MTConnect® American National Standard

Version 1.7.0

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MTConnect® Standard

Part 1.0 – Overview and Fundamentals

Version 1.8.0

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MTConnect Specification and Materials

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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* .

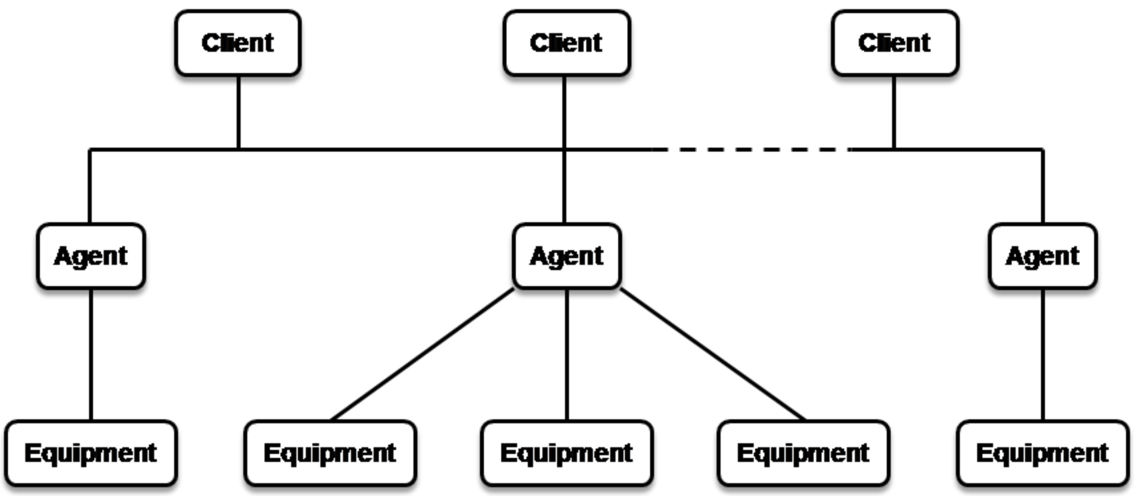

Figure 1: Basic MTConnect Implementation Structure

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

<u>General meaning</u>:

An identifier used to distinguish a piece of information.

Appears in the documents in the following form: id.

<u>Used as an XML attribute</u>:

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`.

raw material

Crude or processed material that can be converted by manufacture, processing, or combination into a new and useful product.

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 *MTConnectStreams 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 1.8.0.

[MTConnect Part 2.0] *MTConnect Standard: Part 2.0 - Devices Information Model*. Version 1.8.0.

[MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Streams Information Model*. Version 1.8.0.

[MTConnect Part 4.0] *MTConnect Standard: Part 4.0 - Assets Information Model*. Version 1.8.0.

[MTConnect Part 5.0] *MTConnect Standard: Part 5.0 - Interfaces*. Version 1.8.0.

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.

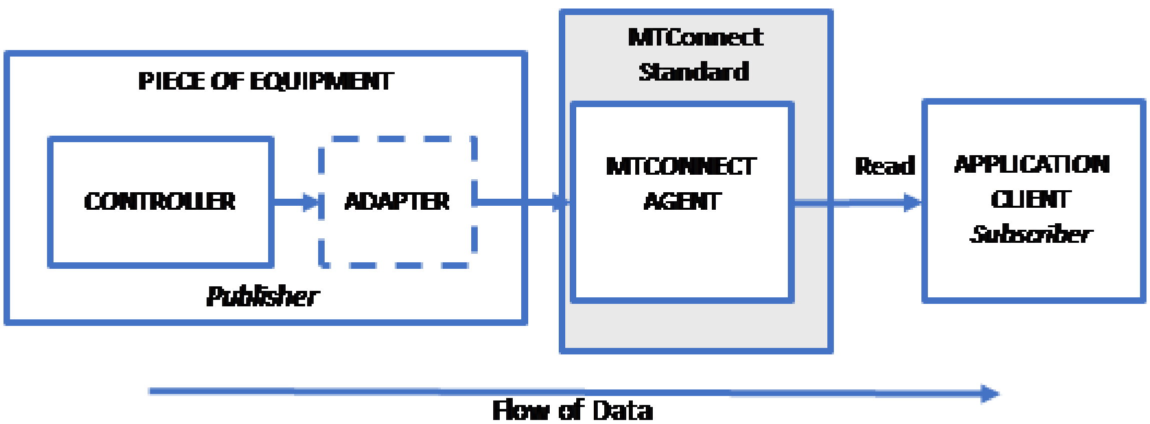

Figure 2: MTConnect Architecture Model

> 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*.

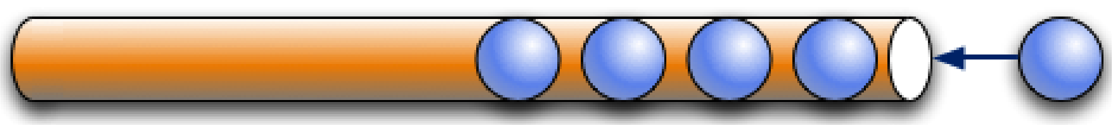

Figure 3: Data Storage in Buffer

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.

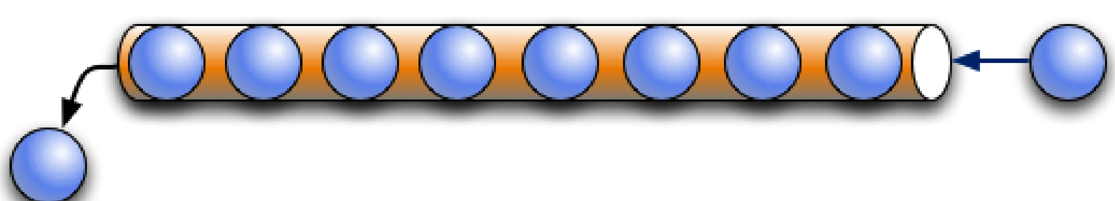

Figure 4: First In First Out Buffer Management

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):

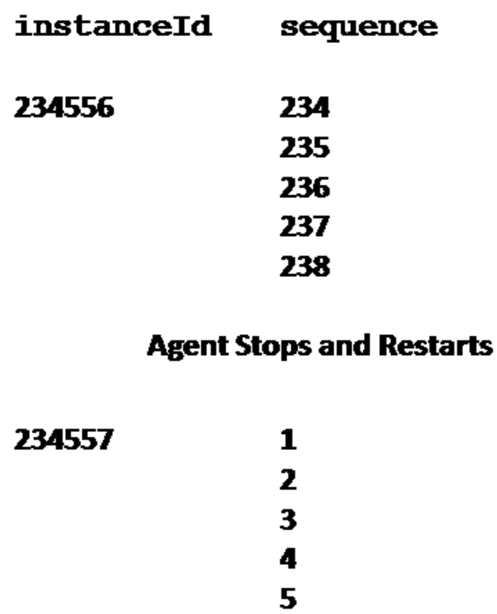

Figure 5: instanceId and sequence

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*.

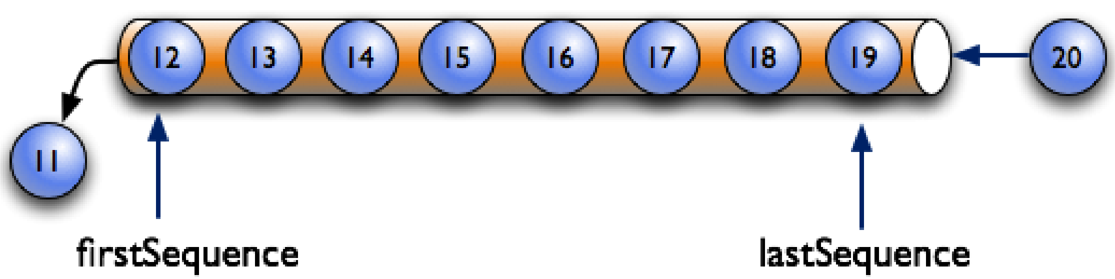

Figure 6: Indentifying the range of data with firstSequence and lastSequence

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`).

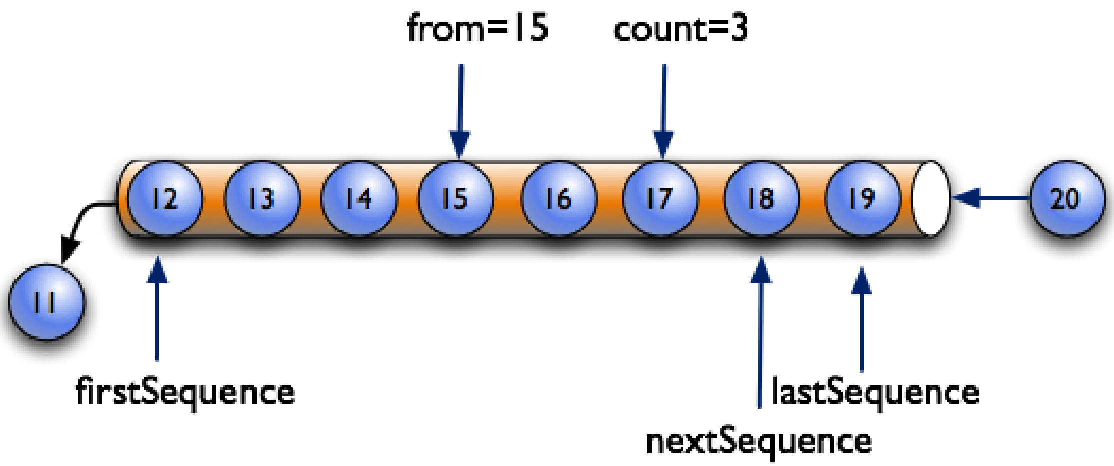

Figure 7: Identifying the range of data with from and count

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.

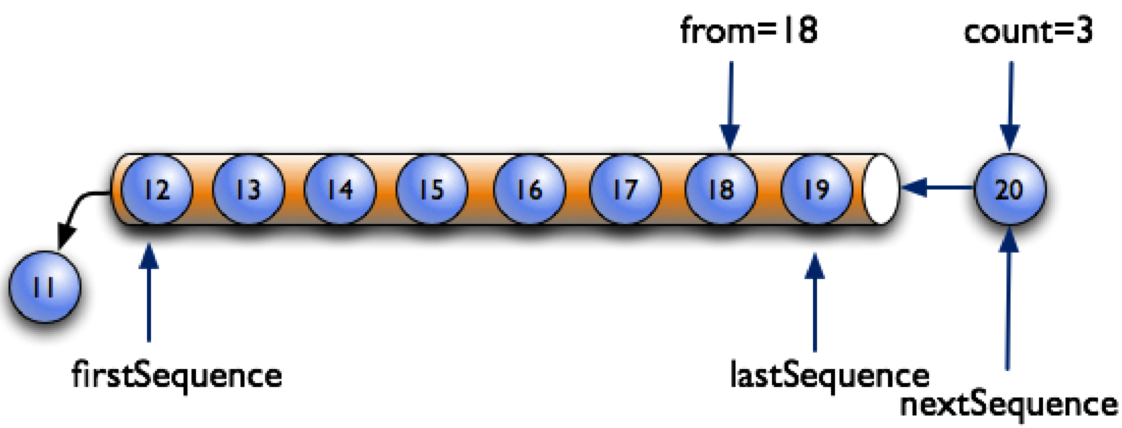

Figure 8: Indentifying the range of data with nextSequence and lastSequence

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:

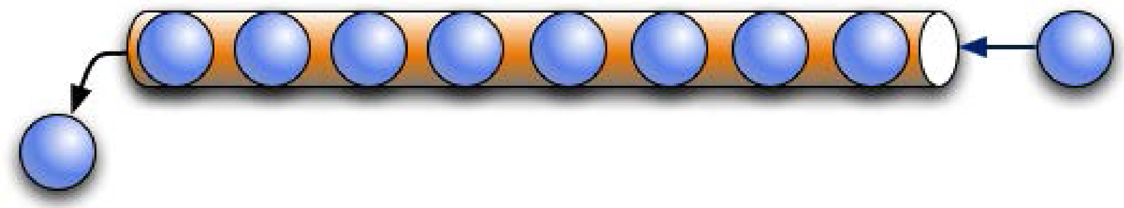

Figure 10: First In First Out Asset Buffer Management

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*:

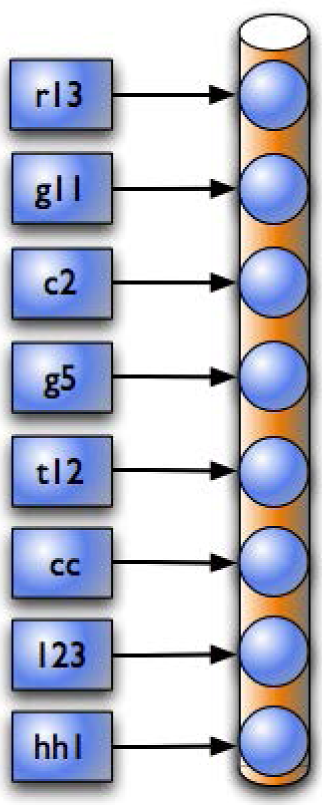

Figure 11: Relationship between assetId and stored Asset documents

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`.

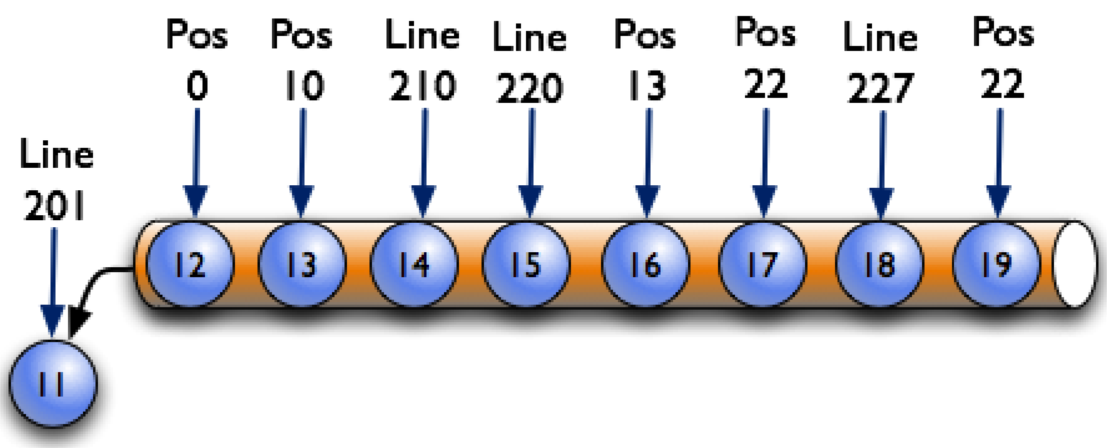

Figure 12: Example Buffer

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*.

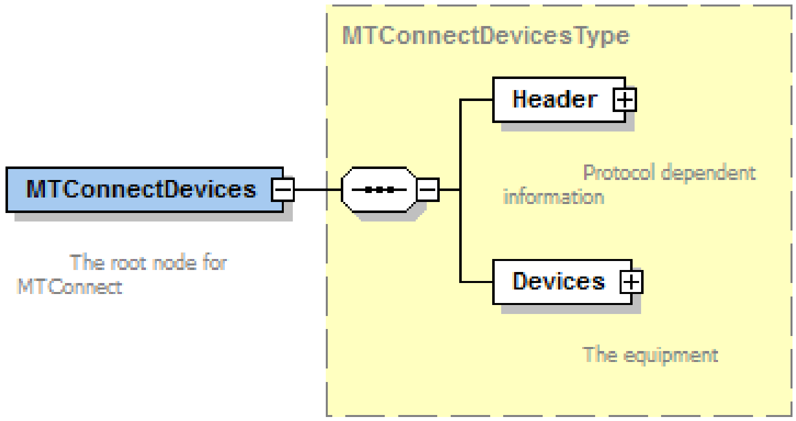

Figure 13: MTConnectDevices Structure

`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*.

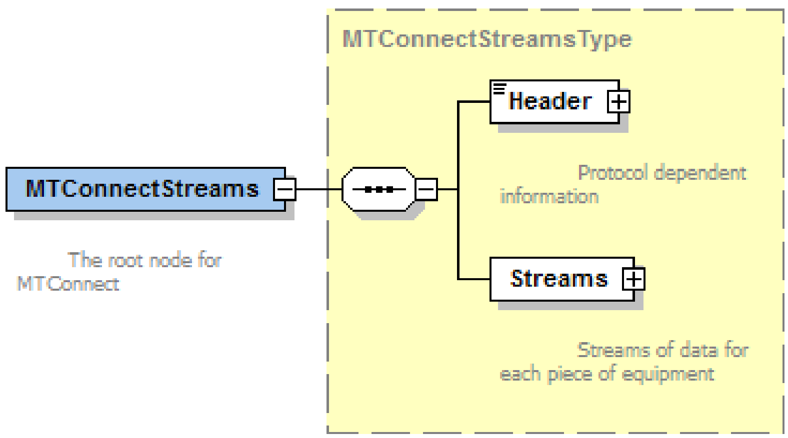

Figure 14: MTConnectStreams Structure

`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*.

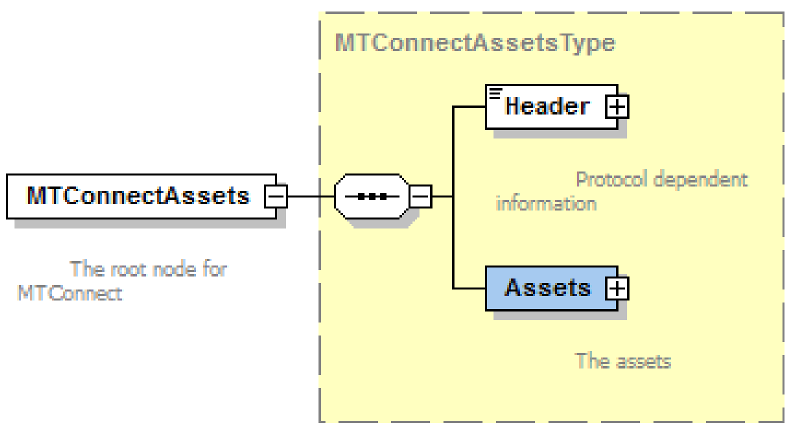

Figure 15: MTConnectAssets Structure

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*.

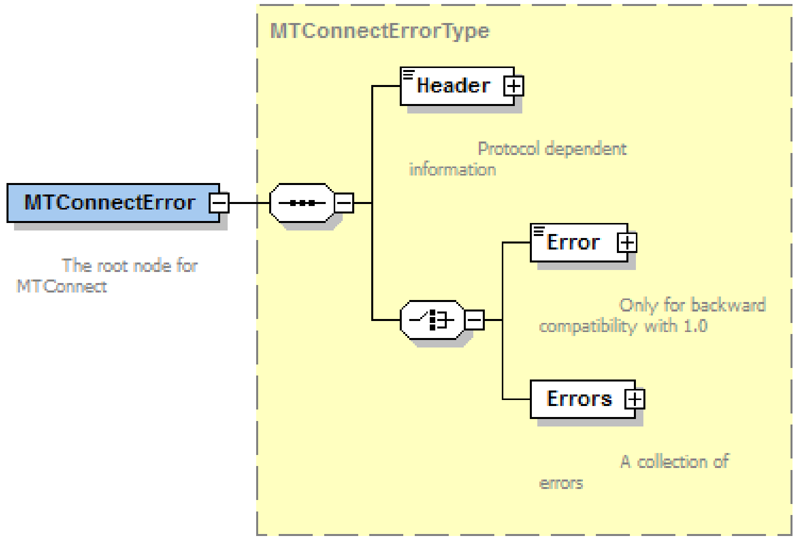

Figure 16: MTConnectError Structure

`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*.

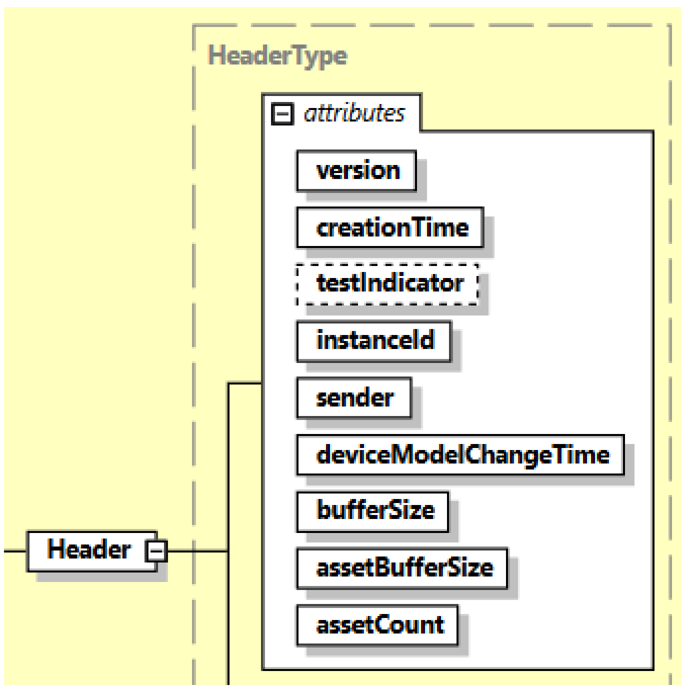

Figure 17: Header Schema Diagram for MTConnectDevices

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*.

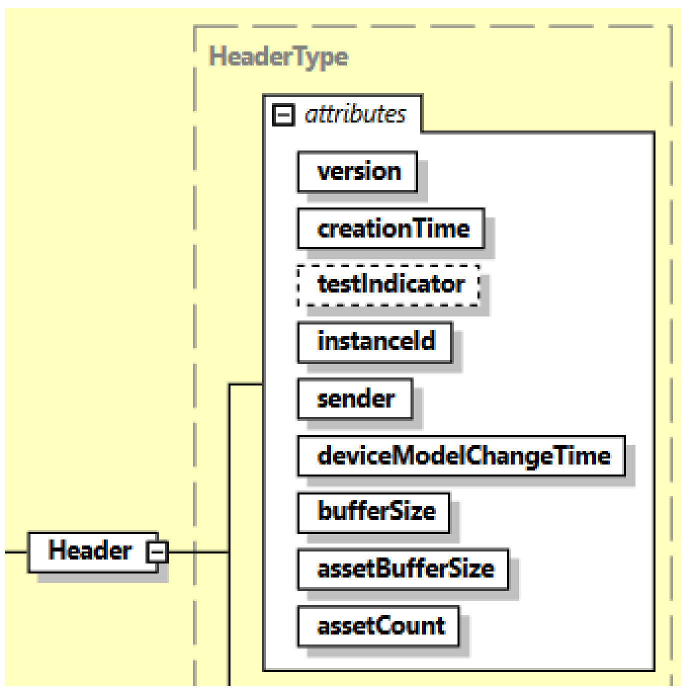

Figure 18: Header Schema Diagram for MTConnectStreams

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*.

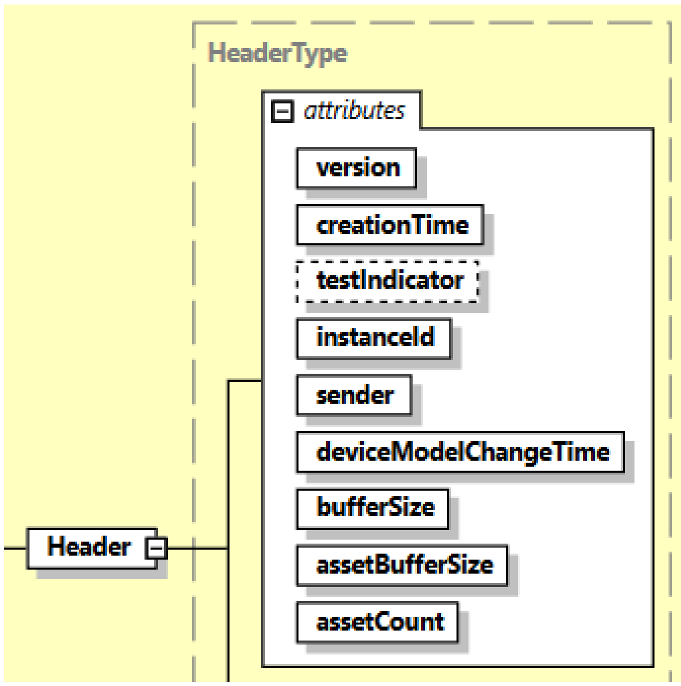

Figure 19: Header Schema Diagram for MTConnectAssets

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*.

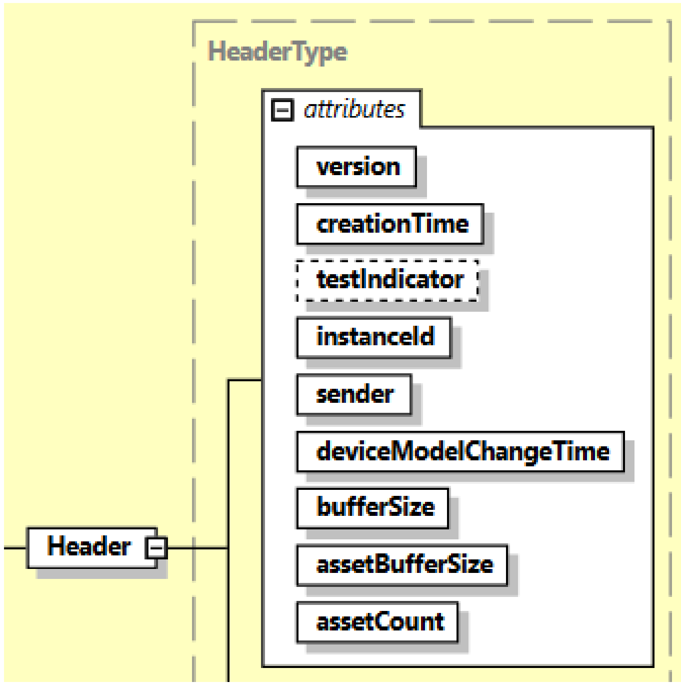

Figure 20: Header Schema Diagram for MTConnectError

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.

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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

```
--a8e12eced4fb871ac096a99bf9728425
Content-type: text/xml
Content-length: 887

<?xml version="1.0" ecoding="UTF-8"?>
<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.

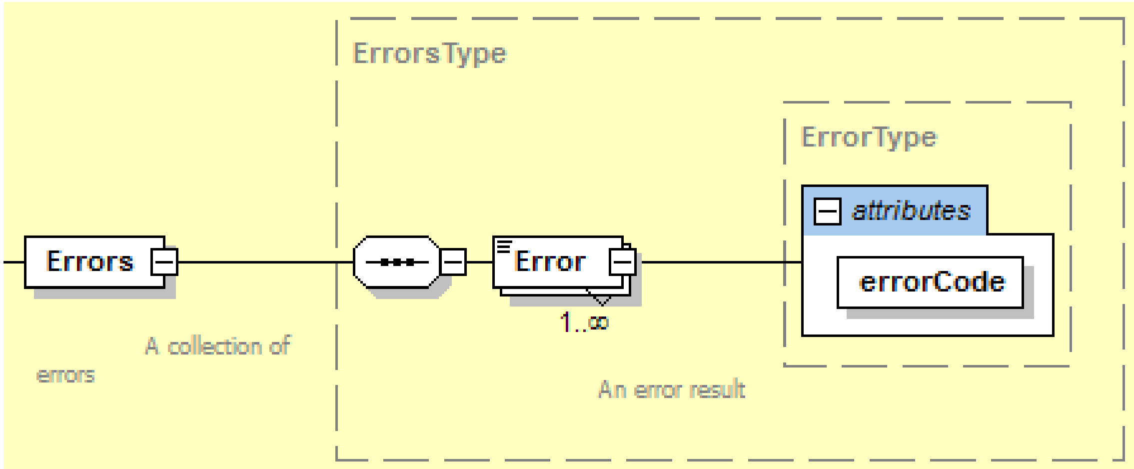

Figure 21: Errors Schema Diagram

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`.

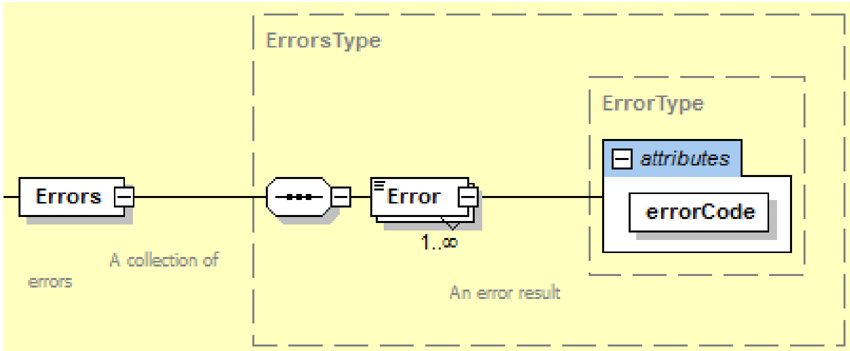

Figure 22: Error Schema Diagram

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

A Bibliography

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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*.

MTConnect® Standard

Part 2.0 – Devices Information Model

Version 1.8.0

Prepared for: MTConnect Institute
Prepared on: September 6, 2021

MTConnect Specification and Materials

Table of Contents

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1 Purpose of This Document

This document, *MTConnect Standard: Part 2.0 - Devices Information Model* of the *MTConnect* Standard, establishes the rules and terminology to be used by designers to describe the function and operation of a piece of equipment and to define the data that is provided by an *Agent* from the equipment. The *Devices Information Model* also defines the structure for the XML document that is returned from an *Agent* in response to a *Probe Request*.

In the MTConnect Standard, equipment represents any tangible property that is used in the operations of a manufacturing facility. Examples of equipment are machine tools, ovens, sensor units, workstations, software applications, and bar feeders.

Note: See *MTConnect Standard: Part 3.0 - Streams Information Model* of the MTConnect Standard for details on the XML documents that are returned from an *Agent* in response to a *Sample Request* or *Current Request*.

2 Terminology and Conventions

Refer to *Section 3* of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 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

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.

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

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.

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*.

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.

Attachment

The connection by which one thing is associated with another.

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*.

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`.

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 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 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 Set

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

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*.

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 Metadata

See *Metadata*

Force

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

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*.

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.

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*.

MTConnect Agent

See definition for *Agent*.

MTConnectDevices Response Document

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

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.

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.

organize

The act of containing and owning one or more elements.

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.

Probe Request

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

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*.

Response Document

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

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*.

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 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*.

Spindle

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

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

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*.

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*.

Top Level

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

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).

XML Schema

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

2.2 Acronyms

AMT

The Association for Manufacturing Technology

2.3 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.8.0.

[MTConnect Part 2.0] *MTConnect Standard: Part 2.0 - Devices Information Model*. Version 1.8.0.

[MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Streams Information Model*. Version 1.8.0.

[MTConnect Part 4.0] *MTConnect Standard: Part 4.0 - Assets Information Model*. Version 1.8.0.

[MTConnect Part 5.0] *MTConnect Standard: Part 5.0 - Interfaces*. Version 1.8.0.

3 Devices Information Model

The *Devices Information Model* provides a representation of the physical and logical configuration for a piece of equipment used for a manufacturing process or for any other purpose. It also provides the definition of data that may be reported by that equipment.

Using information defined in the *Devices Information Model*, a software application can determine the configuration and reporting capabilities of a piece of equipment. To do this, the software application issues a *Probe Request* (defined in *MTConnect Standard Part 1.0 - Overview and Fundamentals Section 8.1.1*) to an *Agent* associated with a piece of equipment. An *Agent* responds to the *Probe Request* with an `MTConnectDevices` XML document that contains information describing both the physical and logical structure of the piece of equipment and a detailed description of each *Data Entity* that can be reported by the *Agent* associated with the piece of equipment. This information allows the client software application to interpret the document and to extract the data with the same meaning, value, and context that it had at its original source.

The `MTConnectDevices` XML document is comprised of two sections: `Header` and `Devices`.

The `Header` section contains protocol related information as defined in *MTConnect Standard Part 1.0 - Overview and Fundamentals Section 6.5.1*.

The `Devices` section of the `MTConnectDevices` document contains a `Device` XML container for each piece of equipment described in the document. Each `Device` container is comprised of two primary types of XML elements - *Structural Elements* and *Data Entities*.

Structural Elements are defined as XML elements that organize information that represents the physical and logical parts and sub-parts of a piece of equipment (See *Section 4 - Structural Elements for MTConnectDevices* for more details).

Data Entities are defined as XML elements that describe data that can be reported by a piece of equipment. In the *Devices Information Model*, *Data Entities* are defined as `DataItem` elements (See *Section 7 - Data Entities for Device* and *Section 8 - Listing of Data Items*).

The *Structural Elements* and *Data Entities* in the `MTConnectDevices` document provide information representing the physical and logical structure for a piece of equipment and the types of data that the piece of equipment can report relative to that structure. The `MTConnectDevices` document does not contain values for the data types reported by the piece of equipment. The `MTConnectStreams` document defined in *MTConnect*

Standard: Part 3.0 - Streams Information Model provides the data values that are reported by the piece of equipment. As such, most *Structural Elements* and *Data Entities* in the `MTConnectDevices` document do not contain CDATA. XML elements that provide values or information in the CDATA will be specifically identified in *Section 4 - Structural Elements for MTConnectDevices*, *Section 7 - Data Entities for Device*, and *Section 9.1 - Sensor*.

Note: The *MTConnect Standard* also defines the information model for *Assets*. An *Asset* is something that is used in the manufacturing process, but is not permanently associated with a single piece of equipment, can be removed from the piece of equipment without compromising its function, and can be associated with other pieces of equipment during its lifecycle. See *MTConnect Standard: Part 4.0 - Assets Information Model* for more details on *Assets*.

4 Structural Elements for MTConnectDevices

Structural Elements are XML elements that form the logical structure for the `MTConnectDevices` XML document. These elements are used to organize information that represents the physical and logical architecture of a piece of equipment. Refer to *Figure 1* for an overview of the *Structural Elements* used in an `MTConnectDevices` document.

A variety of *Structural Elements* are defined to describe a piece of equipment. Some of these elements **MUST** always appear in the `MTConnectDevices` XML document, while others are optional and **MAY** be used, as required, to provide additional structure.

The first, or highest level, *Structural Element* in a `MTConnectDevices` XML document is `Devices`. `Devices` is a container type XML element used to group one or more pieces of equipment into a single XML document. `Devices` **MUST** always appear in the `MTConnectDevices` document.

`Device` is the next *Structural Element* in the `MTConnectDevices` XML document. `Device` is also a container type XML element. A separate `Device` container is used to identify each piece of equipment represented in the `MTConnectDevices` document. Each `Device` container provides information on the physical and logical structure of the piece of equipment and the data associated with that equipment. `Device` can also represent any logical grouping of pieces of equipment that function as a unit or any other data source that provides data through an *Agent*.

One or more `Device` element(s) **MUST** always appear in an `MTConnectDevices` document.

`Components` is the next *Structural Element* in the `MTConnectDevices` XML document. `Components` is also a container type XML element. `Components` is used to group information describing *Lower Level* physical parts or logical functions of a piece of equipment.

If the `Components` container appears in the XML document, it **MUST** contain one or more `Component` type XML elements.

`Component` is the next level of *Structural Element* in the `MTConnectDevices` XML document. `Component` is both an abstract type XML element and a container type element.

As an abstract type element, `Component` will never appear in the XML document describing a piece of equipment and will be replaced by a specific `Component` type defined in *Section 5 - Component Structural Elements*. Each `Component` type is also a container type element. As a container, the `Component` type element is used to organize information describing *Lower Level Structural Elements* or *Data Entities* associated with the `Component`.

If *Lower Level Structural Elements* are described, these elements are by definition child `Component` elements of a parent `Component`. At this next level, the *Lower Level* child `Component` elements are grouped into an XML container called `Components`.

This *Lower Level* `Components` container is comprised of one or more child `Component` XML elements representing the sub-parts of the parent `Component`. Just like the parent `Component` element, the child `Component` element is an abstract type XML element and will never appear in the XML document – only the different *Lower Level* child `Component` types will appear.

This parent-child relationship can continue to any depth required to fully define a piece of equipment.

Example 1 illustrates the relationship between a parent `Component` and *Lower Level* child components:

Example 1: Component Levels

```
<Devices>
  <Device>
    <Components>
      <Axes>    Parent Component
        <Components>
          <Rotary>    Child component of Axes and Parent component of Lower Level components
            <Components>
              <Chuck>    Child Component of Rotary
```

Figure 1 demonstrates the various *Structural Elements* provided to describe a piece of equipment and the relationship between these elements.

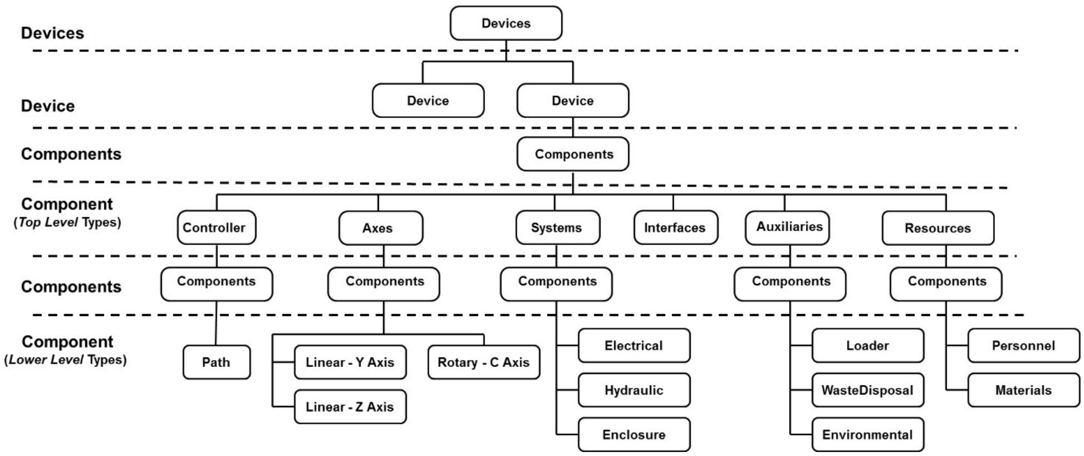

Figure 1: Example Device Structural Elements

`Component` type XML elements **MAY** be further decomposed into `Composition` type XML elements. `Composition` elements describe the lowest level basic structural or functional building blocks contained within a `Component`. Any number of `Composition` elements **MAY** be used. Data provided for a `Component` provides more specific meaning when it is associated with one of the `Composition` elements of the `Component`. The different `Composition` types that **MAY** appear in the XML document are defined in *Section 6 - Composition Type Structural Elements*.

The `Composition` elements are organized into a `Compositions` container. The `Compositions` container **MAY** appear in the XML document further describing a `Component`. If one or more `Composition` element(s) is provided to describe a `Component`, a `Compositions` container **MUST** be defined for the `Component`.

Example 2 represents an XML document structure that demonstrates the relationship between a parent `Component` and its `Composition` elements.

Example 2: Component levels with Composition

