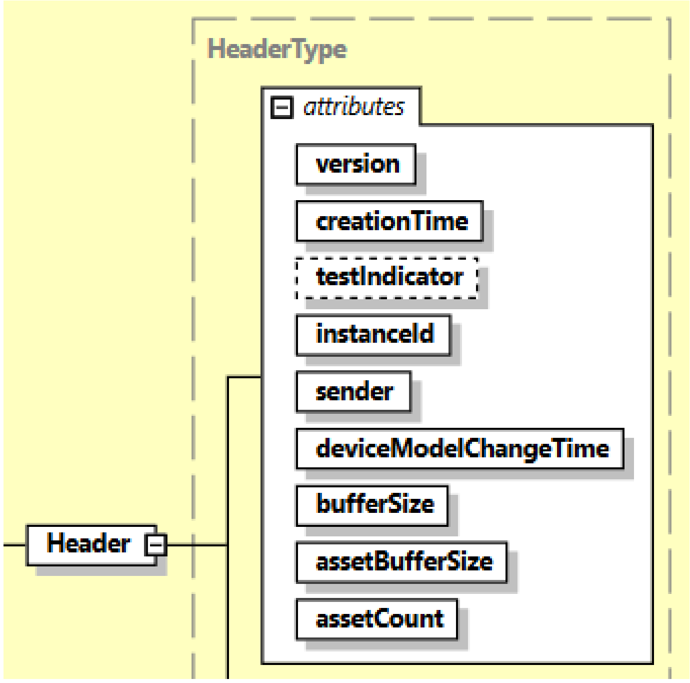


Figure 19: Header Schema Diagram for MTConnectAssets

6.5.3.2 Attributes for Header for MTConnectAssets

Table 7 defines the attributes that may be used to provide additional information in the `Header` element for an *MTConnectAssets Response Document*.

Table 7: MTConnectAssets Header

Attribute	Description	Occurrence
version	The *major*, *minor*, and *revision* number of the MTConnect Standard that defines the *semantic data model* that represents the content of the *Response Document*. It also includes the revision number of the *schema* associated with that specific *semantic data model*. The value reported for version **MUST** be a series of four numeric values, separated by a decimal point, representing a *major*, *minor*, and *revision* number of the MTConnect Standard and the revision number of a specific *schema*. As an example, the value reported for version for a *Response Document* that was structured based on *schema* revision 10 associated with Version 1.4.0 of the MTConnect Standard would be: 1.4.0.10 version is a required attribute.	1
creationTime	creationTime represents the time that an *Agent* published the *Response Document*. creationTime **MUST** be reported in UTC (Coordinated Universal Time) format; e.g., "2010-04-01T21:22:43Z". Note: Z refers to UTC/GMT time, not local time. creationTime is a required attribute.	1

Continuation of Table 7		
Attribute	Description	Occurrence
`testIndicator`	A flag indicating that the *Agent* that published the *Response Document* is operating in a test mode. The contents of the *Response Document* may not be valid and SHOULD be used for testing and simulation purposes only. The values reported for `testIndicator` are: - `true`: The *Agent* is functioning in a test mode. - `false`: The *Agent* is not functioning in a test mode. If `testIndicator` is not specified, the value for `testIndicator` **MUST** be interpreted to be `false`. `testIndicator` is an optional attribute.	0..1
`instanceId`	A number indicating a specific instantiation of the *buffer* associated with the *Agent* that published the *Response Document*. The value reported for `instanceId` **MUST** be a unique unsigned 64-bit integer. The value for `instanceId` **MUST** be changed to a different unique number each time the *buffer* is cleared and a new set of data begins to be collected. `instanceId` is a required attribute.	1

Continuation of Table 7		
Attribute	Description	Occurrence
sender	An identification defining where the *Agent* that published the *Response Document* is installed or hosted. The value reported for sender **MUST** be either an IP Address or Hostname describing where the *Agent* is installed or the URL of the *Agent*; e.g., http://<address>[:port]/. Note: The port number need not be specified if it is the default HTTP port 80. sender is a required attribute.	1
assetBufferSize	A value representing the maximum number of *Asset Documents* that can be stored in the *Agent* that published the *Response Document*. The value reported for assetBufferSize **MUST** be a number representing an unsigned 32-bit integer. assetBufferSize is a required attribute. Note: The implementer is responsible for allocating the appropriate amount of storage capacity required to accommodate the assetBufferSize.	1

Continuation of Table 7		
Attribute	Description	Occurrence
assetCount	A number representing the current number of *Asset Documents* that are currently stored in the *Agent* as of the creationTime that the *Agent* published the *Response Document*. The value reported for assetCount **MUST** be a number representing an unsigned 32-bit integer and **MUST NOT** be larger than the value reported for assetBufferSize. assetCount is a required attribute.	1
deviceModelChangeTime	A timestamp in 8601 format of the last update of the Device information for any device.	1

Example 5 is an example of a Header XML element for an *MTConnectAssets Response Document*:

Example 5: Example of Header XML Element for MTConnectAssets

```
<Header creationTime="2017-02-16T16:44:27Z"
  sender="MyAgent" instanceId="1268463594"
  version="1.4.0.10" assetCount="54"
  assetBufferSize="1024"/>
```

6.5.4 Header for MTConnectError

The Header element for an *MTConnectErrors Response Document* defines information regarding the creation of the document and the data storage capability of the *Agent* that generated the document.

6.5.4.1 XML Schema Structure for Header for MTConnectError

The *XML Schema* in *Figure 20* represents the structure of the Header XML element that **MUST** be provided for an *MTConnectErrors Response Document*.

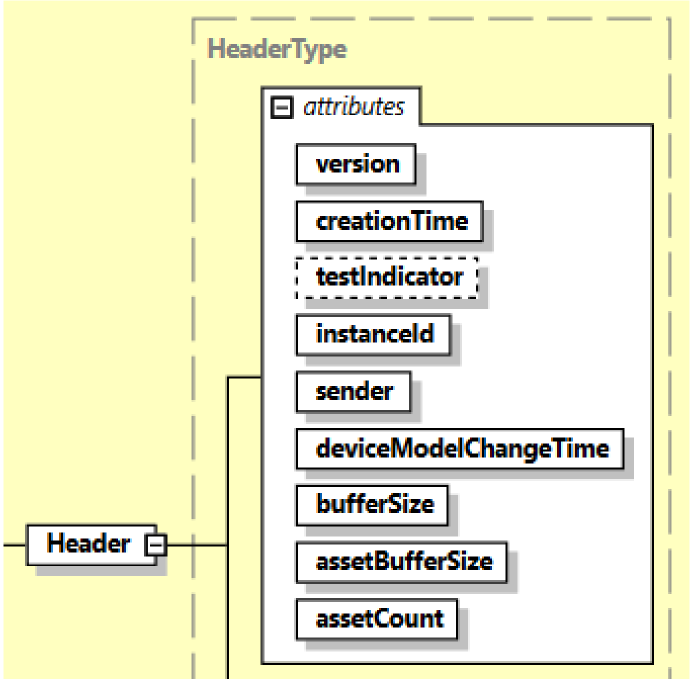


Figure 20: Header Schema Diagram for MTConnectError

6.5.4.2 Attributes for Header for MTConnectError

Table 8 defines the attributes that may be used to provide additional information in the Header element for an *MTConnectErrors Response Document*.

Table 8: MTConnectError Header

Attribute	Description	Occurrence
`version`	The *major*, *minor*, and *revision* number of the MTConnect Standard that defines the *semantic data model* that represents the content of the *Response Document*. It also includes the revision number of the *schema* associated with that specific *semantic data model*. The value reported for `version` **MUST** be a series of four numeric values, separated by a decimal point, representing a *major*, *minor*, and *revision* number of the MTConnect Standard and the revision number of a specific *schema*. As an example, the value reported for `version` for a *Response Document* that was structured based on *schema* revision 10 associated with Version 1.4.0 of the MTConnect Standard would be: 1.4.0.10 `version` is a required attribute.	1
`creationTime`	`creationTime` represents the time that an *Agent* published the *Response Document*. `creationTime` **MUST** be reported in UTC (Coordinated Universal Time) format; e.g., "2010-04-01T21:22:43Z". Note: Z refers to UTC/GMT time, not local time. `creationTime` is a required attribute.	1

Continuation of Table 8		
Attribute	Description	Occurrence
testIndicator	A flag indicating that the *Agent* that published the *Response Document* is operating in a test mode. The contents of the *Response Document* may not be valid and SHOULD be used for testing and simulation purposes only. The values reported for testIndicator are: - true: The *Agent* is functioning in a test mode. - false: The *Agent* is not functioning in a test mode. If testIndicator is not specified, the value for testIndicator **MUST** be interpreted to be false. testIndicator is an optional attribute.	0..1
instanceId	A number indicating a specific instantiation of the *buffer* associated with the *Agent* that published the *Response Document*. The value reported for instanceId **MUST** be a unique unsigned 64-bit integer. The value for instanceId **MUST** be changed to a different unique number each time the *buffer* is cleared and a new set of data begins to be collected. instanceId is a required attribute.	1

Continuation of Table 8

Attribute	Description	Occurrence
sender	An identification defining where the *Agent* that published the *Response Document* is installed or hosted. The value reported for sender **MUST** be either an IP Address or Hostname describing where the *Agent* is installed or the URL of the *Agent*; e.g., http://<address>[:port]/. Note: The port number need not be specified if it is the default HTTP port 80. sender is a required attribute.	1
bufferSize	A value representing the maximum number of *Data Entities* that **MAY** be retained in the *Agent* that published the *Response Document* at any point in time. The value reported for bufferSize **MUST** be a number representing an unsigned 32-bit integer. bufferSize is a required attribute. Note 1: bufferSize represents the maximum number of sequence numbers that **MAY** be stored in the *Agent*. Note 2: The implementer is responsible for allocating the appropriate amount of storage capacity required to accommodate the bufferSize.	1
deviceModelChangeTime	A timestamp in 8601 format of the last update of the Device information for any device.	1

Example 6 is an example of a Header XML element for an *MTConnectErrors Response Document*:

Example 6: Example of Header XML Element for MTConnectError

```
<Header creationTime="2017-02-16T16:44:27Z"
  sender="MyAgent" instanceId="1268463594"
  bufferSize="131072" version="1.4.0.10"/>
```

6.6 Document Body

The *Document Body* contains the information that is published by an *Agent* in response to a *Request* from a client software application. Each *Response Document* has a different XML element that represents the *Document Body*.

The structure of the content of the XML element representing the *Document Body* is defined by the *semantic data models* defined for each *Response Document*.

Table 9 defines the relationship between each of the *Response Documents*, the XML element that represents the *Document Body* for each document, and the *semantic data model* that defines the structure for the content of each of the *Response Documents*:

Table 9: Relationship between Response Document and Semantic Data Model

Response Document	XML Element for Document Body	Semantic Data Model
MTConnectDevices Response Document	`Devices`	*MTConnect Standard: Part 2.0 - Devices Information Model*
MTConnectStreams Response Document	`Streams`	*MTConnect Standard: Part 3.0 - Streams Information Model*
MTConnectAssets Response Document	`Assets`	*MTConnect Standard: Part 4.0 - Assets Information Model*

Continuation of Table 9		
Response Document	XML Element for Document Body	Semantic Data Model
MTConnectErrors Response Document	`Errors` Note: `Errors` **MUST NOT** be used when backwards compatibility with MTConnect Standard Version 1.0.1 and earlier is required.	*MTConnect Standard Part 1.0 - Overview and Fundamentals*

6.7 Extensibility

MTConnect is an extensible standard, which means that implementers **MAY** extend the *Data Models* defined in the various sections of the MTConnect Standard to include information required for a specific implementation. When these *Data Models* are encoded using XML, the methods for extending these *Data Models* are defined by the rules established for extending any XML schema (see the W3C website for more details on extending XML data models).

The following are typical extensions that **MAY** be considered in the MTConnect *Data Models*:

- Additional `type` and `subType` values for *Data Entities*.
- Additional *Structural Elements* as containers.
- Additional Composition elements.
- New *Asset* types that are sub-typed from the abstract *Asset* type.
- *Child Elements* that may be added to specific XML elements contained within the *MTConnect Information Models*. These extended elements **MUST** be identified in a separate *namespace*.

When extending an MTConnect *Data Model*, there are some basic rules restricting changes to the MTConnect *Data Models*.

When extending an MTConnect *Data Model*, an implementer:

- **MUST NOT** add new value for category for *Data Entities*,
- **MUST NOT** add new *Root Elements*,
- **SHOULD NOT** add new *Top Level Components*, and
- **MUST NOT** add any new attributes or include any sub-elements to `Composition`.

> Note: Throughout the documents additional information is provided where extensibility may be acceptable or unacceptable to maintain compliance with the MTConnect Standard.

When a *schema* representing a *Data Model* is extended, the *schema* and *namespace* declaration at the beginning of the corresponding *Response Document* **MUST** be updated to reflect the new *schema* and *namespace* so that a client software application can properly validate the *Response Document*.

An XML example of a *schema* and *namespace* declaration, including an extended *schema* and *namespace*, is shown in *Example 7*:

Example 7: Example of extended schema and namespace in declaration

```
1 <?xml version="1.0" encoding="UTF-8"?>
2   <MTConnectDevices
3    xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
4    xmlns="urn:mtconnect.org:MTConnectDevices:1.3"
5    xmlns:m="urn:mtconnect.org:MTConnectDevices:1.3"
6    xmlns:x="urn:MyLocation:MyFile:MyVersion"
7    xsi:schemaLocation="urn:MyLocation:MyFile:MyVersion
8      /schemas/MyFileName.xsd" />
```

In this example:

- `xmlns:x` is added in Line 6 to identify the *XML Schema* instance for the extended *schema*. *Element Names* identified with an "`x`" prefix are associated with this specific *XML Schema* instance.

> Note: The "x" prefix **MAY** be replaced with any prefix that the implementer chooses for identifying the extended *schema* and *namespace*.

- `xsi:schemaLocation` is modified in Line 7 to associate the *namespace* URN with the URL specifying the location of *schema* file.

- `MyLocation`, `MyFile`, `MyVersion`, and `MyFileName` in Lines 6 and 7 **MUST** be replaced by the actual name, version, and location of the extended *schema*.

When an extended *schema* is implemented, each *Structural Element*, *Data Entity*, and *MTConnect Asset* defined in the extended *schema* **MUST** be identified in each respective *Response Document* by adding a prefix to the XML *Element Name* associated with that *Structural Element*, *Data Entity*, or *MTConnect Asset*. The prefix identifies the *schema* and *namespace* where that XML Element is defined.

7 Protocol and Messaging

An *Agent* performs two *major* communications tasks. It collects information from pieces of equipment and it publishes MTConnect *Response Documents* in response to *Requests* from client software applications.

The MTConnect Standard does not address the method used by an *Agent* to collect information from a piece of equipment. The relationship between the *Agent* and a piece of equipment is implementation dependent. The *Agent* may be fully integrated into the piece of equipment or the *Agent* may be independent of the piece of equipment. Implementation of the relationship between a piece of equipment and an *Agent* is the responsibility of the supplier of the piece of equipment and/or the implementer of the *Agent*.

The communications mechanism between an *Agent* and a client software application requires the following primary components:

- *Physical Connection*: The network transmission technologies that physically interconnect an *Agent* and a client software application. Examples of a *Physical Connection* would be an Ethernet network or a wireless connection.

- Transport Protocol: A set of capabilities that provide the rules and procedures used to transport information between an *Agent* and a client software application through a *Physical Connection*.

- *Application Programming Interface*: The *Request* and *Response* interactions that occur between an *Agent* and a client software application.

- *Message*: The content of the information that is exchanged. The *Message* includes both the content of the MTConnect *Response Document* and any additional information required for the client software application to interpret the *Response Document*.

  > Note: The *Physical Connections*, *Transport Protocols*, and *Application Programming Interface* supported by an *Agent* are independent of the *Message* itself; i.e., the information contained in the MTConnect *Response Documents* is not changed based on the methods used to transport those documents to a client software application.

An *Agent* **MAY** support multiple methods for communicating with client software applications. The MTConnect Standard specifies one methodology for communicating that **MUST** be supported by every *Agent*. This methodology is a REST, which defines a stateless, client-server communications architecture. This REST interface is the architectural pattern that specifies the exchange of information between an *Agent* and a client software application. REST dictates that a server has no responsibility for tracking or coordinating with a client software application regarding which information or how much information the client software application may request from a server. This removes the burden for a server to keep track of client sessions. An *Agent* **MUST** be implemented as a server supporting the RESTful interface.

8 HTTP Messaging Supported by an Agent

This section describes the application of *HTTP Messaging* applied to a REST interface that **MUST** be supported by an *Agent* to realize the MTConnect *Request/Response* information exchange functionality.

8.1 REST Interface

An *Agent* **MUST** provide a REST interface that supports HTTP version 1.0 to communicate with client applications. This interface **MUST** support HTTP (RFC7230) and use URIs (RFC3986) to identify specific information requested from an *Agent*. HTTP is most often implemented on top of the Transmission Control Protocol (TCP) that provides an ordered byte stream of data and the Internet Protocol (IP) that provides unified addressing and routing between computers. However, additional interfaces to an *Agent* may be implemented in conjunction with any other communications technologies.

The REST interface supports an *Application Programming Interface* (API) that adheres to the architectural principles of a stateless, uniform interface to retrieve data and other information related to either pieces of equipment or *MTConnect Assets*. The API allows for access, but not modification of data stored within the *Agent* and is nullipotent, meaning it will not produce any side effects on the information stored in an *Agent* or the function of the *Agent* itself.