```
<Devices>
  <Device>
    <Components>
      <Axes>    (Component)
        <Components>
          <Linear>   (Component)
            <Compositions>
              <Composition>
              <Composition>
              <Composition>
```

Figure 2 demonstrates this relationship between a `Component` and some of its potential `Composition` elements.

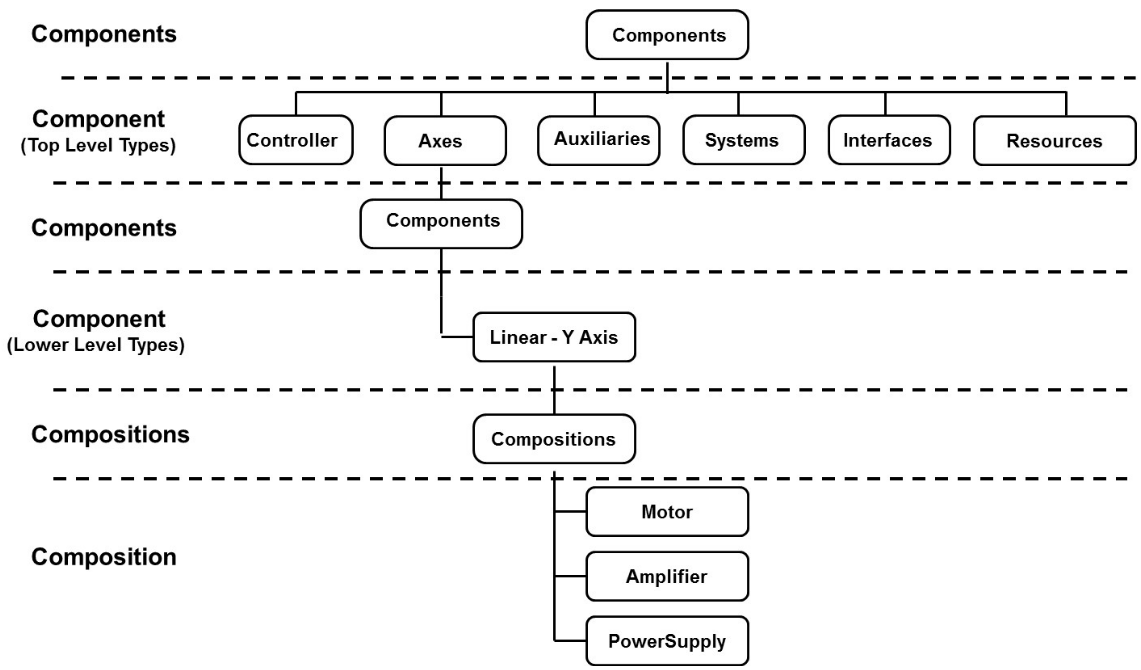

Figure 2: Example Composition Structural Elements

4.1 Devices

`Devices` **MUST** *organize* one or more `Device` elements.

Table 1: MTConnect Devices Element

Element	Description	Occurrence
`Devices`	The first, or highest level, *Structural Element* in a `MTConnectDevices` document. `Devices` is a container type XML element.	1

4.2 Device

A `Device` is a `Component` that represents a piece of equipment that produces *observations* about itself. It *organizes* its parts as `Components`.

A `Device` **MUST** have a `name` and `uuid` attribute to identify itself.

A `Device` **MUST** have the following `DataItems`: `AVAILABILITY`, `ASSET_CHANGED`, and `ASSET_REMOVED`.

See *Section 4.4 - Component* for details on the `Device` model.

Table 2 defines additional attributes for a `Device Component`.

Table 2: Attributes for Device

Attribute	Description	Occurrence
`mtconnectVersion`	The MTConnect version of the *Devices Information Model* used to configure the information to be published for a piece of equipment in an *MTConnect Response Document*.	0..1

4.2.1 Agent

`Agent` is a `Device` representing the *MTConnect Agent* and all its connected data sources.

- It **MUST** be provided by all *MTConnect Agent* implementations.
- It **MUST** provide notifications when devices are added or changed.
- It **MUST** provide connection information for each data source currently supplying data to the *MTConnect Agent*.
- It **MAY** provide information about telemetry relating to data sources.
- It **MAY** provide information about the *MTConnect Agent* resource utilization.

4.3 Components

`Components` is an XML container used to group information describing physical parts or logical functions of a piece of equipment. `Components` contains one or more `Component` XML elements.

Table 3: MTConnect Components Element

Element	Description	Occurrence
`Components`	An XML container that consists of one or more types of `Component` XML elements. If a `Components` XML element is provided, then only one `Components` element **MUST** be defined for a `Device` element.	0..1

4.4 Component

A `Component` XML element is a container type XML element used to organize information describing a physical part or logical function of a piece of equipment. It also provides structure for describing the *Lower Level Structural Elements* associated with the `Component`. `Component` is an abstract type XML element and will never appear directly in the MTConnect XML document. As an abstract type XML element, `Component` will be replaced in the XML document by specific `Component` types. XML elements representing `Component` are described in *Section 5 - Component Structural Elements* and include elements such as `Axes`, `Controller`, and `Systems`.

Table 4: MTConnect Component Element

Element	Description	Occurrence
`Component`	An abstract XML element. Replaced in the XML document by types of `Component` elements representing physical parts and logical functions of a piece of equipment. There can be multiple types of `Component` XML elements in the document.	1..*

4.4.1 XML Schema Structure for Component

Figure 3 represents the structure of a `Component` XML element showing the attributes defined for `Component` and the elements that **MAY** be associated with `Component`.

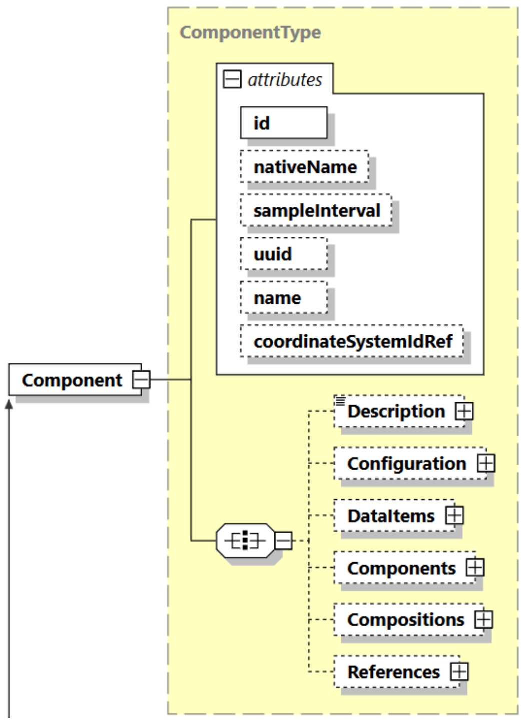

Figure 3: Component Diagram

4.4.2 Attribute for Component

Table 5 defines the attributes that may be used to provide additional information for a `Component` type XML element.

Table 5: Attributes for Component

Attribute	Description	Occurrence
id	The unique identifier for this element. id is a required attribute. An id **MUST** be unique across all the id attributes in the document. An XML ID-type.	1
nativeName	The common name normally associated with a specific physical or logical part of a piece of equipment. nativeName is an optional attribute.	0..1

Continuation of Table 5		
Attribute	Description	Occurrence
sampleInterval	An optional attribute that is an indication provided by a piece of equipment describing the interval in milliseconds between the completion of the reading of the data associated with the Component element until the beginning of the next sampling of that data. This indication is reported as the number of milliseconds between data captures. This information may be used by client software applications to understand how often information from a piece of equipment for a specific Component element is expected to be refreshed. The refresh rate for data from all *Lower Level* Component elements will be the same as for the parent Component element unless specifically overridden by another sampleInterval provided for the *Lower Level* Component element. If the value of sampleInterval is less than one millisecond, the value will be represented as a floating-point number. For example, an interval of 100 microseconds would be 0.1.	0..1 ††
~~sampleRate~~	**DEPRECATED** in MTConnect Version 1.2. Replaced by sampleInterval.	0..1 †††

Continuation of Table 5		
Attribute	Description	Occurrence
uuid	A unique identifier for this XML element. uuid is an optional attribute. The value provided for the uuid **MUST** be unique amongst all uuid identifiers used in an MTConnect installation. For example, this may be a combination of the manufacturer's code and serial number. The uuid **SHOULD** be alphanumeric and not exceed 255 characters. An NMTOKEN XML type.	0..1 [†]
name	The name of the Component element. name is an optional attribute. However, if there are multiple *Lower Level* components that have the same parent and are of the same component type (example Linear), then the name attribute **MUST** be provided for all *Lower Level* components of the same element type to differentiate between the similar components. When provided, name **MUST** be unique for all *Lower Level* components of a parent Component. An NMTOKEN XML type.	0..1
coordinateSystemIdRef	Specifies the CoordinateSystem for this Component and its children.	0..1

Notes: [†]While uuid **MUST** be provided for the Device element, it is optional for Component elements.
[††]The sampleInterval is used to aid a client software application in in-

terpreting values provided by some *Data Entities*. This is the desired sample interval and may vary depending on the capabilities of the piece of equipment. †††Remains in schema for backwards compatibility.

4.4.3 Elements of Component

Table 6 lists the elements defined to provide additional information for a `Component` type XML element.

Table 6: Elements for Component

Element	Description	Occurrence
`Description`	An element that can contain any descriptive content.	0..1
`Configuration`	An XML element that contains technical information about a piece of equipment describing its physical layout or functional characteristics.	0..1
`DataItems`	A container for the *Data Entities* (defined in *Section 8 - Listing of Data Items*) associated with this `Component` element.	0..1 †
`Components`	A container for *Lower Level* `Component` XML elements associated with this parent `Component`.	0..1 †
`Compositions`	A container for the `Composition` elements (defined in *Section 6 - Composition Type Structural Elements*) associated with this `Component` element.	0..1
`References`	A container for the `Reference` elements associated with this `Component` element.	0..1 †

Note: †At least one of `Components`, `DataItems`, or `References` **MUST** be provided.

4.4.3.1 Description for Component

Figure 4 illustrates the structure of the `Description` XML element showing the attributes defined for `Description`. `Description` can contain any descriptive content of this `Component`. This element is defined to contain mixed content and additional XML elements (indicated by the `any` element) **MAY** be added to extend the schema for `Description`.

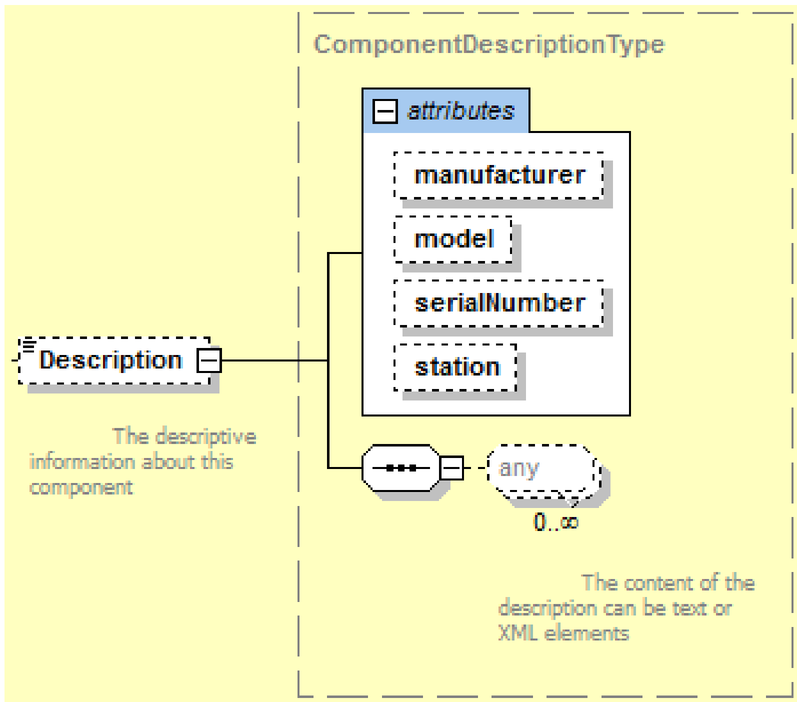

Figure 4: Description of Component Diagram

Table 7 lists the attributes defined for the `Description` XML element.

Table 7: Attributes for Description for Component

Attribute	Description	Occurrence
`manufacturer`	The name of the manufacturer of the physical or logical part of a piece of equipment represented by the `Component` element. `manufacturer` is an optional attribute.	0..1
`model`	The model description of the physical part or logical function of a piece of equipment represented by the `Component` element. `model` is an optional attribute.	0..1

Continuation of Table 7		
Attribute	Description	Occurrence
serialNumber	The serial number associated with the physical part or logical function of a piece of equipment represented by the Component element. serialNumber is an optional attribute.	0..1
station	The station where the physical part or logical function of a piece of equipment represented by the Component element is located when it is part of a manufacturing unit or cell with multiple stations. station is an optional attribute.	0..1

The content of Description **MAY** include any additional descriptive information the implementer chooses to include regarding the Component element. This content **SHOULD** be limited to information not included elsewhere in the MTConnectDevices XML document.

Example 3: Example of Description

```
<Description manufacturer="Example Co"
    serialNumber="EXCO-TT-099PP-XXXX"> Advanced Pulse
    watt-hour transducer with pulse output
</Description>
```

4.4.3.2 Configuration for Component

The Configuration XML element contains technical information about a component. Configuration **MAY** include any information describing the physical layout or functional characteristics of a component, such as capabilities, testing, installation, operation, calibration, or maintenance. Configuration **MAY** also include information representing the inter-relationships between components within a piece of equipment.

Table 8: MTConnect Configuration Element for Component

Element	Description	Occurrence
`Configuration`	An XML element that contains technical information about a component describing its physical layout, functional characteristics, and relationships with other components within a piece of equipment.	0..1

Configuration data for `Component` is structured in the `MTConnectDevices` XML document as shown in *Figure 5* . `AbstractConfiguration` is an abstract type XML element. It will never appear in the XML document representing a piece of equipment. When `Configuration` is provided for a component, that type of `Configuration` will appear in the XML document.

See *Section 9 - Configuration* for details on the types of `Configuration`.

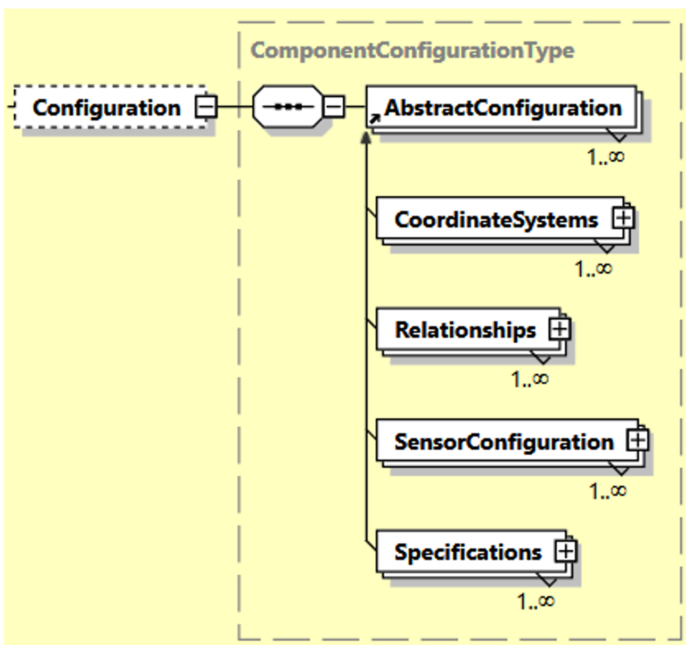

Figure 5: Component Configuration Diagram

4.4.3.3 DataItems for Component

`DataItems` is an XML container that provides structure for organizing the data reported by a piece of equipment that is associated with the `Component`.

See *Section 7 - Data Entities for Device* for details on the `DataItems` XML element.

4.4.3.4 Components within Component

The use of the XML container `Components` within a `Component` element provides the ability to further break down the structure of a `Component` element into even *Lower Level* physical and logical sub-parts. These *Lower Level* elements can add more clarity and granularity to the physical or logical structure of a piece of equipment and the data associated with that equipment.

This parent-child relationship can be extended down to any level necessary to fully describe a piece of equipment. These *Lower Level* `Component` elements use the same XML structure as `Component` defined in *Section 4.4.1 - XML Schema Structure for Component*.

Example 4: Example of parent Component and Child Elements

```
<Devices>
  <Device>
    <Components>
      <Axes> (Component)
        <Components>
          <Linear> (Component)
            <Components>
              <Etc. > (Component)
```

4.4.3.5 Compositions for Component

`Compositions` is an XML container used to organize the lowest level structural building blocks contained within a `Component` as defined below.

4.4.3.6 References for Component

`References` is an XML container used to organize `Reference` elements associated with a `Component` element. See *Section 4.7 - References* for details on `References`.

4.5 Compositions

`Compositions` is an XML container that defines the lowest level structural building blocks contained within a `Component` element.

`Compositions` contains one or more `Composition` XML elements.

Table 9: MTConnect Compositions Element

Element	Description	Occurrence
`Compositions`	An XML container consisting of one or more types of `Composition` XML elements. Only one `Compositions` container **MAY** appear for a `Component` element.	0..1

4.6 Composition

`Composition` XML elements are used to describe the lowest level physical building blocks of a piece of equipment contained within a `Component`.

`Composition` provides the ability to organize information describing parts of its parent `Component`. A `Composition` **MUST NOT** have child `Components`, `Compositions`, or `DataItems` elements.

`Composition` elements are used to add more clarity and granularity to the data being retrieved from a piece of equipment. The meaning of the data associated with a `Component` may be enhanced by designating a specific `Composition` element associated with that data.

An example of the additional detail provided when using `Composition` elements would be:

A `TEMPERATURE` associated with a `Linear` type axis may be further clarified by referencing the `MOTOR` or `AMPLIFIER` type `Composition` element associated with that axis, which differentiates the temperature of the motor from the temperature of the amplifier.

`Composition` is a typed XML element and will always define a specific type of structural building block contained within a `Component`. XML elements representing the types of `Composition` elements are described in *Section 6 - Composition Type Structural Elements* and include elements describing such basic building blocks as motors, amplifiers, filters, and pumps.

Example 5: Example of parent Component and child Composition elements

```
<Devices>
  <Device>
    <Components>
      <Axes> (Component)
        <Components>
```

```
        <Linear> (Component)
          <Compositions>
            <Composition>
            <Composition>
            <Composition>
```

Table 10: MTConnect Composition Element

Element	Description	Occurrence
`Composition`	`Composition` is a functional part of a piece of equipment contained within a `Component` that **MUST NOT** be further decomposed into `Components` or `Compositions`.	1..*

4.6.1 XML Schema Structure for Composition

Figure 6 illustrates a `Composition` XML element showing the attributes defined for `Composition` and the elements that may be associated with `Composition` type XML elements.

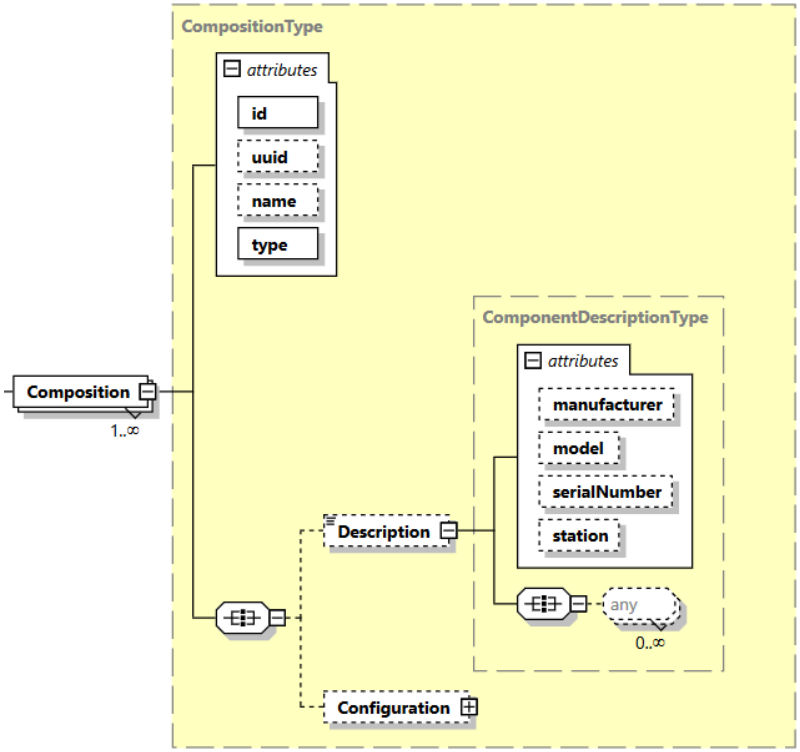

Figure 6: Composition Diagram

4.6.2 Attributes for Composition

Table 11 defines the attributes that may be used to provide additional information for a `Composition` type XML element.

Table 11: Attributes for Composition

Attribute	Description	Occurrence
`id`	The unique identifier for this element. `id` is a required attribute. An `id` **MUST** be unique across all the `id` attributes in the document. An XML ID-type.	1

Continuation of Table 11		
Attribute	Description	Occurrence
uuid	A unique identifier for this XML element. uuid is an optional attribute. The uuid **MUST** be unique amongst all uuid identifiers used in an MTConnect installation. For example, this may be a combination of the manufacturer's code and serial number. The uuid **SHOULD** be alphanumeric and not exceed 255 characters. An NMTOKEN XML type.	0..1
name	The name of the Composition element. If more than one Composition elements have the same type for the same Component, then the name attribute **MUST** be provided. Otherwise, the name attribute is optional. If provided, name **MUST** be unique within a Component element. name is an NMTOKEN XML type	0..1
type	The type of Composition element. type is a required attribute. Examples of types are MOTOR, FILTER, PUMP, and AMPLIFIER. Refer to *Section 6 - Composition Type Structural Elements* for a list of currently defined types.	1

4.6.3 Elements of Composition

Table 12 lists the elements defined to provide additional information for a Composition type XML element.

Table 12: Elements for Composition

Element	Description	Occurrence
`Description`	An element that can contain any descriptive content.	0..1
`Configuration`	An element that contains technical information about a piece of equipment describing its physical layout or functional characteristics. See *Section 9 - Configuration* for details on `Configuration`.	0..1

4.6.3.1 Description for Composition

Figure 7 represents the structure of the `Description` XML element showing the attributes defined for `Description`. `Description` can contain any descriptive content for this `Composition` element. This element is defined to contain mixed content and additional XML elements (indicated by the `any` element) **MAY** be added to extend the schema for `Description`.

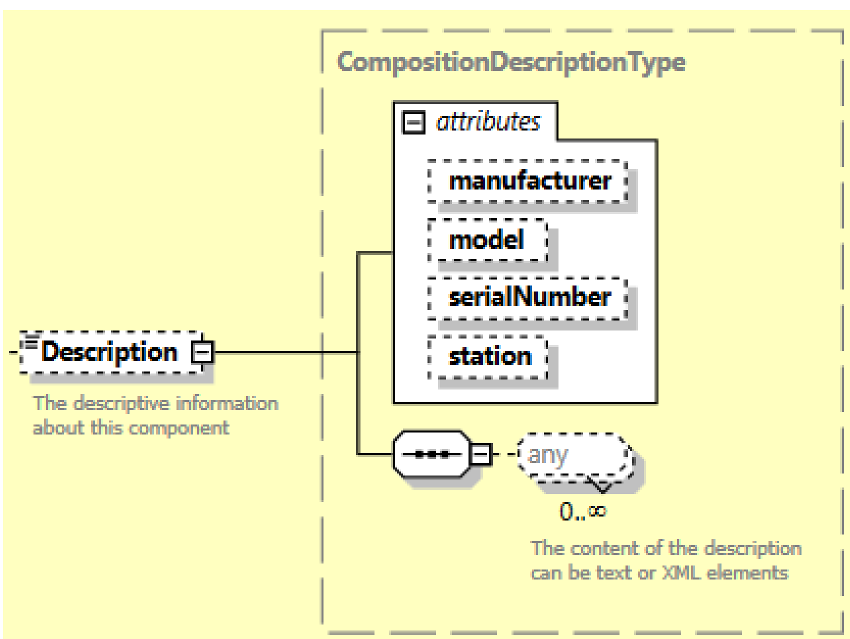

Figure 7: Description of Composition Diagram

Table 13 lists the attributes defined for the `Description` XML element.

Table 13: Attributes for Description for Composition

Attribute	Description	Occurrence
`manufacturer`	The name of the manufacturer of the physical part of a piece of equipment represented by the `Composition` element. `manufacturer` is an optional attribute.	0..1
`model`	The model description of the physical part of a piece of equipment represented by the `Composition` element. `model` is an optional attribute.	0..1
`serialNumber`	The serial number associated with the physical part of a piece of equipment represented by the `Composition` element. `serialNumber` is an optional attribute.	0..1
`station`	The station where the physical part of a piece of equipment represented by the `Composition` element is located when it is part of a manufacturing unit or cell with multiple stations. `station` is an optional attribute.	0..1

The content of `Description` **MAY** include any additional descriptive information the implementer chooses to include regarding the `Composition` element. This content **SHOULD** be limited to information not included elsewhere in the `MTConnectDevices` XML document.

Example 6: Example of Description

```
<Description manufacturer="Example Co"
    serialNumber="A124FFF" station="2"> Spindle motor
    associated with Path 2.
</Description>
```

4.7 References

`References` is an XML container that organizes pointers to information defined elsewhere within the XML document for a piece of equipment.

References may be modeled as part of a Device, Component or Interface type *Structural Element*.

References contains one or more Reference XML elements.

Table 14: MTConnect References Element

Element	Description	Occurrence
References	An XML container consisting of one or more types of Reference XML elements. Only one References container **MUST** appear for a Device, Component, or *Interface* element.	0..1

4.8 Reference

Reference is a pointer to information that is associated with another *Structural Element* defined elsewhere in the XML document for a piece of equipment. That information may be data from the other element or the entire structure of that element.

Reference is an efficient method to associate information with an element without duplicating any of the data or structure. For example, a Bar Feeder System may make a request for the BarFeederInterface and receive all the relevant data for the interface and the associated spindle (Rotary element) that is referenced as part of the BarFeederInterface.

Reference is an abstract type XML element and will never appear directly in the MTConnect XML document. As an abstract type XML element, Reference will be replaced in the XML document by a specific Reference type. The current supported types of Reference are DataItemRef and ComponentRef XML elements.

Figure 8 represents the structure of the Reference XML element.

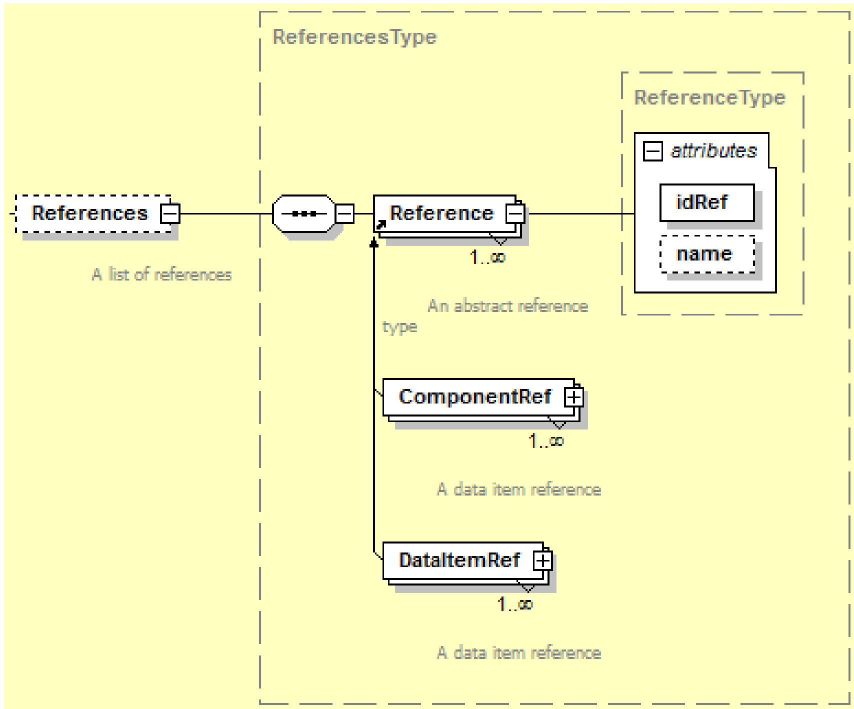

Figure 8: Reference Diagram

4.8.1 ComponentRef

`ComponentRef` XML element is a pointer to all of the information associated with another *Structural Element* defined elsewhere in the XML document for a piece of equipment. `ComponentRef` allows all of the information (*Lower Level* `Components` and all *Data Entities*) that is associated with the other *Structural Element* to be directly associated with this XML element.

Figure 9 represents the structure of a `ComponentRef` XML element showing the attributes defined for `ComponentRef`.

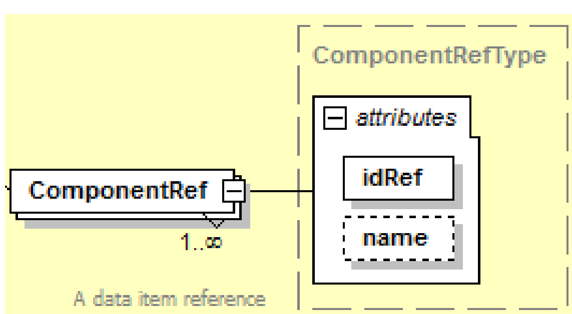

Figure 9: ComponentRef Diagram

Table 15 lists the attributes defined for the `ComponentRef` element.

Table 15: Attributes for ComponentRef

Attribute	Description	Occurrence
`idRef`	A pointer to the `id` attribute of the `Component` that contains the information to be associated with this XML element. `idRef` is a required attribute.	1
`name`	The optional `name` of the `ComponentRef`. Only informative. `name` is an NMTOKEN XML type.	0..1

4.8.2 DataItemRef

`DataItemRef` XML element is a pointer to a *Data Entity* associated with another *Structural Element* defined elsewhere in the XML document for a piece of equipment. `DataItemRef` allows the data associated with a data item defined in another *Structural Element* to be directly associated with this XML element.

Figure 10 represents the structure of a `DataItemRef` XML element showing the attributes defined for `DataItemRef`.

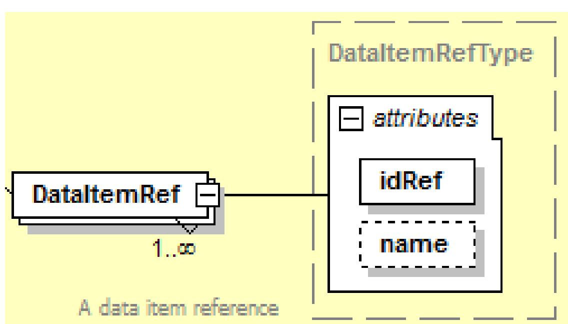

Figure 10: DataItemRef Diagram

Table 16 lists the attributes defined for the `DataItemRef` element.

Table 16: Attributes for DataItemRef

Attribute	Description	Occurrence
`idRef`	A pointer to the `id` attribute of the `DataItem` that contains the information to be associated with this XML element. `idRef` is a required attribute.	1
`name`	The optional `name` of the `DataItemRef`. Only informative. `name` is an NMTOKEN XML type.	0..1

5 Component Structural Elements

`Component` *Structural Elements* are XML containers used to represent physical parts or logical functions of a piece of equipment.

`Component` *Structural Elements* are defined into two major categories:

- *Top Level* `Component` elements are used to group the *Structural Elements* representing the most significant physical or logical functions of a piece of equipment. The *Top Level* `Component` elements provided in an `MTConnectDevices` document **SHOULD** be restricted to those defined in *Table 17*. However, these *Top Level* `Component` elements **MAY** also be used as *Lower Level* `Component` elements; as required.
- *Lower Level* `Component` elements are used to describe the sub-parts of the parent `Component` to provide more clarity and granularity to the physical or logical structure of the *Top Level* `Component` elements.

This section of the *Devices Information Model* provides guidance for the most common relationships between *Top Level* `Component` elements and *Lower Level* child components. However, all `Component` elements **MAY** be used in any configuration, as required, to fully describe a piece of equipment.

As described in *Section 4 - Structural Elements for MTConnectDevices*, `Component` is an abstract type *Structural Element* within the *Devices Information Model* and will never appear directly in the `MTConnectDevices` XML document. As abstract type XML elements, `Component` will be replaced in the XML document by a specific `Component` type.

Table 17 defines the *Top Level* `Component` elements available to describe a piece of equipment.

Table 17: Top Level Component Elements

Top Level Component Element ††	Description
`Axes`	`Axes` *organizes* `Axis` component types.
`Controller`	`Controller` represents the computational regulation and management function of a piece of equipment.

Continuation of Table 17	
Top Level Component Element ††	Description
Systems	Systems *organizes* System component types.
Auxiliaries	Auxiliaries *organizes* Auxiliary component types.
Resources	Resources *organizes* Resource component types.
Interfaces	Interfaces *organizes* Interface component types.
Adapters	Adapters *organizes* Adapter component types.
Structures	Structures *organizes* Structure component types.

Note: ††The following components have been relocated or redefined since they are not classified as restricted *Top Level* components:
- Power was **DEPRECATED** in MTConnect Version 1.1 and was replaced by the *Data Entity* called AVAILABILITY.
- Door has been redefined as a *Lower Level* component of a parent Component element or as a Composition element.
- Actuator, due to its uniqueness, has been redefined as a piece of equipment with the ability to be represented as a *Lower Level* component of a parent Component element or as a Composition element.
- Sensor, due to its uniqueness, has been redefined as a piece of equipment with the ability to be represented as a *Lower Level* component of a parent Component element (See *Section 9.1 - Sensor* for further detail).
- Stock has been redefined as a *Lower Level* component of the Resources *Top Level* Component element.

The common relationship between the *Top Level* Component elements and the *Lower Level* child Component elements are described below. It should be noted that as the MTConnect Standard evolves, more Component types will be added to organize information for new types of equipment and/or new physical or logical sub-parts of equipment.

5.1 Axes

Axes *organizes* Axis component types.

5.1.1 Axis

`Axis` is an abstract `Component` that represents linear or rotational motion for a piece of equipment.

The `Linear` axis `Component` represents linear motion, and the `Rotary` axis `Component` represents rotational motion.

In robotics, the term "Axis" is synonymous with "Joint". A "Joint" is the connection between two parts of the structure that move in relation to each other.

`Linear` and `Rotary` components **MUST** have a `name` attribute that **MUST** follow the conventions described below. Use the `nativeName` attribute for the manufacturer's name of the axis if it differs from the assigned `name`.

MTConnect has two high-level classes for automation equipment as follows: (1) Equipment that controls cartesian coordinate axes and (2) Equipment that controls articulated axes. There are ambiguous cases where some machines exhibit both characteristics; when this occurs, the primary control system's configuration determines the classification.

Examples of cartesian coordinate equipment are CNC Machine Tools, Coordinate measurement machines, as specified in ISO 841, and 3D Printers. Examples of articulated automation equipment are Robotic systems as specified in ISO 8373.

The following sections define the designation of names for the axes and additional guidance when selecting the correct scheme to use for a given piece of equipment.

5.1.2 Cartesian Coordinate Naming Conventions

A Three-Dimensional Cartesian Coordinate control system organizes its axes orthogonally relative to a machine coordinate system where the manufacturer of the equipment specifies the origin.

Axes `name` **SHOULD** comply with ISO 841, if possible.

5.1.2.1 Linear Motion

A piece of equipment **MUST** represent prismatic motion using a `Linear` axis `Component` and assign its `name` using the designations `X`, `Y`, and `Z`. A `Linear` axis `name` **MUST** append a monotonically increasing suffix when there are more than one parallel axes; for example, `X2`, `X3`, and `X4`.

5.1.2.2 Rotary Motion

MTConnect **MUST** assign the `name` to `Rotary` axes exhibiting rotary motion using `A`, `B`, and `C`. A `Rotary` axis `name` **MUST** append a monotonically increasing suffix when more than one `Rotary` axis rotates around the same `Linear` axis; for example, `A2`, `A3`, and `A4`.

5.1.3 Articulated Machine Control Systems

An articulated control system's axes represent the connecting linkages between two adjacent rigid members of an assembly. The `Linear` axis represents prismatic motion, and the `Rotary` axis represents the rotational motion of the two related members. The control organizes the axes in a kinematic chain from the mounting surface (base) to the end-effector or tooling.

5.1.4 Articulated Machine Axis Names

The axes of articulated machines represent forward kinematic relationships between mechanical linkages. Each axis is a connection between linkages, also referred to as joints, and **MUST** be named using a `J` followed by a monotonically increasing number; for example, `J1`, `J2`, `J3`. The numbering starts at the base axis connected or closest to the mounting surface, `J1`, incrementing to the mechanical interface, `Jn`, where `n` is the number of the last axis. The chain forms a parent-child relationship with the parent being the axis closest to the base.

A machine having an axis with more than one child **MUST** number each branch using its numeric designation followed by a branch number and a monotonically increasing number. For example, if `J2` has two children, the first child branch MUST be named `J2.1.1` and the second child branch `J2.2.1`. A child of the first branch **MUST** be named `J2.1.2`, incrementing to `J2.1.n`, where `J2.1.n` is the number of the last axis in that branch.

5.1.5 Rotary Component

A `Rotary` axis represents rotation about a fixed axis.

5.1.6 Linear Component

A `Linear` axis represents prismatic motion along a fixed axis.

5.2 Controller

`Controller` represents the computational regulation and management function of a piece of equipment.

Typical types of controllers for a piece of equipment include CNC (Computer Numerical Control), PAC (Programmable Automation Control), IPC (Industrialized Computer), or IC (Imbedded Computer).

> Note: MTConnect Version 1.1.0 and later implementations **SHOULD** use a *Lower Level* `Component` element called `Path` to represent an individual tool path or other independent function within a `Controller` element. When the `Controller` element is capable of executing more than one simultaneous and independent programs, the implementation **MUST** specify a *Lower Level* `Path` element representing each of the independent functions of the `Controller`.

5.2.1 Path

`Path` is a `Component` that represents the information for an independent operation or function within a `Controller`. For many types of equipment, `Path` represents a set of `Axes`, one or more Program elements, and the data associated with the motion of a control point as it moves through space. However, it **MAY** also represent any independent function within a `Controller` that has unique data associated with that function.

`Path` **SHOULD** provide an `EXECUTION` data item to define the operational state of the `Controller` component of the piece of equipment.

If the `Controller` is capable of performing more than one independent operation or function simultaneously, a separate `Path` component **MUST** be used to organize the data associated with each independent operation or function.

5.3 Systems

`Systems` *organizes* `System` component types.

5.3.1 System

`System` is an abstract `Component` that represents part(s) of a piece of equipment that is permanently integrated into the piece of equipment.

5.3.2 Hydraulic

`Hydraulic` is a `System` that represents the information for a system comprised of all the parts involved in moving and distributing pressurized liquid throughout the piece of equipment.

5.3.3 Pneumatic

`Pneumatic` is a `System` that uses compressed gasses to actuate components or do work within the piece of equipment.

Note: Actuation is usually performed using a cylinder.

5.3.4 Coolant

`Coolant` is a `System` that represents the information for a system comprised of all the parts involved in distribution and management of fluids that remove heat from a piece of equipment.

5.3.5 Lubrication

`Lubrication` is a `System` that represents the information for a system comprised of all the parts involved in distribution and management of fluids used to lubricate portions of the piece of equipment.

5.3.6 Electric

`Electric` is a `System` that represents the information for the main power supply for device piece of equipment and the distribution of that power throughout the equipment.

The electric system will provide all the data with regard to electric current, voltage, frequency, etc. that applies to the piece of equipment as a functional unit. Data regarding electric power that is specific to a Component will be reported as *Data Entities* for that specific Component.

5.3.7 Enclosure

Enclosure is a System that represents the information for a structure used to contain or isolate a piece of equipment or area. The Enclosure system may provide information regarding access to the internal components of a piece of equipment or the conditions within the enclosure. For example, Door may be defined as a *Lower Level* Component or Composition element of the Enclosure system.

5.3.8 Protective

Protective is a System that represents the information for those functions that detect or prevent harm or damage to equipment or personnel. Protective does not include the information relating to the Enclosure system.

5.3.9 ProcessPower

ProcessPower is a System that represents the information for a power source associated with a piece of equipment that supplies energy to the manufacturing process separate from the Electric system. For example, this could be the power source for an EDM machining process, an electroplating line, or a welding system.

5.3.10 Feeder

Feeder is a System that represents the information for a system that manages the delivery of materials within a piece of equipment. For example, this could describe the wire delivery system for an EDM or welding process; conveying system or pump and valve system distributing material to a blending station; or a fuel delivery system feeding a furnace.

5.3.11 Dielectric

`Dielectric` is a `System` that represents the information for a system that manages a chemical mixture used in a manufacturing process being performed at that piece of equipment. For example, this could describe the dielectric system for an EDM process or the chemical bath used in a plating process.

5.3.12 EndEffector

`EndEffector` is a `System` that represents the information for those functions that form the last link segment of a piece of equipment. It is the part of a piece of equipment that interacts with the manufacturing process.

5.3.13 WorkEnvelope

`WorkEnvelope` is a `System` that organizes information about the physical process execution space within a piece of equipment. The `WorkEnvelope` **MAY** provide information regarding the physical workspace and the conditions within that workspace.

5.3.14 Heating

`Heating` is a `System` used to deliver controlled amounts of heat to achieve a target temperature at a specified heating rate.

Note: As an example, the energy delivery method can be either through electric heaters or gas burners.

5.3.15 Cooling

`Cooling` is a `System` used to to extract controlled amounts of heat to achieve a target temperature at a specified cooling rate.

Note: As an example, the energy extraction method can be via cooling water pipes running through the chamber.

5.3.16 Pressure

`Pressure` is a `System` that delivers compressed gas or fluid and controls the pressure and rate of pressure change to a desired target set-point.

Note: For example, the delivery method can be a Compressed Air or N2 tank that is piped via an inlet valve to the chamber.

5.3.17 Vacuum

`Vacuum` is a `System` that evacuates gases and liquids from an enclosed and sealed space to a controlled negative pressure or a molecular density below the prevailing atmospheric level.

5.4 Auxiliaries

`Auxiliaries` *organizes* `Auxiliary` component types.

5.4.1 Auxiliary

`Auxiliary` is an abstract `Component` that represents removable part(s) of a piece of equipment providing supplementary or extended functionality.

5.4.2 Loader

`Loader` is an `Auxiliary` comprised of all the parts involved in moving and distributing materials, parts, tooling, and other items to or from a piece of equipment.

5.4.2.1 BarFeeder

`BarFeeder` is a `Loader` involved in delivering bar stock to a piece of equipment.

5.4.3 WasteDisposal

WasteDisposal is an Auxiliary that represents the information for a unit comprised of all the parts involved in removing manufacturing byproducts from a piece of equipment.

5.4.4 ToolingDelivery

ToolingDelivery is an Auxiliary that represents the information for a unit involved in managing, positioning, storing, and delivering tooling within a piece of equipment.

5.4.4.1 AutomaticToolChanger

AutomaticToolChanger is a ToolingDelivery that represents a tool delivery mechanism that moves tools between a ToolMagazine and a *Spindle* or a Turret. An AutomaticToolChanger may also transfer tools between a location outside of a piece of equipment and a ToolMagazine or Turret.

5.4.4.2 ToolMagazine

ToolMagazine is a ToolingDelivery that represents a tool storage mechanism that holds any number of tools. Tools are located in POTs. POTs are moved into position to transfer tools into or out of the ToolMagazine by an AutomaticToolChanger.

5.4.4.3 Turret

Turret is a ToolingDelivery that represents a tool mounting mechanism that holds any number of tools. Tools are located in STATIONs . Tools are positioned for use in the manufacturing process by rotating the Turret.

5.4.4.4 GangToolBar

GangToolBar is a ToolingDelivery that represents a tool mounting mechanism that holds any number of tools. Tools are located in STATIONs. Tools are positioned for use in the manufacturing process by linearly positioning the GangToolBar.

5.4.4.5 ToolRack

`ToolRack` is a `ToolingDelivery` that represents a linear or matrixed tool storage mechanism that holds any number of tools. Tools are located in `STATION`s.

5.4.5 Environmental

`Environmental` is an `Auxiliary` that represents the information for a unit or function involved in monitoring, managing, or conditioning the environment around or within a piece of equipment.

5.4.6 Sensor

`Sensor` is is an `Auxiliary` that represents the information for a piece of equipment that responds to a physical stimulus and transmits a resulting impulse or value from a sensing unit. When modeled as a component of `Auxiliaries`, sensor **SHOULD** represent an integrated *sensor unit* system that provides signal processing, conversion, and communications. A *sensor unit* may have multiple *sensing elements*; each representing the data for a variety of measured values. See *Section 9.1.2 - Sensor Unit* for more details on *sensor unit*.

> Note: If modeling an individual sensor, then sensor should be associated with the component that the measured value is most closely associated. See *Section 5.9.3 - Sensor*.

5.4.7 Deposition

`Deposition` is an `Auxiliary` that represents the information for a system that manages the addition of material or state change of material being performed in an additive manufacturing process. For example, this could describe the portion of a piece of equipment that manages a material extrusion process or a vat polymerization process.

5.5 Resources

`Resources` *organizes* `Resource` component types.

5.5.1 Resource

Resource is an abstract Component that represents materials or personnel involved in a manufacturing process.

5.5.2 Materials

Materials provides information about materials or other items consumed or used by the piece of equipment for production of parts, materials, or other types of goods. Materials also represents parts or part stock that are present at a piece of equipment or location to which work is applied to transform the part or stock material into a more finished state.

5.5.2.1 Stock

Stock is a Resource that represents the information for the material that is used in a manufacturing process and to which work is applied in a machine or piece of equipment to produce parts.

Stock may be either a continuous piece of material from which multiple parts may be produced or it may be a discrete piece of material that will be made into a part or a set of parts.

5.5.3 Personnel

Personnel is a Resource that provides information about an individual or individuals who either control, support, or otherwise interface with a piece of equipment.

5.6 Interfaces

Interfaces *organizes* Interface component types.

5.6.1 Interface

Interface is a Component that coordinates actions and activities between pieces of equipment.

See *MTConnect Standard: Part 5.0 - Interfaces* for detailed information on `Interface`.

5.7 Adapters

`Adapters` *organizes* `Adapter` component types.

5.7.1 Adapter

`Adapter` is a `Component` that represents the connectivity state of a data source for the *MTConnect Agent*.

It **MAY** contain additional telemetry about the data source and source-specific information.

5.8 Structures

`Structures` *organizes* `Structure` component types.

5.8.1 Structure

`Structure` is a `Component` that represents the part(s) comprising the rigid bodies of the piece of equipment.

5.8.2 Link

`Link` is a `Structure` providing a connection between `Components`.

5.9 Other Components

While most component elements **SHOULD** be modeled in a specific manner, there are some types of component elements that are used ubiquitously in equipment and **MAY** be associated with any number of different types of parent component elements.

These components **MAY** be modeled as *Lower Level* components of the Parent Element.

5.9.1 Actuator

Actuator is a Component that represents the information for an apparatus for moving or controlling a mechanism or system. It takes energy usually provided by air, electric current, or liquid and converts the energy into some kind of motion.

5.9.2 Door

Door is a Component that represents the information for a mechanical mechanism or closure that can cover, for example, a physical access portal into a piece of equipment. The closure can be opened or closed to allow or restrict access to other parts of the equipment.

When Door is represented as a Component, it **MUST** have a data item called DOOR_-STATE to indicate if the door is OPEN, CLOSED, or UNLATCHED. A Component **MAY** contain multiple Door components.

5.9.3 Sensor

Sensor is a Component that represents the information for a piece of equipment that responds to a physical stimulus and transmits a resulting impulse or value. If modeling individual sensors, then sensor should be associated with the component that the measured value is most closely associated.

See *Section 9.1 - Sensor* for more details on the use of Sensor.

5.9.4 Processes

Processes *organizes* information describing the manufacturing process being executed on a piece of equipment.

5.9.4.1 ProcessOccurrence

ProcessOccurrence is a Component that *organizes* information about the execution of a specific process that takes place at a specific place and time, such as a specific instance of part-milling occurring at a specific timestamp.

PROCESS_OCCURRENCE_ID **MUST** be defined for PartOccurrence.

Suggested DataItem types for ProcessOccurrence are: PROCESS_AGGREGATE_ID, PROCESS_KIND_ID, PROCESS_TIME, USER, PROGRAM, and PART_UNIQUE_ID.

5.9.5 Parts

Parts *organizes* information for *Parts* being processed by a piece of equipment.

5.9.5.1 PartOccurrence

PartOccurrence is a Component that *organizes* information about a specific part as it exists at a specific place and time, such as a specific instance of a bracket at a specific timestamp.

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.

PART_ID **MUST** be defined for PartOccurrence.

Suggested DataItem types for PartOccurrence are: PART_UNIQUE_ID, PART_GROUP_ID, PART_KIND_ID, PART_COUNT, PART_STATUS, PROCESS_TIME, PROCESS_OCCURRENCE_ID, and USER.

5.9.6 Lock

Lock is a Component that represents a mechanism which physically prohibits a device or component from opening or operating.

6 Composition Type Structural Elements

Composition *Structural Elements* are used to describe the lowest level physical building blocks of a piece of equipment contained within a Component. By referencing a specific Composition element, further clarification and meaning to data associated with a specific Component can be achieved.

Both Component and Composition elements are *Lower Level* child Component XML elements representing the sub-parts of the parent Component. However, there are distinct differences between Component and Composition type elements.

Component elements may be further defined with *Lower Level* Component elements and may have associated *Data Entities*.

Composition elements represent the lowest level physical part of a piece of equipment. They **MUST NOT** be further defined with *Lower Level* Component elements and they **MUST NOT** have *Data Entities* directly associated with them. They do provide additional information that can be used to enhance the specificity of *Data Entities* associated with the parent Component.

Table 18 defines Composition type elements that are currently available to describe sub-parts of a Component element.

Table 18: Composition type Elements

Element Type	Description
ACTUATOR	A mechanism for moving or controlling a mechanical part of a piece of equipment. It takes energy usually provided by air, electric current, or liquid and converts the energy into some kind of motion.
AMPLIFIER	An electronic component or circuit for amplifying power, electric current, or voltage.
BALLSCREW	A mechanical structure for transforming rotary motion into linear motion.
BELT	An endless flexible band used to transmit motion for a piece of equipment or to convey materials and objects.

Continuation of Table 18	
Element Type	Description
BRAKE	A mechanism for slowing or stopping a moving object by the absorption or transfer of the energy of momentum, usually by means of friction, electrical force, or magnetic force.
CHAIN	An interconnected series of objects that band together and are used to transmit motion for a piece of equipment or to convey materials and objects.
CHOPPER	A mechanism used to break material into smaller pieces.
CHUCK	A mechanism that holds a part, stock material, or any other item in place.
CHUTE	An inclined channel for conveying material.
CIRCUIT_BREAKER	A mechanism for interrupting an electric circuit.
CLAMP	A mechanism used to strengthen, support, or fasten objects in place.
COMPRESSOR	A pump or other mechanism for reducing volume and increasing pressure of gases in order to condense the gases to drive pneumatically powered pieces of equipment.
COOLING_TOWER	A heat exchange system that uses a fluid to transfer heat to the atmosphere.
DOOR	A mechanical mechanism or closure that can cover a physical access portal into a piece of equipment allowing or restricting access to other parts of the equipment.
DRAIN	A mechanism that allows material to flow for the purpose of drainage from, for example, a vessel or tank.
ENCODER	A mechanism to measure position.
EXPIRED_POT	A POT for a tool that is no longer useable for removal from a ToolMagazine or Turret.
EXPOSURE_UNIT	A mechanism for emitting a type of radiation

Continuation of Table 18	
Element Type	Description
EXTRUSION_UNIT	A mechanism for dispensing liquid or powered materials
FAN	Any mechanism for producing a current of air.
FILTER	Any substance or structure through which liquids or gases are passed to remove suspended impurities or to recover solids.
GALVANOMOTOR	An electromechanical actuator that produces deflection of a beam of light or energy in response to electric current through its coil in a magnetic field.
GRIPPER	A mechanism that holds a part, stock material, or any other item in place.
HOPPER	A chamber or bin in which materials are stored temporarily, typically being filled through the top and dispensed through the bottom.
LINEAR_POSITION_FEEDBACK	A mechanism that measures linear motion or position. **DEPRECATION WARNING** : May be deprecated in the future. Recommend using ENCODER.
MOTOR	A mechanism that converts electrical, pneumatic, or hydraulic energy into mechanical energy.
OIL	A viscous liquid.
POT	A tool storage location associated with a ToolMagazine or AutomaticToolChanger.
POWER_SUPPLY	A unit that provides power to electric mechanisms.
PULLEY	A mechanism or wheel that turns in a frame or block and serves to change the direction of or to transmit force.

Continuation of Table 18	
Element Type	Description
PUMP	An apparatus raising, driving, exhausting, or compressing fluids or gases by means of a piston, plunger, or set of rotating vanes.
REEL	A rotary storage unit for material
REMOVAL_POT	A POT for a tool to be removed from a ToolMagazine or Turret to a location outside of the piece of equipment.
RETURN_POT	A POT for a tool removed from *Spindle* or Turret and awaiting for return to a ToolMagazine.
SENSING_ELEMENT	A mechanism that provides a signal or measured value.
SPREADER	A mechanism for flattening or spreading materials
STAGING_POT	A POT for a tool awaiting transfer to a ToolMagazine or Turret from outside of the piece of equipment.
STATION	A storage or mounting location for a tool associated with a Turret, GangToolBar, or ToolRack.
STORAGE_BATTERY	A component consisting of one or more cells, in which chemical energy is converted into electricity and used as a source of power.
SWITCH	A mechanism for turning on or off an electric current or for making or breaking a circuit.
TABLE	A surface for holding an object or material
TANK	A receptacle or container for holding material.
TENSIONER	A mechanism that provides or applies a stretch or strain to another mechanism.
TRANSFER_ARM	A mechanism for physically moving a tool from one location to another.
TRANSFER_POT	A POT for a tool awaiting transfer from a ToolMagazine to *Spindle* or Turret.

Continuation of Table 18	
Element Type	Description
TRANSFORMER	A mechanism that transforms electric energy from a source to a secondary circuit.
VALVE	Any mechanism for halting or controlling the flow of a liquid, gas, or other material through a passage, pipe, inlet, or outlet.
VAT	A container for liquid or powdered materials
WATER	A fluid.
WIRE	A string like piece or filament of relatively rigid or flexible material provided in a variety of diameters.
WORKPIECE	An object or material on which a form of work is performed.

Note: As the MTConnect Standard evolves, more `Composition` types will be added.

7 Data Entities for Device

In the `MTConnectDevices` XML document, *Data Entities* are XML elements that describe data that can be reported by a piece of equipment and are associated with `Device` and `Component` *Structural Elements*. While the *Data Entities* describe the data that can be reported by a piece of equipment in the `MTConnectDevices` document, the actual data values are provided in the *Streams Information Model*. See *MTConnect Standard: Part 3.0 - Streams Information Model* for detail on the reported values.

Each *Data Entity* **SHOULD** be modeled in the `MTConnectDevices` document such that it is associated with the *Structural Element* that the reported data directly applies.

When *Data Entities* are associated with a *Structural Element*, they are organized in a `DataItems` XML element. `DataItems` is a container type XML element. `DataItems` provides the structure for organizing individual `DataItem` elements that represent each *Data Entity*. The `DataItems` container is comprised of one or more `DataItem` type XML element(s).

`DataItem` describes specific types of *Data Entities* that represent a numeric value, a functioning state, or a health status reported by a piece of equipment. `DataItem` provides a detailed description for each *Data Entity* that is reported; it defines the type of data being reported and an array of optional attributes that further describe that data. The different types of `DataItem` elements are defined in *Section 8 - Listing of Data Items*.

Figure 11 demonstrates the relationship between *Data Entities* (`DataItem`) and the various *Structural Elements* in the `MTConnectDevices` XML document.

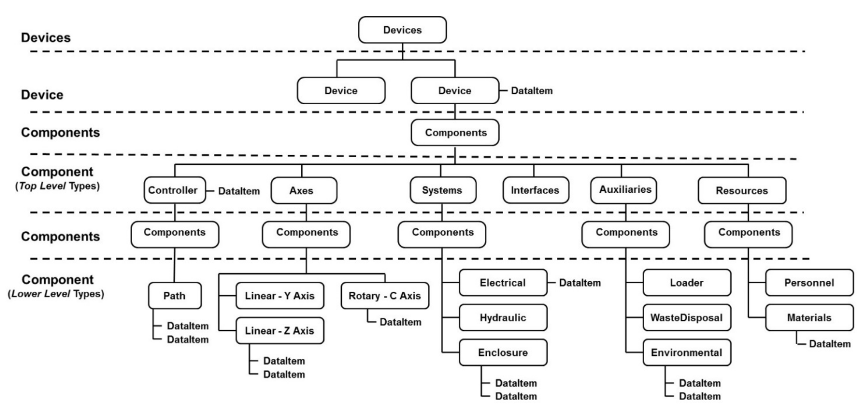

Figure 11: Example Data Entities for Device (DataItem)

7.1 DataItems

The DataItems XML element is the first, or highest, level container for the *Data Entities* associated with a Device or Component XML element. DataItems **MUST** contain only DataItem type elements. DataItems **MUST** contain at least one DataItem type element, but **MAY** contain multiple DataItem type elements.

Table 19: MTConnect DataItems Element

Element	Description	Occurrence
DataItems	An XML container consisting of one or more types of DataItem XML elements. Only one DataItems container **MUST** appear for each *Structural Element* in the XML document.	0..1

7.2 DataItem

A DataItem XML element represents each *Data Entity* that **MAY** be reported by a piece of equipment through an *Agent*. DataItem provides a detailed description for each *Data Entity* that is reported and defines the type of data being reported along with an array of optional attributes that further define that data. XML elements representing DataItem will include elements such as TEMPERATURE, PRESSURE, and VELOCITY.

Table 20: MTConnect DataItem Element

Element	Description	Occurrence
DataItem	*Data Entity* describing a piece of information reported about a piece of equipment.	1..*

7.2.1 XML Schema Structure for DataItem

Figure 12 represents the structure of a DataItem XML element showing the attributes defined for DataItem and the elements that may be associated with DataItem type XML elements.

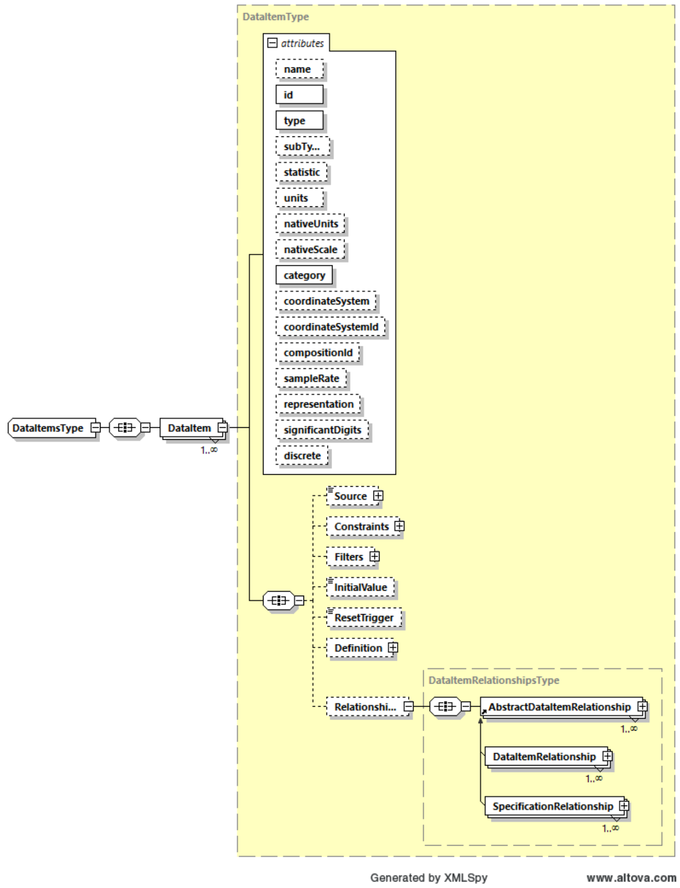

Figure 12: DataItem Diagram

7.2.2 Attributes for DataItem

Table 21 lists the attributes defined to provide information for a `DataItem` type XML element.

`DataItem` **MUST** specify the type of data being reported, the id of the `DataItem`, and the `category` of the `DataItem`.

Table 21: Attributes for DataItem

Attribute	Description	Occurrence
name	The name of the data item. name is provided as an additional human readable identifier for this data item in addition to the id. name is an optional attribute and will be implementation dependent. An NMTOKEN XML type.	0..1
id	The unique identifier for this element. id is a required attribute. The id attribute **MUST** be unique within the MTConnectDevices document. An XML ID-type.	1
type	The type of data being measured. type is a required attribute. Examples of types are POSITION, VELOCITY, ANGLE, BLOCK, and ROTARY_VELOCITY.	1
subType	A sub-categorization of the data item type. subType is an optional attribute. For example, the subType of POSITION can be ACTUAL or COMMANDED. Not all type attributes have a subType.	0..1

Continuation of Table 21		
Attribute	Description	Occurrence
statistic	Describes the type of statistical calculation performed on a series of data samples to provide the reported data value. statistic is an optional attribute. Examples of statistic are AVERAGE, MINIMUM, MAXIMUM, ROOT_MEAN_SQUARE, RANGE, MEDIAN, MODE, and STANDARD_DEVIATION.	0..1
units	The unit of measurement for the reported value of the data item. units is an optional attribute. Data items in the Sample category **MUST** report the standard units for the measured values. See *Section 7.2.2.5 - units Attribute for DataItem* for a list of available standard units identified in the MTConnect Standard.	0..1
nativeUnits	The native units of measurement for the reported value of the data item. nativeUnits is an optional attribute. See *Section 7.2.2.6 - nativeUnits Attribute for DataItem* for a list of available native units identified in the MTConnect Standard.	0..1

Continuation of Table 21		
Attribute	Description	Occurrence
nativeScale	The nativeUnits may not be scaled to directly represent the original measured value. nativeScale **MAY** be used to convert the reported value to represent the original measured value. nativeScale is an optional attribute. As an example, the nativeUnits may be reported as GALLON/MINUTE. The measured value may actually be in 1000 GALLON/MINUTE. The value of the reported data **MAY** be divided by the nativeScale to convert the reported value to its original measured value and units. If provided, the value **MUST** be numeric.	0..1
category	Specifies the kind of information provided by a data item. category is a required attribute. The available options are Sample, Event, or Condition.	1
coordinateSystem	For measured values relative to a coordinate system like POSITION, the coordinate system being used may be reported. coordinateSystem is an optional attribute. The available values for coordinateSystem are WORK and MACHINE.	0..1

Continuation of Table 21		
Attribute	Description	Occurrence
compositionId	The identifier attribute of the Composition element that the reported data is most closely associated. compositionId is an optional attribute.	0..1
sampleRate	The rate at which successive samples of a data item are recorded by a piece of equipment. sampleRate is an optional attribute. sampleRate is expressed in terms of samples per second. If the sampleRate is smaller than one, the number can be represented as a floating point number. For example, a rate 1 per 10 seconds would be 0.1	0..1
representation	Description of a means to interpret data consisting of multiple data points or as a single value. representation is an optional attribute. representation defines the unique format for each set of data. representation for TIME_SERIES, DISCRETE (**DEPRECATED** in *Version 1.5*), DATA_SET, TABLE, and VALUE are defined in *Section 7.2.2.12 - representation Attribute for DataItem*. If representation is not specified, it **MUST** be determined to be VALUE.	0..1

Continuation of Table 21		
Attribute	Description	Occurrence
`significantDigits`	The number of significant digits in the reported value. `significantDigits` is an optional attribute. This **SHOULD** be specified for all numeric values.	0..1
`discrete`	An indication signifying whether each value reported for the *Data Entity* is significant and whether duplicate values are to be suppressed. The value defined **MUST** be either `true` or `false` - an XML boolean type. `true` indicates that each update to the *Data Entity*'s value is significant and duplicate values **MUST NOT** be suppressed. `false` indicates that duplicated values **MUST** be suppressed. If a value is not defined for `discrete`, the default value **MUST** be `false`.	0..1
`coordinateSystemIdRef`	The associated `CoordinateSystem` context for the `DataItem`.	0..1

7.2.2.1 name Attribute for DataItem

The attribute `name` is provided as an additional human readable identifier for a data item. It is not required and is implementation dependent.

7.2.2.2 id Attribute for DataItem

Each `DataItem` element **MUST** be identified with an `id`. The `id` attribute **MUST** be unique across the entire `MTConnectDevices` document for a piece of equipment, including the identifiers for all *Structural Elements*. This unique `id` provides the information required by a client software application to uniquely identify each *Data Entity*.

For example, an XML document may provide three different *Data Entities* representing the position of the axes on a machine (x axis position, y axis position, and z axis position). All three may be modeled in the XML document as `POSITION` type data items for the `Axes` components. The unique `id` allows the client software application to distinguish the data for each of the axes.

7.2.2.3 type and subType Attributes for DataItem

The attribute `type` specifies the kind of data that is represented by the data item.

The attribute `type` **MUST** be specified for every data item.

A data item **MAY** further qualify the data being reported by specifying a `subType`. `subType` is required for certain data item `types`. For example, `POSITION` has the `subType` of `ACTUAL` and `PROGRAMMED`. Both data values can be represented in the document as two separate and different `DataItem` XML elements – `POSITION` with `subType` `ACTUAL` and `POSITION` with `subType` `PROGRAMMED`.

The `type` and `subType` **SHOULD** be used to further identify the meaning of the `DataItem` associated with a `Component` element when a `subType` is applicable. There **SHOULD NOT** be more than one `DataItem` with the same `type`, `subType`, and `compositionId` within a `Component` element.

Section 8 - Listing of Data Items provides a detailed listing of the data item `type` and `subType` elements defined for each `category` of data item available for a piece of equipment: `SAMPLE`, `EVENT`, and `CONDITION`.

7.2.2.4 statistic Attribute for DataItem

A piece of equipment may further process some data types using a statistical calculation like average, mean, or square root. In this case, the `statistic` attribute **MAY** be used to indicate how the data was processed.

`statistic` may be defined for any `SAMPLE` type `DataItem`. All statistic data is reported in the standard units of the `DataItem`.

`statistic` data is always the result of a calculation using data that has been measured over a specified period of time.

The value of `statistic` may be periodically reset. When a piece of equipment reports a `DataItem` with a value that is a `statistic`, the information provided in the XML document for that *Data Entity* **MUST** include an additional attribute called `duration`. The attribute `duration` defines the period of time over which the `statistic` has been calculated. See *MTConnect Standard: Part 3.0 - Streams Information Model* for more information about `duration`.

Table 22 shows the `statistic` calculations that can be defined for a `DataItem`.

Table 22: DataItem attribute statistic type

Statistic	Description
AVERAGE	Mathematical Average value calculated for the data item during the calculation period.
KURTOSIS	**DEPRECATED** in *Version 1.6*. ~~A measure of the "peakedness" of a probability distribution; i.e., the shape of the distribution curve.~~
MAXIMUM	Maximum or peak value recorded for the data item during the calculation period.
MEDIAN	The middle number of a series of numbers.
MINIMUM	Minimum value recorded for the data item during the calculation period.
MODE	The number in a series of numbers that occurs most often.
RANGE	Difference between the maximum and minimum value of a data item during the calculation period. Also represents Peak-to-Peak measurement in a waveform.
ROOT_MEAN_SQUARE	Mathematical Root Mean Square (RMS) value calculated for the data item during the calculation period.
STANDARD_DEVIATION	Statistical Standard Deviation value calculated for the data item during the calculation period.

7.2.2.5 units Attribute for DataItem

Table 23 lists the units that are defined as the standard unit of measure for each type of `DataItem`. All `SAMPLE` type data items **MUST** report data values in standard units.

Table 23: DataItem attribute units type

Units	Description
AMPERE	Amps
CELSIUS	Degrees Celsius
COUNT	A count of something.
COUNT/SECOND	Count per second.
CUBIC_MILLIMETER	Geometric volume in millimeters
CUBIC_MILLIMETER/SECOND	Change of geometric volume per second
CUBIC_MILLIMETER/SECOND^2	Change in geometric volume per second squared
DECIBEL	Sound Level
DEGREE	Angle in degrees
DEGREE/SECOND	Angular degrees per second
DEGREE/SECOND^2	Angular acceleration in degrees per second squared
DEGREE_3D	A space-delimited, floating-point representation of the angular rotation in degrees around the X, Y, and Z axes relative to a cartesian coordinate system respectively in order as A, B, and C. If any of the rotations is not known, it **MUST** be zero (0).
GRAM/CUBIC_METER	Gram per cubic meter.
HERTZ	Frequency measured in cycles per second
JOULE	A measurement of energy.
KILOGRAM	Kilograms
LITER	Measurement of volume of a fluid
LITER/SECOND	Liters per second

Continuation of Table 23	
Units	Description
MICRO_RADIAN	Measurement of Tilt
MILLIGRAM	Milligram
MILLIGRAM/CUBIC_MILLIMETER	Milligram per cubic millimeter
MILLILITER	Milliliter
MILLIMETER	Millimeters
MILLIMETER/REVOLUTION	Millimeters per revolution.
MILLIMETER/SECOND	Millimeters per second
MILLIMETER/SECOND^2	Acceleration in millimeters per second squared
MILLIMETER_3D	A point in space identified by X, Y, and Z positions and represented by a space-delimited set of numbers each expressed in millimeters.
NEWTON	Force in Newtons
NEWTON_METER	Torque, a unit for force times distance.
OHM	Measure of Electrical Resistance
PASCAL	Pressure in Newtons per square meter
PASCAL/SECOND	Pascal per second.
PASCAL_SECOND	Measurement of Viscosity
PERCENT	Percentage
PH	A measure of the acidity or alkalinity of a solution.
REVOLUTION/MINUTE	Revolutions per minute
REVOLUTION/SECOND	Revolutions per second.
REVOLUTION/SECOND^2	Revolutions per second squared.
SECOND	A measurement of time.
SIEMENS/METER	A measurement of Electrical Conductivity

Continuation of Table 23	
Units	Description
UNIT_VECTOR_3D	A 3D Unit Vector. Space delimited list of three floating point numbers.
VOLT	Volts
VOLT_AMPERE	Volt-Ampere (VA)
VOLT_AMPERE_REACTIVE	Volt-Ampere Reactive (VAR)
WATT	Watts
WATT_SECOND	Measurement of electrical energy, equal to one Joule

7.2.2.6 nativeUnits Attribute for DataItem

The `DataItem` **MAY** specify the *engineering units* used by the information source using the optional attribute `nativeUnits`. The `nativeUnits` are inclusive of the *engineering units* for the `units` attribute (See *Table 23*). One **MAY** use a prefixed value, for example `nativeUnits="x:MILE"`, to extend the *Controlled Vocabulary* with a namespace.

MTConnect specifies the following *Controlled Vocabulary* for `nativeUnits` in *Table 24*:

Table 24: DataItem attribute nativeunits type

Native Units	Description
BAR	Pressure in Bar.
CENTIPOISE	A measure of Viscosity
DEGREE/MINUTE	Rotational velocity in degrees per minute
FAHRENHEIT	Temperature in Fahrenheit
FOOT	Feet
FOOT/MINUTE	Feet per minute
FOOT/SECOND	Feet per second
FOOT/SECOND^2	Acceleration in feet per second squared

Continuation of Table 24	
Native Units	Description
FOOT_3D	A point in space identified by X, Y, and Z positions and represented by a space-delimited set of numbers each expressed in feet.
GALLON/MINUTE	Gallons per minute.
HOUR	A measurement of time in hours
INCH	Inches
INCH/MINUTE	Inches per minute
INCH/SECOND	Inches per second
INCH/SECOND^2	Acceleration in inches per second squared
INCH_3D	A point in space identified by X, Y, and Z positions and represented by a space-delimited set of numbers each expressed in inches.
INCH_POUND	A measure of torque in inch pounds.
KELVIN	A measurement of temperature
KILOWATT	A measurement in kilowatt.
KILOWATT_HOUR	Kilowatt hours which is 3.6 mega joules.
LITER	Measurement of volume of a fluid
LITER/MINUTE	Measurement of rate of flow of a fluid
MILLIMETER/MINUTE	Velocity in millimeters per minute
MILLIMETER_MERCURY	Pressure in Millimeter of Mercury (mmHg).
MINUTE	A measurement of time in minutes
OTHER	Unsupported units
PASCAL/MINUTE	Pascal per minute.
POUND	US pounds
POUND/INCH^2	Pressure in pounds per square inch (PSI).
RADIAN	Angle in radians
RADIAN/MINUTE	Velocity in radians per minute.
RADIAN/SECOND	Rotational acceleration in radian per second squared

Continuation of Table 24	
Native Units	Description
RADIAN/SECOND^2	Rotational acceleration in radian per second squared
REVOLUTION/SECOND	Rotational velocity in revolution per second
TORR	Pressure in Torr.

7.2.2.7 nativeScale Attribute for DataItem

The units of measure for some measured values may be different from the nativeUnits defined in *Section 7.2.2.8 - category Attribute for DataItem*. In the cases where the units of measure use a different weighting or range than is provided by nativeUnits, the nativeScale attribute can be used to define the original units of measure.

As an example, a velocity measured in units of 100 ft/min can be represented as nativeUnits="FEET/MINUTE" and nativeScale="100".

7.2.2.8 category Attribute for DataItem

Many DataItem types provide two forms of data, a value (reported as either a SAMPLE or EVENT category) and a health status (reported as a CONDITION category). Therefore, each occurrence of a DataItem in the XML document **MUST** report a category attribute. This category attribute provides the information required by a client software application to determine the specific meaning of the data provided.

Each *Data Entity* provided by a piece of equipment **MUST** be identified with one of the following: SAMPLE, EVENT, CONDITION.

A SAMPLE is the reading of the value of a continuously variable or analog data value. A continuous value can be measured at any point-in-time and will always produce a result. An example of a continuous data value is the position of a linear axis called X.

The data provided for a SAMPLE category data item is always a floating point number or integers that have an infinite number of possible values. This is different from a state or discrete type data item that has a limited number of possible values. A data item of category SAMPLE **MUST** also provide the units attribute.

An EVENT is a data item representing a discrete piece of information from the piece of equipment. EVENT does not have intermediate values that vary over time, as does SAMPLE. An EVENT is information that, when provided at any specific point in time, represents the current state of the piece of equipment.

There are two types of EVENT: those representing state, with two or more discrete values, and those representing messages that contain plain text data.

An example of a state type EVENT is the value of the data item DOOR_STATE, which can be OPEN, CLOSED, or UNLATCHED. (Note: No other values are valid to represent the value of DOOR_STATE.)

An example of a message type EVENT is the value for a data item PROGRAM. The value representing PROGRAM can be any valid string of characters.

A CONDITION is a data item that communicates information about the health of a piece of equipment and its ability to function. A valid value for a data item in the category CONDITION can be one of Normal, Warning, or Fault.

A data item of category CONDITION **MAY** report multiple values (CONDITION) at one time whereas a data item of category SAMPLE or EVENT can only have a single value at any one point in time.

7.2.2.9 coordinateSystem Attribute for DataItem

The values reported by a piece of equipment for some types of data will be associated to a specific positioning measurement system used by the equipment. The coordinateSystem attribute **MAY** be used to specify the coordinate system used for the measured value.

The coordinateSystem attribute is used by a client software application to interpret the spatial relationship between values reported by a piece of equipment.

If coordinateSystem is not provided, all values representing positional data for Axes **MUST** be interpreted using the MACHINE coordinate system and all values representing positional data for Path **MUST** be interpreted using the WORK coordinate system.

Table 25 defines the types of coordinateSystem currently supported by the MTConnectDevices XML document:

Table 25: DataItem attribute coordinateSystem type

Coordinate System	Description
MACHINE	An unchangeable coordinate system that has machine zero as its origin.

Continuation of Table 25

Coordinate System	Description
WORK	The coordinate system that represents the working area for a particular workpiece whose origin is shifted within the MACHINE coordinate system. If the WORK coordinates are not currently defined in the piece of equipment, the MACHINE coordinates will be used.

7.2.2.10 compositionId Attribute for DataItem

compositionId attribute identifies the id of the Composition element where the reported data is most closely associated.

An example would be a TEMPERATURE associated with a Linear type axis may be further clarified by referencing the MOTOR or AMPLIFIER type Composition element associated with that axis, which differentiates the temperature of the motor from the temperature of the amplifier.

The compositionId attribute provides the information required by a client software application to interpret the data with a greater specificity and to disambiguate between multiple *Data Entities* of the same data type associated with a Component element.

7.2.2.11 sampleRate Attribute for DataItem

The value for some data types provided by a piece of equipment may be reported as a single set of data containing a series of values that have been recorded at a fixed sample rate. When such data is reported, the sampleRate defines the rate at which successive samples of data were recorded.

The sampleRate attribute provides the information required by a client software application to interpret the data and the sampling time relationship between successive values contained in the set of data.

sampleRate is expressed in terms of samples per second. If the sample rate is smaller than one, the number can be represented as a floating point number. For example, a rate 1 per 10 seconds would be 0.1

7.2.2.12 representation Attribute for DataItem

Some data types provide data that may consist of a series of values or a file of data, not a single value. Other data types provide a series of data values that may require additional information so that the data may be correctly understood by a client software application.

When such data is provided, the `representation` attribute **MUST** be used to define the format for the data provided.

The types of `representation` defined are provided in *Table 26*.

Note: See *MTConnect Standard: Part 3.0 - Streams Information Model* for more information on the structure and format of each `representation`.

Table 26: DataItem attribute representation type

Representation	Description
`DATA_SET`	The reported value(s) are represented as a set of *key-value pairs*. Each reported value in the *Data Set* **MUST** have a unique key.
`DISCRETE` **DEPRECATED** in *Version 1.5*	**DEPRECATED** as a `representation` in MTConnect Version. 1.5. Replaced by the `discrete` attribute for a *Data Entity* – *Section 7.2.2.14 - discrete Attribute for DataItem*. ~~A Data Entity where each discrete occurrence of the data may have the same value as the previous occurrence of the data. There is no reported state change between occurrences of the data.~~ ~~In this case, duplicate occurrences of the same data value SHOULD NOT be suppressed.~~ ~~An example of a DISCRETE data type would be a parts counter that reports the completion of each part versus the accumulation of parts. Another example would be a Message that does not typically have a reset state and may re-occur each time a specific message is triggered.~~

Continuation of Table 26

Representation	Description
TIME_SERIES	A series of sampled data. The data is reported for a specified number of samples and each sample is reported with a fixed period.
VALUE	The measured value of the sample data. If no representation is specified for a data item, the representation **MUST** be determined to be VALUE.
TABLE	A *Table* is a two dimensional set of *key-value pairs* where the Entry represents a row, and the value is a set of *key-value pair* Cell elements. The *Table* follows the same behavior as the *Data Set* for change tracking, clearing, and history. When an Entry changes, all Cell elements update as a single unit following the behavior of a *Data Set*. Note: It is best to use the VARIABLE DataItem type if the Cell elements represent multiple semantic types. Each Entry in the *Table* **MUST** have a unique key. Each Cell of each Entry in the *Table* **MUST** have a unique key. See *Section 5.6.5* of *MTConnect Standard: Part 3.0 - Streams Information Model*, for a description of Entry and Cell elements.

7.2.2.13 significantDigits Attribute for DataItem

significantDigits is used to specify the level of precision (number of significant digits) for the value provided for a data item.

significantDigits attribute is not required for a data item, but it is recommended and **SHOULD** be used for any data item reporting a numeric value.

7.2.2.14 discrete Attribute for DataItem

An indication signifying whether each value reported for the *Data Entity* is significant and whether duplicate values are to be suppressed.

The value defined **MUST** be either `true` or `false` - an XML boolean type.

`true` indicates that each update to the *Data Entity*'s value is significant and duplicate values **MUST NOT** be suppressed.

`false` indicates that duplicated values **MUST** be suppressed.

If a value is not defined for `discrete`, the default value **MUST** be `false`.

7.2.3 Elements for DataItem

Table 27 lists the elements defined to provide additional information for a `DataItem` type XML element.

Table 27: Elements for DataItem

Element	Description	Occurrence
`Source`	`Source` is an optional XML element that identifies the `Component`, `DataItem`, or `Composition` representing the area of the piece of equipment from which a measured value originates. Additionally, `Source` **MAY** provide information relating to the identity of a measured value. This information is reported as CDATA for `Source`. (example, a PLC tag)	0..1
`Constraints`	`Constraints` is an optional container that provides a set of expected values that can be reported for this `DataItem`. `Constraints` are used by a software application to evaluate the validity of the reported data.	0..1
`Filters`	An optional container for the `Filter` elements associated with this `DataItem` element.	0..1

Continuation of Table 27		
Element	Description	Occurrence
`InitialValue`	`InitialValue` is an optional XML element that defines the starting value for a data item as well as the value to be set for the data item after a reset event. Only one `InitialValue` element may be defined for a data item. The value will be constant and cannot change. If no `InitialValue` element is defined for a data item that is periodically reset, then the starting value for the data item **MUST** be a value of 0.	0..1
`ResetTrigger`	`ResetTrigger` is an optional XML element that identifies the type of event that may cause a reset to occur. It is additional information regarding the meaning of the data that establishes an understanding of the time frame that the data represents so that the data may be correctly understood by a client software application.	0..1
`Definition`	The `Definition` defines the meaning of `Entry` and `Cell` elements associated with the `DataItem` when the `representation` is either `DATA_SET` or `TABLE`.	0..1
`Relationships`	`Relationships` *organizes* one or more `DataItemRelationship` and `SpecificationRelationship`.	0..1

7.2.3.1 Source Element for DataItem

`Source` is an optional XML element that may be used to identify the physical part of a piece of equipment where the data represented by `DataItem` originated and/or it may be used to identify a complex name or an alternate name used to identify the data where it originated (e.g. a PLC tag name).

As an example, data related to a servo motor on an `Axes` component may actually originate from a measurement made in the `Controller` element.

In the case where the real name associated with a `DataItem` element is either complex or does not meet the format requirements of a NMTOKEN XML type, the real name of the element may not be able to be expressed in the `name` attribute. Additionally, a second or alternate name may be required to describe a piece of data. An example of this case would be the identity of the bit address in a PLC that represents this piece of data (PLC address I0015.4). When these cases occur, the alternate name can be provided as the value for the CDATA for `Source`.

The XML schema in *Figure 13* represents the structure of the `Source` XML element showing the attributes defined for `Source`.

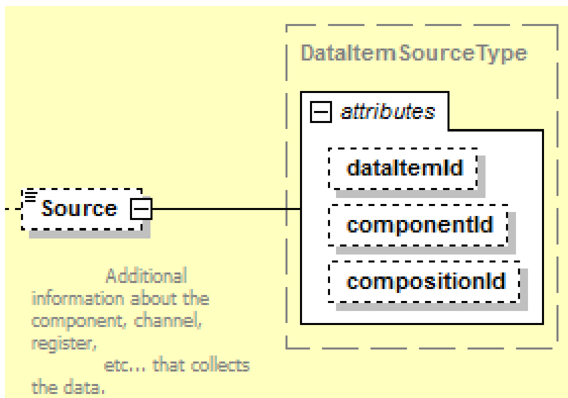

Figure 13: Source Diagram

7.2.3.1.1 Attributes for Source

Table 28 identifies the attributes available to identify `Source` for a measured value:

Table 28: Attributes for Source

Attribute	Description	Occurrence
`componentId`	The identifier attribute of the `Component` element that represents the physical part of a piece of equipment where the data represented by the `DataItem` element originated. A *Valid Data Value* reported for `componentId` **MUST** be the value of the `id` attribute for the `Component` element identified. `componentId` is an optional attribute.	0..1

Continuation of Table 28

Attribute	Description	Occurrence
`dataItemId`	The identifier attribute of the `DataItem` that represents the originally measured value of the data referenced by this data item. A *Valid Data Value* reported for `dataItemId` **MUST** be the value of the `id` attribute for the `DataItem` element identified. `dataItemId` is an optional attribute.	0..1
`compositionId`	The identifier attribute of the `Composition` element that represents the physical part of a piece of equipment where the data represented by the `DataItem` element originated. A *Valid Data Value* reported for `compositionId` **MUST** be the value of the `id` attribute for the `Composition` element identified. `compositionId` is an optional attribute.	0..1

Note: †One of componentID, componsitionId , or dataItemId MUST be provided.

7.2.3.2 Constraints Element for DataItem

For some types of `DataItem` elements, the expected value(s) for the data reported for the `DataItem` **MAY** be restricted to specific values or a range of values.

`Constraints` is an optional XML element that provides a way to define the expected value(s) or the upper and lower limits for the range of values that are expected to be reported in response to a *Current Request* or *Sample Request*.

`Constraints` are used by a software application to evaluate the validity of the data reported.

The value associated with each `Constraint` element is reported in the CDATA for that element.

7.2.3.2.1 Schema for Constraints

The XML schema in *Figure 14* represents the structure of the `Constraints` XML element and the elements defined for `Constraints`.

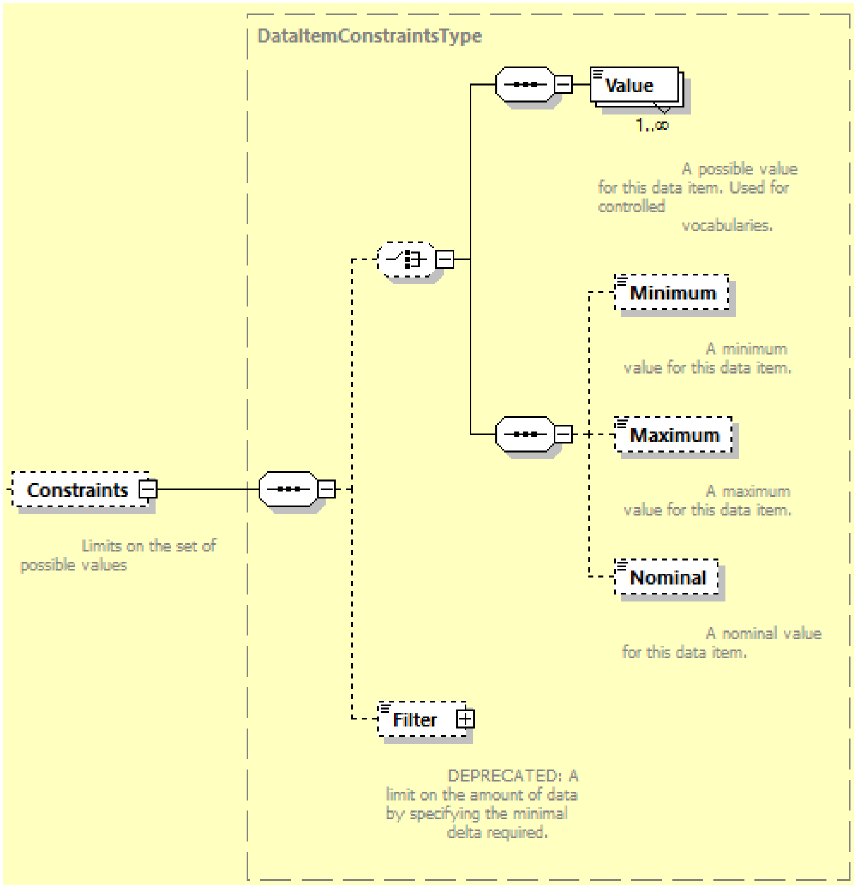

Figure 14: Constraints Diagram

Table 29 identifies the elements available to identify `Constraints` for a measured value:

Table 29: Elements for Constraints

Element	Description	Occurrence
`Value`	`Value` represents a single data value that is expected to be reported for a `DataItem` element. The data value is provided in the CDATA for this element and may be any numeric or text content. When there are multiple data values that may be expected to be reported for a `DataItem` element, multiple `Value` elements may be defined. In the case where only one `Value` element is defined, the data returned in response to a *Current Request* or *Sample Request* request **MUST** be the data value defined for `Value` element. `Value` **MUST NOT** be used in conjunction with any other `Constraint` elements.	0..*
`Maximum`	If the data reported for a data item is a range of numeric values, the expected value reported **MAY** be described with an upper limit defined by this constraint. The data value is provided in the CDATA for this element and **MUST** be a value using the same units as the reported data.	0..1
`Minimum`	If the data reported for a data item is a range of numeric values, the expected value reported **MAY** be described with a lower limit defined by this constraint. The data value is provided in the CDATA for this element and **MUST** be a value using the same units as the reported data.	0..1
`Nominal`	The target or expected value for this data item. The data value is provided in the CDATA for this element and **MUST** be a value using the same units as the reported data.	0..1

Continuation of Table 29		
Element	Description	Occurrence
~~`Filter`~~	**DEPRECATED** in Version 1.4 – Moved to the `Filters` element of a `DataItem`. ~~If the data reported for a DataItem is a numeric value, a new value MUST NOT be reported if the change from the last reported value is less than the delta given as the CDATA of this element. Filter is an abstract type XML element. As such, Filter will never appear in the XML document, but will be replaced by a Filter type. The only currently supported Filter type is MINIMUM_DELTA. The CDATA MUST be an absolute value using the same Units as the reported data. Additional filter types MAY be supported in the future.~~	0..1 [†]

Note: [†]Remains in schema for backwards compatibility.

7.2.3.3 Filters Element for DataItem

`Filters` is an optional XML container that organizes the `Filter` elements for `DataItem`.

`Filters` contains one or more `Filter` XML elements.

Table 30: MTConnect Filters Element

Element	Description	Occurrence
`Filters`	An XML container consisting of one or more types of `Filter` XML elements. Only one `Filters` container **MAY** appear for a `DataItem` element.	0..1

7.2.3.3.1 Filter

Filter provides a means to control when an *Agent* records updated information for a data item. Currently, there are two types of Filter elements defined in the MTConnect Standard - MINIMUM_DELTA and PERIOD. More Filter types may be added in the future.

The value associated with each Filter element is reported in the CDATA for that element.

Figure 15 represents the structure for Filter XML element.

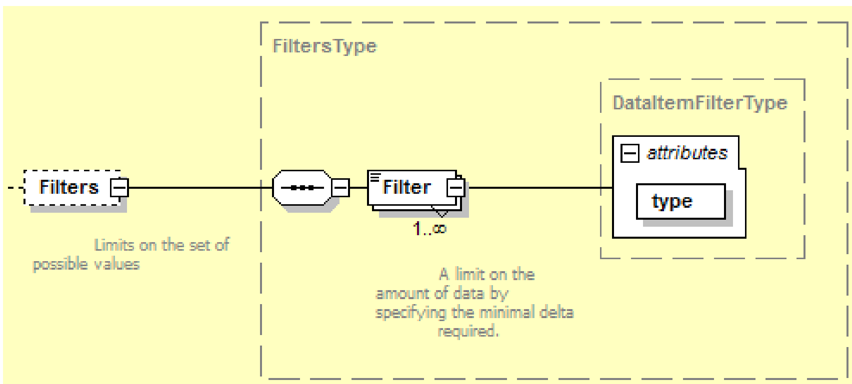

Figure 15: Filter Diagram

Table 31 describes the types of Filter defined for a DataItem element and the expected behavior of an *Agent* when a Filter is applied to DataItem element.

Table 31: DataItem Element Filter type

type	Description	Occurrence
MINIMUM_DELTA	For a MINIMUM_DELTA type Filter, a new value **MUST NOT** be reported for a data item unless the measured value has changed from the last reported value by at least the delta given as the CDATA of this element. The CDATA **MUST** be an absolute value using the same units as the reported data.	0..1 †

Continuation of Table 31		
type	Description	Occurrence
PERIOD	For a PERIOD type Filter, the data reported for a data item is provided on a periodic basis. The PERIOD for reporting data is defined in the CDATA for the Filter. The CDATA **MUST** be an absolute value reported in seconds representing the time between reported samples of the value of the data item. If the PERIOD is smaller than one second, the number can be represented as a floating point number. For example, a PERIOD of 100 milliseconds would be 0.1.	0..1 †

†Note: Either MINIMUM_DELTA or PERIOD can be defined, not both.

7.2.3.4 InitialValue Element for DataItem

InitialValue is an XML element that defines the value to be set for the data item after a reset event.

The value associated with the InitialValue element is reported in the CDATA for this element and **MUST** be an absolute value using the same units as the reported data.

7.2.3.5 ResetTrigger Element for DataItem

The value of some data types is periodically reset to the value of the InitialValue element. These reset events may be based upon a specific elapsed time or may be triggered by a physical or logical reset action that causes the reset to occur. ResetTrigger provides additional information regarding the meaning of the data – establishing an understanding of the time frame that the data represents so that the data may be correctly understood by a client software application.

Table 32: MTConnect ResetTrigger Element

Element	Description	Occurrence
`ResetTrigger`	`ResetTrigger` is an XML element that describes the reset action that causes a reset to occur. It is additional information regarding the meaning of the data that establishes an understanding of the time frame that the data represents so that the data may be correctly understood by a client software application.	0..1

The reset action that **MAY** cause a reset to occur is provided in the CDATA for this element.

The reset actions that may cause a reset to occur are described in *Table 33*.

Table 33: DataItem Element ResetTrigger type

Reset Actions	Description
`ACTION_COMPLETE`	The value of the *Data Entity* that is measuring an action or operation is to be reset upon completion of that action or operation.
`ANNUAL`	The value of the *Data Entity* is to be reset at the end of a 12-month period.
`DAY`	The value of the *Data Entity* is to be reset at the end of a 24-hour period.
`LIFE`	The value of the *Data Entity* is not reset and accumulates for the entire life of the piece of equipment.
`MAINTENANCE`	The value of the *Data Entity* is to be reset upon completion of a maintenance event.
`MONTH`	The value of the *Data Entity* is to be reset at the end of a monthly period.
`POWER_ON`	The value of the *Data Entity* is to be reset when power was applied to the piece of equipment after a planned or unplanned interruption of power has occurred.

Continuation of Table 33	
Reset Actions	Description
SHIFT	The value of the *Data Entity* is to be reset at the end of a work shift.
WEEK	The value of the *Data Entity* is to be reset at the end of a 7-day period.

7.2.3.6 Definition Element for DataItem

Figure 16 represents the *XML Schema* structure for Definition element.

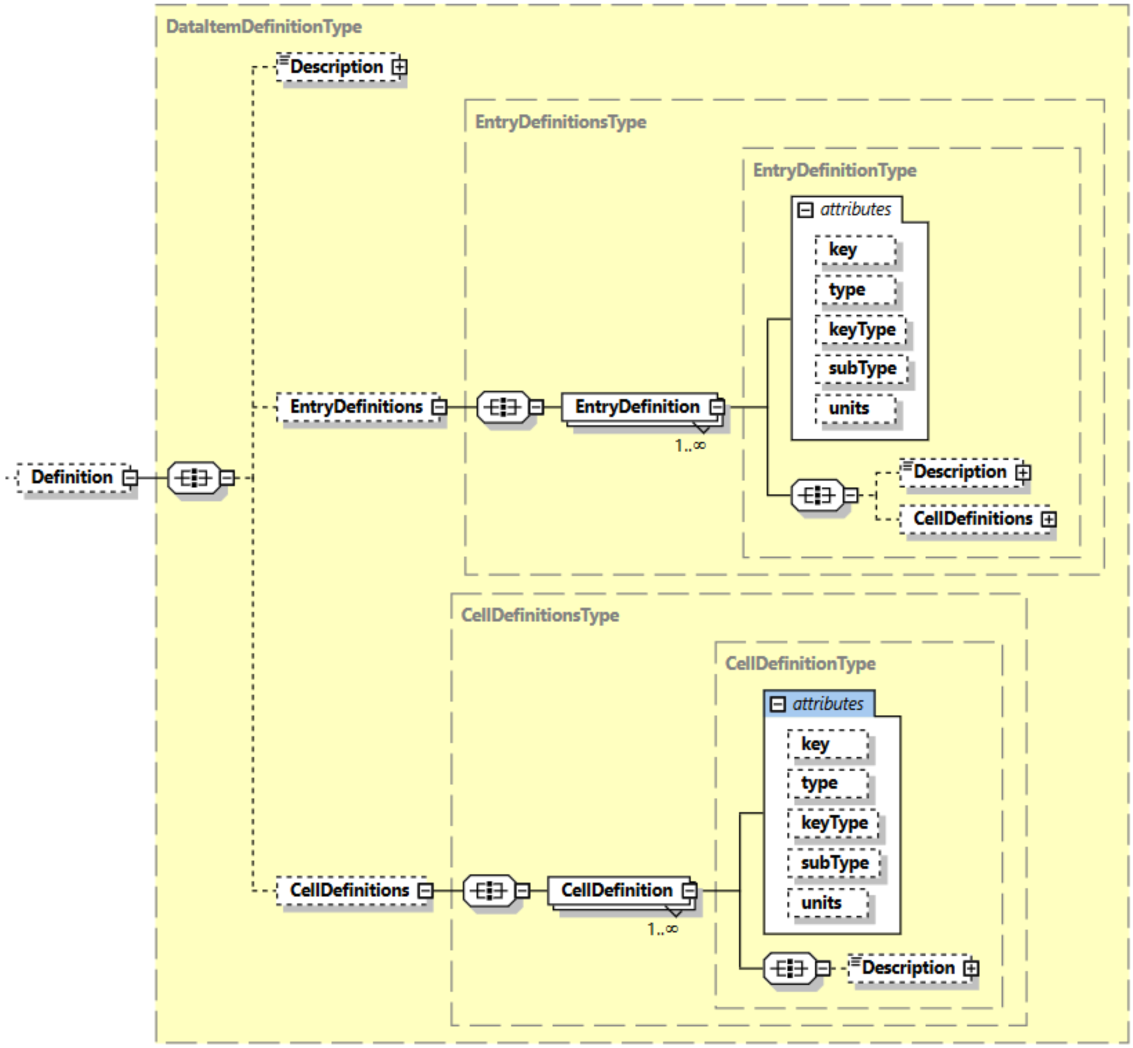

Figure 16: Definition Diagram

The `Definition` provides additional descriptive information for any `DataItem` representations. When the `representation` is either `DATA_SET` or `TABLE`, it gives the specific meaning of a `key` and **MAY** provide a `Description`, `type`, and `units` for semantic interpretation of data.

Table 34: Elements for Definition

Element	Description	Occurrence
`Description`	The `Description` of the `Definition`. See `Component Description`	0..1

Continuation of Table 34		
Element	Description	Occurrence
EntryDefinitions	The EntryDefinitions aggregates EntryDefinition .	0..1
CellDefinitions	The CellDefinitions aggregates CellDefinition.	0..1

7.2.3.6.1 EntryDefinitions Element for Definition

The EntryDefinitions aggregates EntryDefinition for Definition.

Elements for EntryDefinitions

Table 35: Elements for EntryDefinitions

Element	Description	Occurrence
EntryDefinition	The semantic definition of an Entry	1..*

7.2.3.6.2 EntryDefinition Element for Definition

When the representation is DATA_SET, the EntryDefinition provides the Description, units, and type of each Entry identified by a unique key.

When the representation is TABLE, the EntryDefinition provides a Description and a set of CellDefinitions for an Entry identified by a unique key.

The key for the EntryDefinion **MUST** be unique for a given DataItem Definition.

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Table 36: Attributes for EntryDefinition

Attribute	Description	Occurrence
`key`	The unique identification of the `Entry` in the `Definition`. The description applies to all `Entry` *observations* having this `key`.	0..1
`keyType`	The `DataItem` `type` that defines the meaning of the `key`.	0..1
`units`	Same as `DataItem` units. See *Section 7.2.2.5 - units Attribute for DataItem*. Only valid for `representation` of `DATA_SET`.	0..1
`type`	Same as `DataItem` `type`. See *Section 8 - Listing of Data Items*.	0..1
`subType`	Same as `DataItem` `subType`. See *Section 8 - Listing of Data Items*.	0..1

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Table 37: Elements for EntryDefinition

Element	Description	Occurrence
`Description`	The `Description` of the `EntryDefinition`. See `Component` `Description`	0..1
`CellDefinitions`	The `CellDefinitions` aggregates `CellDefinition` if the representation is `TABLE`.	0..1

1254 **7.2.3.6.3 CellDefinitions Element for Definition**

1255 The `CellDefinitions` aggregates `CellDefinition` declarations.

Elements for CellDefinitions

Table 38: Elements for CellDefinitions

Element	Description	Occurrence
`CellDefinition`	The semantic definition of a `Cell`.	1..*

7.2.3.6.4 CellDefinition Element for CellDefinitions

When the `representation` is `TABLE`, the `CellDefinition` provides the `Description` and the `units` associated each `Cell` by `key`.

The `key` for the `CellDefinion` **MUST** be unique for a given `Definition` or `EntryDefinition`.

Attributes for CellDefinition

Table 39: Attributes for CellDefinition

Attribute	Description	Occurrence
`key`	The unique identification of the `Entry` in the `Definition`. The description applies to all `Entry` *observations* having this `key`.	0..1
`keyType`	The `DataItem` `type` that defines the meaning of the `key`.	0..1
`units`	Same as `DataItem` units. See *Section 7.2.2.5 - units Attribute for DataItem*.	0..1
`type`	Same as `DataItem` `type`. See *Section 8 - Listing of Data Items*.	0..1
`subType`	Same as `DataItem` `subType`. See *Section 8 - Listing of Data Items*.	0..1

Elements for CellDefinition

Table 40: Elements for CellDefinition

Element	Description	Occurrence
Description	The Description of the CellDefinition. See Component Description	0..1

7.2.3.7 Relationships Element for DataItem

Relationships *organizes* DataItemRelationship and SpecificationRelationship.

See *Section 9.2 - Relationships* for definitions of Relationships and Relationship.

7.2.3.7.1 DataItemRelationship

A Relationship providing a semantic reference to another DataItem described by the type property.

Table 41: Attributes for DataItemRelationship

Attribute	Description	Occurrence
name	A descriptive name associated with this Relationship. An NMTOKEN XML type.	0..1
type	Specifies how the DataItem is related. The value provided for type **MUST** be one of the following values: ATTACHMENT: A reference to a DataItem that associates the values with an external entity. COORDINATE_SYSTEM: The referenced DataItem provides the id of the effective Coordinate System. LIMIT: The referenced DataItem provides process limits. OBSERVATION: The referenced DataItem provides the observed values.	1

Continuation of Table 41		
Attribute	Description	Occurrence
idRef	A reference to the related DataItem id. An NMTOKEN XML type.	1

7.2.3.7.2 SpecificationRelationship

A Relationship providing a semantic reference to a Specification described by the type property.

Table 42: Attributes for SpecificationRelationship

Attribute	Description	Occurrence
name	A descriptive name associated with this Relationship. An NMTOKEN XML type.	0..1
type	Specifies how the Specification is related. The value provided for type **MUST** be one of the following values: LIMIT: The referenced Specification provides process limits.	1
idRef	A reference to the related Specification id. An NMTOKEN XML type.	1

8 Listing of Data Items

In the MTConnect Standard, DataItem elements are defined and organized based upon the category and type attributes. The category attribute provides a high level grouping for DataItem elements based on the kind of information that is reported by the data item.

These categories are:

- SAMPLE