HTTP Messaging is comprised of two basic functions – an *HTTP Request* and an *HTTP Response*. A client software application forms a *Request* for information from an *Agent* by specifying a specific set of information using an *HTTP Request*. In response, an *Agent* provides either an *HTTP Response* or replies with an *HTTP Error Message* as defined below.

8.2 HTTP Request

The MTConnect Standard defines that an *Agent* **MUST** support the `HTTP GET` verb – no other HTTP methods are required to be supported.

An *HTTP Request* **MAY** include three sections:

- an *HTTP Request Line*
- *HTTP Header Fields*

- an *HTTP Body*

The MTConnect Standard defines that an *HTTP Request* issued by a client application **SHOULD** only have two sections:

- an *HTTP Request Line*
- *HTTP Header Fields*

The *HTTP Request Line* identifies the specific information being requested by the client software application. If an *Agent* receives any information in an *HTTP Request* that is not specified in the MTConnect Standard, the *Agent* **MAY** ignore it.

The structure of an *HTTP Request Line* consists of the following portions:

- *HTTP Request Method*: `GET`
- *HTTP Request URL*: `http://<authority>/<path>[?<query>]`
- *HTTP Version*: `HTTP/1.0`

For the following discussion, the *HTTP Request URL* will only be considered since the Method will always be `GET` and the MTConnect Standard only requires `HTTP/1.0`.

8.2.1 authority Portion of an HTTP Request Line

The `authority` portion consists of the DNS name or IP address associated with an *Agent* and an optional TCP port number [:`port`] that the *Agent* is listening to for incoming *Requests* from client software applications. If the port number is the default Port 80, `port` is not required.

Example forms for `authority` are:

- `http://machine/`
- `http://machine:5000/`
- `http://192.168.1.2:5000/`

8.2.2 path Portion of an HTTP Request Line

The `<Path>` portion of the *HTTP Request Line* has the follow segments:

- `/<name or uuid>/<request>`

In this portion of the *HTTP Request Line*, name or uuid designates that the information to be returned in a *Response Document* is associated with a specific piece of equipment that has published data to the *Agent*. See Part 2 - *Devices Information Model* for details on name or uuid for a piece of equipment.

> Note: If `name` or `uuid` are not specified in the *HTTP Request Line*, an *Agent* **MUST** return the information for all pieces of equipment that have published data to the *Agent* in the *Response Document*.

In the `<Path>` portion of the *HTTP Request Line*, `<request>` designates one of the *Requests* defined in *Section 5.4 - Request/Response Information Exchange*. The value for `<request>` **MUST** be `probe`, `current`, `sample`, or `asset`(s) representing the *Probe Request*, *Current Request*, *Sample Request*, and *Asset Request* respectively.

8.2.3 query Portion of an HTTP Request Line

The [`?<query>`] portion of the *HTTP Request Line* designates an HTTP *Query*. *Query* is a string of parameters that define filters used to refine the content of a *Response Document* published in response to an *HTTP Request*.

8.3 MTConnect Request/Response Information Exchange Implemented with HTTP

An *Agent* **MUST** support *Probe Requests*, *Current Requests*, *Sample Requests*, and *Asset Requests*.

The following sections define how the *HTTP Request Line* is structured to support each of these types of *Requests* and the information that an *Agent* **MUST** provide in response to these *Requests*.

8.3.1 Probe Request Implemented Using HTTP

An *Agent* responds to a *Probe Request* with an *MTConnectDevices Response Document* that contains the *Equipment Metadata* for pieces of equipment that are requested and currently represented in the *Agent*.

There are two forms of the *Probe Request*:

- The first form includes an *HTTP Request Line* that does not specify a specific path portion (`name` or `uuid`). In response to this *Request*, the *Agent* returns an *MTConnectDevices Response Document* with information for all pieces of equipment represented in the *Agent*.

  1. `http://<authority>/probe`

- The second form includes an *HTTP Request Line* that specifies a specific path portion that defines either a `name` or `uuid`. In response to this *Request*, the *Agent* returns an *MTConnectDevices Response Document* with information for only the one piece of equipment associated with that `name` or `uuid`.

  1. `http://<authority>/<name or uuid>/probe`

8.3.1.1 Path Portion of the HTTP Request Line for a Probe Request

The following segments of `path` **MUST** be supported in an *HTTP Request Line* for a *Probe Request*:

Table 10: Path of the HTTP Request Line for a Probe Request

Path Segments	Description
`name` or `uuid`	If present, specifies that only the *Equipment Metadata* for the piece of equipment represented by the `name` or `uuid` will be published. If not present, *Metadata* for all pieces of equipment associated with the *Agent* will be published.
`<request>`	`probe` **MUST** be provided.

8.3.1.2 Query Portion of the HTTP Request Line for a Probe Request

The *HTTP Request Line* for a *Probe Request* **SHOULD NOT** contain a `query`. If the

Request does contain a `query`, the *Agent* **MUST** ignore the `query`.

8.3.1.3 Response to a Probe Request

The *Response* to a *Probe Request* **SHOULD** be an *MTConnectDevices Response Document* for one or more pieces of equipment as designated by the `path` portion of the *Request*.

The *Response Document* returned in response to a *Probe Request* **MUST** always provide the most recent information available to an *Agent*.

The *Response* **MUST** also include an *HTTP Status Code*. If problems are encountered by an *Agent* while responding to a *Probe Request*, the *Agent* **MUST** also publish an *MTConnectErrors Response Document*.

8.3.1.4 HTTP Status Codes for a Probe Request

The following *HTTP Status Codes* **MUST** be supported as possible responses to a *Probe Request*:

Table 11: HTTP Status Codes for a Probe Request

HTTP Status Code	Code Name	Description
200	OK	The *Request* was handled successfully.
400	Bad Request	The *Request* could not be interpreted. The *Agent* **MUST** return a 400 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies either `INVALID_URI` or `INVALID_REQUEST` as the `errorCode`.
404	Not Found	The *Request* could not be interpreted. The *Agent* **MUST** return a 404 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `NO_DEVICE` as the `errorCode`.

Continuation of Table 11		
HTTP Status Code	Code Name	Description
405	Method Not Allowed	A method other than `GET` was specified in the *Request* or the piece of equipment specified in the *Request* could not be found. The *Agent* **MUST** return a 405 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `UNSUPPORTED` as the `errorCode`.
406	Not Acceptable	The *HTTP Accept Header* in the *Request* was not one of the supported representations. The *Agent* **MUST** return a 406 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `UNSUPPORTED` as the `errorCode`.
431	Request Header Fields Too Large	The fields in the *HTTP Request* exceed the limit of the implementation of the *Agent*. The *Agent* **MUST** return a 431 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `INVALID_REQUEST` as the `errorCode`.
500	Internal Server Error	There was an unexpected error in the *Agent* while responding to a *Request*. The *Agent* **MUST** return a 500 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `INTERNAL_ERROR` as the `errorCode`.

8.3.2 Current Request Implemented Using HTTP

An *Agent* responds to a *Current Request* with an *MTConnectStreams Response Document* that contains the current value of *Data Entities* associated with each piece of *Streaming Data* available from the *Agent*, subject to any filtering defined in the *Request*.

There are two forms of the *Current Request*:

- The first form is given without a specific path portion (`name` or `uuid`). In response to this *Request*, the *Agent* returns an *MTConnectStreams Response Document* with information for all pieces of equipment represented in the *buffer* of the *Agent*.
  1. `http://<authority>/current[?query]`
- The second form includes a specific path portion that defines either a `name` or `uuid`. In response to this *Request*, the *Agent* returns an *MTConnectStreams Response Document* with information for only the one piece of equipment associated with the `name` or `uuid` defined in the *Request*.
  1. `http://<authority>/<name or uuid>/current[?query]`

8.3.2.1 Path Portion of the HTTP Request Line for a Current Request

The following segments of path **MUST** be supported for an *HTTP Request Line* for a *Current Request*:

Table 12: Path of the HTTP Request Line for a Current Request

Path Segments	Description
`name` or `uuid`	If present, specifies that only the *Equipment Metadata* for the piece of equipment represented by the `name` or `uuid` will be published. If not present, *Metadata* for all pieces of equipment associated with the *Agent* will be published.
`<request>`	`current` **MUST** be provided.

8.3.2.2 Query Portion of the HTTP Request Line for a Current Request

A *Query* may be used to more precisely define the specific information to be included in a *Response Document*. Multiple parameters may be used in a *Query* to further refine the information to be included. When multiple parameters are provided, each parameter is separated by an ampersand (&) character and each parameter appears only once in the *Query*. The parameters within the *Query* may appear in any sequence.

The following `query` parameters **MUST** be supported in an *HTTP Request Line* for a *Current Request*:

Table 13: Query Parameters of the HTTP Request Line for a Current Request

Query Parameters	Description
`path`	An XPath that defines specific information or a set of information to be included in an *MTConnectStreams Response Document*. The value for the XPath is the location of the information defined in the *Devices Information Model* that represents the *Structural Element*(s) and/or the specific *Data Entities* to be included in the *MTConnectStreams Response Document* . When a `Component` element is referenced by the XPath, all *Lower Level* components and the *Data Entities* associated with those elements **MUST** be included in the *MTConnectStreams Response Document*.