  A SAMPLE reports a continuously variable or analog data value.

- EVENT

  An EVENT reports information representing a functional state, with two or more discrete values, associated with a component or it contains a message. The data provided may be a numeric value or text.

- CONDITION

  A CONDITION reports information about the health of a piece of equipment and its ability to function.

The type attribute specifies the specific kind of data that is reported. For some types of data items, a subType attribute may also be used to differentiate between multiple data items of the same type where the information reported by the data item has a different, but related, meaning.

Many types of data items provide two forms of data: a value (reported as either a SAMPLE or EVENT) and a health status (reported as a CONDITION). These DataItem types **MAY** be defined in more than one category based on the data that they report.

8.1 Data Items in category SAMPLE

The types of DataItem elements in the SAMPLE category report data representing a continuously changing or analog data value. This data can be measured at any point-in-time and will always produce a result. The data provided may be a scalar floating point number or integers that have an infinite number of possible values. The units attribute **MUST** be defined and reported for each DataItem in this category.

Table 43 defines the types and subtypes of DataItem elements defined for the SAMPLE category. The subtypes are indented below their associated types.

Table 43: DataItem type subType for category SAMPLE

DataItem type/subType	Description	Units
ACCELERATION	The positive rate of change of velocity. If a subType is not specified, the reported value for the data **MUST** default to the subType of ACTUAL.	MILLIMETER/SECOND^2
ACTUAL	The measured or reported value of an *observation*.	MILLIMETER/SECOND^2
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIMETER/SECOND^2
PROGRAMMED	Directive value without offsets and adjustments.	MILLIMETER/SECOND^2
ACCUMULATED_TIME	The measurement of accumulated time for an activity or event. **DEPRECATION WARNING** : May be deprecated in the future. Recommend using PROCESS_TIMER and EQUIPMENT_TIMER.	SECOND

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
~~AMPERAGE~~	**DEPRECATED** in *Version 1.6*. Replaced by AMPERAGE_AC and AMPERAGE_DC.	~~AMPERE~~
~~ACTUAL~~	~~The measured amperage being delivered from a power source.~~	~~AMPERE~~
~~ALTERNATING~~	~~The measurement of alternating current. If not specified further in statistic, defaults to RMS voltage.~~	~~AMPERE~~
~~DIRECT~~	~~The measurement of DC current.~~	~~AMPERE~~
~~TARGET~~	~~The desired or preset amperage to be delivered from a power source.~~	~~AMPERE~~
AMPERAGE_AC	The measurement of an electrical current that reverses direction at regular short intervals. A subType **MUST** always be specified. If not specified further in statistic, defaults to RMS amperage.	AMPERE
ACTUAL	The measured or reported value of an *observation*.	AMPERE
COMMANDED	Directive value including adjustments such as an offset or overrides.	AMPERE
PROGRAMMED	Directive value without offsets and adjustments.	AMPERE

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
AMPERAGE_DC	The measurement of an electric current flowing in one direction only. A subType **MUST** always be specified.	AMPERE
ACTUAL	The measured or reported value of an *observation*.	AMPERE
COMMANDED	Directive value including adjustments such as an offset or overrides.	AMPERE
PROGRAMMED	Directive value without offsets and adjustments.	AMPERE
ANGLE	The measurement of angular position.	DEGREE
ACTUAL	The measured or reported value of an *observation*.	DEGREE
COMMANDED	Directive value including adjustments such as an offset or overrides.	DEGREE
ANGULAR_-ACCELERATION	The positive rate of change of angular velocity. If a subType is not specified, the reported value for the data **MUST** default to the subType of ACTUAL.	DEGREE/SECOND^2
ACTUAL	The measured or reported value of an *observation*.	DEGREE/SECOND^2
COMMANDED	Directive value including adjustments such as an offset or overrides.	DEGREE/SECOND^2
PROGRAMMED	Directive value without offsets and adjustments.	DEGREE/SECOND^2

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
ANGULAR_-DECELERATION	Negative rate of change of angular velocity.	DEGREE/SECOND^2
ACTUAL	The measured or reported value of an *observation*.	DEGREE/SECOND^2
COMMANDED	Directive value including adjustments such as an offset or overrides.	DEGREE/SECOND^2
PROGRAMMED	Directive value without offsets and adjustments.	DEGREE/SECOND^2
ANGULAR_VELOCITY	Rate of change of angular position.	DEGREE/SECOND
ASSET_UPDATE_RATE	The average rate of change of values for assets in the MTConnect streams. The average is computed over a rolling window defined by the implementation.	COUNT/SECOND
AXIS_FEEDRATE	The feedrate of a linear axis.	MILLIMETER/SECOND
ACTUAL	The measured or reported value of an *observation*.	MILLIMETER/SECOND
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIMETER/SECOND
JOG	The feedrate specified by a logic or motion program, by a pre-set value, or set by a switch as the feedrate for a linear axis when operating in a manual state or method (jogging).	MILLIMETER/SECOND

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
~~OVERRIDE~~	~~The operator's overridden value. Percent of commanded.~~ **DEPRECATED** in Version 1.3. See EVENT category data items.	~~PERCENT~~
PROGRAMMED	Directive value without offsets and adjustments.	MILLIMETER/SECOND
RAPID	Performing an operation faster or in less time than nominal rate.	MILLIMETER/SECOND
CAPACITY_FLUID	The fluid capacity of an object or container.	MILLILITER
CAPACITY_SPATIAL	The geometric capacity of an object or container.	CUBIC_MILLIMETER
CONCENTRATION	Percentage of one component within a mixture of components.	PERCENT
CONDUCTIVITY	The ability of a material to conduct electricity.	SIEMENS/METER
CUTTING_SPEED	The speed difference (relative velocity) between the cutting mechanism and the surface of the workpiece it is operating on.	MILLIMETER/SECOND
ACTUAL	The measured or reported value of an *observation*.	MILLIMETER/SECOND
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIMETER/SECOND
PROGRAMMED	Directive value without offsets and adjustments.	MILLIMETER/SECOND

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
DECELERATION	Negative rate of change of velocity.	MILLIMETER/SECOND^2
ACTUAL	The measured or reported value of an *observation*.	MILLIMETER/SECOND^2
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIMETER/SECOND^2
PROGRAMMED	Directive value without offsets and adjustments.	MILLIMETER/SECOND^2
DENSITY	The volumetric mass of a material per unit volume of that material.	MILLIGRAM/CUBIC_-MILLIMETER
DEPOSITION_-ACCELERATION_-VOLUMETRIC	The rate of change in spatial volume of material deposited in an additive manufacturing process.	CUBIC_-MILLIMETER/SECOND^2
ACTUAL	The measured or reported value of an *observation*.	CUBIC_-MILLIMETER/SECOND^2
COMMANDED	Directive value including adjustments such as an offset or overrides.	CUBIC_-MILLIMETER/SECOND^2
DEPOSITION_DENSITY	The density of the material deposited in an additive manufacturing process per unit of volume.	MILLIGRAM/CUBIC_-MILLIMETER
ACTUAL	The measured or reported value of an *observation*.	MILLIGRAM/CUBIC_-MILLIMETER
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIGRAM/CUBIC_-MILLIMETER
DEPOSITION_MASS	The mass of the material deposited in an additive manufacturing process.	MILLIGRAM

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
ACTUAL	The measured or reported value of an *observation*.	MILLIGRAM
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIGRAM
DEPOSITION_RATE_-VOLUMETRIC	The rate at which a spatial volume of material is deposited in an additive manufacturing process.	CUBIC_-MILLIMETER/SECOND
ACTUAL	The measured or reported value of an *observation*.	CUBIC_-MILLIMETER/SECOND
COMMANDED	Directive value including adjustments such as an offset or overrides.	CUBIC_-MILLIMETER/SECOND
DEPOSITION_VOLUME	The spatial volume of material to be deposited in an additive manufacturing process.	CUBIC_MILLIMETER
ACTUAL	The measured or reported value of an *observation*.	CUBIC_MILLIMETER
COMMANDED	Directive value including adjustments such as an offset or overrides.	CUBIC_MILLIMETER
DIAMETER	The measured dimension of a diameter.	MILLIMETER
DISPLACEMENT	The change in position of an object.	MILLIMETER
ELECTRICAL_ENERGY	The value of Wattage used or generated by a component over an interval of time.	WATT_SECOND

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
EQUIPMENT_TIMER	The measurement of the amount of time a piece of equipment or a sub-part of a piece of equipment has performed specific activities. Often used to determine when maintenance may be required for the equipment. Multiple subTypes of EQUIPMENT_TIMER **MAY** be defined. A subType **MUST** always be specified.	SECOND
DELAY	The elapsed time of a temporary halt of action.	SECOND
LOADED	Measurement of the time that the sub-parts of a piece of equipment are under load. Example: For traditional machine tools, this is a measurement of the time that the cutting tool is assumed to be engaged with the part.	SECOND
OPERATING	Measurement of the time that the major sub-parts of a piece of equipment are powered or performing any activity whether producing a part or product or not. Example: For traditional machine tools, this includes WORKING, plus idle time.	SECOND

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
POWERED	The measurement of time that primary power is applied to the piece of equipment and, as a minimum, the controller or logic portion of the piece of equipment is powered and functioning or components that are required to remain on are powered. Example: Heaters for an extrusion machine that are required to be powered even when the equipment is turned off	SECOND
WORKING	Measurement of the time that a piece of equipment is performing any activity the equipment is active and performing a function under load or not. Example: For traditional machine tools, this includes LOADED, plus rapid moves, tool changes, etc.	SECOND
FILL_LEVEL	The measurement of the amount of a substance remaining compared to the planned maximum amount of that substance.	PERCENT
FLOW	The rate of flow of a fluid.	LITER/SECOND
FREQUENCY	The measurement of the number of occurrences of a repeating event per unit time.	HERTZ

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
~~GLOBAL_POSITION~~	**DEPRECATED** in Version 1.1	None
HUMIDITY_ABSOLUTE	The amount of water vapor expressed in grams per cubic meter.	GRAM/CUBIC_METER
ACTUAL	The measured or reported value of an *observation*.	GRAM/CUBIC_METER
COMMANDED	Directive value including adjustments such as an offset or overrides.	GRAM/CUBIC_METER
HUMIDITY_RELATIVE	The amount of water vapor present expressed as a percent to reach saturation at the same temperature.	PERCENT
ACTUAL	The measured or reported value of an *observation*.	PERCENT
COMMANDED	Directive value including adjustments such as an offset or overrides.	PERCENT
HUMIDITY_SPECIFIC	The ratio of the water vapor present over the total weight of the water vapor and air present expressed as a percent.	PERCENT
ACTUAL	The measured or reported value of an *observation*.	PERCENT
COMMANDED	Directive value including adjustments such as an offset or overrides.	PERCENT
LENGTH	The length of an object.	MILLIMETER
REMAINING	The remaining total length of an object.	MILLIMETER
STANDARD	The standard or original length of an object.	MILLIMETER

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
USEABLE	The remaining useable length of an object.	MILLIMETER
~~LEVEL~~	**DEPRECATED** in Version 1.2. See FILL_LEVEL	None
LINEAR_FORCE	A *Force* applied to a mass in one direction only.	NEWTON
LOAD	The measurement of the actual versus the standard rating of a piece of equipment.	PERCENT
MASS	The measurement of the mass of an object(s) or an amount of material.	KILOGRAM
OBSERVATION_-UPDATE_RATE	The average rate of change of values for data items in the MTConnect streams. The average is computed over a rolling window defined by the implementation.	COUNT/SECOND
ORIENTATION	A measured or calculated orientation of a plane or vector relative to a cartesian coordinate system. ORIENTATION **SHOULD** have a coordinateSytemIdRef or a coordinateSystem attribute, otherwise the coordinateSystem attribute **MUST** default to WORK coordinates.	DEGREE_3D
ACTUAL	The measured or reported value of an *observation*.	DEGREE_3D

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
COMMANDED	Directive value including adjustments such as an offset or overrides.	DEGREE_3D
PATH_FEEDRATE	The feedrate for the axes, or a single axis, associated with a Path component– a vector.	MILLIMETER/SECOND
ACTUAL	The measured or reported value of an *observation*.	MILLIMETER/SECOND
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIMETER/SECOND
JOG	The feedrate specified by a logic or motion program, by a pre-set value, or set by a switch as the feedrate for the axes, or a single axis, associated with a Path when operating in a manual state or method (jogging).	MILLIMETER/SECOND
~~OVERRIDE~~	~~The operator's overridden value. Percent of commanded.~~ **DEPRECATED** in Version 1.3. See EVENT category data items.	~~PERCENT~~
PROGRAMMED	Directive value without offsets and adjustments.	MILLIMETER/SECOND
RAPID	Performing an operation faster or in less time than nominal rate.	MILLIMETER/SECOND
PATH_FEEDRATE_-PER_REVOLUTION	The feedrate for the axes, or a single axis.	MILLIMETER/REVO-LUTION
ACTUAL	The measured or reported value of an *observation*.	MILLIMETER/REVO-LUTION

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIMETER/REVO-LUTION
PROGRAMMED	Directive value without offsets and adjustments.	MILLIMETER/REVO-LUTION
PATH_POSITION	A measured or calculated position of a control point associated with a piece of equipment. The control point **MUST** be reported as a set of space-delimited floating-point numbers representing a point in 3-D space. The position of the control point **MUST** be reported in units of MILLIMETER and listed in order of X, Y, and Z referenced to the coordinate system of the piece of equipment. Any control point representing a position in 1-D or 2-D space **MAY** be represented in terms of 3-D space by setting any undefined coordinate to zero (0). PATH_POSITION **SHOULD** be further defined with a coordinateSystem attribute. If a coordinateSystem attribute is not specified, the position of the control point **MUST** be reported in WORK coordinates.	MILLIMETER_3D

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
ACTUAL	The measured or reported value of an *observation*.	MILLIMETER_3D
PROGRAMMED	Directive value without offsets and adjustments.	MILLIMETER_3D
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIMETER_3D
PROBE	The position provided by a measurement probe. **DEPRECATION WARNING**: May be deprecated in the future.	MILLIMETER_3D
TARGET	The goal of the operation or process.	MILLIMETER_3D
PH	The measurement of the acidity or alkalinity.	PH
POSITION	A measured or calculated position of a Component element as reported by a piece of equipment. POSITION **SHOULD** be further defined with a coordinateSytem attribute. If a coordinateSystem attribute is not specified, the position of the control point **MUST** be reported in MACHINE coordinates.	MILLIMETER
ACTUAL	The measured or reported value of an *observation*.	MILLIMETER
COMMANDED	Directive value including adjustments such as an offset or overrides.	MILLIMETER

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
PROGRAMMED	Directive value without offsets and adjustments.	MILLIMETER
TARGET	The goal of the operation or process.	MILLIMETER
POWER_FACTOR	The measurement of the ratio of real power flowing to a load to the apparent power in that AC circuit.	PERCENT
PRESSURE	The force per unit area measured relative to atmospheric pressure. Commonly referred to as gauge pressure.	PASCAL
PRESSURE_ABSOLUTE	The force per unit area measured relative to a vacuum.	PASCAL

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
PROCESS_TIMER	The measurement of the amount of time a piece of equipment has performed different types of activities associated with the process being performed at that piece of equipment. Multiple subtypes of PROCESS_TIMER may be defined. Typically, PROCESS_TIMER **SHOULD** be modeled as a data item for the Device element, but **MAY** be modeled for either a Controller or Path *Structural Element* in the XML document. A subType **MUST** always be specified.	SECOND
DELAY	The elapsed time of a temporary halt of action.	SECOND
PROCESS	The measurement of the time from the beginning of production of a part or product on a piece of equipment until the time that production is complete for that part or product on that piece of equipment. This includes the time that the piece of equipment is running, producing parts or products, or in the process of producing parts.	SECOND

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
PRESSURIZATION_-RATE	The change of pressure per unit time.	PASCAL/SECOND
ACTUAL	The measured or reported value of an *observation*.	PASCAL/SECOND
COMMANDED	Directive value including adjustments such as an offset or overrides.	PASCAL/SECOND
PROGRAMMED	Directive value without offsets and adjustments.	PASCAL/SECOND
RESISTANCE	The degree to which a substance opposes the passage of an electric current.	OHM
ROTARY_VELOCITY	The rotational speed of a rotary axis.	REVOLUTION/MINUTE
ACTUAL	The measured or reported value of an *observation*.	REVOLUTION/MINUTE
COMMANDED	Directive value including adjustments such as an offset or overrides.	REVOLUTION/MINUTE
~~OVERRIDE~~	~~The operator's overridden value. Percent of commanded.~~ **DEPRECATED** in Version 1.3. See EVENT category data items.	~~PERCENT~~
PROGRAMMED	Directive value without offsets and adjustments.	REVOLUTION/MINUTE
SOUND_LEVEL	The measurement of a sound level or sound pressure level relative to atmospheric pressure.	DECIBEL

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
A_SCALE	A Scale weighting factor. This is the default weighting factor if no factor is specified	DECIBEL
B_SCALE	B Scale weighting factor	DECIBEL
C_SCALE	C Scale weighting factor	DECIBEL
D_SCALE	D Scale weighting factor	DECIBEL
NO_SCALE	No weighting factor on the frequency scale	DECIBEL
~~SPINDLE_SPEED~~	**DEPRECATED** in Version 1.2. Replaced by ROTARY_VELOCITY	~~REVOLUTION/MINUTE~~
~~ACTUAL~~	~~The rotational speed of a rotary axis. ROTARY_MODE **MUST** be SPINDLE.~~	~~REVOLUTION/MINUTE~~
~~COMMANDED~~	~~The rotational speed the as specified by the Controller type Component.~~	~~REVOLUTION/MINUTE~~
~~OVERRIDE~~	~~The operator's overridden value. Percent of commanded.~~	~~PERCENT~~
STRAIN	The amount of deformation per unit length of an object when a load is applied.	PERCENT
TEMPERATURE	The measurement of temperature.	CELSIUS
ACTUAL	The measured or reported value of an *observation*.	CELSIUS
COMMANDED	Directive value including adjustments such as an offset or overrides.	CELSIUS

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
TENSION	The measurement of a force that stretches or elongates an object.	NEWTON
TILT	The measurement of angular displacement.	MICRO_RADIAN
TORQUE	The turning force exerted on an object or by an object.	NEWTON_METER
VELOCITY	The rate of change of position.	MILLIMETER/SECOND
VISCOSITY	The measurement of a fluids resistance to flow.	PASCAL_SECOND
~~VOLTAGE~~	**DEPRECATED** in *Version 1.6*. Replaced by VOLTAGE_AC and VOLTAGE_DC.	~~VOLT~~
~~ACTUAL~~	~~The measured voltage being delivered from a power source.~~	~~VOLT~~
~~ALTERNATING~~	~~The measurement of alternating voltage. If not specified further in statistic, defaults to RMS voltage.~~	~~VOLT~~
~~DIRECT~~	~~The measurement of DC voltage.~~	~~VOLT~~
~~TARGET~~	~~The desired or preset voltage to be delivered from a power source.~~	~~VOLT~~

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
VOLTAGE_AC	The measurement of the electrical potential between two points in an electrical circuit in which the current periodically reverses direction. A subType **MUST** be specified. If not specified further in statistic, defaults to RMS voltage.	VOLT
ACTUAL	The measured or reported value of an *observation*.	VOLT
COMMANDED	Directive value including adjustments such as an offset or overrides.	VOLT
PROGRAMMED	Directive value without offsets and adjustments.	VOLT
VOLTAGE_DC	The measurement of the electrical potential between two points in an electrical circuit in which the current is unidirectional. A subType **MUST** be specified.	VOLT
ACTUAL	The measured or reported value of an *observation*.	VOLT
COMMANDED	Directive value including adjustments such as an offset or overrides.	VOLT
PROGRAMMED	Directive value without offsets and adjustments.	VOLT

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
VOLT_AMPERE	The measurement of the apparent power in an electrical circuit, equal to the product of root-mean-square (RMS) voltage and RMS current (commonly referred to as VA).	VOLT_AMPERE
VOLT_AMPERE_-REACTIVE	The measurement of reactive power in an AC electrical circuit (commonly referred to as VAR).	VOLT_AMPERE_-REACTIVE
VOLUME_FLUID	The fluid volume of an object or container.	MILLILITER
ACTUAL	The measured or reported value of an *observation*.	MILLILITER
START	Boundary when an activity or an event commences.	MILLILITER
ENDED	Boundary when an activity or an event terminates.	MILLILITER
CONSUMED	Reported or measured value of the amount used in the manufacturing process.	MILLILITER
WASTE	Reported or measured value of the amount discarded.	MILLILITER
PART	Reported or measured value of amount included in the *Part*.	MILLILITER
VOLUME_SPATIAL	The geometric volume of an object or container.	CUBIC_MILLIMETER
ACTUAL	The measured or reported value of an *observation*.	CUBIC_MILLIMETER

Continuation of Table 43: DataItem type subType for category SAMPLE		
DataItem type/subType	Description	Units
START	Boundary when an activity or an event commences.	CUBIC_MILLIMETER
ENDED	Boundary when an activity or an event terminates.	CUBIC_MILLIMETER
CONSUMED	Reported or measured value of the amount used in the manufacturing process.	CUBIC_MILLIMETER
WASTE	Reported or measured value of the amount discarded.	CUBIC_MILLIMETER
PART	Reported or measured value of amount included in the *Part*.	CUBIC_MILLIMETER
WATTAGE	The measurement of power flowing through or dissipated by an electrical circuit or piece of equipment.	WATT
ACTUAL	The measured or reported value of an *observation*.	WATT
TARGET	The goal of the operation or process.	WATT
X_DIMENSION	Measured dimension of an entity relative to the X direction of the referenced coordinate system.	MILLIMETER
Y_DIMENSION	Measured dimension of an entity relative to the Y direction of the referenced coordinate system.	MILLIMETER
Z_DIMENSION	Measured dimension of an entity relative to the Z direction of the referenced coordinate system.	MILLIMETER

8.2 Data Items in category EVENT

DataItem types in the EVENT category represent a discrete piece of information from a piece of equipment. EVENT does not have intermediate values that vary over time.

An EVENT is information that, when provided at any specific point in time, represents the current state of the piece of equipment.

There are two types of EVENT: those representing state, with two or more discrete values, and those representing messages that contain plain text data.

Table 44 defines the DataItem types and subtypes defined for the EVENT category. The subtypes are indented below their associated types.

Table 44: DataItem type subType for category EVENT

DataItem type subType	Description
ACTIVATION_COUNT	Accumulation of the number of times a function has attempted to, or is planned to attempt to, activate or be performed. Use the discrete attribute with value true to report non-aggregate count. See *Section 7.2.3.5 - ResetTrigger Element for DataItem* to reset the count. The *Valid Data Value* **MUST** be numeric.
ALL	An accumulation representing all actions, items, or activities being counted independent of the outcome. ALL is the default subType.
BAD	An accumulation representing actions, items, or activities being counted that do not conform to specification or expectation.
GOOD	An accumulation representing actions, items, or activities being counted that conform to specification or expectation.
TARGET	The goal of the operation or process.
REMAINING	An accumulation representing actions, items, or activities yet to be counted.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
COMPLETE	An accumulation representing actions, items, or activities that have been completed, independent of the outcome.
FAILED	An accumulation representing actions or activities that were attempted, but failed to complete or resulted in an unexpected or unacceptable outcome.
ABORTED	An accumulation representing actions or activities that were attempted, but terminated before they could be completed.
ACTIVE_AXES	The set of axes currently associated with a Path or Controller *Structural Element*. If this DataItem is not provided, it will be assumed that all axes are currently associated with the Controller *Structural Element* and with an individual Path. The *Valid Data Value* for ACTIVE_AXES **SHOULD** be a space-delimited set of axes reported as the value of the name attribute for each axis. If name is not available, the piece of equipment **MUST** report the value of the nativeName attribute for each axis.
ACTUATOR_STATE	Represents the operational state of an apparatus for moving or controlling a mechanism or system. The *Valid Data Value* **MUST** be ACTIVE or INACTIVE.
ADAPTER_SOFTWARE_VERSION	The originator's software version of the *Adapter*. The *Valid Data Value* **MUST** be a string.
ADAPTER_URI	The URI of the *Adapter*. The *Valid Data Value* **MUST** be a string.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
~~ALARM~~	**DEPRECATED** in Version 1.1. Replaced with CONDITION category.
ALARM_LIMIT	A set of limits used to trigger warning or alarm indicators. The *Valid Data Value* **MUST** be a float. The representation attribute **MUST** be DATA_SET. The EntryDefinition key **MUST** be from the following: 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. LOWER_WARNING: The lower boundary indicating increased concern and supervision may be required. LOWER_LIMIT: The lower conformance boundary for a variable. Note: immediate concern or action may be required.
APPLICATION	The application on a component. The *Valid Data Value* **MUST** be a text string. A subType **MUST** always be specified.
LICENSE	The license code to validate or activate the hardware or software.
VERSION	The version of the hardware or software.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
RELEASE_DATE	The date the hardware or software was released for general use. It **MUST** be reported in ISO 8601 format.
INSTALL_DATE	The date the hardware or software was installed. It **MUST** be reported in ISO 8601 format.
MANUFACTURER	The corporate identity for the maker of the hardware or software.
AVAILABILITY	Represents the *Agent*'s ability to communicate with the data source. This **MUST** be provided for a Device Element and **MAY** be provided for any other *Structural Element*. The *Valid Data Value* **MUST** be AVAILABLE or UNAVAILABLE.
AXIS_COUPLING	Describes the way the axes will be associated to each other. This is used in conjunction with COUPLED_AXES to indicate the way they are interacting. The *Valid Data Value* **MUST** be TANDEM, SYNCHRONOUS, MASTER, and SLAVE. The coupling **MUST** be viewed from the perspective of a specific axis. Therefore, a MASTER coupling indicates that this axis is the master for the COUPLED_AXES.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
AXIS_FEEDRATE_OVERRIDE	The value of a signal or calculation issued to adjust the feedrate of an individual linear type axis. The value provided for AXIS_FEEDRATE_OVERRIDE is expressed as a percentage of the designated feedrate for the axis. When AXIS_FEEDRATE_OVERRIDE is applied, the resulting commanded feedrate for the axis is limited to the value of the original feedrate multiplied by the value of the AXIS_FEEDRATE_OVERRIDE. There **MAY** be different subtypes of AXIS_FEEDRATE_OVERRIDE; each representing an override value for a designated subtype of feedrate depending on the state of operation of the axis. The subtypes of operation of an axis are currently defined as PROGRAMMED, JOG, and RAPID.
JOG	The value of a signal or calculation issued to adjust the feedrate of an individual linear type axis when that axis is being operated in a manual state or method (jogging). When the JOG subtype of AXIS_FEEDRATE_OVERRIDE is applied, the resulting commanded feedrate for the axis is limited to the value of the original JOG subtype of the AXIS_FEEDRATE multiplied by the value of the JOG subtype of AXIS_FEEDRATE_OVERRIDE.
PROGRAMMED	Directive value without offsets and adjustments.
RAPID	Performing an operation faster or in less time than nominal rate.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
AXIS_INTERLOCK	An indicator of the state of the axis lockout function when power has been removed and the axis is allowed to move freely. The *Valid Data Value* **MUST** be ACTIVE or INACTIVE.
AXIS_STATE	An indicator of the controlled state of a Linear or Rotary component representing an axis. The *Valid Data Value* **MUST** be HOME, TRAVEL, PARKED, or STOPPED.
BLOCK	The line of code or command being executed by a Controller *Structural Element*. The value reported for Block **MUST** include the entire expression for a line of program code, including all parameters.
BLOCK_COUNT	The total count of the number of blocks of program code that have been executed since execution started. BLOCK_COUNT counts blocks of program code executed regardless of program structure (e.g., looping or branching within the program). The starting value for BLOCK_COUNT **MAY** be established by an initial value provided in the Constraint element defined for the data item.
CHUCK_INTERLOCK	An indication of the state of an interlock function or control logic state intended to prevent the associated CHUCK component from being operated. The *Valid Data Value* **MUST** be ACTIVE or INACTIVE.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
MANUAL_UNCLAMP	An indication of the state of an operator controlled interlock that can inhibit the ability to initiate an unclamp action of an electronically controlled chuck. The *Valid Data Value* **MUST** be ACTIVE or INACTIVE. When MANUAL_UNCLAMP is ACTIVE, it is expected that a chuck cannot be unclamped until MANUAL_UNCLAMP is set to INACTIVE.
CHUCK_STATE	An indication of the operating state of a mechanism that holds a part or stock material during a manufacturing process. It may also represent a mechanism that holds any other mechanism in place within a piece of equipment. The *Valid Data Value* **MUST** be OPEN, CLOSED, or UNLATCHED.
CLOCK_TIME	The value provided by a timing device at a specific point in time. CLOCK_TIME **MUST** be reported in ISO 8601 format.
~~CODE~~	**DEPRECATED** in Version 1.1.
COMPOSITION_STATE	An indication of the operating condition of a mechanism represented by a Composition type element. A subType **MUST** always be specified. A compositionId **MUST** always be specified.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
ACTION	An indication of the operating state of a mechanism represented by a Composition type component. The operating state indicates whether the Composition element is activated or disabled. The *Valid Data Value* **MUST** be ACTIVE or INACTIVE.
LATERAL	An indication of the position of a mechanism that may move in a lateral direction. The mechanism is represented by a Composition type component. The position information indicates whether the Composition element is positioned to the right, to the left, or is in transition. The *Valid Data Value* **MUST** be RIGHT, LEFT, or TRANSITIONING.
MOTION	An indication of the open or closed state of a mechanism. The mechanism is represented by a Composition type component. The operating state indicates whether the state of the Composition element is open, closed, or unlatched. The *Valid Data Value* **MUST** be OPEN, UNLATCHED, or CLOSED.
SWITCHED	An indication of the activation state of a mechanism represented by a Composition type component. The activation state indicates whether the Composition element is activated or not. The *Valid Data Value* **MUST** be ON or OFF.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
VERTICAL	An indication of the position of a mechanism that may move in a vertical direction. The mechanism is represented by a Composition type component. The position information indicates whether the Composition element is positioned to the top, to the bottom, or is in transition. The *Valid Data Value* **MUST** be UP, DOWN, or TRANSITIONING.
CONNECTION_STATUS	The status of the connection between an *Adapter* and an *Agent*. The *Valid Data Value* **MUST** be CLOSED, LISTEN, or ESTABLISHED.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
CONTROL_LIMIT	A set of limits used to indicate whether a process variable is stable and in control. The *Valid Data Value* **MUST** be a float. The representation attribute **MUST** be DATA_SET. The EntryDefinition key **MUST** be from the following: 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. NOMINAL: The ideal or desired value for a variable. LOWER_WARNING: The lower boundary indicating increased concern and supervision may be required. LOWER_LIMIT: The lower conformance boundary for a variable. Note: immediate concern or action may be required.
CONTROLLER_MODE	The current mode of the Controller component. The *Valid Data Value* **MUST** be AUTOMATIC, MANUAL, MANUAL_DATA_INPUT, SEMI_AUTOMATIC, or EDIT.
CONTROLLER_MODE_OVERRIDE	A setting or operator selection that changes the behavior of a piece of equipment. A subType **MUST** always be specified.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
DRY_RUN	A setting or operator selection used to execute a test mode to confirm the execution of machine functions. The *Valid Data Value* **MUST** be ON or OFF. When DRY_RUN is ON, the equipment performs all of its normal functions, except no part or product is produced. If the equipment has a spindle, spindle operation is suspended.
MACHINE_AXIS_LOCK	A setting or operator selection that changes the behavior of the controller on a piece of equipment. The *Valid Data Value* **MUST** be ON or OFF. When MACHINE_AXIS_LOCK is ON, program execution continues normally, but no equipment motion occurs
OPTIONAL_STOP	A setting or operator selection that changes the behavior of the controller on a piece of equipment. The *Valid Data Value* **MUST** be ON or OFF. The program execution is stopped after a specific program block is executed when OPTIONAL_STOP is ON. In the case of a G-Code program, a program BLOCK containing a M01 code designates the command for an OPTIONAL_STOP. EXECUTION **MUST** change to OPTIONAL_STOP after a program block specifying an optional stop is executed and the OPTIONAL_STOP selection is ON.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
SINGLE_BLOCK	A setting or operator selection that changes the behavior of the controller on a piece of equipment. The *Valid Data Value* **MUST** be ON or OFF. Program execution is paused after each BLOCK of code is executed when SINGLE_BLOCK is ON. When SINGLE_BLOCK is ON, EXECUTION **MUST** change to INTERRUPTED after completion of each BLOCK of code.
TOOL_CHANGE_STOP	A setting or operator selection that changes the behavior of the controller on a piece of equipment. The *Valid Data Value* **MUST** be ON or OFF. Program execution is paused when a command is executed requesting a cutting tool to be changed. EXECUTION **MUST** change to INTERRUPTED after completion of the command requesting a cutting tool to be changed and TOOL_CHANGE_STOP is ON.
COUPLED_AXES	Refers to the set of associated axes. The *Valid Data Value* for COUPLED_AXES **SHOULD** be a space-delimited set of axes reported as the value of the name attribute for each axis. If name is not available, the piece of equipment **MUST** report the value of the nativeName attribute for each axis.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
CYCLE_COUNT	Accumulation of the number of times a cyclic function has attempted to, or is planned to attempt to execute. Use the discrete attribute with value true to report non-aggregate count. See *Section 7.2.3.5 - ResetTrigger Element for DataItem* to reset the count. The *Valid Data Value* **MUST** be numeric.
ALL	An accumulation representing all actions, items, or activities being counted independent of the outcome. ALL is the default subType.
BAD	An accumulation representing actions, items, or activities being counted that do not conform to specification or expectation.
GOOD	An accumulation representing actions, items, or activities being counted that conform to specification or expectation.
TARGET	The goal of the operation or process.
REMAINING	An accumulation representing actions, items, or activities yet to be counted.
COMPLETE	An accumulation representing actions, items, or activities that have been completed, independent of the outcome.
FAILED	An accumulation representing actions or activities that were attempted, but failed to complete or resulted in an unexpected or unacceptable outcome.
ABORTED	An accumulation representing actions or activities that were attempted, but terminated before they could be completed.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
DATE_CODE	The time and date code associated with a material or other physical item. DATE_CODE **MUST** be reported in ISO 8601 format.
MANUFACTURE	The time and date code relating to the production of a material or other physical item.
EXPIRATION	The time and date code relating to the expiration or end of useful life for a material or other physical item.
FIRST_USE	The time and date code relating the first use of a material or other physical item.
DEACTIVATION_COUNT	Accumulation of the number of times a function has attempted to, or is planned to attempt to, deactivate or cease. Use the discrete attribute with value true to report non-aggregate count. See *Section 7.2.3.5 - ResetTrigger Element for DataItem* to reset the count. The *Valid Data Value* **MUST** be numeric.
ALL	An accumulation representing all actions, items, or activities being counted independent of the outcome. ALL is the default subType.
BAD	An accumulation representing actions, items, or activities being counted that do not conform to specification or expectation.
GOOD	An accumulation representing actions, items, or activities being counted that conform to specification or expectation.
TARGET	The goal of the operation or process.
REMAINING	An accumulation representing actions, items, or activities yet to be counted.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
COMPLETE	An accumulation representing actions, items, or activities that have been completed, independent of the outcome.
FAILED	An accumulation representing actions or activities that were attempted, but failed to complete or resulted in an unexpected or unacceptable outcome.
ABORTED	An accumulation representing actions or activities that were attempted, but terminated before they could be completed.
DEVICE_ADDED	DEVICE_ADDED is an Event that provides the UUID of a new device added to an *MTConnect Agent*. *Valid Data Value* is the value of the Device's UUID that was added to the *MTConnect Agent*.
DEVICE_CHANGED	DEVICE_CHANGED is an Event that provides the UUID of the device whose *Metadata* has changed. *Valid Data Value* is the value of the Device's UUID for which the metadata has changed.
DEVICE_REMOVED	DEVICE_REMOVED is an Event that provides the UUID of a device removed from an *MTConnect Agent*. *Valid Data Value* is the value of the Device's UUID that was removed from the *MTConnect Agent*.
DEVICE_UUID	The identifier of another piece of equipment that is temporarily associated with a component of this piece of equipment to perform a particular function. The *Valid Data Value* **MUST** be a NMTOKEN XML type.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
DIRECTION	The direction of motion. A subType **MUST** always be specified
LINEAR	The direction of linear motion. The *Valid Data Value* **MUST** be POSTIVE, NEGATIVE, or NONE.
ROTARY	The direction of rotary motion using the right-hand rule convention. The *Valid Data Value* **MUST** be CLOCKWISE, COUNTER_CLOCKWISE, or NONE.
DOOR_STATE	The operational state of a DOOR type component or composition element. The *Valid Data Value* **MUST** be OPEN, UNLATCHED, or CLOSED.
EMERGENCY_STOP	The current state of the emergency stop signal for a piece of equipment, controller path, or any other component or subsystem of a piece of equipment. The *Valid Data Value* **MUST** be ARMED (the circuit is complete and the device is allowed to operate) or TRIGGERED (the circuit is open and the device must cease operation).
END_OF_BAR	An indication of whether the end of a piece of bar stock being feed by a bar feeder has been reached. The *Valid Data Value* **MUST** be expressed as a Boolean expression of YES or NO.
AUXILIARY	When multiple locations on a piece of bar stock are referenced as the indication for the END_OF_BAR, the additional location(s) **MUST** be designated as AUXILIARY indication(s) for the END_OF_BAR.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
PRIMARY	Specific applications **MAY** reference one or more locations on a piece of bar stock as the indication for the `END_OF_BAR`. The main or most important location **MUST** be designated as the `PRIMARY` indication for the `END_OF_BAR`. If no `subType` is specified, `PRIMARY` **MUST** be the default `END_OF_BAR` indication.
EQUIPMENT_MODE	An indication that a piece of equipment, or a sub-part of a piece of equipment, is performing specific types of activities. `EQUIPMENT_MODE` **MAY** have more than one subtype defined. A `subType` **MUST** always be specified.
DELAY	The elapsed time of a temporary halt of action.
LOADED	An indication that the sub-parts of a piece of equipment are under load. Example: For traditional machine tools, this is an indication that the cutting tool is assumed to be engaged with the part. The *Valid Data Value* **MUST** be `ON` or `OFF`.
OPERATING	An indication that the major sub-parts of a piece of equipment are powered or performing any activity whether producing a part or product or not. Example: For traditional machine tools, this includes when the piece of equipment is `WORKING` or it is idle. The *Valid Data Value* **MUST** be `ON` or `OFF`.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
POWERED	An indication that primary power is applied to the piece of equipment and, as a minimum, the controller or logic portion of the piece of equipment is powered and functioning or components that are required to remain on are powered. Example: Heaters for an extrusion machine that required to be powered even when the equipment is turned off. The *Valid Data Value* **MUST** be ON or OFF.
WORKING	An indication that a piece of equipment is performing any activity the equipment is active and performing a function under load or not. Example: For traditional machine tools, this includes when the piece of equipment is LOADED, making rapid moves, executing a tool change, etc. The *Valid Data Value* **MUST** be ON or OFF.
EXECUTION	The execution status of the component. The *Valid Data Value* **MUST** be READY, ACTIVE, INTERRUPTED, WAIT, FEED_HOLD, STOPPED, OPTIONAL_STOP, PROGRAM_STOPPED, or PROGRAM_COMPLETED.
FIRMWARE	The embedded software of a component. The *Valid Data Value* **MUST** be a text string. A subType **MUST** always be specified.
LICENSE	The license code to validate or activate the hardware or software.
VERSION	The version of the hardware or software.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
RELEASE_DATE	The date the hardware or software was released for general use. It **MUST** be reported in ISO 8601 format.
INSTALL_DATE	The date the hardware or software was installed. It **MUST** be reported in ISO 8601 format.
MANUFACTURER	The corporate identity for the maker of the hardware or software.
FUNCTIONAL_MODE	The current intended production status of the device or component. Typically, the FUNCTIONAL_MODE **SHOULD** be modeled as a data item for the Device element, but **MAY** be modeled for any *Structural Element* in the XML document. The *Valid Data Value* **MUST** be PRODUCTION, SETUP, TEARDOWN, MAINTENANCE, or PROCESS_DEVELOPMENT.
HARDNESS	The measurement of the hardness of a material. The measurement does not provide a unit. A subType **MUST** always be specified to designate the hardness scale associated with the measurement.
BRINELL	A scale to measure the resistance to deformation of a surface.
LEEB	A scale to measure the elasticity of a surface.
MOHS	A scale to measure the resistance to scratching of a surface.
ROCKWELL	A scale to measure the resistance to deformation of a surface.
SHORE	A scale to measure the resistance to deformation of a surface.
VICKERS	A scale to measure the resistance to deformation of a surface.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
HARDWARE	The hardware of a component. The *Valid Data Value* **MUST** be a text string. A subType **MUST** always be specified.
LICENSE	The license code to validate or activate the hardware or software.
VERSION	The version of the hardware or software.
RELEASE_DATE	The date the hardware or software was released for general use. It **MUST** be reported in ISO 8601 format.
INSTALL_DATE	The date the hardware or software was installed. It **MUST** be reported in ISO 8601 format.
MANUFACTURER	The corporate identity for the maker of the hardware or software.
INTERFACE_STATE	The current functional or operational state of an Interface type element indicating whether the interface is active or is not currently functioning. The *Valid Data Value* **MUST** be ENABLED or DISABLED.
LIBRARY	The software library on a component. The *Valid Data Value* **MUST** be a text string. A subType **MUST** always be specified.
LICENSE	The license code to validate or activate the hardware or software.
VERSION	The version of the hardware or software.
RELEASE_DATE	The date the hardware or software was released for general use. It **MUST** be reported in ISO 8601 format.
INSTALL_DATE	The date the hardware or software was installed. It **MUST** be reported in ISO 8601 format.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
MANUFACTURER	The corporate identity for the maker of the hardware or software.
~~LINE~~	~~The current line of code being executed.~~ ~~The data will be an alpha numeric value representing the line number of the current line of code being executed.~~ **DEPRECATED** in Version 1.4.0.
~~MAXIMUM~~	~~The maximum line number of the code being executed.~~
~~MINIMUM~~	~~The minimum line number of the code being executed.~~
LINE_LABEL	An optional identifier for a BLOCK of code in a PROGRAM.
LINE_NUMBER	A reference to the position of a block of program code within a control program. The line number **MAY** represent either an absolute position starting with the first line of the program or an incremental position relative to the occurrence of the last LINE_LABEL. LINE_NUMBER does not change subject to any looping or branching in a control program. A subType **MUST** be defined.
ABSOLUTE	The position of a block of program code relative to the beginning of the control program.
INCREMENTAL	The position of a block of program code relative to the occurrence of the last LINE_LABEL encountered in the control program.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
LOAD_COUNT	Accumulation of the number of times an operation has attempted to, or is planned to attempt to, load materials, parts, or other items. Use the discrete attribute with value true to report non-aggregate count. See *Section 7.2.3.5 - ResetTrigger Element for DataItem* to reset the count. The *Valid Data Value* **MUST** be numeric.
ALL	An accumulation representing all actions, items, or activities being counted independent of the outcome. ALL is the default subType.
BAD	An accumulation representing actions, items, or activities being counted that do not conform to specification or expectation.
GOOD	An accumulation representing actions, items, or activities being counted that conform to specification or expectation.
TARGET	The goal of the operation or process.
REMAINING	An accumulation representing actions, items, or activities yet to be counted.
COMPLETE	An accumulation representing actions, items, or activities that have been completed, independent of the outcome.
FAILED	An accumulation representing actions or activities that were attempted, but failed to complete or resulted in an unexpected or unacceptable outcome.
ABORTED	An accumulation representing actions or activities that were attempted, but terminated before they could be completed.
LOCK_STATE	The state or operating mode of a Lock.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
MATERIAL	The identifier of a material used or consumed in the manufacturing process. The *Valid Data Value* **MUST** be a text string.
MATERIAL_LAYER	Identifies the layers of material applied to a part or product as part of an additive manufacturing process. The *Valid Data Value* **MUST** be an integer.
ACTUAL	The measured or reported value of an *observation*.
TARGET	The goal of the operation or process.
MESSAGE	Any text string of information to be transferred from a piece of equipment to a client software application.
MTCONNECT_VERSION	The reference version of the MTConnect Standard supported by the *Adapter*. The *Valid Data Value* **MUST** be a string.
NETWORK	Network details of a component. The *Valid Data Value* **MUST** be a text string. A `subType` **MUST** always be specified. If the `subType` is `WIRELESS`, the *Valid Data Value* **MUST** be `YES` or `NO`.
IPV4_ADDRESS	The IPV4 network address of the component.
IPV6_ADDRESS	The IPV6 network address of the component.
GATEWAY	The Gateway for the component network.
SUBNET_MASK	The SubNet mask for the component network.
VLAN_ID	The layer2 Virtual Local Network (VLAN) ID for the component network.
MAC_ADDRESS	Media Access Control Address. The unique physical address of the network hardware.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
WIRELESS	Identifies whether the connection type is wireless.
OPERATING_SYSTEM	The Operating System of a component. The *Valid Data Value* **MUST** be a text string. A subType **MUST** always be specified.
LICENSE	The license code to validate or activate the hardware or software.
VERSION	The version of the hardware or software.
RELEASE_DATE	The date the hardware or software was released for general use. It **MUST** be reported in ISO 8601 format.
INSTALL_DATE	The date the hardware or software was installed. It **MUST** be reported in ISO 8601 format.
MANUFACTURER	The corporate identity for the maker of the hardware or software.
OPERATOR_ID	The identifier of the person currently responsible for operating the piece of equipment. **DEPRECATION WARNING** : May be deprecated in the future. See USER below.
PALLET_ID	The identifier for a pallet. The *Valid Data Value* **MUST** be a text string.
PART_COUNT	The aggregate count of parts. Use the discrete attribute with value true to report non-aggregate part count. See *Section 7.2.3.5 - ResetTrigger Element for DataItem* to reset the count. The *Valid Data Value* **MUST** be numeric.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
ALL	An accumulation representing all actions, items, or activities being counted independent of the outcome. ALL is the default subType.
BAD	An accumulation representing actions, items, or activities being counted that do not conform to specification or expectation.
GOOD	An accumulation representing actions, items, or activities being counted that conform to specification or expectation.
TARGET	The goal of the operation or process.
REMAINING	An accumulation representing actions, items, or activities yet to be counted.
COMPLETE	An accumulation representing actions, items, or activities that have been completed, independent of the outcome.
FAILED	An accumulation representing actions or activities that were attempted, but failed to complete or resulted in an unexpected or unacceptable outcome.
ABORTED	An accumulation representing actions or activities that were attempted, but terminated before they could be completed.
PART_DETECT	An indication designating whether a part or work piece has been detected or is present. The *Valid Data Value* **MUST** be PRESENT or NOT_PRESENT.
PART_GROUP_ID	Identifier given to a collection of individual parts. If no subType is specified, UUID is default. The *Valid Data Value* **MUST** be a string.
UUID	The globally unique identifier as specified in ISO 11578 or RFC 4122.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
LOT	An identifier that references a group of parts tracked as a lot.
BATCH	An identifier that references a group of parts produced in a batch.
RAW_MATERIAL	Material that is used to produce parts.
HEAT_TREAT	An identifier used to reference a material heat number.
PART_ID	An identifier of a part in a manufacturing operation. The *Valid Data Value* **MUST** be a text string.
PART_KIND_ID	Identifier given to link the individual occurrence to a class of parts, typically distinguished by a particular part design. If no subType is specified, UUID is default. The *Valid Data Value* **MUST** be a string.
UUID	The globally unique identifier as specified in ISO 11578 or RFC 4122.
PART_NUMBER	Identifier of a particular part design or model.
PART_FAMILY	An identifier given to a group of parts having similarities in geometry, manufacturing process, and/or functions.
PART_NAME	A word or set of words by which a part is known, addressed, or referred to.
~~PART_NUMBER~~	**DEPRECATED** in *Version 1.7*. PART_NUMBER is now a subType of PART_KIND_ID.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
PART_PROCESSING_STATE	The particular condition of the part occurrence at a specific time. The *Valid Data Value* **MUST** be NEEDS_PROCESSING, IN_PROCESS, PROCESSING_ENDED, PROCESSING_ENDED_COMPLETE, PROCESSING_ENDED_STOPPED, PROCESSING_ENDED_ABORTED, PROCESSING_ENDED_LOST, PROCESSING_ENDED_SKIPPED, PROCESSING_ENDED_REJECTED, WAITING_FOR_TRANSIT, IN_TRANSIT, or TRANSIT_COMPLETE.
PART_STATUS	State or condition of a part. If unique identifier is given, part status is for that individual. If group identifier is given without a unique identifier, then the status is assumed to be for the whole group. The *Valid Data Value* **MUST** be PASS or FAIL.
PART_UNIQUE_ID	Identifier given to a distinguishable, individual part. If no subType is specified, UUID is default. The *Valid Data Value* **MUST** be a string.
UUID	The globally unique identifier as specified in ISO 11578 or RFC 4122.
SERIAL_NUMBER	A serial number that uniquely identifies a specific part.
RAW_MATERIAL	Material that is used to produce parts.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
PATH_FEEDRATE_OVERRIDE	The value of a signal or calculation issued to adjust the feedrate for the axes associated with a Path component that may represent a single axis or the coordinated movement of multiple axes. The value provided for PATH_FEEDRATE_OVERRIDE is expressed as a percentage of the designated feedrate for the path. When PATH_FEEDRATE_OVERRIDE is applied, the resulting commanded feedrate for the path is limited to the value of the original feedrate multiplied by the value of the PATH_FEEDRATE_OVERRIDE. There **MAY** be different subtypes of PATH_FEEDRATE_OVERRIDE; each representing an override value for a designated subtype of feedrate depending on the state of operation of the path. The states of operation of a path are currently defined as PROGRAMMED, JOG, and RAPID.
JOG	The value of a signal or calculation issued to adjust the feedrate of the axes associated with a Path component when the axes, or a single axis, are being operated in a manual mode or method (jogging). When the JOG subtype of PATH_FEEDRATE_OVERRIDE is applied, the resulting commanded feedrate for the axes, or a single axis, associated with the path are limited to the value of the original JOG subtype of the PATH_FEEDRATE multiplied by the value of the JOG subtype of PATH_FEEDRATE_OVERRIDE.
PROGRAMMED	Directive value without offsets and adjustments.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
RAPID	Performing an operation faster or in less time than nominal rate.
PATH_MODE	Describes the operational relationship between a Path *Structural Element* and another Path *Structural Element* for pieces of equipment comprised of multiple logical groupings of controlled axes or other logical operations. The *Valid Data Value* **MUST** be INDEPENDENT, MASTER, SYNCHRONOUS, or MIRROR. The default value **MUST** be INDEPENDENT if PATH_MODE is not specified.
POWER_STATE	The indication of the status of the source of energy for a *Structural Element* to allow it to perform its intended function or the state of an enabling signal providing permission for the *Structural Element* to perform its functions. The *Valid Data Value* **MUST** be ON or OFF. **DEPRECATION WARNING** : May be deprecated in the future.
CONTROL	The state of the enabling signal or control logic that enables or disables the function or operation of the *Structural Element*.
LINE	The state of the power source for the *Structural Element*.
~~POWER_STATUS~~	**DEPRECATED** in Version 1.1.0.
PROCESS_AGGREGATE_ID	Identifier given to link the individual occurrence to a group of related occurrences, such as a process step in a process plan. The *Valid Data Value* **MUST** be a string.
PROCESS_STEP	Identifier of the step in the process plan that this occurrence corresponds to. Synonyms include "operation id".

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
PROCESS_PLAN	Identifier of the process plan that this occurrence belongs to. Synonyms include "routing id", "job id".
ORDER_NUMBER	Identifier of the authorization of the process occurrence. Synonyms include "job id", "work order".
PROCESS_KIND_ID	Identifier given to link the individual occurrence to a class of processes or process definition. The *Valid Data Value* **MUST** be a string.
UUID	The globally unique identifier as specified in ISO 11578 or RFC 4122.
PROCESS_NAME	A word or set of words by which a process being executed (process occurrence) by the device is known, addressed, or referred to.
ISO_STEP_EXECUTABLE	A reference to a ISO 10303 Executable.
PROCESS_OCCURRENCE_ID	An identifier of a process being executed by the device. The *Valid Data Value* **MUST** be a string.
PROCESS_STATE	The particular condition of the process occurrence at a specific time. The *Valid Data Value* **MUST** be INITIALIZING, READY, ACTIVE, COMPLETE, INTERRUPTED, or ABORTED.
PROCESS_TIME	The time and date associated with an activity or event. PROCESS_TIME **MUST** be reported in ISO 8601 format.
START	Boundary when an activity or an event commences.
COMPLETE	The time and date associated with the completion of an activity or event.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
TARGET_COMPLETION	The projected time and date associated with the end or completion of an activity or event.
PROGRAM	The identity of the logic or motion program being executed by the piece of equipment. The *Valid Data Value* **MUST** be a text string.
SCHEDULE	The identity of a control program that is used to specify the order of execution of other programs.
MAIN	The identity of the primary logic or motion program currently being executed. It is the starting nest level in a call structure and may contain calls to sub programs.
ACTIVE	The identity of the logic or motion program currently executing.
PROGRAM_COMMENT	A comment or non-executable statement in the control program. The *Valid Data Value* **MUST** be a text string.
SCHEDULE	The identity of a control program that is used to specify the order of execution of other programs.
MAIN	The identity of the primary logic or motion program currently being executed. It is the starting nest level in a call structure and may contain calls to sub programs.
ACTIVE	The identity of the logic or motion program currently executing.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
PROGRAM_EDIT	An indication of the status of the Controller components program editing mode. On many controls, a program can be edited while another program is currently being executed. The *Valid Data Value* **MUST** be: ACTIVE: The controller is in the program edit mode. READY: The controller is capable of entering the program edit mode and no function is inhibiting a change of mode. NOT_READY: A function is inhibiting the controller from entering the program edit mode.
PROGRAM_EDIT_NAME	The name of the program being edited. This is used in conjunction with PROGRAM_EDIT when in ACTIVE state. The *Valid Data Value* **MUST** be a text string.
PROGRAM_HEADER	The non-executable header section of the control program. If not specified, the default subType is MAIN. The *Valid Data Value* **MUST** be a text string.
SCHEDULE	The identity of a control program that is used to specify the order of execution of other programs.
MAIN	The identity of the primary logic or motion program currently being executed. It is the starting nest level in a call structure and may contain calls to sub programs.
ACTIVE	The identity of the logic or motion program currently executing.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
PROGRAM_LOCATION	The Uniform Resource Identifier (URI) for the source file associated with PROGRAM.
SCHEDULE	An identity of a control program that is used to specify the order of execution of other programs.
MAIN	The identity of the primary logic or motion program currently being executed. It is the starting nest level in a call structure and may contain calls to sub programs.
ACTIVE	The identity of the logic or motion program currently executing.
PROGRAM_LOCATION_TYPE	Defines whether the logic or motion program defined by PROGRAM is being executed from the local memory of the controller or from an outside source. The *Valid Data Value* **MUST** be LOCAL or EXTERNAL.
SCHEDULE	An identity of a control program that is used to specify the order of execution of other programs.
MAIN	The identity of the primary logic or motion program currently being executed. It is the starting nest level in a call structure and may contain calls to sub programs.
ACTIVE	The identity of the logic or motion program currently executing.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
PROGRAM_NEST_LEVEL	An indication of the nesting level within a control program that is associated with the code or instructions that is currently being executed. If an initial value is not defined, the nesting level associated with the highest or initial nesting level of the program **MUST** default to zero (0). The value reported for PROGRAM_NEST_LEVEL **MUST** be an integer.
ROTARY_MODE	The current operating mode for a Rotary type axis. The *Valid Data Value* **MUST** be SPINDLE, INDEX, or CONTOUR.
ROTARY_VELOCITY_OVERRIDE	The value of a command issued to adjust the programmed velocity for a Rotary type axis. This command represents a percentage change to the velocity calculated by a logic or motion program or set by a switch for a Rotary type axis. ROTARY_VELOCITY_OVERRIDE is expressed as a percentage of the programmed ROTARY_VELOCITY.
ROTATION	A three space angular rotation relative to a coordinate system. When the DataItem has a coordinateSystemIdRef attribute and the CoordinateSystem does not specify a Rotation, the value of the *observation* is the rotation of the the referenced CoordinateSystem. The units **MUST** be DEGREE_3D

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
SENSOR_ATTACHMENT	A SensorAttachment is an Event defining an *Attachment* between a sensor and an entity. The *Valid Data Value* **MUST** be a string. The EntryDefinition key **MUST** be from the following: SENSOR_ID: The identity of a sensor used to observe some measurement of an item.
SERIAL_NUMBER	The serial number associated with a Component, Asset, or Device. The *Valid Data Value* **MUST** be a text string.
SPECIFICATION_LIMIT	A set of limits defining a range of values designating acceptable performance for a variable. The *Valid Data Value* **MUST** be a float. The representation attribute **MUST** be DATA_SET. The EntryDefinition key **MUST** be from the following: UPPER_LIMIT: The upper conformance boundary for a variable. Note: immediate concern or action may be required. NOMINAL: The ideal or desired value for a variable. LOWER_LIMIT: The lower conformance boundary for a variable. Note: immediate concern or action may be required.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
SPINDLE_INTERLOCK	An indication of the status of the spindle for a piece of equipment when power has been removed and it is free to rotate. The *Valid Data Value* **MUST** be: ACTIVE if power has been removed and the spindle cannot be operated. INACTIVE if power to the spindle has not been deactivated.
TOOL_ASSET_ID	The identifier of an individual tool asset.The *Valid Data Value* **MUST** be a text string.
TOOL_GROUP	An identifier for the tool group associated with a specific tool. Commonly used to designate spare tools.
~~TOOL_ID~~	**DEPRECATED** in Version 1.2.0. See TOOL_ASSET_ID. ~~The identifier of the tool currently in use for a given Path.~~
TOOL_NUMBER	The identifier assigned by the Controller component to a cutting tool when in use by a piece of equipment. The *Valid Data Value* **MUST** be a text string.
TOOL_OFFSET	A reference to the tool offset variables applied to the active cutting tool. The *Valid Data Value* **MUST** be a text string. The reported value returned for TOOL_OFFSET identifies the location in a table or list where the actual tool offset values are stored. **DEPRECATED** in V1.5 ~~A subType **MUST** always be specified.~~
LENGTH	A reference to a length type tool offset.
RADIAL	A reference to a radial type tool offset.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
`TRANSFER_COUNT`	Accumulation of the number of times an operation has attempted to, or is planned to attempt to, transfer materials, parts, or other items from one location to another. Use the `discrete` attribute with value `true` to report non-aggregate count. See *Section 7.2.3.5 - ResetTrigger Element for DataItem* to reset the count. The *Valid Data Value* **MUST** be numeric.
`ALL`	An accumulation representing all actions, items, or activities being counted independent of the outcome. `ALL` is the default `subType`.
`BAD`	An accumulation representing actions, items, or activities being counted that do not conform to specification or expectation.
`GOOD`	An accumulation representing actions, items, or activities being counted that conform to specification or expectation.
`TARGET`	The goal of the operation or process.
`REMAINING`	An accumulation representing actions, items, or activities yet to be counted.
`COMPLETE`	An accumulation representing actions, items, or activities that have been completed, independent of the outcome.
`FAILED`	An accumulation representing actions or activities that were attempted, but failed to complete or resulted in an unexpected or unacceptable outcome.
`ABORTED`	An accumulation representing actions or activities that were attempted, but terminated before they could be completed.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
TRANSLATION	A three space linear translation relative to a coordinate system. When the DataItem has a coordinateSystemIdRef attribute and the CoordinateSystem does not specify a Translation, the value of the *observation* is the translation of the referenced CoordinateSystem. The units **MUST** be MILLIMETER_3D
UNLOAD_COUNT	Accumulation of the number of times an operation has attempted to, or is planned to attempt to, unload materials, parts, or other items. Use the discrete attribute with value true to report non-aggregate count. See *Section 7.2.3.5 - ResetTrigger Element for DataItem* to reset the count. The *Valid Data Value* **MUST** be numeric.
ALL	An accumulation representing all actions, items, or activities being counted independent of the outcome. ALL is the default subType.
BAD	An accumulation representing actions, items, or activities being counted that do not conform to specification or expectation.
GOOD	An accumulation representing actions, items, or activities being counted that conform to specification or expectation.
TARGET	The goal of the operation or process.
REMAINING	An accumulation representing actions, items, or activities yet to be counted.
COMPLETE	An accumulation representing actions, items, or activities that have been completed, independent of the outcome.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
FAILED	An accumulation representing actions or activities that were attempted, but failed to complete or resulted in an unexpected or unacceptable outcome.
ABORTED	An accumulation representing actions or activities that were attempted, but terminated before they could be completed.
USER	The identifier of the person currently responsible for operating the piece of equipment. A subType **MUST** always be specified.
MAINTENANCE	The identifier of the person currently responsible for performing maintenance on the piece of equipment.
OPERATOR	The identifier of the person currently responsible for operating the piece of equipment.
SET_UP	The identifier of the person currently responsible for preparing a piece of equipment for production or restoring the piece of equipment to a neutral state after production.
VALVE_STATE	The state of a valve is one of open, closed, or transitioning between the states. The *Valid Data Value* **MUST** be OPEN, OPENING, CLOSED, or CLOSING.
ACTUAL	The measured or reported value of an *observation*.
PROGRAMMED	An instructed target value without offsets and adjustments.
VARIABLE	A data value whose meaning may change over time due to changes in the operation of a piece of equipment or the process being executed on that piece of equipment.

Continuation of Table 44: DataItem type subType for category EVENT	
DataItem type subType	Description
WAIT_STATE	An indication of the reason that EXECUTION is reporting a value of WAIT. The *Valid Data Value* **MUST** be POWERING_UP, POWERING_DOWN, PART_LOAD, PART_UNLOAD, TOOL_LOAD, TOOL_UNLOAD, MATERIAL_LOAD, MATERIAL_UNLOAD, SECONDARY_PROCESS, PAUSING, or RESUMING.
WIRE	The identifier for the type of wire used as the cutting mechanism in Electrical Discharge Machining or similar processes. The *Valid Data Value* **MUST** be a text string.
WORKHOLDING_ID	The identifier for the current workholding or part clamp in use by a piece of equipment. The *Valid Data Value* **MUST** be a text string.
WORK_OFFSET	A reference to the offset variables for a work piece or part associated with a Path in a Controller type component. The *Valid Data Value* **MUST** be a text string. The reported value returned for WORK_OFFSET identifies the location in a table or list where the actual work offset values are stored.

8.3 Data Items in category CONDITION

`CONDITION` category data items report data representing a *Structural Element*'s status regarding its ability to operate or it provides an indication whether the data reported for the *Structural Element* is within an expected range.

`CONDITION` is reported differently than `SAMPLE` or `EVENT`. `CONDITION` **MUST** be reported as `Normal`, `Warning`, or `Fault`.

All `DataItem` types in the `SAMPLE` category **MAY** have associated `CONDITION` states. `CONDITION` states indicate whether the value for the data is within an expected range and **MUST** be reported as `Normal`, or the value is unexpected or out of tolerance for the data and a `Warning` or `Fault` **MUST** be provided.

Some `DataItem` types in the `EVENT` category **MAY** have associated `CONDITION` states.

Additional `CONDITION` types are provided to represent the health and fault status of *Structural Elements*. *Table 45* defines these additional `DataItem` types.

`CONDITION` type data items are unlike other data item types since they **MAY** have multiple concurrently active values at any point in time.

Table 45: DataItem type for category CONDITION

DataItem type	Description
`ACTUATOR`	An indication of a fault associated with an actuator.
`CHUCK_INTERLOCK`	An indication of the operational condition of the interlock function for an electronically controller chuck.
`COMMUNICATIONS`	An indication that the piece of equipment has experienced a communications failure.
`DATA_RANGE`	An indication that the value of the data associated with a measured value or a calculation is outside of an expected range.
`DIRECTION`	An indication of a fault associated with the direction of motion of a *Structural Element*.
`END_OF_BAR`	An indication that the end of a piece of bar stock has been reached.
`HARDWARE`	An indication of a fault associated with the hardware subsystem of the *Structural Element*.

Continuation of Table 45	
DataItem type	Description
INTERFACE_STATE	An indication of the operation condition of an Interface component.
LOGIC_PROGRAM	An indication that an error occurred in the logic program or programmable logic controller (PLC) associated with a piece of equipment.
MOTION_PROGRAM	An indication that an error occurred in the motion program associated with a piece of equipment.
SYSTEM	An indication of a fault associated with a piece of equipment or component that cannot be classified as a specific type.

9 Configuration

`Configuration` contains technical information about a component describing its physical layout, functional characteristics, and relationships with other components within a piece of equipment.

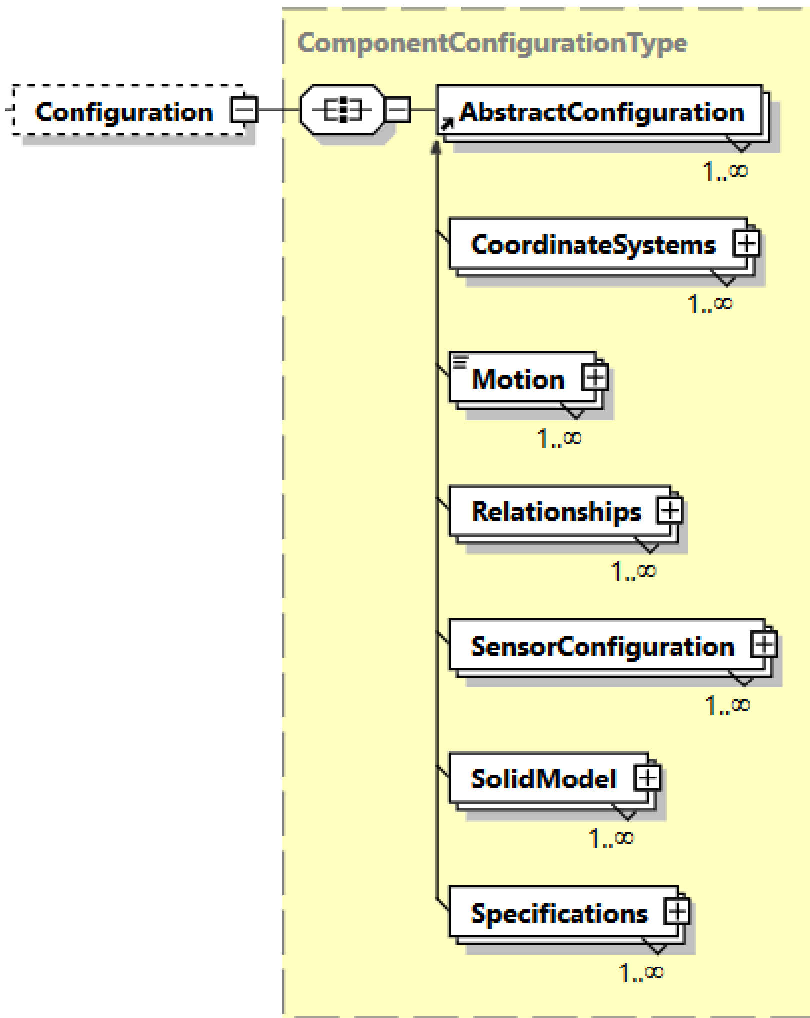

Figure 17: Configuration Element

Table 46 lists the types of `Configuration` defined for a `Component`.

Table 46: Types of Configuration

type	Description
`CoordinateSystems`	`CoordinateSystems` *organizes* `CoordinateSystem` elements for a `Component` and its children.
`Motion`	`Motion` defines the movement of the `Component` relative to a coordinate system.
`Relationships`	`Relationships` *organizes* `Relationship` elements for a `Component`.
`SensorConfiguration`	`SensorConfiguration` contains configuration information about a `Sensor`.
`SolidModel`	`SolidModel` references a file with the three-dimensional geometry of the `Component` or `Composition`.
`Specifications`	`Specifications` *organizes* `Specification` elements for a `Component`.

9.1 Sensor

Sensor is a unique type of a piece of equipment. A *Sensor* is typically comprised of two major components: a *sensor unit* that provides signal processing, conversion, and communications and the *sensing elements* that provides a signal or measured value.

The *sensor unit* is modeled as a *Lower Level* `Component` called `Sensor`. The *sensing element* may be modeled as a `Composition` element of a `Sensor` element and the measured value would be modeled as a `DataItem` (See *Section 8 - Listing of Data Items* for more information on `DataItem` elements). Each *sensor unit* may have multiple *sensing elements*; each representing the data for a variety of measured values.

Example: A pressure transducer could be modeled as a `Sensor` (`Component`) with a `name` = *Pressure Transducer B* and its measured value could be modeled as a `PRESSURE` type `DataItem`.

While a *Sensor* may be modeled in the XML document in different ways, it will always be modeled to associate the information measured by each *sensor element* with the *Structural Element* to which the measured value is most closely associated.

9.1.1 Sensor Data

The most basic implementation of a sensor occurs when the *sensing element* itself is not identified in the data model, but the data that is measured by the *sensing element* is provided as a data item associated with a `Component`. An example would be the measured value of the temperature of a spindle motor. This would be represented as a `DataItem` called `TEMPERATURE` that is associated with the `Rotary` type axis element called "C" as shown in *Example 7*:

Example 7: Example of Sensing Element provided as data item associated with a Component