Continuation of Table 13	
Query Parameters	Description
at	Requests that the *MTConnect Response Documents* **MUST** include the current value for all *Data Entities* relative to the time that a specific *sequence number* was recorded. The value associated with the at parameter references a specific *sequence number*. The value **MUST** be an unsigned 64-bit value. The at parameter **MUST NOT** be used in conjunction with the interval parameter since this would cause an *Agent* to repeatedly return the same data. If the value provided for the at parameter is a negative number or is not a, the *Request* **MUST** be determined to be invalid. The *Agent* **MUST** return a 400 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies an INVALID_REQUEST errorCode. If the value provided for the at parameter is either lower than the value of firstSequence or greater than the value of lastSequence, the *Request* **MUST** be determined to be invalid. The *Agent* **MUST** return a 404 *HTTP Status Code*. The *Agent* **MUST** also publish an *MTConnectErrors Response Document* that identifies an OUT_OF_RANGE errorCode. Note: Some information stored in the *buffer* of an *Agent* may not be returned for a *Current Request* with a *Query* containing an at parameter if the *sequence number* associated with the most current value for that information is greater than the *sequence number* specified in the *Query*.
interval	The *Agent* **MUST** continuously publish *Response Documents* when the query parameters include interval using the value as the period between adjacent publications. The interval value **MUST** be in milliseconds, and **MUST** be a positive integer greater than zero (0). The *Query* **MUST NOT** specify both interval and at parameters.

2049 8.3.2.3 Response to a Current Request

The *Response* to a *Current Request* **SHOULD** be an *MTConnectStreams Response Document* for one or more pieces of equipment designated by the `path` portion of the *Request*.

The *Response* to a *Current Request* **MUST** always provide the most recent information available to an *Agent* or, when the `at` parameter is specified, the value of the data at the given *sequence number*.

The *Data Entities* provided in the *MTConnectStreams Response Document* will be limited to those specified in the combination of the `path` segment of the *Current Request* and the value of the XPath defined for the `path` attribute provided in the `query` segment of that *Request*.

8.3.2.4 HTTP Status Codes for a Current Request

The following *HTTP Status Codes* **MUST** be supported as possible responses to a *Current Request*:

Table 14: HTTP Status Codes for a Current Request

HTTP Status Code	Code Name	Description
200	OK	The *Request* was handled successfully.
400	Bad Request	The *Request* could not be interpreted. The *Agent* **MUST** return a 400 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies either `INVALID_URI`, `INVALID_REQUEST`, or `INVALID_XPATH` as the `errorCode`. If the `query` parameters do not contain a valid value or include an invalid parameter, the *Agent* **MUST** return a 400 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `QUERY_ERROR` as the `errorCode`.

Continuation of Table 14		
HTTP Status Code	Code Name	Description
404	Not Found	The *Request* could not be interpreted. The *Agent* **MUST** return a 404 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `NO_DEVICE` as the `errorCode`. If the value of the `at` parameter was greater than the `lastSequence` or is less than the `firstSequence`, the *Agent* **MUST** return a 404 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `OUT_OF_RANGE` as the `errorCode`.
405	Method Not Allowed	A method other than `GET` was specified in the *Request* or the piece of equipment specified in the *Request* could not be found. The *Agent* **MUST** return a 405 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `UNSUPPORTED` as the `errorCode`.
406	Not Acceptable	The *HTTP Accept Header* in the *Request* was not one of the supported representations. The *Agent* **MUST** return a 406 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `UNSUPPORTED` as the `errorCode`.
431	Request Header Fields Too Large	The fields in the *HTTP Request* exceed the limit of the implementation of the *Agent*. The *Agent* **MUST** return a 431 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `INVALID_REQUEST` as the `errorCode`.

Continuation of Table 14		
HTTP Status Code	Code Name	Description
500	Internal Server Error	There was an unexpected error in the *Agent* while responding to a *Request*. The *Agent* **MUST** return a 500 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `INTERNAL_ERROR` as the `errorCode`.

8.3.3 Sample Request Implemented Using HTTP

An *Agent* responds to a *Sample Request* with an *MTConnectStreams Response Document* that contains a set of values for *Data Entities* currently available for *Streaming Data* from the *Agent*, subject to any filtering defined in the *Request*.

There are two forms to the *Sample Request*:

- The first form is given without a specific `path` portion (`name` or `uuid`). In response to this *Request*, the *Agent* returns an *MTConnectStreams Response Document* with information for all pieces of equipment represented in the *Agent*.

  ```
  1. http://<authority>/sample[?query]
  ```

- The second form includes a specific `path` portion that defines either a `name` or `uuid`.

  In response to this *Request*, the *Agent* returns an *MTConnectStreams Response Document* with information for only the one piece of equipment associated with the `name` or `uuid` defined in the *Request*.

  ```
  1. http://<authority>/<name or uuid>/sample?query
  ```

8.3.3.1 Path Portion of the HTTP Request Line for a Sample Request

The following segments of `path` **MUST** be supported in the *HTTP Request Line* for a *Sample Request*:

Table 15: Path of the HTTP Request Line for a Sample Request

Path Segments	Description
`name` or `uuid`	If present, specifies that only the *Equipment Metadata* for the piece of equipment represented by the `name` or `uuid` will be published. If not present, *Metadata* for all pieces of equipment associated with the *Agent* will be published.
`<request>`	`sample` **MUST** be provided.

8.3.3.2 Query Portion of the HTTP Request Line for a Sample Request

A *Query* may be used to more precisely define the specific information to be included in a *Response Document*. Multiple parameters may be used in a *Query* to further refine the information to be included. When multiple parameters are provided, each parameter is separated by an & character and each parameter appears only once in the *Query*. The parameters within the *Query* may appear in any sequence.

The following `query` parameters **MUST** be supported in an *HTTP Request Line* for a *Sample Request*:

Table 16: Query Parameters of the HTTP Request Line for a Sample Request

Query Parameters	Description
`path`	An XPath that defines specific information or a set of information to be included in an *MTConnectStreams Response Document*. The value for the XPath is the location of the information defined in the *Devices Information Model* that represents the *Structural Element*(s) and/or the specific *Data Entities* to be included in the *MTConnectStreams Response Document* . When a `Component` element is referenced by the XPath, all *Lower Level* components and the *Data Entities* associated with those elements **MUST** be included in the *MTConnectStreams Response Document*.

Continuation of Table 16	
Query Parameters	Description
`from`	The `from` parameter designates the *sequence number* of the first *observation* in the *buffer* the *Agent* **MUST** consider publishing in the *Response Document*. The value of `from` **MUST** be an unsigned 64-bit integer. If `from` is zero (0), it **MUST** be set to the `firstSequence`, the oldest *observation* in the *buffer*. If `from` and `count` parameters are not given, `from` **MUST** default to the `firstSequence`. If `from` is not given and `count` parameter is given, see `count` for default behavior. If the `from` parameter is less than the `firstSequence` or greater than `lastSequence`, the *Agent* **MUST** return a `404` *HTTP Status Code* and **MUST** publish an *MTConnectErrors Response Document* with an `OUT_OF_RANGE` `errorCode`. If the `from` parameter is not a positive numeric value, the *Agent* **MUST** return a `400` *HTTP Status Code* and **MUST** publish an *MTConnectErrors Response Document* with an `INVALID_REQUEST` `errorCode`.

Continuation of Table 16

Query Parameters	Description
`interval`	The *Agent* **MUST** continuously publish *Response Documents* when the query parameters include `interval` using the value as the minimum period between adjacent publications. The `interval` value **MUST** be in milliseconds, and **MUST** be a positive integer greater than or equal to zero (0). The *Query* **MUST NOT** specify both `interval` and `from` parameters. If the value for the `interval` parameter is zero (0), the *Agent* **MUST** publish *Response Documents* at the fastest rate possible. If the period between the publication of a *Response Document* and reception of *observations* exceeds the `interval`, the *Agent* **MUST** wait for a maximum of `heartbeat` milliseconds for *observations*. Upon the arrival of *observations*, the *Agent* **MUST** immediately publish a *Response Document*. When the period equals or exceeds the `heartbeat`, the *Agent* **MUST** publish an empty *Response Document*.

Continuation of Table 16	
Query Parameters	Description
count	The count parameter designates the maximum number of *observations* the *Agent* **MUST** publish in the *Response Document*. The value of count **MUST** be a signed integer. The count **MUST NOT** be zero (0). When the count is greater than zero (0), the from parameter **MUST** default to the firstSequence. The evaluation of *observations* starts at from and moves forward accumulating newer *observations* until the number of *observations* equals the count or the *observation* at lastSequence is considered. When the count is less than zero (0), the from parameter **MUST** default to the lastSequence. The evaluation of *observations* starts at from and moves backward accumulating older *observations* until the number of *observations* equals the absolute value of count or the *observation* at firstSequence is considered. count **MUST NOT** be less than zero (0) when an interval parameter is given. If count is not provided, it **MUST** default to 100. If the absolute value of count is greater than the size of the *buffer* or equal to zero (0), the *Agent* **MUST** return a 404 *HTTP Status Code* and **MUST** publish an *MTConnectErrors Response Document* with an OUT_OF_RANGE errorCode. If the count parameter is not a numeric value, the *Agent* **MUST** return a 400 *HTTP Status Code* and **MUST** publish an *MTConnectErrors Response Document* with an INVALID_REQUEST errorCode.

Continuation of Table 16	
Query Parameters	Description
`heartbeat`	Sets the time period for the *heartbeat* function in an *Agent*. The value for `heartbeat` represents the amount of time after a *Response Document* has been published until a new *Response Document* **MUST** be published, even when no new data is available. The value for `heartbeat` is defined in milliseconds. If no value is defined for `heartbeat`, the value **SHOULD** default to 10 seconds. `heartbeat` **MUST** only be specified if interval is also specified.

Continuation of Table 16	
Query Parameters	Description
`to`	The to parameter specifies the sequence number of the observation in the buffer that will be the upper bound of the observations in the Response Document. • The value of `to` **MUST** be an unsigned 64-bit integer. • The value of `to` **MUST** be greater than the `firstSequence`. • The value of `to` **MUST** be less than or equal to the `lastSequence`. • The value of `to` **MUST** be greater than `from`. • If `to` and `count` are given, the `count` parameter **MUST** be greater than zero. • If `to` and `count` are given, the maximum number of *observations* published in the *Response Document* **MUST NOT** be greater than the value of `count`. • If `to` is not given, see the `from` parameter for default behavior. • If the `to` parameter is less than the `firstSequence` or greater than `lastSequence`, the *Agent* **MUST** return a `404` *HTTP Status Code* and **MUST** publish an *MTConnectErrors Response Document* with an `OUT_OF_RANGE` `errorCode`. • If the `to` parameter is not a positive numeric value, the *Agent* **MUST** return a `400` *HTTP Status Code* and **MUST** publish an *MTConnectErrors Response Document* with an `INVALID_REQUEST` `errorCode`.

Continuation of Table 16	
Query Parameters	Description
to (continued)	• If the to parameter is less than the from parameter, the *Agent* **MUST** return a 400 *HTTP Status Code* and **MUST** publish an *MTConnectErrors Response Document* with an INVALID_REQUEST errorCode. • If the to parameter is given and the count parameter is less than zero, the *Agent* **MUST** return a 400 *HTTP Status Code* and **MUST** publish an *MTConnectErrors Response Document* with an INVALID_REQUEST errorCode.

8.3.3.3 Response to a Sample Request

The *Response* to a *Sample Request* **SHOULD** be an *MTConnectStreams Response Document* for one or more pieces of equipment designated by the path portion of the *Request*.

The *Response* to a *Sample Request* **MUST** always provide the most recent information available to an *Agent* or, when the at parameter is specified, the value of the data at the given *sequence number*.

The *Data Entities* provided in the *MTConnectStreams Response Document* will be limited to those specified in the combination of the path segment of the *Sample Request* and the value of the XPath defined for the path attribute provided in the query segment of that *Request*.

When the value of from references the value of the next *sequence number* (nextSequence) and there are no additional *Data Entities* available in the buffer, the response document will have an empty <Streams/> element in the MTConnectStreams document to indicate no data is available at the point in time that the *Agent* published the *Response Document*.

8.3.3.4 HTTP Status Codes for a Sample Request

The following *HTTP Status Codes* **MUST** be supported as possible responses to a *Sample Request*:

Table 17: HTTP Status Codes for a Sample Request

HTTP Status Code	Code Name	Description
200	OK	The *Request* was handled successfully.
400	Bad Request	The *Request* could not be interpreted. The *Agent* **MUST** return a 400 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies either `INVALID_URI`, `INVALID_REQUEST`, or `INVALID_XPATH` as the `errorCode`. If the `query` parameters do not contain a valid value or include an invalid parameter, the *Agent* **MUST** return a 400 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `QUERY_ERROR` as the `errorCode`.
404	Not Found	The *Request* could not be interpreted. The *Agent* **MUST** return a 404 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `NO_DEVICE` as the `errorCode`. If the value of the `at` parameter was greater than the `lastSequence` or is less than the `firstSequence`, the *Agent* **MUST** return a 404 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `OUT_OF_RANGE` as the `errorCode`.
405	Method Not Allowed	A method other than `GET` was specified in the *Request* or the piece of equipment specified in the *Request* could not be found. The *Agent* **MUST** return a 405 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `UNSUPPORTED` as the `errorCode`.

Continuation of Table 17		
HTTP Status Code	Code Name	Description
406	Not Acceptable	The *HTTP Accept Header* in the *Request* was not one of the supported representations. The *Agent* **MUST** return a 406 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `UNSUPPORTED` as the `errorCode`.
431	Request Header Fields Too Large	The fields in the *HTTP Request* exceed the limit of the implementation of the *Agent*. The *Agent* **MUST** return a 431 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `INVALID_REQUEST` as the `errorCode`.
500	Internal Server Error	There was an unexpected error in the *Agent* while responding to a *Request*. The *Agent* **MUST** return a 500 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies `INTERNAL_ERROR` as the `errorCode`.

8.3.4 Asset Request Implemented Using HTTP

An *Agent* responds to an *Asset Request* with an *MTConnectAssets Response Document* that contains information for *MTConnect Assets* from the *Agent*, subject to any filtering defined in the *Request*.

There are multiple forms to the *Asset Request*:

- The first form is given without a specific `path` portion (`name` or `uuid`). In response to this *Request*, the *Agent* returns an *MTConnectAssets Response Document* that contains information for all *Asset Document* represented in the *Agent*.

  1. `http://<authority>/assets`

- The second form includes a specific `path` portion that defines the identity (`asset_id`) for one or more specific *Asset Documents*. In response to this *Request*, the *Agent* returns an*MTConnectAssets Response Document* that contains information for the specific Assets represented in the *Agent* and defined by each of the `asset_id` values provided in the *Request*. Each `asset_id` is separated by a ";".

  1. `http://<authority>/asset/asset_id;asset_id;asset_id....`

Note: An *HTTP Request Line* may include combinations of `path` and `query` to achieve the desired set of *Asset Documents* to be included in a specific *MTConnectAssets Response Document*.

8.3.4.1 Path Portion of the HTTP Request Line for an Asset Request

The following segments of path **MUST** be supported in the *HTTP Request Line* for an *Asset Request*:

Table 18: Path of the HTTP Request Line for an Asset Request

Path Segments	Description
`<request>`	`asset` or `assets` **MUST** be provided.
`asset_id`	Identifies the `id` attribute of an *MTConnect Asset* to be provided by an *Agent*.

8.3.4.2 Query Portion of the HTTP Request Line for an Asset Request

A *Query* may be used to more precisely define the specific information to be included in a *Response Document*. Multiple parameters may be used in a *Query* to further refine the information to be included. When multiple parameters are provided, each parameter is separated by an & character and each parameter appears only once in the *Query*. The parameters within the *Query* may appear in any sequence.

The following `query` parameters **MUST** be supported in an *HTTP Request Line* for an *Asset Request*:

Table 19: Query Parameters of the HTTP Request Line for an Asset Request

Query Parameters	Description
`type`	Defines the type of *MTConnect Asset* to be returned in the *MTConnectAssets Response Document*. The type for an *Asset* is the term used in the *Asset Information Model* to describe different types of *Assets*. It is the term that is substituted for the `Asset` container and describes the highest-level element in the *Asset* hierarchy. See *MTConnect Standard: Part 4.0 - Assets Information Model*, *Section 3.2.3* for more information on the type of an *Asset*.
`removed`	*Assets* can have an attribute that indicates whether the *Asset* has been removed from a piece of equipment. The valid values for `removed` are `true` or `false`. If the value of the `removed` parameter in the `query` is `true`, then *Asset Documents* for *Assets* that have been marked as removed from a piece of equipment will be included in the *Response Document*. If the value of the `removed` parameter in the `query` is `false`, then *Asset Documents* for *Assets* that have been marked as `removed` from a piece of equipment will not be included in the *Response Document*. If `removed` is not defined in a `query`, the default value for `removed` **MUST** be determined to be `false`.
`count`	Defines the maximum number of *Asset Documents* to return in an *MTConnectAssets Response Document*. If `count` is not defined in the `query`, the default vale for `count` **MUST** be determined to be 100.

8.3.4.3 Response to an Asset Request

The *Response* to an *Asset Request* **SHOULD** be an *MTConnectAssets Response Document* containing information for one or more *Asset Documents* designated by the *Request*. The *Response* to an *Asset Request* **MUST** always provide the most recent information available to an *Agent*.

The *Asset Documents* provided in the *MTConnectAssets Response Document* will be limited to those specified in the combination of the path segment of the *Asset Request* and the parameters provided in the query segment of that *Request*.