```
<Components>
    <Axes
        <Components>
            <Rotary id="c" name="C">
                <DataItems>
                    <DataItem type="TEMPERATURE"
                        id="ctemp" category="SAMPLE"
                        name="Stemp" units="DEGREE"/>
                </DataItems>
            </Rotary>
        </Components>
    </Axes>
</Components>
```

A sensor may measure values associated with any `Component` or `Device` element. Some examples of how sensor data may be modeled are represented in *Figure 18* :

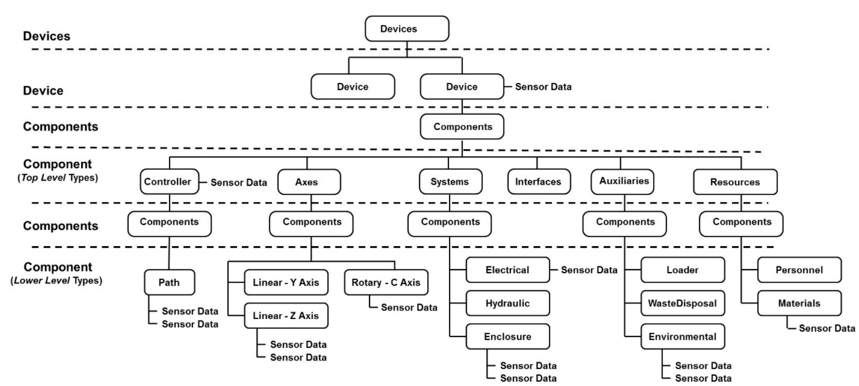

Figure 18: Sensor Data Associations

9.1.2 Sensor Unit

A *sensor unit* is an intelligent piece of equipment that manages the functions of one or more *sensing elements*.

Typical functions of the *sensor unit* include:

- convert low level signals from the *sensing elements* into data that can be used by other pieces of equipment. (Example: Convert a non-linear millivolt signal from a temperature sensor into a scaled temperature value that can be transmitted to another piece of equipment.)
- process *sensing element* data into calculated values. (Example: temperature sensor data is converted into calculated values of average temperature, maximum temperature, minimum temperature, etc.)
- provide calibration and configuration information associated with each *sensing element*
- monitor the health and integrity of the *sensing elements* and the *sensor unit*. (Example: The *sensor unit* may provide diagnostics on each *sensing element* (e.g., open wire detection) and itself (e.g., measure internal temperature of the *sensor unit*).

Depending on how the *sensor unit* is used, it may be considered as either an independent piece of equipment and modeled in the XML document as a `Device`, or it may be modeled as a *Top Level* `Component` called `Sensor` if it is integral to a piece of equipment.

A `Sensor` **MAY** have its own `uuid` so it can be tracked throughout its lifetime.

The following examples demonstrate how a *Sensor* may be modeled in the XML document differently based on how the *Sensor* functions within the overall piece of equipment

Example#1: If the `Sensor` provides vibration measurement data for the spindle on a piece of equipment, it could be modeled as a `Sensor` for rotary axis named C.

Example 8: Example of Sensor for rotary axis

```
<Components>
  <Axes
    <Components>
      <Rotary id="c" name="C">
        <Components>
          <Sensor id="spdlm" name="Spindlemonitor">
            <DataItems>
              <DataItem type="DISPLACEMENT" id="cvib"
```

```
                  category="SAMPLE" name="Svib"
                  units="MILLIMETER"/>
              </DataItems>
            </Sensor >
          <Components>
        </Rotary>
      </Components>
    </Axes>
</Components>
```

Example#2: If a `Sensor` provides measurement data for multiple `Component` elements within a piece of equipment and is not associated with any particular `Component` element, it **MAY** be modeled in the XML document as an independent *Lower Level* `Component` and the data associated with measurements are associated with their associated `Component` elements.

This example represents a *sensor unit* with two *sensing elements*, one measures spindle vibration and the other measures the temperature for the X axis. The *sensor unit* also has a *sensing element* measuring the internal temperature of the *sensor unit*.

Example 9: Example of Sensor Unit with Sensing Element

```
<Device id="d1" uuid="HM1" name="HMC_3Axis">
  <Description>3 Axis Mill</Description>
  <Components>
    <Axes
      <Components>
        <Sensor id="sens1" name="Sensorunit">
          <DataItems>
            <DataItem type="TEMPERATURE" id="sentemp"
              category="SAMPLE" name="Sensortemp"
              units="DEGREE"/>
          </DataItems>
        </Sensor >
        <Rotary id="c" name="C">
          <DataItems>
            <DataItem type="DISPLACEMENT" id="cvib"
              %category="SAMPLE" name="Svib"
              units="MILLIMETER">
                <Source componentId="sens1"/>
            <DataItem/>
          </DataItems>
        </Rotary>
        <Linear id="x" name="X">
          <DataItems>
            <DataItem type="TEMPERATURE" id="xt"
              category="SAMPLE" name="Xtemp"
              units="DEGREE">
                <Source componentId="sens1"/>
            <DataItem/>
```

```
            </DataItems>
          </Linear>
        <Components>
      </Axes>
    </Components>
</Device>
```

9.1.3 Sensor Configuration

When a `Sensor` unit is modeled in the XML document as a `Component` or as a separate piece of equipment, it may provide additional configuration information for the *sensor elements* and the *sensor unit* itself.

`Configuration` data provides information required for maintenance and support of the sensor.

`Configuration` data is only available when the `Sensor` unit is modeled as a `Component` or a separate piece of equipment. For details on the modeling of configuration data in the XML document, see *Section 4.4.3.2 - Configuration for Component*.

When `Sensor` represents the *sensor unit* for multiple *sensing element*(s), each sensing element is represented by a `Channel`. The *sensor unit* itself and each `Channel` representing one *sensing element* **MAY** have its own configuration data.

`SensorConfiguration` can contain any descriptive content for a *sensor unit*. This element is defined to contain mixed content and additional XML elements (indicated by the `any` element in *Figure 19*) **MAY** be added to extend the schema for `SensorConfiguration`.

Figure 19 represents the structure of the `SensorConfiguration` XML element showing the attributes defined for `SensorConfiguration`.

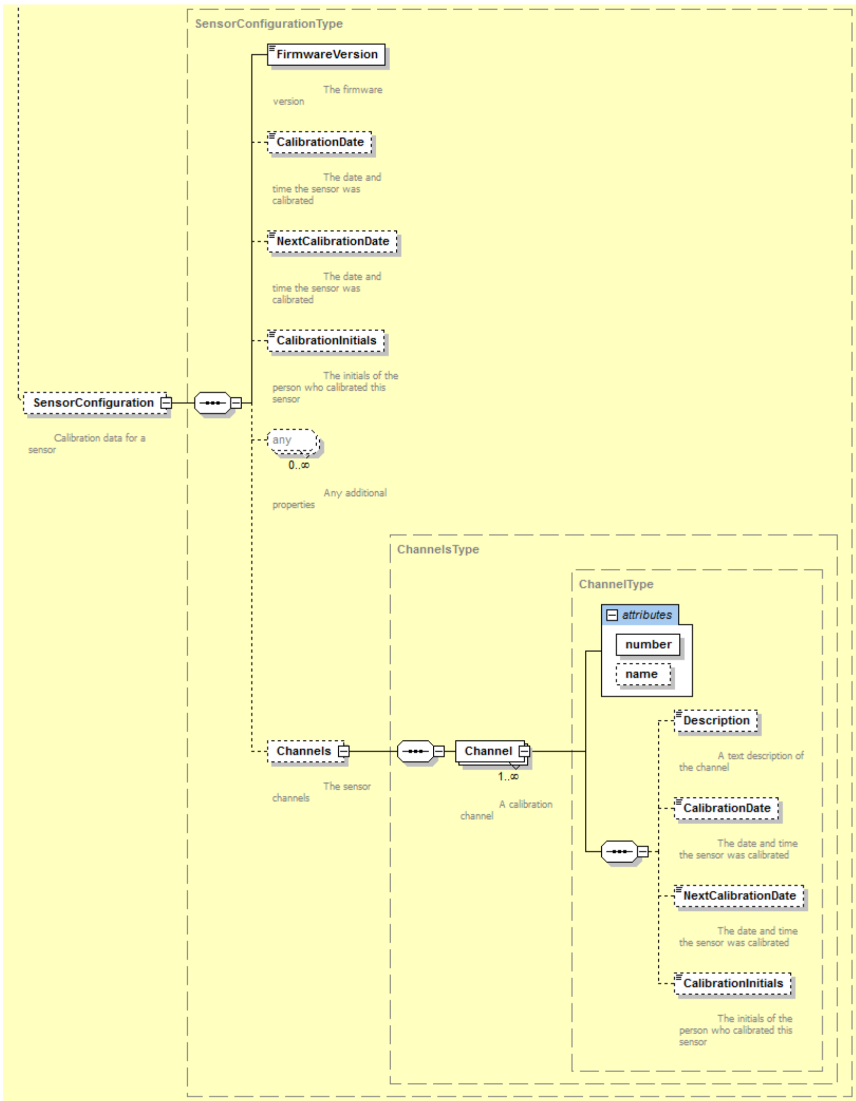

Figure 19: SensorConfiguration Diagram

Table 47: MTConnect SensorConfiguration Element

Element	Description	Occurrence
SensorConfiguration	An element that can contain descriptive content defining the configuration information for Sensor. For Sensor, the valid configuration is SensorConfiguration which provides data from a subset of items commonly found in a transducer electronic data sheet for sensors and actuators called TEDS. TEDS formats are defined in IEEE 1451.0 and 1451.4 transducer interface standards (ref 15 and 16, respectively). MTConnect does not support all of the data represented in the TEDS data, nor does it duplicate the function of the TEDS data sheets.	0..1

9.1.3.1 Elements for SensorConfiguration

Table 48 defines the configuration elements available for SensorConfiguration:

Table 48: Elements for SensorConfiguration

Element	Description	Occurrence
FirmwareVersion	Version number for the sensor unit as specified by the manufacturer. FirmwareVersion is a required element if SensorConfiguration is used. The data value for FirmwareVersion is provided in the CDATA for this element and **MAY** be any numeric or text content.	1

Continuation of Table 48		
Element	Description	Occurrence
CalibrationDate	Date upon which the *sensor unit* was last calibrated. The data value for CalibrationDate is provided in the CDATA for this element and **MUST** be represented in the W3C ISO 8601 format.	0..1
NextCalibrationDate	Date upon which the *sensor unit* is next scheduled to be calibrated. The data value for NextCalibrationDate is provided in the CDATA for this element and **MUST** be represented in the W3C ISO 8601 format.	0..1
CalibrationInitials	The initials of the person verifying the validity of the calibration data. The data value for CalibrationInitials is provided in the CDATA for this element and **MAY** be any numeric or text content.	0..1
Channels	When Sensor represents multiple *sensing elements*, each *sensing element* is represented by a Channel for the Sensor. Channels is an XML container used to organize information for the *sensing elements*.	0..1

9.1.3.1.1 Attributes for Channel

Channel represents each *sensing element* connected to a *sensor unit*. *Table 49* defines the attributes for Channel:

Table 49: Attributes for Channel

Attribute	Description	Occurrence
number	A unique identifier that will only refer to a specific *sensing element*. number is a required attribute. For example, this can be the manufacturer code and the serial number. number **SHOULD** be alphanumeric and not exceeding 255 characters. An NMTOKEN XML type.	1
name	The name of the *sensing element*. name is an optional attribute. name **SHOULD** be unique within the *sensor unit* to allow for easier data integration. An NMTOKEN XML type.	0..1

1477 #### 9.1.3.1.2 Elements for Channel

1478 *Table 50* describes the elements provided for Channel.

Table 50: Elements for Channel

Element	Description	Occurrence
Description	An XML element that can contain any descriptive content. The CDATA of Description **MAY** include any additional descriptive information the implementer chooses to include regarding a *sensor element*.	0..1

Continuation of Table 50		
Element	Description	Occurrence
`CalibrationDate`	Date upon which the *sensor unit* was last calibrated to the *sensor element*. The data value for `CalibrationDate` is provided in the CDATA for this element and **MUST** be represented in the W3C ISO 8601 format.	0..1
`NextCalibrationDate`	Date upon which the *sensor element* is next scheduled to be calibrated with the *sensor unit*. The data value for `NextCalibrationDate` is provided in the CDATA for this element and **MUST** be represented in the W3C ISO 8601 format.	0..1
`CalibrationInitials`	The initials of the person verifying the validity of the calibration data. The data value for `CalibrationInitials` is provided in the CDATA for this element and **MAY** be any numeric or text content.	0..1

Example 10 is an example of the configuration data for `Sensor` that is modeled as a `Component`. It has `Configuration` data for the *sensor unit*, one `Channel` named A/D:1, and two `DataItems` – ~~`Voltage`~~ (as a `SAMPLE`) and ~~`Voltage`~~ (as a `CONDITION` or alarm).

Example 10: Example of configuration data for Sensor

```
<Sensor id="sensor" name="sensor">
  <Configuration>
    <SensorConfiguration>
      <FirmwareVersion>2.02</FirmwareVersion>
      <CalibrationDate>2010-05-16</CalibrationDate>
      <NextCalibrationDate>2010-05-16</NextCalibrationDate>
      <CalibrationInitials>WS</CalibrationInitials>
      <Channels>
        <Channel number="1" name="A/D:1">
          <Description>A/D With Thermister</Description>
        </Channel>
```