If the removed query parameter is not provided with a value of true, *Asset Documents* for *Assets* that have been marked as removed will not be provided in the response.

8.3.4.4 HTTP Status Codes for a Asset Request

The following *HTTP Status Codes* **MUST** be supported as possible responses to an *Asset Request*:

Table 20: HTTP Status Codes for an Asset Request

HTTP Status Code	Code Name	Description
200	OK	The *Request* was handled successfully.
400	Bad Request	The *Request* could not be interpreted. The *Agent* **MUST** return a 400 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies either INVALID_URI or INVALID_REQUEST as the errorCode. If the query parameters do not contain a valid value or include an invalid parameter, the *Agent* **MUST** return a 400 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies QUERY_ERROR as the errorCode.
404	Not Found	The *Request* could not be interpreted. The *Agent* **MUST** return a 404 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies NO_DEVICE or ASSET_NOT_FOUND as the errorCode.

Continuation of Table 20

HTTP Status Code	Code Name	Description
405	Method Not Allowed	A method other than GET was specified in the *Request* or the piece of equipment specified in the *Request* could not be found. The *Agent* **MUST** return a 405 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies UNSUPPORTED as the errorCode.
406	Not Acceptable	The *HTTP Accept Header* in the *Request* was not one of the supported representations. The *Agent* **MUST** return a 406 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies UNSUPPORTED as the errorCode.
431	Request Header Fields Too Large	The fields in the *HTTP Request* exceed the limit of the implementation of the *Agent*. The *Agent* **MUST** return a 431 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies INVALID_REQUEST as the errorCode.
500	Internal Server Error	There was an unexpected error in the *Agent* while responding to a *Request*. The *Agent* **MUST** return a 500 *HTTP Status Code*. Also, the *Agent* **MUST** publish an *MTConnectErrors Response Document* that identifies INTERNAL_ERROR as the errorCode.

8.3.5 HTTP Errors

When an *Agent* receives an *HTTP Request* that is incorrectly formatted or is not supported by the *Agent*, the *Agent* **MUST** publish an *HTTP Error Message* which includes a specific status code from the tables above indicating that the *Request* could not be handled by the *Agent*.

Also, if the *Agent* experiences an internal error and is unable to provide the requested *Response Document*, it **MUST** publish an *HTTP Error Message* that includes a specific status code from the table above.

When an *Agent* encounters an error in interpreting or responding to an *HTTP Request*, the *Agent* **MUST** also publish an *MTConnectErrors Response Document* that provides additional details about the error. See *Section 9 - Error Information Model* for details on the *MTConnectErrors Response Document*.

8.3.6 Streaming Data

HTTP *Data Streaming* is a method for a server to provide a continuous stream of information in response to a single *Request* from a client software application. *Data Streaming* is a version of a *Publish/Subscribe* method of communications.

When an *HTTP Request* includes an `interval` <query> parameter, an *Agent* **MUST** provide data with a minimum delay between the end of one data transmission and the beginning of the next data transmission defined by the value (in milliseconds) provided for `interval` parameter. A value of zero (0) for the `interval` parameter indicates that the *Agent* should deliver data at the highest rate possible.

The format of the response **MUST** use a MIME encoded message with each section separated by a MIME boundary. Each section **MUST** contain an entire *MTConnectStreams Response Document*.

If there are no available *Data Entities* to be published after the `interval` time has elapsed, an *Agent* **MUST** wait until additional information is available to be published. If no new no new information is available to be published within the time defined by the `heartbeat` parameter, the *Agent* **MUST** then send a new section to ensure the receiver that the *Agent* is functioning correctly. In this case, the content of the `MTConnectStreams` document **MUST** be empty since no data is available.

For more information on MIME see IETF RFC 1521 and RFC 822.

An example of the format for a *HTTP Request* that includes an `interval` parameter is:

Example 8: Example for HTTP Request with interval parameter

```
http://localhost:5000/sample?interval=1000
```

HTTP Response Header:

Example 9: HTTP Response header

```
1 HTTP/1.1 200 OK
2 Connection: close
3 Date: Sat, 13 Mar 2010 08:33:37 UTC
4 Status: 200 OK
5 Content-Disposition: inline
6 X-Runtime: 144ms
7 Content-Type: multipart/x-mixed-replace;boundary=
8 a8e12eced4fb871ac096a99bf9728425
9 Transfer-Encoding: chunked
```

Lines 1-9 in *Example 9* represent a standard header for a MIME `multipart/x-mixed-replace` message. The boundary is a separator for each section of the stream. Lines 7-8 indicate this is a multipart MIME message and the boundary between sections.

With streaming protocols, the `Content-length` **MUST** be omitted and `Transfer-Encoding` **MUST** be set to `chunked` (line 9). See IETF RFC 7230 for a full description of the HTTP protocol and chunked encoding.

Example 10: HTTP Response header 2

```
10 --a8e12eced4fb871ac096a99bf9728425
11 Content-type: text/xml
12 Content-length: 887
13
14 <?xml version="1.0" ecoding="UTF-8"?>
15 <MTConnectStreams ...>...
```

Each section of the document begins with a boundary preceded by two hyphens (-). The `Content-type` and `Content-length` MIME header fields **MUST** be provided for each section and **MUST** be followed by `<CR><LF><CR><LF>` (ASCII code for `<CR>` is 13 and `<LF>` is 10) before the XML document. The header and the `<CR><LF><CR><LF>` **MUST NOT** be included in the computation of the content length.

An *Agent* **MUST** continue to stream results until the client closes the connection. The *Agent* **MUST NOT** stop the streaming for any other reason other than the *Agent* process shutting down or the client application becoming unresponsive and not receiving data (as indicated by not consuming data and the write operation blocking).

8.3.6.1 Heartbeat

When *Streaming Data* is requested from a *Sample Request*, an *Agent* **MUST** support a *heartbeat* to indicate to a client application that the HTTP connection is still viable during times when there is no new data available to be published. The *heartbeat* is indicated by an *Agent* by sending an MTConnect *Response Document* with an empty Steams container (See *MTConnect Standard: Part 3.0 - Streams Information Model*, *Section 4.1 Streams* for more details on the `Streams` container) to the client software application.

The *heartbeat* **MUST** occur on a periodic basis given by the optional `heartbeat` query parameter and **MUST** default to 10 seconds. An *Agent* **MUST** maintain a separate *heartbeat* for each client application for which the *Agent* is responding to a *Data Streaming Request*.

An *Agent* **MUST** begin calculating the interval for the time-period of the *heartbeat* for each client application immediately after a *Response Document* is published to that specific client application.

The *heartbeat* remains in effect for each client software application until the *Data Streaming Request* is terminated by either the *Agent* or the client application.

8.3.7 References

A *Structural Element* **MAY** include a set of *References* of the following types that **MAY** alter the content of the *MTConnectStreams Response Documents* published in response to a *Current Request* or a *Sample Request* as specified:

- A *Component Reference* (`ComponentRef`) modifies the set of resulting *Data Entities*, limited by a path query parameter of a *Current Request* or *Sample Request*, to include the *Data Entities* associated with the *Structural Element* whose value for its `id` attribute matches the value provided for the `idRef` attribute of the `ComponentRef` element. Additionally, *Data Entities* defined for any *Lower Level Structural Element*(s) associated with the identified *Structural Element* **MUST** also be returned. The result is equivalent to appending `//[@id=<"idRef">]` to the path query parameters of the *Current Request* or *Sample Request*. See *Section 8.3.2 - Current Request Implemented Using HTTP* for more details on path queries.
- A *Data Item Reference* (`DataItemRef`) modifies the set of resulting *Data Entities*, limited by a path query parameter of a *Current Request* or *Sample Request*, to include the *Data Entity* whose value for its `id` attribute matches the value provided for the `idRef` attribute of the `DataItemRef` element. The result is equivalent to appending `//[@id=<"idRef">]` to the path query parameters of the *Current Request* or *Sample Request*. See *Section 8.3.2 - Current Request Implemented Using HTTP* for more details on path queries.

9 Error Information Model

The *Error Information Model* establishes the rules and terminology that describes the *Response Document* returned by an *Agent* when it encounters an error while interpreting a *Request* for information from a client software application or when an *Agent* experiences an error while publishing the *Response* to a *Request* for information.

An *Agent* provides the information regarding errors encountered when processing a *Request* for information by publishing an *MTConnectErrors Response Document* to the client software application that made the *Request* for information.

9.1 MTConnectError Response Document

The *MTConnectErrors Response Document* is comprised of two sections: `Header` and `Errors`.

The `Header` section contains information defining the creation of the document and the data storage capability of the *Agent* that generated the document. (See *Section 6.5.4 - Header for MTConnectError*)

The `Errors` section of the *MTConnectErrors Response Document* is a *Structural Element* that organizes *Data Entities* describing each of the errors reported by an *Agent*.