```
      </Channels>
    </SensorConfiguration>
  </Configuration>
  <DataItems>
    <DataItem category="CONDITION" id="senvc"
      type="VOLTAGE" />
    <DataItem category="SAMPLE" id="senv"
      type="VOLTAGE" units="VOLT" subType="DIRECT" />
  </DataItems>
</Sensor>
```

9.2 Relationships

`Relationships` is an XML container that organizes information defining the association between pieces of equipment that function independently but together perform a manufacturing operation. `Relationships` may also define the association between components within a piece of equipment.

`Relationships` may be modeled as part of a `Device` or a `Component` *Structural Element*.

`Relationships` contains one or more `Relationship` XML elements.

Table 51: MTConnect Relationships Element

Element	Description	Occurrence
`Relationships`	XML container consisting of one or more `Relationship` XML elements. Only one `Relationships` container **MUST** appear for a `Device` or a `Component` element.	0..1

9.2.1 Relationship

`Relationship` is an XML element that describes the association between two pieces of equipment that function independently but together perform a manufacturing operation. `Relationship` may also be used to define the association between two components within a piece of equipment.

`Relationship` is an abstract type XML element, `Relationship` will be replaced in the XML document by specific `Relationship` types. XML elements representing `Relationship` are described in *Section 9.2.1.1 - DeviceRelationship* and *Section 9.2.1.2 - ComponentRelationship*.

A separate `Relationship` type element **MAY** be defined to describe each pair of associations with a piece of equipment or between `Component` elements within a piece of equipment.

Pieces of equipment may only be associated with other pieces of equipment and `Component` elements may only be associated with other `Component` elements within a specific piece of equipment.

The XML schema diagram in *Figure 20* represents the structure of the `Relationship` XML element.

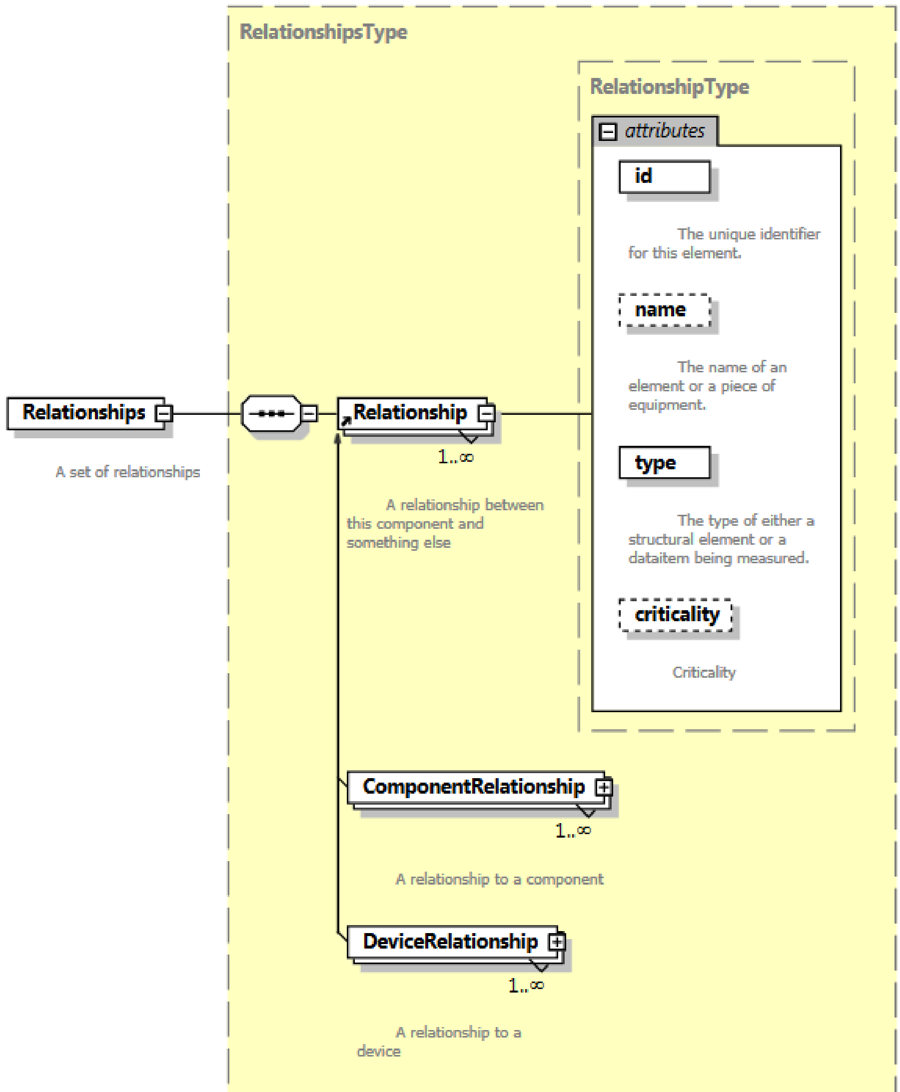

Figure 20: Relationship Diagram

9.2.1.1 DeviceRelationship

`DeviceRelationship` describes the association between two pieces of equipment that function independently but together perform a manufacturing operation.

The XML schema diagram in *Figure 21* represents the structure of a `DeviceRelationship` XML element showing the attributes defined for `DeviceRelationship`.

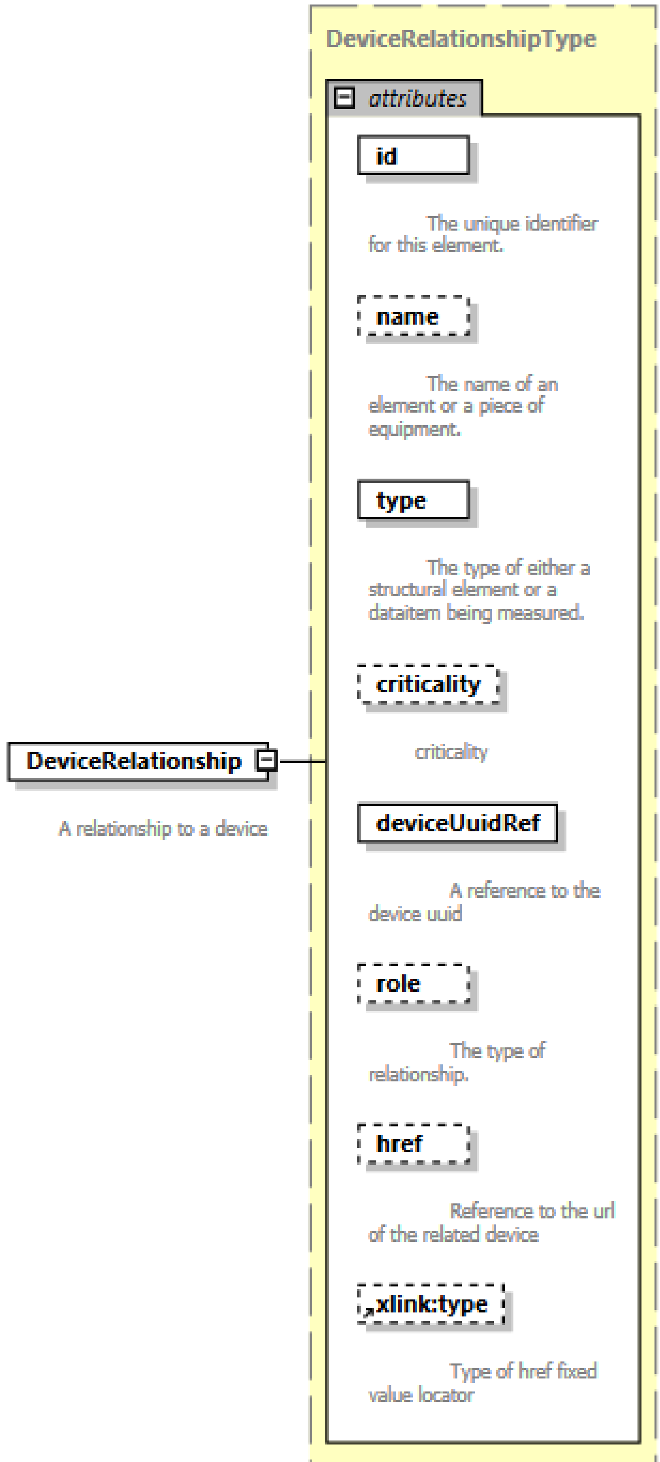

Figure 21: DeviceRelationship Diagram

The *Table 52* lists the attributes defined for the `DeviceRelationship` element.

Table 52: Attributes for DeviceRelationship

Attribute	Description	Occurrence
`id`	The unique identifier for this `DeviceRelationship`. `id` is a required attribute. The `id` attribute **MUST** be unique within the `MTConnectDevices` document. An XML ID-type.	1
`name`	The name associated with this `DeviceRelationship`. `name` is provided as an additional human readable identifier for this `DeviceRelationship`. `name` is an optional attribute. An NMTOKEN XML type.	0..1
`type`	Defines the authority that this piece of equipment has relative to the associated piece of equipment. `type` is a required attribute. The value provided for `type` **MUST** be one of the following values: `PARENT`: This piece of equipment functions as a parent in the relationship with the associated piece of equipment. `CHILD`: This piece of equipment functions as a child in the relationship with the associated piece of equipment. `PEER`: This piece of equipment functions as a peer which provides equal functionality and capabilities in the relationship with the associated piece of equipment.	1

Continuation of Table 52		
Attribute	Description	Occurrence
criticality	Defines whether the services or functions provided by the associated piece of equipment is required for the operation of this piece of equipment. criticality is an optional attribute. The value provided for criticality **MUST** be one of the following values: CRITICAL: The services or functions provided by the associated piece of equipment is required for the operation of this piece of equipment. NONCRITICAL: The services or functions provided by the associated piece of equipment is not required for the operation of this piece of equipment.	0..1
deviceUuidRef	A reference to the associated piece of equipment. The value provided for deviceUuidRef **MUST** be the value provided for the uuid attribute of the Device element of the associated piece of equipment. deviceUuidRef is a required attribute. An NMTOKEN XML type.	1

Continuation of Table 52		
Attribute	Description	Occurrence
role	Defines the services or capabilities that the referenced piece of equipment provides relative to this piece of equipment. role is an optional attribute. The value provided for role **MUST** be one of the following values: SYSTEM: The associated piece of equipment performs the functions of a System for this piece of equipment. In MTConnect, System provides utility type services to support the operation of a piece of equipment and these services are required for the operation of a piece of equipment. AUXILIARY: The associated piece of equipment performs the functions as an Auxiliary for this piece of equipment. In MTConnect, Auxiliary extends the capabilities of a piece of equipment, but is not required for the equipment to function.	0..1
href	A URI identifying the *Agent* that is publishing information for the associated piece of equipment. href **MUST** also include the UUID for that specific piece of equipment. href is of type xlink:href from the W3C XLink specification: (https://www.w3.org/TR/xlink11/). href is an optional attribute.	0..1
xlink:type	The XLink type attribute **MUST** have a fixed value of locator as defined in W3C XLink 1.1 https://www.w3.org/TR/xlink11/ *section 5.4 Locator Attribute (href)*. If the href attribute is provided, it **MUST** conform to the URI syntactic rules as defined in IETF RFC 3986 for Uniform Resource Identifiers. (https://www.ietf.org/rfc/rfc3986.txt)	0..1

9.2.1.2 ComponentRelationship

`ComponentRelationship` describes the association between two components within a piece of equipment that function independently but together perform a capability or service within a piece of equipment.

The XML schema in *Figure 22* represents the structure of a `ComponentRelationship` XML element showing the attributes defined for `ComponentRelationship`.

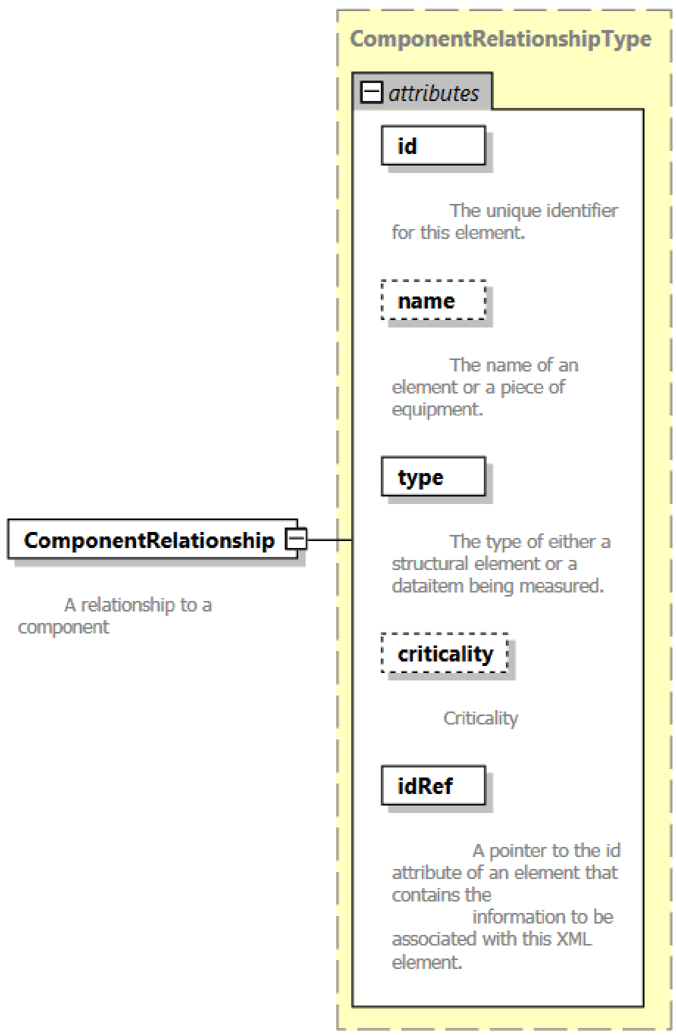

Figure 22: ComponentRelationship Diagram

The *Table 53* lists the attributes defined for the `ComponentRelationship` element.

Table 53: Attributes for ComponentRelationship

Attribute	Description	Occurrence
id	The unique identifier for this ComponentRelationship. id is a required attribute. The id attribute **MUST** be unique within the MTConnectDevices document. An XML ID-type.	1
name	The name associated with this ComponentRelationship. name is provided as an additional human readable identifier for this ComponentRelationship. name is an optional attribute. An NMTOKEN XML type.	0..1
type	Defines the authority that this component element has relative to the associated component element. type is a required attribute. The value provided for type **MUST** be one of the following values: PARENT: This component functions as a parent in the relationship with the associated component element. CHILD: This component functions as a child in the relationship with the associated component element. PEER: This component functions as a peer which provides equal functionality and capabilities in the relationship with the associated component element.	1

Continuation of Table 53		
Attribute	Description	Occurrence
criticality	Defines whether the services or functions provided by the associated component element is required for the operation of this piece of equipment. criticality is an optional attribute. The value provided for criticality **MUST** be one of the following values: CRITICAL: The services or functions provided by the associated component element is required for the operation of this piece of equipment. NONCRITICAL: The services or functions provided by the associated component element is not required for the operation of this piece of equipment.	0..1
idRef	A reference to the associated component element. The value provided for idRef **MUST** be the value provided for the id attribute of the associated Component element. idRef is a required attribute. An NMTOKEN XML type.	1

9.3 Specifications

Specifications is an XML container in the Configuration of a Component that contains one or more Specification elements describing the design characteristics for a piece of equipment.

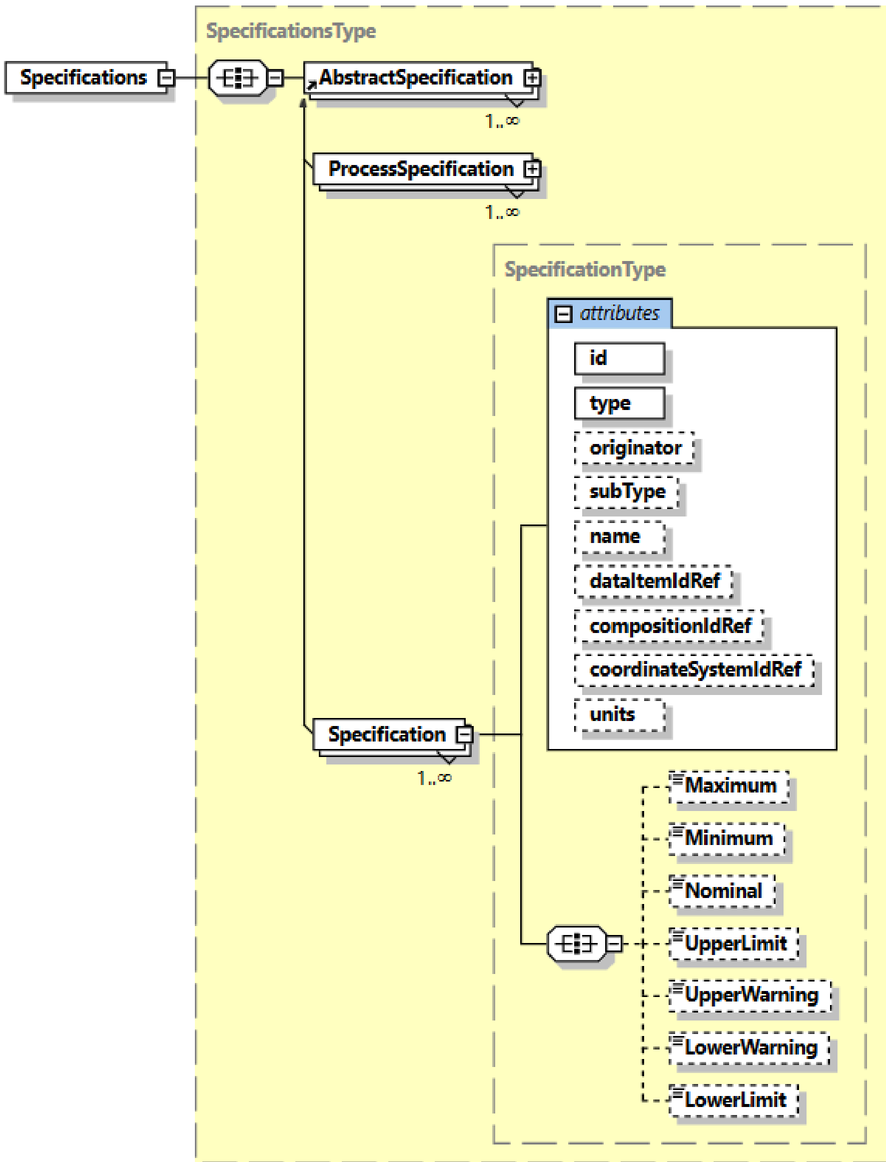

Figure 23: Specifications Diagram

9.3.1 Specification

Specification elements define information describing the design characteristics for a piece of equipment.

9.3.1.1 Attributes for Specification

Table 54 lists the attributes defined to provide information for a Specification element.

Table 54: Attributes for Specification

Attribute	Description	Occurrence
type	Same as DataItem type. See *Section 8 - Listing of Data Items*.	1
subType	Same as DataItem subtypes. See *Section 8 - Listing of Data Items*.	0..1
dataItemIdRef	A reference to the id attribute of the DataItem associated with this element.	0..1
units	Same as DataItem units. See *Section 7.2.2.5 - units Attribute for DataItem*.	0..1
compositionIdRef	A reference to the id attribute of the Composition associated with this element.	0..1
name	The name provides additional meaning and differentiates between Specifications. A name **MUST** exist when two Specifications have the same type and subType within a Component.	0..1
coordinateSystemIdRef	References the CoordinateSystem for geometric Specification elements.	0..1

Continuation of Table 54		
Attribute	Description	Occurrence
id	The unique identifier for this Specification. The id attribute **MUST** be unique within the MTConnectDevices document. An XML ID-type.	0..1
originator	A reference to the creator of the Specification. The values reported for originator are: MANUFACTURER: The manufacturer of a piece of equipment or Component. USER: The owner or implementer of a piece of equipment or Component. Note: The default value for originator is MANUFACTURER.	0..1

9.3.1.2 Elements for Specification

Table 55 lists the elements defined to provide information for a `Specification` element.

Table 55: Elements for Specification

Element	Description	Occurrence
`Maximum`	A numeric upper constraint.	0..1
`UpperLimit`	The upper conformance boundary for a variable. Note: immediate concern or action may be required.	0..1
`UpperWarning`	The upper boundary indicating increased concern and supervision may be required.	0..1
`Nominal`	The ideal or desired value for a variable.	0..1
`LowerWarning`	The lower boundary indicating increased concern and supervision may be required.	0..1
`LowerLimit`	The lower conformance boundary for a variable. Note: immediate concern or action may be required.	0..1
`Minimum`	A numeric lower constraint.	0..1

9.3.2 ProcessSpecification

`ProcessSpecification` provides information used to assess the conformance of a variable to process requirements.

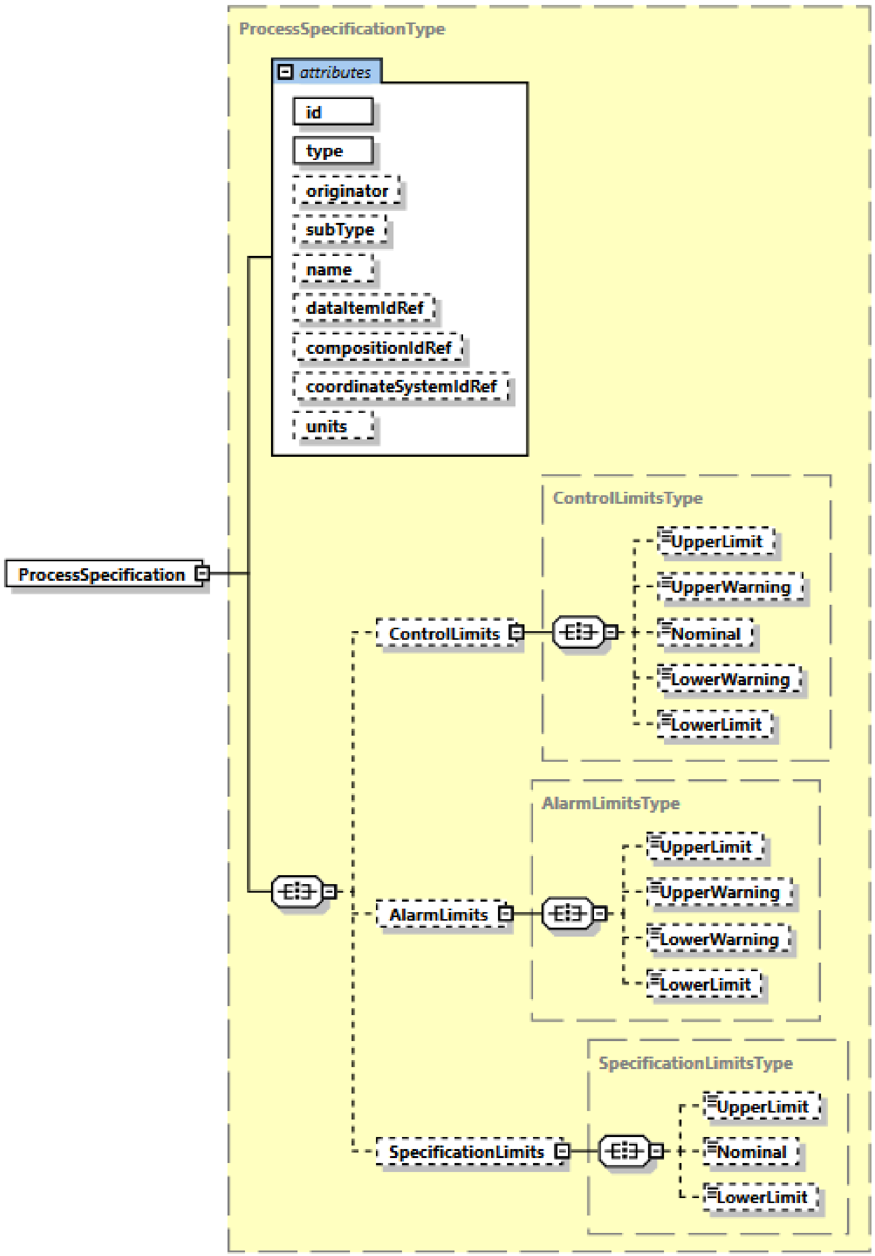

Figure 24: ProcessSpecification Diagram

See *Section 9.3.1.1 - Attributes for Specification* for definitions on attributes of ProcessSpecification.

9.3.2.1 Elements for ProcessSpecification

Table 56 lists the elements defined to provide information for a ProcessSpecification element.

Table 56: Elements for ProcessSpecification

Element	Description	Occurrence
ControlLimits	A set of limits used to indicate whether a process variable is stable and in control.	0..1
SpecificationLimits	A set of limits defining a range of values designating acceptable performance for a variable.	0..1
AlarmLimits	A set of limits used to trigger warning or alarm indicators.	0..1

9.3.2.2 ControlLimits

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

9.3.2.2.1 Elements for ControlLimits

Table 57: Elements for ControlLimits

Element	Description	Occurrence
UpperLimit	The upper conformance boundary for a variable. Note: immediate concern or action may be required.	0..1
UpperWarning	The upper boundary indicating increased concern and supervision may be required.	0..1
Nominal	The ideal or desired value for a variable.	0..1
LowerWarning	The lower boundary indicating increased concern and supervision may be required.	0..1

Continuation of Table 57		
Element	Description	Occurrence
LowerLimit	The lower conformance boundary for a variable. Note: immediate concern or action may be required.	0..1

9.3.2.3 SpecificationLimits

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

9.3.2.3.1 Elements for SpecificationLimits

Table 58: Elements for SpecificationLimits

Element	Description	Occurrence
UpperLimit	The upper conformance boundary for a variable. Note: immediate concern or action may be required.	0..1
Nominal	The ideal or desired value for a variable.	0..1
LowerLimit	The lower conformance boundary for a variable. Note: immediate concern or action may be required.	0..1

9.3.2.4 AlarmLimits

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

9.3.2.4.1 Elements for AlarmLimits

Table 59: Elements for AlarmLimits

Element	Description	Occurrence
`UpperLimit`	The upper conformance boundary for a variable. Note: immediate concern or action may be required.	0..1
`UpperWarning`	The upper boundary indicating increased concern and supervision may be required.	0..1
`LowerWarning`	The lower boundary indicating increased concern and supervision may be required.	0..1
`LowerLimit`	The lower conformance boundary for a variable. Note: immediate concern or action may be required.	0..1

9.4 CoordinateSystems

`CoordinateSystems` aggregates `CoordinateSystem` configurations for a `Component`.

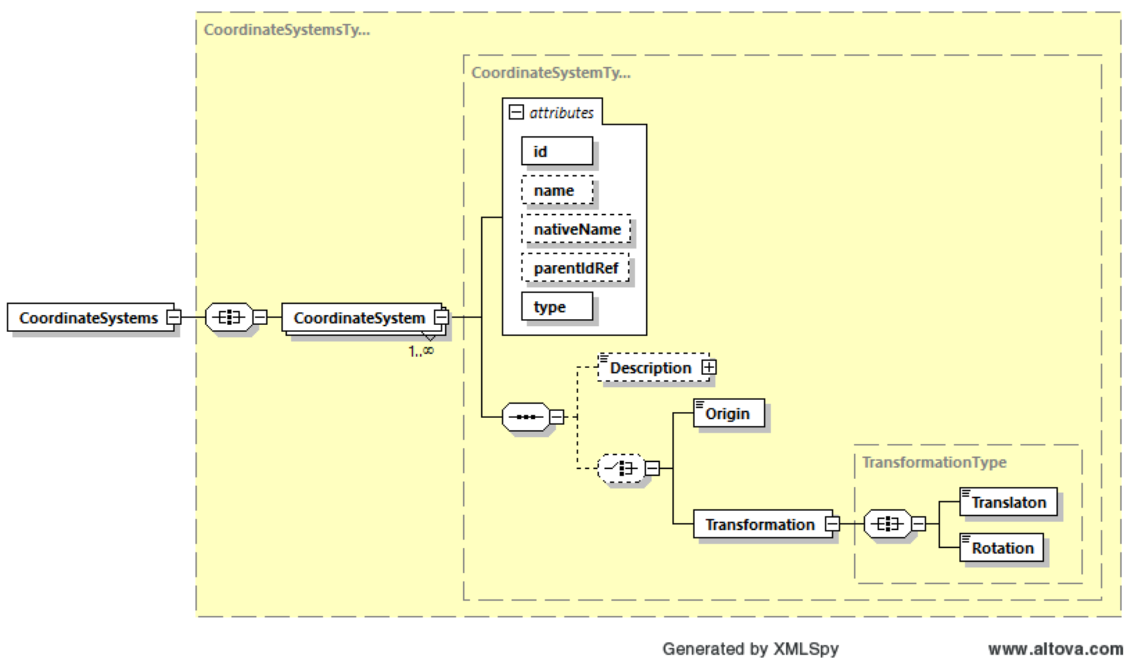

Figure 25: CoordinateSystems Diagram

9.4.1 CoordinateSystem

A `CoordinateSystem` is a reference system that associates a unique set of n parameters with each point in an n-dimensional space. *Ref: ISO 10303-218:2004*

9.4.1.1 Attributes for CoordinateSystem

Table 60 lists the attributes defined to provide information for a `CoordinateSystem` element.

Table 60: Attributes for CoordinateSystem

Attribute	Description	Occurrence
`id`	The unique identifier for this element.	1
`name`	The name of the coordinate system. If more than one `CoordinateSystem` elements have the same `type` for the same `Component`, then the name attribute **MUST** be provided. Otherwise, the `name` attribute is optional. `name` provides as an additional human-readable identifier in addition to the `id`.	0..1
`nativeName`	The manufacturer's name or users name for the coordinate system.	0..1
`parentIdRef`	A pointer to the `id` attribute of the parent `CoordinateSystem`.	0..1
`type`	The type of coordinate system.	1

9.4.1.1.1 CoordinateSystem types

Table 61 defines the various types of coordinate systems.

Table 61: CoordinateSystem types

type	Description
WORLD	stationary coordinate system referenced to earth, which is independent of the robot motion. *Ref:ISO 9787:2013* For non-robotic devices, stationary coordinate system referenced to earth, which is independent of the motion of a piece of equipment.
BASE	coordinate system referenced to the base mounting surface. *Ref:ISO 9787:2013* A base mounting surface is a connection surface between the arm and its supporting structure.*Ref:ISO 9787:2013* For non-robotic devices, it is the connection surface between the device and its supporting structure.
OBJECT	coordinate system referenced to the object. *Ref:ISO 9787:2013*
TASK	coordinate system referenced to the site of the task. *Ref:ISO 9787:2013*
MECHANICAL_INTERFACE	coordinate system referenced to the mechanical interface. *Ref:ISO 9787:2013*
TOOL	coordinate system referenced to the tool or to the end effector attached to the mechanical interface. *Ref:ISO 9787:2013*
MOBILE_PLATFORM	coordinate system referenced to one of the components of a mobile platform. *Ref:ISO 8373:2012*
MACHINE	coordinate system referenced to the home position and orientation of the primary axes of a piece of equipment.
CAMERA	coordinate system referenced to the sensor which monitors the site of the task. *Ref:ISO 9787:2013*

9.4.1.2 Elements for CoordinateSystem

Table 62 lists the elements defined to provide information for a CoordinateSystem element.

Table 62: Elements for CoordinateSystem

Element	Description	Occurrence
Origin	The coordinates of the origin position of a coordinate system. The coordinate **MUST** be in MILLIMETER_3D.	0..1
Transformation	The process of transforming to the origin position of the coordinate system from a parent coordinate system using Translation and Rotation.	0..1
Description	The natural language description of the CoordinateSystem.	0..1

Notes: Only one of Origin or Transformation can be defined for a CoordinateSystem.

9.4.1.2.1 Elements for Transformation

Table 63 lists the elements defined to provide information for a Transformation element.

Table 63: Elements for Transformation

Element	Description	Occurrence
Translation	Translations along X, Y, and Z axes are expressed as x,y, and z respectively within a 3-dimensional vector. The values **MUST** be given in MILLIMETER_3D.	0..1

Continuation of Table 63		
Element	Description	Occurrence
Rotation	Rotations about X, Y, and Z axes are expressed in A, B, and C respectively within a 3-dimensional vector. The values **MUST** be given in DEGREE_3D. Positive A, B, and C are in the directions to advance right-hand screws in the positive X, Y, and Z directions, respectively. *Ref:ISO 9787:2013*	0..1

9.5 Motion

Motion defines the movement of the Component relative to a coordinate system. Motion specifies the kinematic chain of the Components.

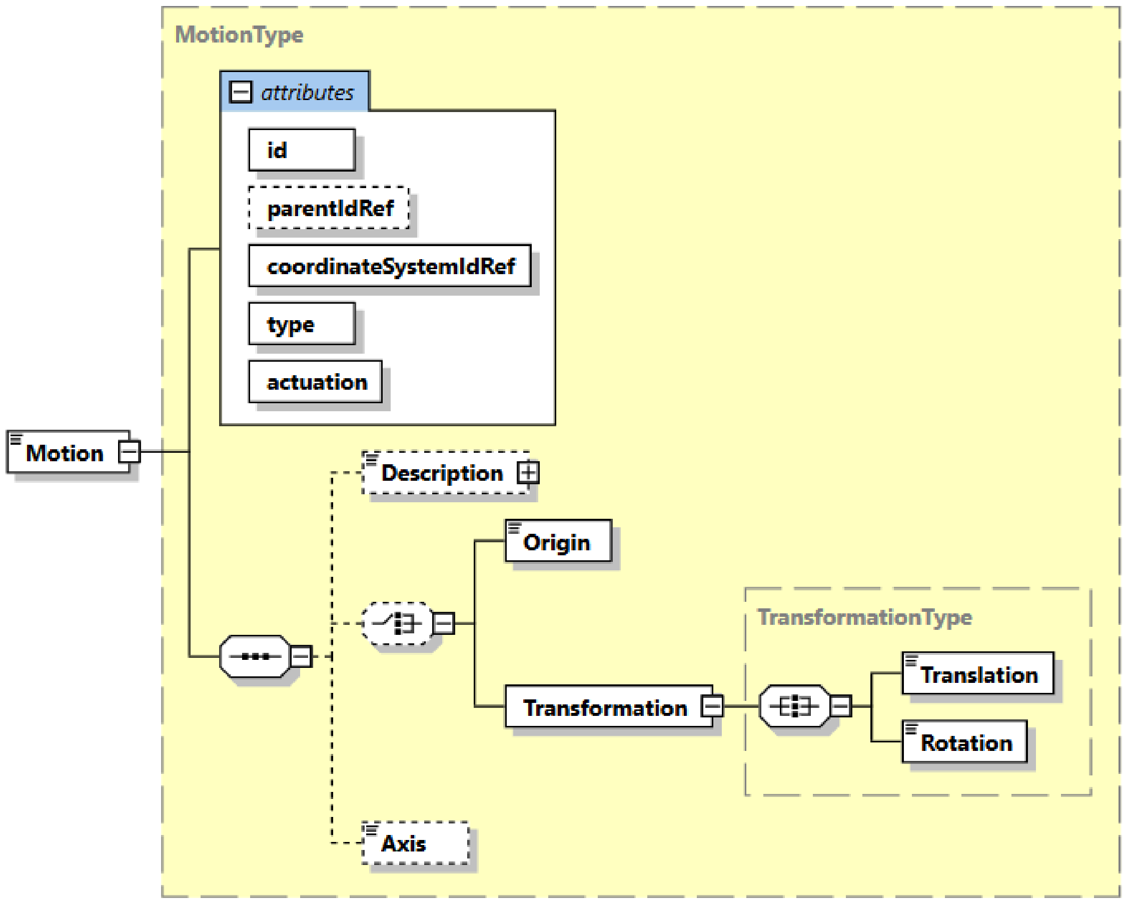

Figure 26: Motion Diagram

9.5.1 Attributes for Motion

Table 64 lists the attributes defined to provide information for a `Motion` element.

Table 64: Attributes for Motion

Attribute	Description	Occurrence
`id`	The unique identifier for this element.	1

Continuation of Table 64		
Attribute	Description	Occurrence
parentIdRef	A pointer to the id attribute of the parent Motion. The kinematic chain connects all components using the parent relations. All motion is connected to the motion of the parent. The first node in the chain will not have a parent.	0..1
coordinateSystemIdRef	The coordinate system within which the kinematic motion occurs.	1
type	Describes the type of motion.	1
actuation	Describes if this Component is actuated directly or indirectly as a result of other motion.	1

1597 #### 9.5.1.1 Motion types

1598 *Table 65* defines the types of Motion.

Table 65: Motion types

type	Description
REVOLUTE	Rotates around an axis with a fixed range of motion.
CONTINUOUS	Revolves around an axis with a continuous range of motion.
PRISMATIC	Sliding linear motion along an axis with a fixed range of motion.
FIXED	The axis does not move.

1599 #### 9.5.1.2 Motion actuation types

1600 *Table 66* defines the types of actuation of Motion.

Table 66: Motion actuation types

type	Description
DIRECT	The movement is initiated by the Component.
VIRTUAL	The motion is computed and is used for expressing an imaginary movement.
NONE	There is no actuation of this Axis. Note: Actuation of NONE can be either a derived REVOLUTE or PRISMATIC motion or static FIXED relationship.

9.5.2 Elements for Motion

Table 67 lists the elements defined to provide information for a Motion element.

Table 67: Elements for Motion

Element	Description	Occurrence
Description	An element that can contain any descriptive content.	0..1
Axis	Axis defines the axis along or around which the Component moves relative to a coordinate system. The value of Axis **MUST** be in UNIT_VECTOR_3D.	1
Origin	A fixed point from which measurement or motion commences. The value **MUST** be in MILLIMETER_3D.	0..1
Transformation	The Transformation of the parent Origin or Transformation using Translation and Rotation. At a minimum, a Translation or Rotation **MUST** be given. See *Section 9.4.1.2.1 - Elements for Transformation* for definitions of Translation and Rotation.	0..1

Notes: Only one of `Origin` or `Transformation` can be defined for a `Motion`.

9.6 SolidModel

A `SolidModel` is a `Configuration` that references a file with the three-dimensional geometry of the `Component` or `Composition`. The geometry **MAY** have a transformation and a scale to position the `Component` with respect to the other `Components`. A geometry file can contain a set of assembled items, in this case, the `SolidModel` reference the `id` of the assembly model file and the specific item within that file.

The `SolidModel` **MAY** provide a translation, rotation, and scale to correctly place it relative to the other geometries in the machine. If the `Component` can move and has a `Motion Configuration`, the `SolidModel` will move when the `Component` or `Composition` moves.

Either an `href` or a `solidModelIdRef` and an `itemRef` **MUST** be specified.

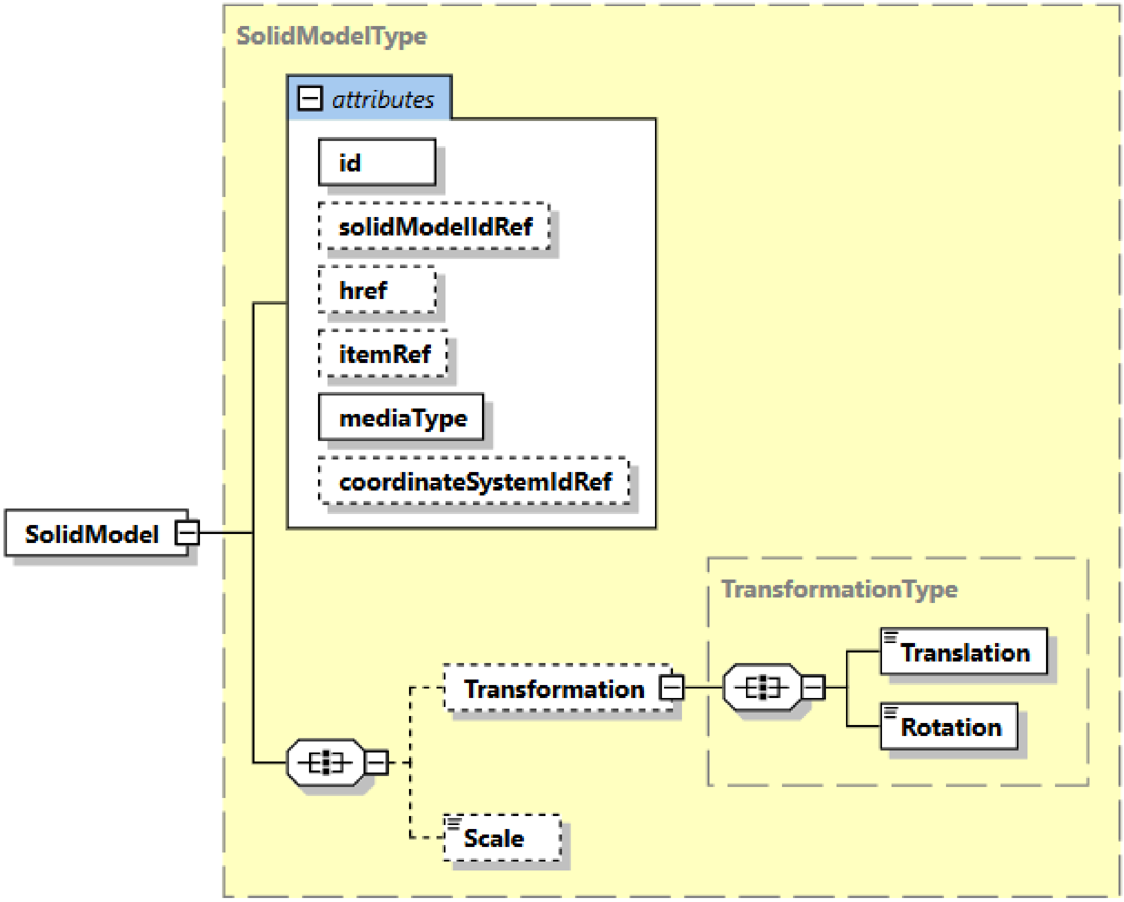

Figure 27: SolidModel Diagram

9.6.1 Attributes for SolidModel

Table 68 lists the attributes defined to provide information for a `SolidModel` element.

Table 68: Attributes for SolidModel

Attribute	Description	Occurrence
`id`	The unique identifier for this entity within the `MTConnectDevices` document.	1
`solidModelIdRef`	The associated model file if an item reference is used.	0..1

Continuation of Table 68		
Attribute	Description	Occurrence
href	The URL giving the location of the Solid Model. If not present, the model referenced in the solidModelIdRef is used. href is of type xlink:href from the W3C XLink specification.	0..1
itemRef	The reference to the item within the model within the related geometry. A solidModelIdRef **MUST** be given. Note: Item defined in ASME Y14.100 - A nonspecific term used to denote any unit or product, including materials, parts, assemblies, equipment, accessories, and computer software.	0..1
mediaType	The format of the referenced document.	1
coordinateSystemIdRef	A reference to the coordinate system for this SolidModel.	0..1

9.6.1.1 SolidModel mediaType

Table 69 defines the type of mediaType for SolidModel.

Table 69: SolidModel mediaType

type	Description
STEP	ISO 10303 STEP AP203 or AP242 format.
STL	Stereolithography file format.
GDML	Geometry Description Markup Language.
OBJ	Wavefront OBJ file format.
COLLADA	ISO 17506.
IGES	Initial Graphics Exchange Specification.

Continuation of Table 69	
type	Description
3DS	Autodesk file format.
ACIS	Dassault file format.
X_T	Parasolid XT Siemens data interchange format.

9.6.2 Elements for SolidModel

Table 70 lists the elements defined to provide information for a SolidModel element.

Table 70: Elements for SolidModel

Element	Description	Occurrence
Transformation	The translation of the origin to the position and orientation. At a minimum, a Translation or Rotation **MUST** be given. See *Section 9.4.1.2.1 - Elements for Transformation* for definitions of Translation and Rotation.	0..1
Scale	The SolidModel Scale is either a single multiplier applied to all three dimensions or a three space multiplier given in the X, Y, and Z dimensions in the coordinate system used for the SolidModel.	0..1

Appendices

A Bibliography

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IEEE STD 1451.4-1994, Standard for a Smart Transducer Interface for Sensors and Actuators – Mixed-Mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats, IEEE Instrumentation and Measurement Society, TC-9, The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y. 10016, SH95225, December 15, 2004.

MTConnect® Standard

Part 3.0 – Streams Information Model

Version 1.8.0

Prepared for: MTConnect Institute
Prepared on: September 6, 2021

MTConnect Specification and Materials

Table of Contents

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1 Purpose of This Document

This document, *MTConnect Standard: Part 3.0 - Streams Information Model* of the MTConnect Standard, establishes the rules and terminology that describes the information returned by an MTConnect *Agent* from a piece of equipment. The *Streams Information Model* also defines, in *Section 3 - Streams Information Model*, the structure for the XML documents that are returned from an *Agent* in response to a *Sample Request* or *Current Request*.

MTConnect Standard: Part 3.0 - Streams Information Model is not a stand-alone document. This document is used in conjunction with *MTConnect Standard Part 1.0 - Overview and Fundamentals* which defines the fundamentals of the operation of the MTConnect Standard and *MTConnect Standard: Part 2.0 - Devices Information Model* that defines the semantic model representing the information that may be returned from a piece of equipment.

Note: *MTConnect Standard: Part 5.0 - Interfaces* provides details on extensions to the *Streams Information Model* required to describe the interactions between pieces of equipment.

In the MTConnect Standard, equipment represents any tangible property that is used in the operation of a manufacturing facility. Examples of equipment are machine tools, ovens, sensor units, workstations, software applications, and bar feeders.

2 Terminology and Conventions

Refer to *Section 3* of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 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

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.

URI

Stands for Universal Resource Identifier.

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

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`.

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.

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*.

Attachment

The connection by which one thing is associated with another.

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*.

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`.

Condition

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

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 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 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 Set

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

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*.

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*.

Equipment Metadata

See *Metadata*

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.

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*.

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.

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*.

MTConnect Agent

See definition for *Agent*.

MTConnectDevices Response Document

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

MTConnectStreams Response Document

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

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.

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*.

Probe Request

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

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*.

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.

Response Document

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

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*.

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*.

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*.

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*.

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*.

Top Level

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

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).

XML Schema

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

2.2 Acronyms

AMT

The Association for Manufacturing Technology

2.3 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.8.0.

[MTConnect Part 2.0] *MTConnect Standard: Part 2.0 - Devices Information Model*. Version 1.8.0.

[MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Streams Information Model*. Version 1.8.0.

[MTConnect Part 5.0] *MTConnect Standard: Part 5.0 - Interfaces*. Version 1.8.0.

3 Streams Information Model

The *Streams Information Model* provides a representation of the data reported by a piece of equipment used for a manufacturing process, or used for any other purpose. Additional descriptive information associated with the reported data is defined in the `MTConnect-Devices` document, which is described in *MTConnect Standard: Part 2.0 - Devices Information Model*.

Information defined in the *Streams Information Model* allows a software application to (1) determine the value for *Data Entities* returned from a piece of equipment and (2) interpret the data associated with those *Data Entities* with the same meaning, value, and context that it had at its original source. To do this, the software application issues one of two HTTP requests to an *Agent* associated with a piece of equipment. They are:

- `sample`: Returns a designated number of time stamped *Data Entities* from an *Agent* associated with a piece of equipment; subject to any HTTP filtering associated with the request. See *Section 8.3.3* of *MTConnect Standard Part 1.0 - Overview and Fundamentals* of the MTConnect Standard for details on the `sample` HTTP request.
- `current`: Returns a snapshot of either the most recent values or the values at a given sequence number for all *Data Entities* associated with a piece of equipment from an *Agent*; subject to any HTTP filtering associated with the request. See *Section 8.3.2* of *MTConnect Standard Part 1.0 - Overview and Fundamentals* of the MTConnect Standard for details on the `current` HTTP request.

An *Agent* responds to either the `sample` or `current` HTTP request with an `MTConnectStreams` XML document. This document contains information describing *Data Entities* reported by an *Agent* associated with a piece of equipment. A client software application may correlate the information provided in the `MTConnectStreams` XML document with the physical and logical structure for that piece of equipment defined in the `MTConnectDevices` document to form a clear and unambiguous understanding of the information provided. (See details on the structure for a piece of equipment described in *MTConnect Standard: Part 2.0 - Devices Information Model*).

The `MTConnectStreams` XML document is comprised of two sections: `Header` and `Streams`.

The `Header` section contains protocol related information as defined in *Section 6.5* of *MTConnect Standard Part 1.0 - Overview and Fundamentals* of the MTConnect Standard.

The `Streams` section of the `MTConnectStreams` document contains a `DeviceStream` XML container for each piece of equipment represented in the document. Each `DeviceStream` container is comprised of two primary types of XML elements – *Structural Elements* and *Data Entities*. The contents of the `DeviceStream` container are described in detail in this document, *MTConnect Standard: Part 3.0 - Streams Information Model* of the MTConnect Standard.

Structural Elements are defined for both the `MTConnectDevices` and the `MTConnectStreams` XML documents. These *Structural Elements* are used to provide a logical organization of the information provided in each document. While used for a similar purpose, the *Structural Elements* in the `MTConnectStreams` document are specifically designed to be distinctly different from those in the `MTConnectDevices` document:

- `MTConnectDevices` document: *Structural Elements* organize information that represents the physical and logical parts and sub-parts of a piece of equipment. (See *MTConnect Standard: Part 2.0 - Devices Information Model*, Section 4 of the MTConnect Standard for more details on *Structural Elements* used in the `MTConnectDevices` document).

- `MTConnectStreams` document: *Structural Elements* provide the structure to organize the data returned from a piece of equipment and establishes the proper context for that data. The *Structural Elements* specifically defined for use in the `MTConnectStreams` document are `DeviceStream` (see *Section 4.2 - DeviceStream*) and `ComponentStream` (see *Section 4.3 - ComponentStream*).

  `DeviceStream` and `ComponentStream` elements have a direct correlation to each of the *Structural Elements* defined in the `MTConnectDevices` document.

Data Entities that describe data reported by a piece of equipment are also defined for both the `MTConnectDevices` and the `MTConnectStreams` XML documents. The *Data Entities* provided in both documents directly relate to each other. However, *Data Entities* are used for different purposes in each document:

- `MTConnectDevices` document: *Data Entity* elements define the data that may be returned from a piece of equipment. *MTConnect Standard: Part 2.0 - Devices Information Model*, *Sections 7 and 8* lists the possible *Data Entity* XML elements that can be returned in a `MTConnectDevices` document.

- `MTConnectStreams` document: *Data Entity* elements provide the data reported by a piece of equipment. This data is organized in separate `ComponentStream` XML containers for each of the *Structural Elements* defined in the `MTConnectDevices` document associated with the data that is reported by a piece of equipment.

Within each ComponentStream XML container in the MTConnectStreams document, *Data Entities* are organized into three types of XML container elements - Samples, Events, and Conditions. (See *Section 5 - Data Entities* and *Section 6 - Listing of Data Entities* for more information on these elements.)

4 Structural Elements for MTConnectStreams

Structural Elements are XML elements that form the logical structure for the MTConnectStreams XML document. These elements are used to organize the information and data that is reported by an *Agent* for a piece of equipment. See *Figure 1* for an overview of the *Structural Elements* used in an MTConnectStreams document.

The first, or highest level, *Structural Element* in an MTConnectStreams XML document is Streams. Streams is a container type XML element used to group the data reported from one or more pieces of equipment into a single XML document. Streams **MUST** always appear in the MTConnectStreams document.

DeviceStream is the next *Structural Element* in the MTConnectStreams document. DeviceStream is also a XML container type element. A separate DeviceStream container is used to organize the information and data reported by each piece of equipment represented in the MTConnectStreams document. There **MUST** be at least one DeviceStream element in the Streams container.

A DeviceStream element provides the data reported by a piece of equipment. Each DeviceStream element **MUST** contain the attributes name and uuid to correlate the DeviceStream with a specific Device defined in the MTConnectDevices document. Once the DeviceStream element is associated with a specific piece of equipment based on this identity, all data reported by that piece of equipment is directly associated with that unique identity and that association does not need to be repeated for every piece of data reported. A client software application may then directly relate the information provided in the MTConnectDevices document with the data provided in the MTConnectStreams document based on this identity.

ComponentStream is the next level XML element in the MTConnectStreams document. ComponentStream is also a container type XML element. There **MUST** be a separate ComponentStream XML element for each of the *Structural Elements* (Device elements, *Top Level* Component elements, or *Lower Level* Component elements) defined for that piece of equipment in the associated MTConnectDevices XML document. A ComponentStream representing a *Structural Element* will only appear if there is data reported for that *Structural Element*. (Note: See *MTConnect Standard: Part 2.0 - Devices Information Model* of the MTConnect Standard for a description of the *Structural Elements* for a piece of equipment).

There are three (3) *Structural Elements* – Samples, Events, and Condition at the next level of the MTConnectStreams document. Each one of these *Structural Elements* is a container type XML element. These *Structural Elements* group the data reported for each component of a piece of equipment according to the *Data Entity* categories defined in *MTConnect Standard: Part 2.0 - Devices Information Model*, Sections 7 and 8.

- `Samples` contains `SAMPLE` category *Data Entities* defined in the `MTConnectDevices` XML document (See *MTConnect Standard: Part 2.0 - Devices Information Model*, Section 8.1)
- `Events` contains `EVENT` category *Data Entities* defined in the `MTConnectDevices` XML document (See *MTConnect Standard: Part 2.0 - Devices Information Model*, Section 8.2)
- `Condition` contains `CONDITION` category *Data Entities* defined in the `MTConnectDevices` XML document (See *MTConnect Standard: Part 2.0 - Devices Information Model*, Section 8.3)

There **MUST** be at least one of `Samples`, `Events`, or `Condition` elements in each `ComponentStream` container.

Figure 1 XML tree structure illustrates the various *Structural Elements* used to organize the data reported by a piece of equipment and the relationship between these elements.

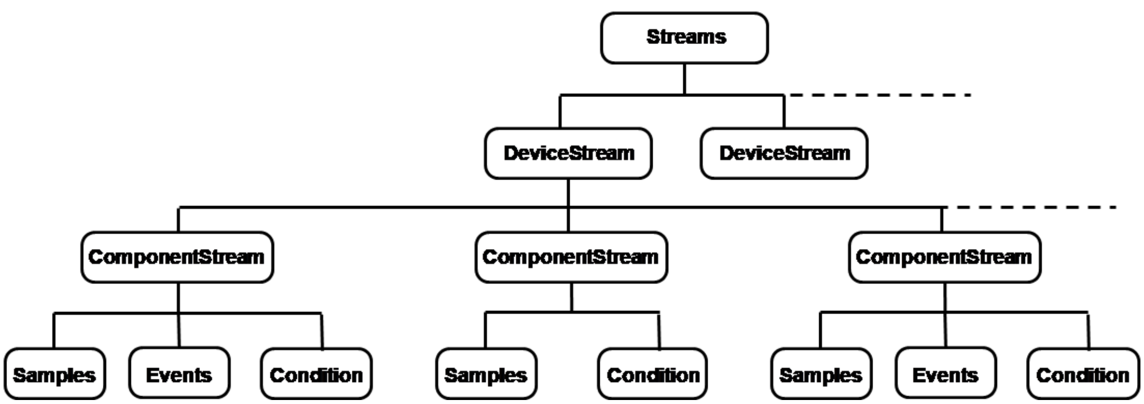

Figure 1: Streams Data Structure

Example 1 is a sample from an `MTConnectStreams` XML document that contains the response from an *Agent* representing two pieces of equipment, *mill-1* and *mill-2*. The data from each piece of equipment is reported in a separate `DeviceStream` container.

Example 1: Example of DeviceStream

```
<MTConnectStreams ...>
  <Header ... />
  <Streams>
    <DeviceStream name="mill-1" uuid="1">
      <ComponentStream component="Device" name="mill-1"
```