9.1.1 Structural Element for MTConnectError

Structural Elements are XML elements that form the logical structure for an XML document. The *MTConnectErrors Response Document* has only one *Structural Element*. This *Structural Element* is `Errors`. `Errors` is an XML container element that organizes the information and data associated with all errors relevant to a specific *Request* for information.

The following *XML Schema* represents the structure of the `Errors` XML element.

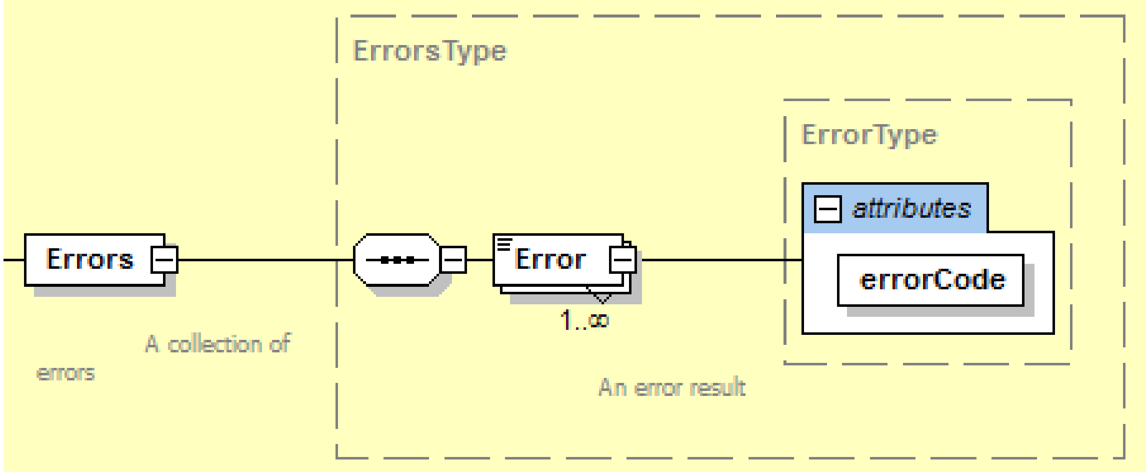


Figure 21: Errors Schema Diagram

Table 21: MTConnect Errors Element

Element	Description	Occurrence
`Errors`	An XML container element in an *MTConnectErrors Response Document* provided by an *Agent* when an error is encountered associated with a *Request* for information from a client software application. There **MUST** be only one `Errors` element in an *MTConnectErrors Response Document*. The `Errors` element **MUST** contain at least one `Error` *Data Entity* element.	1

Note: When compatibility with Version 1.0.1 and earlier of the MTConnect Standard is required for an implementation, the *MTConnectErrors Response Document* contains only a single `Error` *Data Entity* and the `Errors` *Structural Element* **MUST NOT** appear in the document.

9.1.2 Error Data Entity

When an *Agent* encounters an error when responding to a *Request* for information from a client software application, the information describing the error(s) is reported as a *Data Entity* in an *MTConnectErrors Response Document*. *Data Entities* are organized in the `Errors` XML container.

There is only one type of *Data Entity* defined for an *MTConnectErrors Response Document*. That *Data Entity* is called `Error`.

The following is an illustration of the structure of an XML document demonstrating how `Error` *Data Entities* are reported in an *MTConnectErrors Response Document*:

Example 11: Example of Error in MTConnectError

```
<MTConnectError}>
  <Header/>
  <Errors>
    <Error/>
    <Error/>
    <Error/>
  </Errors>
</MTConnectError}>
```

The `Errors` element **MUST** contain at least one *Data Entity*. Each *Data Entity* describes the details for a specific error reported by an *Agent* and is represented by the XML element named `Error`.

`Error` XML elements **MAY** contain both attributes and CDATA that provide details further defining a specific error. The CDATA **MAY** provide the complete text provided by an *Agent* for the specific error.

9.1.2.1 XML Schema Structure for Error

The *XML Schema* in *Figure 22* represents the structure of an `Error` XML element showing the attributes defined for `Error`.

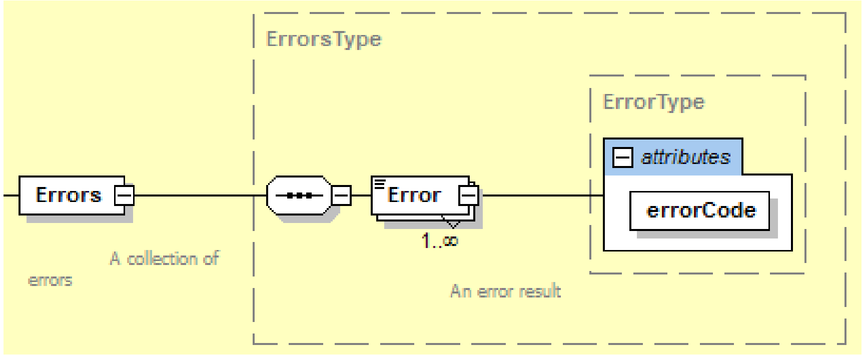


Figure 22: Error Schema Diagram

9.1.2.2 Attributes for Error

Error has one attribute. *Table 22* defines this attribute that provides additional information for an Error XML element.

Table 22: Attributes for Error

Attribute	Description	Occurrence
errorCode	Provides a descriptive code that indicates the type of error that was encountered by an *Agent* when attempting to respond to a *Request* for information. errorCode is a required attribute.	1

9.1.2.3 Values for errorCode

There is a limited vocabulary defined for errorCode. The value returned for errorCode **MUST** be one of the following:

Table 23: Values for errorCode

Value for errorCode	Description
`ASSET_NOT_FOUND`	The *Request* for information specifies an *MTConnect Asset* that is not recognized by the *Agent*.
`INTERNAL_ERROR`	The *Agent* experienced an error while attempting to published the requested information.
`INVALID_REQUEST`	The *Request* contains information that was not recognized by the *Agent*.
`INVALID_URI`	The URI provided was incorrect.
`INVALID_XPATH`	The XPath identified in the *Request* for information could not be parsed correctly by the *Agent*. This could be caused by an invalid syntax or the XPath did not match a valid identify for any information stored in the *Agent*.
`NO_DEVICE`	The identity of the piece of equipment specified in the *Request* for information is not associated with the *Agent*.
`OUT_OF_RANGE`	The *Request* for information specifies *Streaming Data* that includes sequence number(s) for pieces of data that are beyond the end of the *buffer*.
`QUERY_ERROR`	The *Agent* was unable to interpret the *Query*. The *Query* parameters do not contain valid values or include an invalid parameter.
`TOO_MANY`	The `count` parameter provided in the *Request* for information requires either of the following: - *Streaming Data* that includes more pieces of data than the *Agent* is capable of organizing in an *MTConnectStreams Response Document*. - Assets that include more *Asset Documents* in an *MTConnectAssets Response Document* than the *Agent* is capable of handling.
`UNAUTHORIZED`	The *Requester* does not have sufficient permissions to access the requested information.
`UNSUPPORTED`	A valid *Request* was provided, but the *Agent* does not support the feature or type of *Request*.

9.1.2.4 CDATA for Error

The CDATA for `Error` contains a textual description of the error and any additional information an *Agent* is capable of providing regarding a specific error. The *Valid Data Value* returned for `Error` **MAY** be any text string.

9.1.3 Examples for MTConnectError

Example 12 is an example demonstrating the structure of an *MTConnectErrors Response Document*:

Example 12: Example of structure for MTConnectError

```
<?xml version="1.0" encoding="UTF-8"?>
  <MTConnectError
  xmlns="urn:mtconnect.org:MTConnectError:1.4"
  xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
  xsi:schemaLocation="urn:mtconnect.org:MTConnectError
    :1.4/schemas/MTConnectError_1.4.xsd">
  <Header creationTime="2010-03-12T12:33:01Z"
    sender="MyAgent" version="1.4.1.10"
    bufferSize="131000" instanceId="1383839" />
  <Errors>
    <Error errorCode="OUT_OF_RANGE" >Argument was
      out of range</Error>
    <Error errorCode="INVALID_XPATH" >Bad
      path</Error>
  </Errors>
</MTConnectError>
```

Example 13 is an example demonstrating the structure of an *MTConnectErrors Response Document* when backward compatibility with Version 1.0.1 and earlier of the MTConnect Standard is required. In this case, the *Document Body* contains only a single `Error` *Data Entity* and the `Errors` *Structural Element* **MUST NOT** appear in the document.

Example 13: Example of structure for MTConnectError when backward compatibility is required

```
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectError
  xmlns="urn:mtconnect.org:MTConnectError:1.1"
  xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
  xsi:schemaLocation="urn:mtconnect.org:MTConnectError
    :1.1/schemas/MTConnectError_1.1.xsd">
  <Header creationTime="2010-03-12T12:33:01Z"
    sender="MyAgent" version="1.1.0.10"
    bufferSize="131000" instanceId="1383839" />
  <Error errorCode="OUT_OF_RANGE" >Argument was out
    of range</Error>
</MTConnectError>
```

Appendices

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View the following site for RFC references: http://www.faqs.org/rfcs/.

B Fundamentals of Using XML to Encode Response Documents

The MTConnect Standard specifies the structures and constructs that are used to encode *Response Documents*. When these *Response Documents* are encoded using XML, there are additional rules defined by the XML standard that apply for creating an XML compliant document. An implementer should refer to the W3C website for additional information on XML documentation and implementation details - http://www.w3.org/XML.

The following provides specific terms and guidelines referenced in the MTConnect Standard for forming *Response Documents* with XML:

- `tag`: A `tag` is an XML construct that forms the foundation for an XML expression. It defines the scope (beginning and end) of an XML expression. The main types of tags are:
- `start-tag`: Designates the beginning on an XML element; e.g., <*Element Name*>
- `end-tag`: Designates the end on an XML element; e.g., </*Element Name*>.

  Note: If an element has no *Child Elements* or CDATA, the `end-tag` may be shortened to />.
- `Element`: An element is an XML statement that is the primary building block for a document encoded using XML. An element begins with a `start-tag` and ends with a matching `end-tag`. The characters between the `start-tag` and the `end-tag` are the element's content. The content may contain attributes, CDATA, and/or other elements. If the content contains additional elements, these elements are called *Child Elements*.

  An example would be: <*Element Name*>Content of the Element</*Element Name*>.
- *Child Element*: An XML element that is contained within a higher-level *Parent Element*. A *Child Element* is also known as a sub-element. XML allows an unlimited hierarchy of *Parent Element-Child Element* relationships that establishes the structure that defines how the various pieces of information in the document relate to each other. A *Parent Element* may have multiple associated *Child Elements*.
- *Element Name*: A descriptive identifier contained in both the `start-tag` and `end-tag` that provides the name of an XML element.
- `Attribute`: A construct consisting of a name–value pair that provides additional information about that XML element. The format for an attribute is `name="value"`; where the value for the attribute is enclosed in a set of quotation (") marks. An XML attribute **MUST** only have a single value and each attribute can appear at most once in each element. Also, each attribute **MUST** be defined in a *schema* to either be required or optional.

- An example of attributes for an XML element is *Example 14*:

Example 14: Example of attributes for an element

```
<DataItem category="SAMPLE" id="S1load"
  nativeUnits="PERCENT"  type="LOAD"
  units="PERCENT"/>
```

In this example, `DataItem` is the `ElementName`. `category`, `id`, `nativeUnits`, `type`, and `units` are the names of the attributes. “`SAMPLE`", “`S1load`", “`PERCENT`", “`LOAD`", and “`PERCENT`" are the values for each of the respective attributes.

- CDATA: CDATA is an XML term representing *Character Data*. *Character Data* contains a value(s) or text that is associated with an XML element. CDATA can be restricted to certain formats, patterns, or words.

An example of CDATA associated with an XML element would be *Example 15*:

Example 15: Example of cdata associated with element

```
<Message id="M1">This is some text</Message>
```

In this example, `Message` is the `ElementName` and `This is some text` is the CDATA.

- *namespace*: An XML *namespace* defines a unique vocabulary for named elements and attributes in an XML document. An XML document may contain content that is associated with multiple *namespaces*. Each *namespace* has its own unique identifier.

Elements and attributes are associated with a specific *namespace* by placing a prefix on the name of the element or attribute that associates that name to a specific *namespace*; e.g., `x:MyTarget` associates the element name `MyTarget` with the *namespace* designated by `x:` (the prefix).

namespaces are used to avoid naming conflicts within an XML document. The naming convention used for elements and attributes may be associated with either the default *namespace* specified in the *Header* of an XML document or they may be associated with one or more alternate *namespaces*. All elements or attributes associated with a *namespace* that is not the default *namespace*, must include a prefix (e.g., x:) as part of the name of the element or attribute to associate it with the proper *namespace*. See *Appendix C* for details on the structure for XML *Headers*.

The names of the elements and attributes declared in a *namespace* may be identified with a different prefix than the prefix that signifies that specific *namespace*. These prefixes are called *namespace* aliases. As an example, MTConnect Standard specific *namespaces* are designated as `m:` and the names of the elements and attributes defined in that *namespace* have an alias prefix of `mt:` which designates these names as MTConnect Standard specific vocabulary; e.g., `mt:MTConnectDevices`.

XML documents are encoded with a hierarchy of elements. In general, XML elements may contain *Child Elements*, CDATA, or both. However, in the MTConnect Standard, an element **MUST NOT** contain mixed content; meaning it cannot contain both *Child Elements* and CDATA.

The *semantic data model* defined for each *Response Document* specifies the elements and *Child Elements* that may appear in a document. The *semantic data model* also defines the number of times each element and *Child Element* may appear in the document.

Example 16 demonstrates the hierarchy of XML elements and *Child Elements* used to form an XML document:

Example 16: Example of hierarchy of XML elements

```
<Root Level>    (Parent Element)
  <First Level>  (Child Element to Root Level and
  Parent Element to Second Level)
    <Second Level>  (Child Element to First Level
    and Parent Element to Third Level)
      <Third Level name="N1"></Third Level>
      (Child Element to Second Level)
      <Third Level name="N2"></Third Level>
      (Child Element to Second Level)
      <Third Level name="N3"></Third Level>
      (Child Element to Second Level)
    </Second Level>   (end-tag for Second Level)
  </First Level>   (end-tag for First Level)
</Root Level>   (end-tag for Root Level)
```

In the *Example 16*, *Root Level* and *First Level* have one *Child Element* (sub-elements) each and Second Level has three *Child Elements*; each called *Third Level*. Each *Third Level* element has a different name attribute. Each level in the structure is an element and each lower level element is a *Child Element*.

C Schema and Namespace Declaration Information

There are four pseudo-attributes typically included in the *Header* of a *Response Document* that declare the *schema* and *namespace* for the document. Each of these pseudo-attributes provides specific information for a client software application to properly interpret the content of the *Response Document*.

The pseudo-attributes include:

- `xmlns:xsi` – The `xsi` portion of this attribute name stands for *XML Schema* instance. An *XML Schema* instance provides information that may be used by a software application to interpret XML specific information within a document. See the W3C website for more details on `xmlns:xsi`.

- `xmlns` – Declares the default *namespace* associated with the content of the *Response Document*. The default *namespace* is considered to apply to all elements and attributes whenever the name of the element or attribute does not contain a prefix identifying an alternate *namespace*.

  The value of this attribute is an URN identifying the name of the file that defines the details of the *namespace* content. This URN provides a unique identify for the *namespace*.

- `xmlns:m` – Declares the MTConnect specific *namespace* associated with the content of the *Response Document*. There may be multiple *namespaces* declared for an XML document. Each may be associated to the default *namespace* or it may be totally independent. The `:m` designates that this is a specific MTConnect *namespace* which is directly associated with the default *namespace*.

  Note: See *Section 6.7 - Extensibility* for details regarding extended *namespaces*.

  The value associated with this attribute is an URN identifying the name of the file that defines the details of the *namespace* content.

- `xsi:schemaLocation` - Declares the name for the *schema* associated with the *Response Document* and the location of the file that contains the details of the *schema* for that document.

  The value associated with this attribute has two parts:

  - A URN identifying the name of the specific *XML Schema* instance associated with the *Response Document*.

  - The path to the location where the file describing the specific *XML Schema* instance is located. If the file is located in the same root directory where the *Agent* is installed, then the local path MAY be declared. Otherwise, a fully qualified URL must be declared to identify the location of the file.

> Note: In the format of the value associated with `xsi:schemaLocation`, the URN and the path to the *schema* file **MUST** be separated by a “space”.

In *Example 17*, the first line is the *XML Declaration*. The second line is a *Root Element* called `MTConnectDevices`. The remaining four lines are the pseudo-attributes of `MTConnectDevices` that declare the XML *schema* and *namespace* associated with an *MTConnectDevices Response Document*.

Example 17: Example of schema and namespace declaration

```
<?xml version="1.0" encoding="UTF-8"?>
  <MTConnectDevices
   xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
   xmlns="urn:mtconnect.org:MTConnectDevices:1.3"
   xmlns:m="urn:mtconnect.org:MTConnectDevices:1.3"
   xsi:schemaLocation="urn:mtconnect.org:
    MTConnectDevices:1.3 /schemas/MTConnectDevices\_1.3.xsd">
```

The format for the values provided for each of the pseudo-attributes **MUST** reference the *semantic data model* (e.g., `MTConnectDevices`, `MTConnectStreams`, `MTConnectAssets`, or `MTConnectError`) and the version (i.e.; `1.1, 1.2, 1.3`, etc.) of the MTConnect Standard that depict the *schema* and *namespace*(s) associated with a specific *Response Document*.

When an implementer chooses to extend an MTConnect *Data Model* by adding custom data types or additional *Structural Elements*, the *schema* and *namespace* for that *Data Model* should be updated to reflect the additional content. When this is done, the *namespace* and *schema* information in the *Header* should be updated to reflect the URI for the extended *namespace* and *schema*.