```
          componentId="d1">
        <Events>
          <Availability dataItemId="avail1" name="avail"
              sequence="5"
              timestamp="2010-04-06T06:19:35.153141">
            AVAILABLE</Availability>
        </Events>
      </ComponentStream>
    </DeviceStream>
    <DeviceStream name="mill-2" uuid="2">
      <ComponentStream component="Device" name="mill-2"
          componentId="d2">
        <Events>
          <Availability dataItemId="avail2" name="avail"
              sequence="15"
              timestamp="2010-04-06T06:19:35.153141">
            AVAILABLE</Availability>
        </Events>
      </ComponentStream>
    </DeviceStream>
  </Streams>
</MTConnectStreams>
```

In *Example 1*, it should be noted that the *sequence numbers* are unique across the two pieces of equipment. Client software applications **MUST NOT** assume that the `Events` and `Samples` sequence numbers are strictly in sequence. All sequence numbers **MAY NOT** be included. For instance, such a case would occur when HTTP filtering is applied to the request and the `SAMPLE`, `EVENT`, and `CONDITION` data types for other components are not returned. Another case would occur when an *Agent* is supporting more than one piece of equipment and data from only one piece of equipment is requested. Refer to MT-Connect Standard *MTConnect Standard Part 1.0 - Overview and Fundamentals*, *Section 5* for more information on *sequence numbers*.

4.1 Streams

`Streams` is a container type XML element that **MUST** contain only `DeviceStream` elements. `Streams` **MAY** contain any number of `DeviceStream` elements. If there is no data to be reported for a request for data, an `MTConnectStreams` document **MUST** be returned with an empty `Streams` container. *Data Entities* **MAY NOT** be directly associated with the `Streams` container.

The XML schema in *Figure 2* represents the structure of the `Streams` XML element.

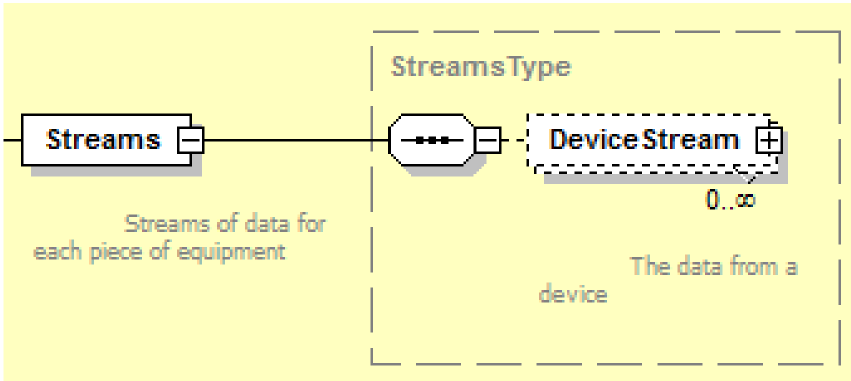

Figure 2: Streams Schema Diagram

Table 1: MTConnect Streams Element

Element	Description	Occurrence
`Streams`	The first, or highest, level XML container element in an `MTConnectStreams` *Response* Document provided by an *Agent* in response to a `sample` or `current` HTTP *Request*. There **MAY** be only one `Streams` element in an `MTConnectStreams` *Response* Document for each piece of equipment represented in the document. An empty `Streams` container **MAY** be provided to indicate that no data is available for the given *Request*. The `Streams` element **MAY** contain any number of `DeviceStream` elements, one for each piece of equipment represented in the `MTConnectStreams` document.	1

4.2 DeviceStream

DeviceStream is a XML container that organizes data reported from a single piece of equipment. A DeviceStream element **MUST** be provided for each piece of equipment reporting data in an MTConnectStreams document.

A DeviceStream **MAY** contain any number of ComponentStream elements; limited to one for each component element represented in the MTConnectDevices document. If the response to the request for data from an *Agent* does not contain any data for a specific piece of equipment, an empty DeviceStream element **MAY** be created to indicate that the piece of equipment exists, but there was no data available. In this case, there will be no ComponentStream elements provided.

Table 2: MTConnect DeviceStream Element

Element	Description	Occurrence
DeviceStream	An XML container element provided in the Streams container in the MTConnectStreams document. There **MAY** be one or more DeviceStream elements in a Streams container; one for each piece of equipment represented in the MTConnectStreams document.	0..*

4.2.1 XML Schema for DeviceStream

The XML schema in *Figure 3* represents the structure of the DeviceStream XML element showing the attributes defined for DeviceStream and the elements that **MAY** be associated with DeviceStream.

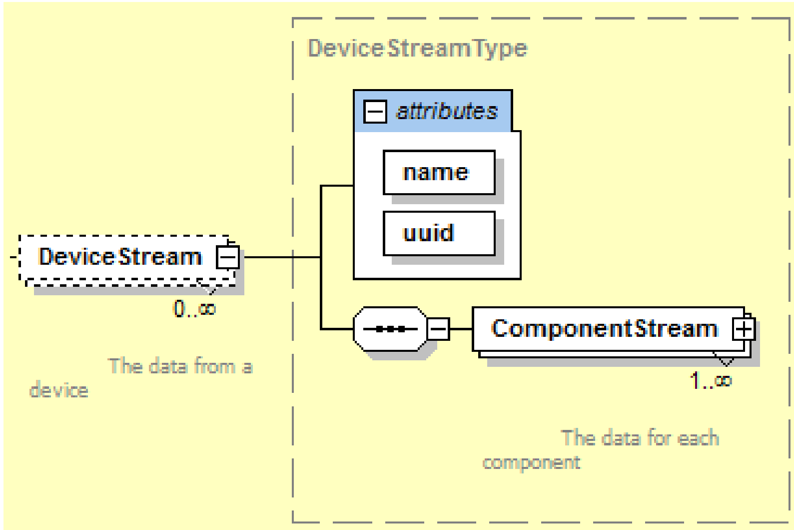

Figure 3: DeviceStream Schema Diagram

4.2.2 Attributes for DeviceStream

Table 3 defines the attributes that **MUST** be provided to uniquely identify each specific piece of equipment associated with the information provided in each `DeviceStream`.

Table 3: Attributes for DeviceStream

Attribute	Description	Occurrence
`name`	The name of an element or a piece of equipment. The `name` associated with the piece of equipment reporting the data contained in this `DeviceStream` container. `name` is a required attribute. The value reported for `name` **MUST** be the same as the value defined for the `name` attribute of the same piece of equipment in the `MTConnectDevices` document An NMTOKEN XML type. **WARNING**: `name` may become an optional attribute in future versions of the MTConnect Standard.	1

Continuation of Table 3

Attribute	Description	Occurrence
`uuid`	The `uuid` associated with the piece of equipment reporting the data contained in this `DeviceStream` container. `uuid` is a required attribute. The value reported for `uuid` **MUST** be the same as the value defined for the `uuid` attribute of the same piece of equipment in the `MTConnectDevices` document.	1

4.2.3 Elements for DeviceStream

Table 4 lists the XML element(s) that **MAY** be provided in the `DeviceStream` XML element.

Table 4: Elements for DeviceStream

Element	Description	Occurrence
`ComponentStream`	An XML container type element that organizes data returned from an *Agent* in response to a `current` or `sample` HTTP request. Any number of `ComponentStream` elements **MAY** be provided in a `DeviceStream` container. There **MUST** be a separate `ComponentStream` XML element for each of the *Structural Elements* (`Device` elements, *Top Level* `Component` elements, or *Lower Level* `Component` elements) defined for that piece of equipment in the associated `MTConnectDevices` XML document. A `ComponentStream` representing a *Structural Element* will only appear if there is data reported for that *Structural Element*.	1..*

4.3 ComponentStream

`ComponentStream` is a XML container that organizes the data associated with each *Structural Element* (`Device` element, *Top Level* `Component`, or *Lower Level* `Component` element) defined for that piece of equipment in the associated `MTConnectDevices` XML document. The data reported in each `ComponentStream` element **MUST** be grouped into individual XML containers based on the value of the `category` attribute (`SAMPLE`, `EVENT`, or `CONDITION`) defined for each *Data Entity* in the `MTConnectDevices` XML document. These containers are `Samples`, `Events`, and `Condition`.

4.3.1 XML Schema for ComponentStream

The XML schema in *Figure 4* represents the structure of a `ComponentStream` XML element showing the attributes defined for `ComponentStream` and the elements that **MAY** be associated with `ComponentStream`.

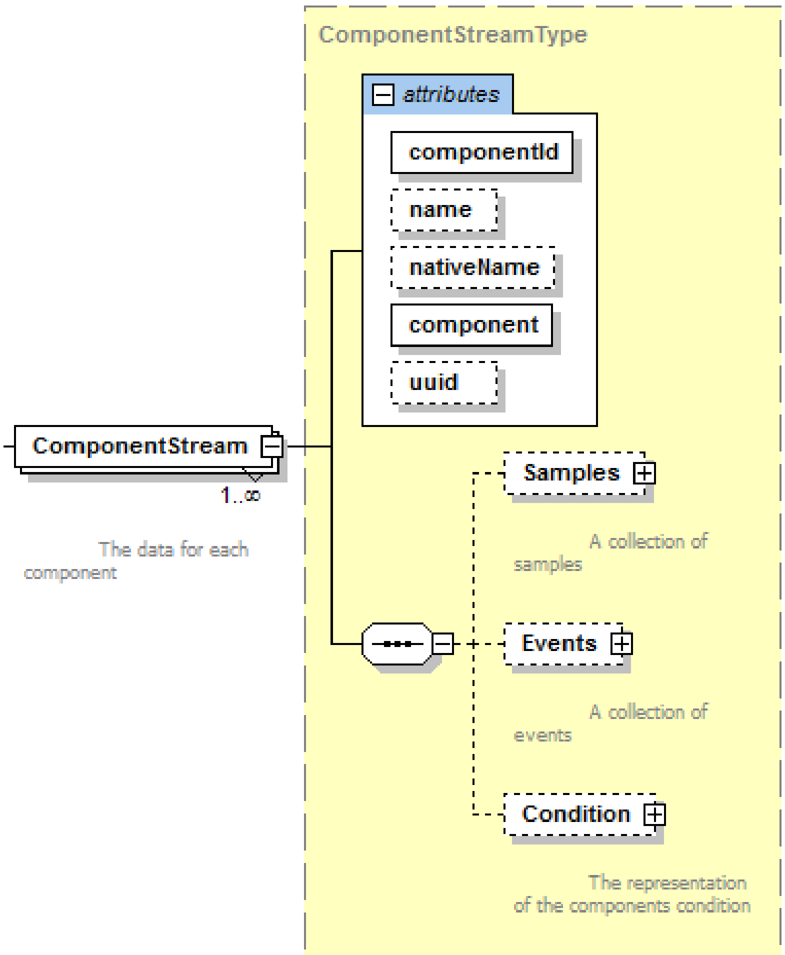

Figure 4: ComponentStream Schema Diagram

`ComponentStream` is similar to `DeviceStream` in that the attributes uniquely identify the *Structural Element* with which the data reported is directly associated. This information does not have to be repeated for each *Data Entity*. In the case of the `DeviceStream`, the attributes uniquely identify the piece of equipment associated with the data. In the case of the `ComponentStream`, the attributes identify the specific *Structural Element* within a piece of equipment associated with each *Data Entity*.

4.3.2 Attributes for ComponentStream

The *Table 5* defines the attributes used to uniquely identify the specific *Structural Element*(s) of a piece of equipment associated with the data reported in the `MTConnectStreams` document.

Table 5: Attributes for ComponentStream

Attribute	Description	Occurrence
componentId	The identifier of the *Structural Element* (Device element, *Top Level* Component element, or *Lower Level* Component element) as defined by the id attribute of the corresponding *Structural Element* in the MTConnectDevices XML document. componentId is a required attribute. The identifier **MUST** be the same as that defined in the MTConnectDevices document to associate the data reported in the ComponentStream container with the *Structural Element* identified in the MTConnectDevices document.	1
name	The name of the ComponentStream element. name is an optional attribute. If name is not defined for a specific *Structural Element* in the MTConnectDevices document, it **MUST NOT** be provided for the corresponding ComponentStream element in the MTConnectStreams document. If name is defined for a specific *Structural Element* in the MTConnectDevices document, it **MAY** be provided for the corresponding ComponentStream element in the MTConnectStreams document. If provided, the value reported for name **MUST** be the same as the value defined for the name attribute of the corresponding *Structural Element* (Device element, *Top Level* Component element, or *Lower Level* Component element) defined in the MTConnectDevices XML document. An NMTOKEN XML type.	0..1

Continuation of Table 5		
Attribute	Description	Occurrence
nativeName	nativeName identifies the common name normally associated with the ComponentStream element. nativeName is an optional attribute. If nativeName is not defined for a specific *Structural Element* in the MTConnectDevices document, it **MUST NOT** be provided for the corresponding ComponentStream element in the MTConnectStreams document. If nativeName is defined for a specific *Structural Element* in the MTConnectDevices document, it **MAY** be provided for the corresponding ComponentStream element in the MTConnectStreams document. If provided, the value reported for nativeName **MUST** be the same as the value defined for the nativeName attribute of the corresponding *Structural Element* (Device element, *Top Level* Component element, or *Lower Level* Component element) defined in the MTConnectDevices XML document.	0..1

Continuation of Table 5		
Attribute	Description	Occurrence
`component`	`component` identifies the *Structural Element* (`Device`, *Top Level* `Component`, or *Lower Level* `Component`) associated with the `ComponentStream` element. `component` is a required attribute. The value reported for component **MUST** be the same as the value defined for the Element Name of the XML container representing the corresponding *Structural Element* (`Device` element, *Top Level* `Component` element, or *Lower Level* `Component` element) defined in the `MTConnectDevices` XML document. Examples of `Component` are `Device`, `Axes`, `Controller`, `Linear`, `Electric` and `Loader`.	1
`uuid`	`uuid` of the `ComponentStream` element. `uuid` is an optional attribute. If `uuid` is not defined for a specific *Structural Element* in the `MTConnectDevices` document, it **MUST NOT** be provided for the corresponding `ComponentStream` element in the `MTConnectStreams` document. If `uuid` is defined for a specific *Structural Element* in the `MTConnectDevices` document, it **MAY** be provided for the corresponding `ComponentStream` element in the `MTConnectStreams` document, but it is not required. If provided, the value reported for `uuid` **MUST** be the same as the value defined for the `uuid` attribute of the corresponding *Structural Element* (`Device` element, *Top Level* `Component` element, or *Lower Level* `Component` element) defined in the `MTConnectDevices` XML document.	0..1

4.3.3 Elements for ComponentStream

In the ComponentStream container, an *Agent* **MUST** organize the data reported in each ComponentStream into individual Samples, Events, or Condition XML containers based on the value of the category attribute (i.e., SAMPLE, EVENT, or CONDITION) defined for each *Data Entity* defined in the MTConnectDevices XML document.

Each ComponentStream element **MUST** include at least one Events, Samples, or Condition XML container element. *Data Entities* returned in each of the ComponentStream container elements are defined in the *Table 6*.

Table 6: Elements for ComponentStream

Element	Description	Occurrence
Samples	An XML container type element. Samples organizes the SAMPLE type *Data Entities* defined in the MTConnectDevices document that are reported in each ComponentStream XML element.	0..1 †
Events	An XML container type element. Events organizes the EVENT type *Data Entities* defined in the MTConnectDevices document that are reported in each ComponentStream XML element.	0..1 †
Condition	An XML container type element. Condition organizes the CONDITION type *Data Entities* defined in the MTConnectDevices document that are reported in each ComponentStream XML element.	0..1 †

Note: †The ComponentStream element **MUST** contain at least one of these element types.

5 Data Entities

When a piece of equipment reports values associated with DataItem elements defined in the MTConnectDevices document, that information is organized as *Data Entities* in the MTConnectStreams document. These *Data Entities* are organized in containers within each ComponentStream element based on the category attribute defined for the corresponding DataItem in the MTConnectDevices document:

DataItem elements defined with a category attribute of SAMPLE in the MTConnectDevices document are mapped to the Samples XML container in the associated ComponentStream element.

DataItem elements defined with a category attribute of EVENT in the MTConnectDevices document are mapped to the Events XML container in the associated ComponentStream element.

DataItem elements defined with a category attribute of CONDITION in the MTConnectDevices document are mapped to the Condition XML container in the associated ComponentStream element.

The XML tree in *Figure 5* demonstrates how *Data Entities* are organized in these containers.

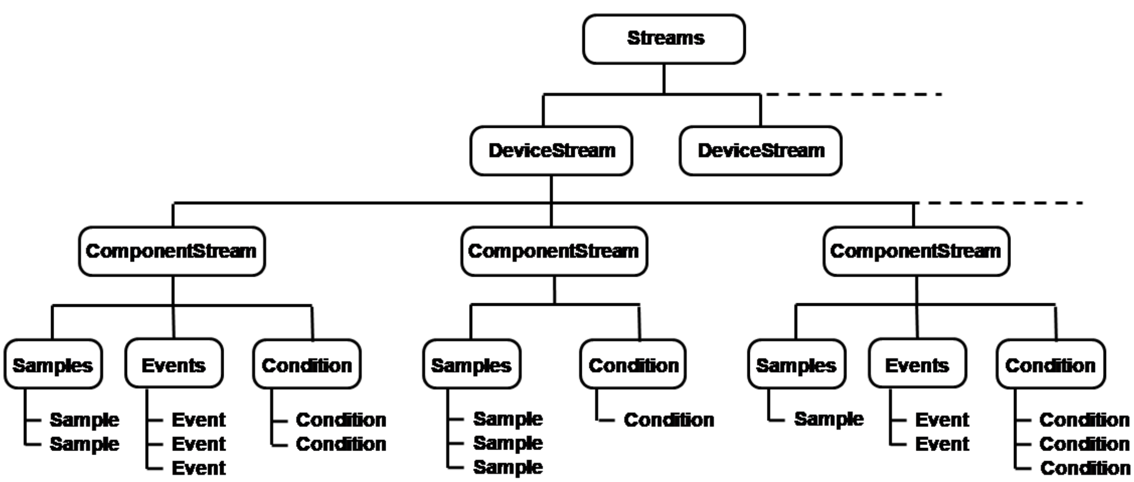

Figure 5: ComponentStream XML Tree Diagram

Example 2 is an illustration of the structure of an XML document demonstrating how *Data Entities* are reported in a MTConnectStreams document:

Example 2: Example of MTConnectStreams

```
<MTConnectStreams>
  <Header/>
  <Streams>
    <DeviceStream>
      <ComponentStream>
        <Samples>
          <Sample/>
          <Sample/>
        </Samples>
        <Events>
          <Event/>
          <Event/>
        </Events>
        <Condition>
          <Condition/>
          <Condition/>
        </Condition>
      </ComponentStream>
      <ComponentStream>
        <Samples>
          <Sample/>
          <Sample/>
        </Samples>
        <Events>
          <Event/>
          <Event/>
        </Events>
        <Condition>
          <Condition/>
          <Condition/>
        </Condition>
      </ComponentStream>
    </DeviceStream>
  </Streams>
</MTConnectStreams>
```

Note: There are no specific requirements defining the sequence in which the `ComponentStream` XML elements are organized in the `MTConnectStreams` document. They **MAY** be organized in any sequence based on the implementation of an *Agent*. The sequence in which the `ComponentStream` XML elements appear does not impact the ability for a client software application to interpret the information that it receives in the document.

When an *Agent* responds to a `current` HTTP request, the information returned in the `MTConnectStreams` document **MUST** include the most current value for every *Data Entity* defined in the `MTConnectDevices` document subject to any filtering included within the request.

When an *Agent* responds to a `sample` HTTP request, the information returned in the `MTConnectStreams` document **MUST** include the occurrences for each *Data Entity* that are available to an *Agent* subject to filtering and the count parameter included within the request (see *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a full definition of the protocol).

5.1 Element Names for Data Entities

In the `MTConnectDevices` document, *Data Entities* are grouped as `DataItem` XML elements within each `Device`, *Top Level* `Component`, and *Lower Level* `Component` *Structural Element*. The *Data Entities* reported in the `MTConnectStreams` document associated with each of these *Structural Elements* are represented with an *Element Name* based on the `category` and `type` defined for each of the `DataItem` elements in the `MTConnectDevices` document.

5.1.1 Element Names when MTConnectDevices category is SAMPLE or EVENT

The *Data Entities* reported in the `MTConnectStreams` document associated with each `DataItem` element defined in the `MTConnectDevices` document with a `category` attribute of `SAMPLE` or `EVENT` **MUST** be identified in the `MTConnectStreams` document with an *Element Name* derived from the `type` attribute defined for that `DataItem` element in the `MTConnectDevices` document.

The element name **MUST** derive from the `DataItem` `type` converted to *Pascal-Case* by removing underscores (_) and capitalizing each word. The conversion **MUST NOT** apply to the following abbreviated words: `PH`, `AC`, `DC` and `URI`. `MTCONNECT` **MUST** be converted to `MTConnect`.

Example 3 describes the most common method used to derive the *Element Name* for a *Data Entity* reported in the `MTConnectStreams` document from the information describing that `DataItem` element in the `MTConnectDevices` document:

DataItem Represented in the MTConnectDevices Document

Example 3: DataItem Represented in MTConnectDevices Document

```
<DataItem type="AXIS_FEEDRATE" id="xf" name="Xfrt"
    category="SAMPLE" units="MILLIMETER/SECOND"
    nativeUnits="MILLIMETER/SECOND/>
```

- DataItem: The XML *Element Name* for this *Data Entity*.

  Note: *Element Name* must not be confused with the name attribute for the data item element.

- type, category, units, and nativeUnits: Attributes that provide additional information regarding each data item in the MTConnectDevices document.

Response Format reported in the MTConnectStreams Document

Example 4: Response Format reported in the MTConnectStreams Document

```
<AxisFeedrate name="Xfrt" sequence="61315517"
    timestamp="2016-07-28T02:06:01.364428Z"
    dataItemId="xf">10.83333</AxisFeedrate>
```

- AXIS_FEEDRATE: The *Element Name* provided in the MTConnectStreams response format for the data item. The *Element Name* for a data item is defined by the type attribute of AXIS_FEEDRATE in the MTConnectDevices document. The *Element Name* **MUST** be provided in Pascal case format (first letter of each word is capitalized).

5.1.2 Changes to Element Names when representation attribute is used

The *Element Name* for a *Data Entity* reported in the MTConnectStreams document is extended when the representation attribute is used to further describe that DataItem element in the MTConnectDevices document.

5.1.3 Element Names when MTConnectDevices category is CONDITION

Data Entities defined in the MTConnectDevices document with a category attribute of CONDITION are reported with an *Element Name* that is defined differently from other *Data Entity* types. The *Element Name* for these *Data Entities* are defined based on the *Fault State* (Normal, Warning, or Fault) associated with each *Data Entity* at the time that a value for that *Data Entity* is reported. See *Section 5.8.1 - Element Names for Condition* and *Section 5.9 - Unavailability of Fault State for Condition* for details on how these *Data Entities* are reported in the MTConnectStreams document.

5.2 Samples Container

Samples is a XML container type element. Samples organizes the *Data Entities* returned in the MTConnectStreams XML document for those DataItem elements defined with a category attribute of SAMPLE in the MTConnectDevices document.

A separate Samples container will be provided for the data returned for the DataItem elements associated with each *Structural Element* of a piece of equipment defined in the MTConnectDevices document.

Table 7: MTConnect Samples Element

Element	Description	Occurrence
Samples	An XML container type element that organizes the data reported in the MTConnectStreams document for DataItem elements defined in the MTConnectDevices document with a category attribute of SAMPLE. A separate Samples container **MUST** be provided for each ComponentStream element for which data is returned for a DataItem element defined in the MTConnectDevices document with a category attribute of SAMPLE. If provided in the document, a Samples XML container **MUST** contain at least one Sample element.	0..1

5.3 Sample Data Entities

A Sample XML element provides the information and data reported from a piece of equipment for those DataItem elements defined with a category attribute of SAMPLE in the MTConnectDevices document.

Sample is an abstract type XML element and will never appear directly in the MTConnectStreams XML document. As an abstract type XML element, Sample will be replaced in the XML document by a specific type of Sample specified by the *Element Name* for that *Data Entity*. The different types of Sample elements are defined in *Section 6.1 - Sample Element Names*. Examples of XML elements representing Sample include PathPosition, Temperature.

Table 8: MTConnect Sample Element

Element	Description	Occurrence
`Sample`	An XML element that provides the information and data reported from a piece of equipment for those `DataItem` elements defined with a `category` attribute of `SAMPLE` in the `MTConnectDevices` document. `Sample` is an abstract type XML element. It is replaced in the `MTConnectStreams` document by a specific type of `Sample` element. There **MAY** be multiple types of `Sample` elements in a `Samples` container.	1..*

5.3.1 XML Schema Structure for Sample

The XML schema in *Figure 6* represents the structure of a `Sample` XML element showing the attributes defined for `Sample` elements.

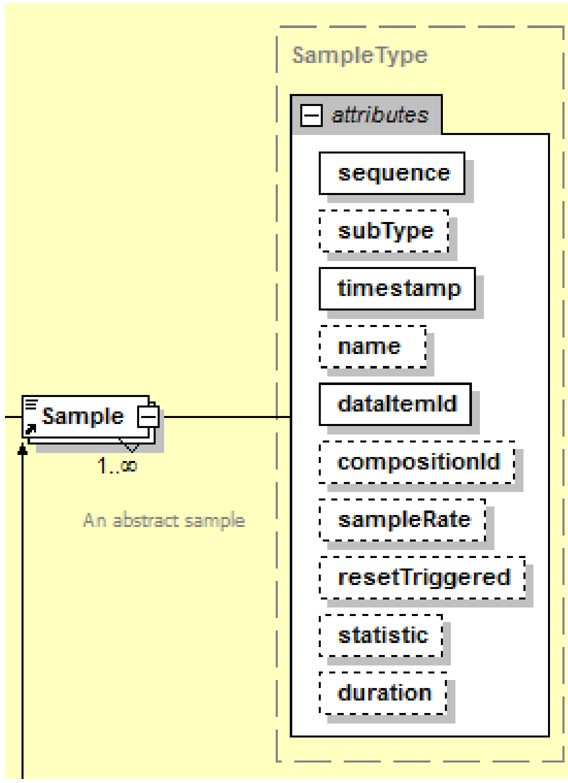

Figure 6: Sample Schema Diagram

5.3.2 Attributes for Sample

The *Table 9* defines the attributes used to provide additional information for a `Sample` XML element.

Table 9: Attributes for Sample

Attribute	Description	Occurrence
`sequence`	A number representing the sequential position of an occurrence of the `Sample` in the data buffer of an *Agent*. `sequence` is a required attribute. `sequence` **MUST** have a value represented as an unsigned 64-bit value from 1 to $2^{64} - 1$.	1

Continuation of Table 9		
Attribute	Description	Occurrence
`subType`	The `subType` of the *Data Entity*. `subType` is an optional attribute. `subType` **MUST** match the `subType` attribute of the `DataItem` element as defined in the `MTConnectDevices` document that the `Sample` element represents.	0..1
`timestamp`	The most accurate time available to a piece of equipment that represents the point in time that the data reported for the `Sample` was measured. When the `Sample` element represents a `DataItem` element defined in the `MTConnectDevices` document with a `representation` or `statistic` attribute, `timestamp` **MUST** represent the time that the data collection was completed. `timestamp` is a required attribute.	1
`name`	The name of the `Sample` element. `name` is an optional attribute. `name` **MUST** match the `name` attribute of the `DataItem` element defined in the `MTConnectDevices` document that the `Sample` element represents. An NMTOKEN XML type.	0..1
`dataItemId`	The unique identifier for the `Sample` element. `dataItemId` is a required attribute. `dataItemId` **MUST** match the id attribute of the `DataItem` element defined in the `MTConnectDevices` document that the `Sample` element represents.	1

Continuation of Table 9		
Attribute	Description	Occurrence
sampleRate	The rate at which successive samples of the value of a data item are recorded. sampleRate is expressed in terms of samples per second. sampleRate is an optional attribute. If the sampleRate is smaller than one, the number can be represented as a decimal type floating-point number. For example, a rate of 1 per 10 seconds would be 0.1 sampleRate **MUST** be provided when the representation attribute of the DataItem element defined in the MTConnectDevices document that this Sample element represents is TIME_SERIES. For DataItem elements where the representation attribute defined in the MTConnectDevices document that this Sample element represents is not TIME_SERIES, it **MUST** be assumed that the data reported is represented by a single value and sampleRate **MUST NOT** be reported in the MTConnectStreams document.	0..1
statistic	The type of statistical calculation defined by the statistic attribute of the DataItem element defined in the MTConnectDevices document that this Sample element represents. statistic is an optional attribute.	0..1

Continuation of Table 9		
Attribute	Description	Occurrence
duration	The time-period over which the data was collected. duration is an optional attribute. duration **MUST** be provided when thestatistic attribute of the DataItem element is defined in the MTConnectDevices document that this Sample element represents.	0..1
resetTriggered	For those DataItem elements that report data that may be periodically reset to an initial value, resetTriggered identifies when a reported value has been reset and what has caused that reset to occur. resetTriggered is an optional attribute. resetTriggered **MUST** only be provided for the specific occurrence of a *Data Entity* reported in the MTConnectStreams document when the reset occurred and **MUST NOT** be provided for any other occurrence of the *Data Entity* reported in a MTConnectStreams document.	0..1
compositionId	The identifier of the Composition element defined in the MTConnectDevices document associated with the data reported for the Sample element. compositionId is an optional attribute.	0..1

5.3.2.1 duration Attribute for Sample

`Sample` elements that represent the result of a computed value of a statistic **MUST** contain a `duration` attribute. For these *Data Entities*, the `timestamp` associated with the `Sample` **MUST** reference the time the data collection was completed. `timestamp` **MUST NOT** represent any other time associated with the data collection or the calculation of the statistic. The actual time the interval began can be computed by subtracting the `duration` from the `timestamp`.

Two `Sample` elements **MAY** have overlapping time periods when statistics are computed at different frequencies. For example, there may be two *Data Entities* reporting a statistic representing the average value for the readings of the same measured signal calculated over one and five minute intervals. These *Data Entities* can both have the same start time for their calculations (e.g., 05:10:00), but the `timestamp` and `duration` will be 05:11:00 and 60 seconds, respectively, for the *Data Entity* reporting the one-minute average and 05:15:00 and 300 seconds, respectively, for the *Data Entity* reporting the five-minute average. This allows for varying statistical methods to be applied with different interval lengths each having different values for the `timestamp` and `duration` attributes.

5.3.2.2 resetTriggered Attribute for Sample

Some *Data Entities* **MAY** have their reported value reset to an initial value. These reset actions may be based upon a specific elapsed time or may be triggered by a physical or logical reset action that causes the reset to occur. Examples of *Data Entities* that **MAY** have their reported value reset to an initial value are *Data Entities* representing a counter, a timer, or a statistic.

`resetTriggered` defines the `type` of reset action that caused the value of the reported data to be reset. The value reported for `resetTriggered` **MAY** be defined by the `ResetTrigger` element for the *Data Entity* in the `MTConnectDevices` document that this `Sample` element represents. If the `ResetTrigger` element is not defined in the `MTConnectDevices` document, a `resetTriggered` attribute **SHOULD** be reported in the `MTConnectStreams` document if the `type` of reset action can be determined and reported by the piece of equipment.

`resetTriggered` **MUST** only be reported for the first occurrence of a *Data Entity* after a reset action has occurred and **MUST NOT** be provided for any other occurrence of the *Data Entity* reported in a `MTConnectStreams` document. When a reset occurs, the piece of equipment **MUST** report an occurrence of the *Data Entity* that was reset even if that occurrence of the *Data Entity* would normally be suppressed based on the filtering criteria established in the `MTConnectDevices` document that this `Sample` element represents.

The *Table 10* provides the values that **MAY** be reported for `resetTriggered`:

Table 10: Values for resetTriggered

Value for resetTriggered	Description
`ACTION_COMPLETE`	The value of the *Data Entity* that is measuring an action or operation was reset upon completion of that action or operation.
`ANNUAL`	The value of the *Data Entity* was reset at the end of a 12-month period.
`DAY`	The value of the *Data Entity* was reset at the end of a 24-hour period.
`MAINTENANCE`	The value of the *Data Entity* was reset upon completion of a maintenance event.
`MANUAL`	The value of the *Data Entity* was reset based on a physical reset action.
`MONTH`	The value of the *Data Entity* was reset at the end of a monthly period.
`POWER_ON`	The value of the *Data Entity* was reset when power was applied to the piece of equipment after a planned or unplanned interruption of power has occurred.
`SHIFT`	The value of the *Data Entity* was reset at the end of a work shift.
`WEEK`	The value of the *Data Entity* was reset at the end of a 7-day period.

5.3.3 Valid Data Values for Sample

All `Sample` elements reported in an `MTConnectStreams` XML document **MUST** provide a value in the CDATA of the *Data Entity*.

The value returned in the CDATA **MUST** be reported as either a *Valid Data Value* representing the information reported from a piece of equipment or `UNAVAILABLE` when a *Valid Data Value* cannot be determined.

The *Valid Data Value* reported for a `Sample` represents the reading of the value of a continuously variable or analog data source.

The `representation` attribute for a `SAMPLE` category `DataItem` element defined in the `MTConnectDevices` document specifies how an *Agent* **MUST** record instances of the data associated with that data item and how often that data **MUST** be reported as a `Sample` element in the `MTConnectStreams` document.

The data reported for a `Sample` element associated with a `SAMPLE` category `DataItem` element with a `representation` of `VALUE` can be measured at any point-in-time and **MUST** always produce a result with a single data value.

> Note: If a `representation` attribute is not specified in the `MTConnectDevices` document for a `DataItem` element, it **MUST** be assumed that the data reported in the `MTConnectStreams` document for the *Data Entity* has a `representation` type of `VALUE`.

In the case of a `Sample` element associated with a `SAMPLE` category `DataItem` element with a `representation` attribute of `TIME_SERIES`, the data provided **MUST** be a series of data values representing multiple sequential samples of the measured value that will be provided only at the end of the completion of a sampling period. (See Section *Section 5.6.1 - Observations for DataItem with representation of TIME_SERIES* for more information on `TIME_SERIES` type data).

In the case of a `Sample` element associated with a `SAMPLE` category `DataItem` element with a `representation` attribute of `DATA_SET`, the data reported for each *key-value pair* **MUST** be provided in the same *Valid Data Values* and units as specified by the `type` attribute for the `DataItem` element.

When an *Agent* responds to a *Current Request*, the information returned in the `MTConnectStreams` document for a *Data Entity* defined to represent a *Data Set* **MUST** include the full set of *key-value pairs* that are valid for that *Data Entity*. If the *Current Request* includes an `at` query parameter, the *Agent* **MUST** provide the set of *key-value pairs* that are valid at the specified *sequence number*.

When an *Agent* responds to a *Sample Request*, the information returned in the `MTConnectStreams` document for a *Data Entity* defined to represent a *Data Set* **MUST** include only those *key-value pairs* that are valid for the *Data Entity* at each *sequence number*.

Data values provided for a `Sample` **MUST** always be a floating-point number. In the MTConnect Standard, floating-point numbers are defined as XML xs:float `type` numbers as defined by W3C. Any of the following number formats are valid XML floating `type` numbers: 1267.43233E12, -1E4, 12.78e-2, 12, 137.2847, 0, and INF.

> Note: For some `Sample` elements, the *Valid Data Value* **MAY** be restricted to specific formats. See Section 6.1 of this document for a description of any restrictions of the acceptable format for *Valid Data Value*.

For `Sample` elements, a client software application can determine the appropriate accuracy of the value reported for the *Data Entity* by applying the significantDigits attribute defined for the corresponding `DataItem` element defined in the `MTConnectDevices` document.

The *Valid Data Value* reported as CDATA for a `Sample` element **MUST** be formatted as part of the content between the element tags in the XML element representing that *Data Entity*. As an example, a `Position` is formatted as shown in *Example 5*.

Example 5: Example showing CDATA of a DataItem Element

```
<Position sequence="112" name="Xabs"
    timestamp="2016-07-28T02:06:01.364428Z"
    dataItemId="10">123.3333</Position>
```

In this example, the 123.3333 is the CDATA for `Position`. All CDATA in a `Sample` element is typed, which means that the value reported for the *Data Entity* **MUST** be formatted as defined in Section 6.1 for each *Data Entity* so that it can be validated.

5.3.4 Unavailability of Valid Data Values for Sample

If an *Agent* cannot determine a *Valid Data Value* for a `Sample` element, the value returned for the CDATA for the *Data Entity* **MUST** be reported as `UNAVAILABLE`.

Example 6 demonstrates how an *Agent* reports the value for a `Sample` in the CDATA when it is unable to determine a *Valid Data Value*:

Example 6: Example of CDATA when Data Entity is UNAVAILABLE

```
<Samples>
  <PathPosition dataItemId="p2"
      timestamp="2009-03-04T19:45:50.458305"
      subType="ACTUAL" name="Zact"
      sequence="15065113">UNAVAILABLE</PathPosition>
  <Temperature dataItemId="t6"
      timestamp="2009-03-04T19:45:50.458305" name="temp"
      sequence="150651134">UNAVAILABLE</Temperature>
</Samples>
```

5.4 Events Container

`Events` is a XML container type element. `Events` organizes the *Data Entities* returned in the `MTConnectStreams` XML document for those `DataItem` elements defined with a `category` attribute of `EVENT` in the `MTConnectDevices` document.

A separate Events container will be provided for the data returned for the DataItem elements associated with each *Structural Element* of a piece of equipment defined in the MTConnectDevices document.

Table 11: MTConnect Event Element

Element	Description	Occurrence
Events	An XML container type element that organizes the data reported in the MTConnectStreams document for DataItem elements defined in the MTConnectDevices document with a category attribute of EVENT. A separate Events container **MUST** be provided for each ComponentStream element for which data is returned for a DataItem element defined in the MTConnectDevices document with a category attribute of EVENT. If provided in the document, an Events XML container **MUST** contain at least one Event element.	0..1

5.5 Event Data Entities

An Event XML element provides the information and data provided from a piece of equipment for those DataItem elements defined with a category attribute of EVENT in the MTConnectDevices document.

Event is an abstract type XML element and will never appear directly in the MTConnectStreams XML document. As an abstract type XML element, Event will be replaced in the XML document by a specific type of Event specified by the *Element Name* for that *Data Entity*. The different types of Event elements are defined in *Section 6.2 - Event Element Names*. Examples of XML elements representing Event include Block and Execution.

Event is similar to Sample, but its value can change with unpredictable frequency. Events do not report intermediate values. As an example, when Availability transitions from UNAVAILABLE to AVAILABLE, there is no intermediate state that can be inferred.

Event elements **MAY** report data values defined by a controlled vocabulary as specified in *Section 6.2 - Event Element Names*, by numeric values, or by a character string representing text or a message provided by the piece of equipment.

Table 12: MTConnect Event Element

Element	Description	Occurrence
`Event`	An XML element which provides the information and data reported from a piece of equipment for those `DataItem` elements defined with a `category` attribute of `EVENT` in the `MTConnectDevices` document. `Event` is an abstract type XML element. It is replaced in the `MTConnectStreams` document by a specific type of `Event` element. There **MAY** be multiple types of `Event` elements in a `Events` container.	1..*

5.5.1 XML Schema Structure for Event

The XML schema in *Figure 7* represents the structure of an `Event` XML element showing the attributes defined for `Event` elements.

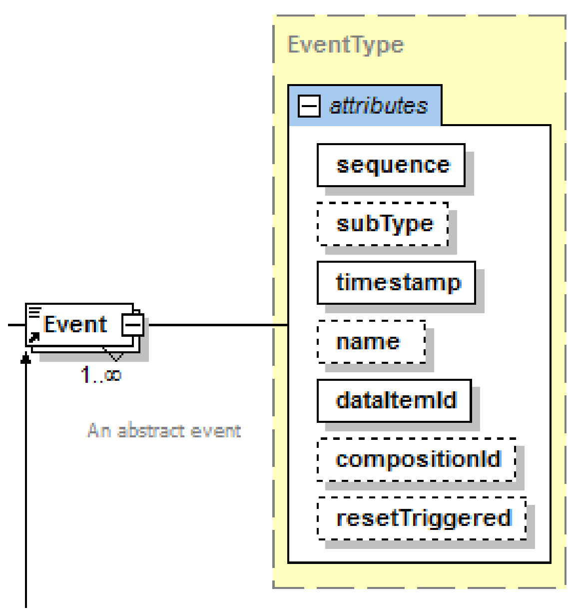

Figure 7: Event Schema Diagram

5.5.2 Attributes for Event

Table 13 defines the attributes that **MAY** be used to provide additional information for an `Event` XML element.

Table 13: Attributes for Event

Attribute	Description	Occurrence
`sequence`	A number representing the sequential position of an occurrence of the `Event` in the data buffer of an *Agent*. `sequence` is a required attribute. `sequence` **MUST** have a value represented as an unsigned 64-bit value from 1 to $2^{64} - 1$.	1
`subType`	The `subType` of the *Data Entity*. `subType` is an optional attribute. `subType` **MUST** match the `subType` attribute of the `DataItem` element as defined in the `MTConnectDevices` document that the `Event` element represents.	0..1
`timestamp`	The most accurate time available to a piece of equipment that represents the point in time that the data reported for the `Event` was measured. `timestamp` is a required attribute.	1
`name`	The name of the `Event` element. `name` is an optional attribute. `name` **MUST** match the `name` attribute of the `DataItem` element defined in the `MTConnectDevices` document that the `Event` element represents. An NMTOKEN XML type.	0..1

Continuation of Table 13		
Attribute	Description	Occurrence
dataItemId	The unique identifier for theEvent element. dataItemId is a required attribute. dataItemId **MUST** match the id attribute of the DataItem element defined in the MTConnectDevices document that the Event element represents.	1
resetTriggered	For those DataItem elements that report data that may be periodically reset to an initial value, resetTriggered identifies when a reported value has been reset and what has caused that reset to occur. resetTriggered is an optional attribute. resetTriggered **MUST** only be provided for the specific occurrence of a *Data Entity* reported in the MTConnectStreams document when the reset occurred and **MUST NOT** be provided for any other occurrence of the *Data Entity* reported in a MTConnectStreams document.	0..1
compositionId	The identifier of the Composition element defined in the MTConnectDevices document associated with the data reported for the Event element. compositionId is an optional attribute.	0..1

5.5.3 Valid Data Values for Event

Event elements reported in an MTConnectStreams XML document **MUST** provide a value in the CDATA of the *Data Entity*.

The value reported in the CDATA **MUST** be reported as either a *Valid Data Value* representing the information reported from a piece of equipment or UNAVAILABLE when a *Valid Data Value* cannot be determined.

The *Valid Data Value* reported for an `Event` represents a distinct piece of information provided from a piece of equipment. Unlike `Sample`, `Event` does not report intermediate values that vary over time. `Event` reports information that, when provided at any specific point in time, represents the current state of the piece of equipment.

The `representation` attribute for an `EVENT` category data item defined in the `MTConnectDevices` document specifies how an *Agent* **MUST** record instances of data associated with that data item and how that data **MUST** be reported as an `Event` element in the `MTConnectStreams` document.

The data reported for an `Event` element associated with an `EVENT` category data item with a `representation` attribute of `VALUE` **MUST** be either an integer, a floating-point number, a descriptive value (text string) representing one of two or more state values defined for that data item, or a text string representing a message.

If a `representation` attribute is not specified for a data item in an `MTConnectDevices` document, the designation for the `representation` attribute **MUST** be interpreted as `VALUE`.

In the case of an `Event` element associated with a `EVENT` category `DataItem` element with a `representation` attribute of `DATA_SET`, the data reported for each *key-value pair* **MUST** be provided in the same *Valid Data Values* and units as specified by the `type` attribute for the `DataItem` element.

When an *Agent* responds to a *Current Request*, the information returned in the `MTConnectStreams` document for a *Data Entity* defined to represent a *Data Set* **MUST** include the full set of *key-value pairs* that are valid for that *Data Entity*. If the *Current Request* includes an `at` query parameter, the *Agent* **MUST** provide the set of *key-value pairs* that are valid at the specified *sequence number*.

When an *Agent* responds to a *Sample Request*, the information returned in the `MTConnectStreams` document for a *Data Entity* defined to represent a *Data Set* **MUST** include only those *key-value pairs* that are valid for the *Data Entity* at each *sequence number*
The *Valid Data Value* reported as CDATA for an `Event` element **MUST** be formatted as part of the content between the element tags in the XML element representing that *Data Entity*. As an example, `Event` elements are formatted as shown in *Example 7*:

Example 7: Example of Event Element

```
<PartCount dataItemId="pc4"
    timestamp="2009-02-26T02:02:36.48303"
    name="pcount" sequence="185">238</PartCount>
<ControllerMode dataItemId="p3"
    timestamp="2009-02-26T02:02:35.716224"
    name="mode" sequence="192">AUTOMATIC</ControllerMode>
    <Block dataItemId="cn2" name="block" sequence="206"
```

```
        timestamp="2009-02-26T02:02:37.394055">G0Z1</Block>
```

In these examples, `238` is the CDATA for `PartCount` and is a numeric value; `AUTOMATIC` is the CDATA for the `ControllerMode` and is a descriptive value representing a state for the *Data Entity*; and `G0Z1` is a text string representing a message describing the program code associated with the `Block` *Data Entity*.

5.5.4 Unavailability of Valid Data Value for Event

If an *Agent* cannot determine a *Valid Data Value* for an `Event` element, the value returned for the CDATA for the *Data Entity* **MUST** be reported as `UNAVAILABLE`.

The example in *Example 8* demonstrates how an *Agent* reports the value for an `Event` in the CDATA when it is unable to determine a *Valid Data Value*:

Example 8: Example of Event Element when data value is UNAVAILABLE

```
<Events>
  <ControllerMode dataItemId="p3"
      timestamp="2009-02-26T02:02:35.716224" name="mode"
      sequence="182">UNAVAILABLE</ControllerMode>
</Events>
```

5.6 Representations

A `representation` specifies the format and structure of the information for an *observation*. The default `representation` is `VALUE` indicating the format as specified in *MTConnect Standard: Part 3.0 - Streams Information Model*.

A `representation`, other than `VALUE`, will modify the *Element Name* of the *observation* by appending the pascal case of the `representation` as follows:

- A `DataItem` with `type` `TEMPERATURE` and `representation` of `TIME_SERIES` becomes `TemperatureTimeSeries`
- **DEPRECATED** A `DataItem` with `type` `PART_COUNT` and `representation` of `DISCRETE` (**DEPRECATED** in *Version 1.5*) becomes `PartCountDiscrete`
- A `DataItem` with `type` `VARIABLE` and `representation` of `DATA_SET` becomes `VariableDataSet`

- A DataItem with type WORK_OFFSET and representation of TABLE becomes WorkOffsetTable

The following constraints apply to each representation:

- A DataItem with representation TIME_SERIES **MUST** have a category SAMPLE
- **DEPRECATED** A DataItem with representation DISCRETE (**DEPRECATED** in *Version 1.5*) **MUST** have a category EVENT
- A DataItem with representation DATA_SET **MUST** have a category EVENT or SAMPLE
- A DataItem with representation TABLE **MUST** have a category EVENT or SAMPLE

5.6.1 Observations for DataItem with representation of TIME_SERIES

A DataItem with TIME_SERIES representation **MUST** have a category of SAMPLE.

A *Time Series observation* **MUST** have a sampleCount attribute.

Time Series observation **MUST** report multiple values at fixed intervals in a single *observation*. At minimum, one of DataItem or *observation* **MUST** specify the sampleRate in *hertz* (values/second); fractional rates are permitted. When the *observation* and the DataItem specify the sampleRate, the *observation* sampleRate supersedes the DataItem.

The *observation* **MUST** set the timestamp to the time the last value was observed. The duration **MAY** indicate the time interval from the first to the last value in the series.

In XML, the format of the *Time Series observation* **MUST** be space-separated floating-point numbers.

5.6.1.1 XML Schema for Time Series Observation

Figure 8 shows the attributes that can be applied to all TIME_SERIES *observations*.

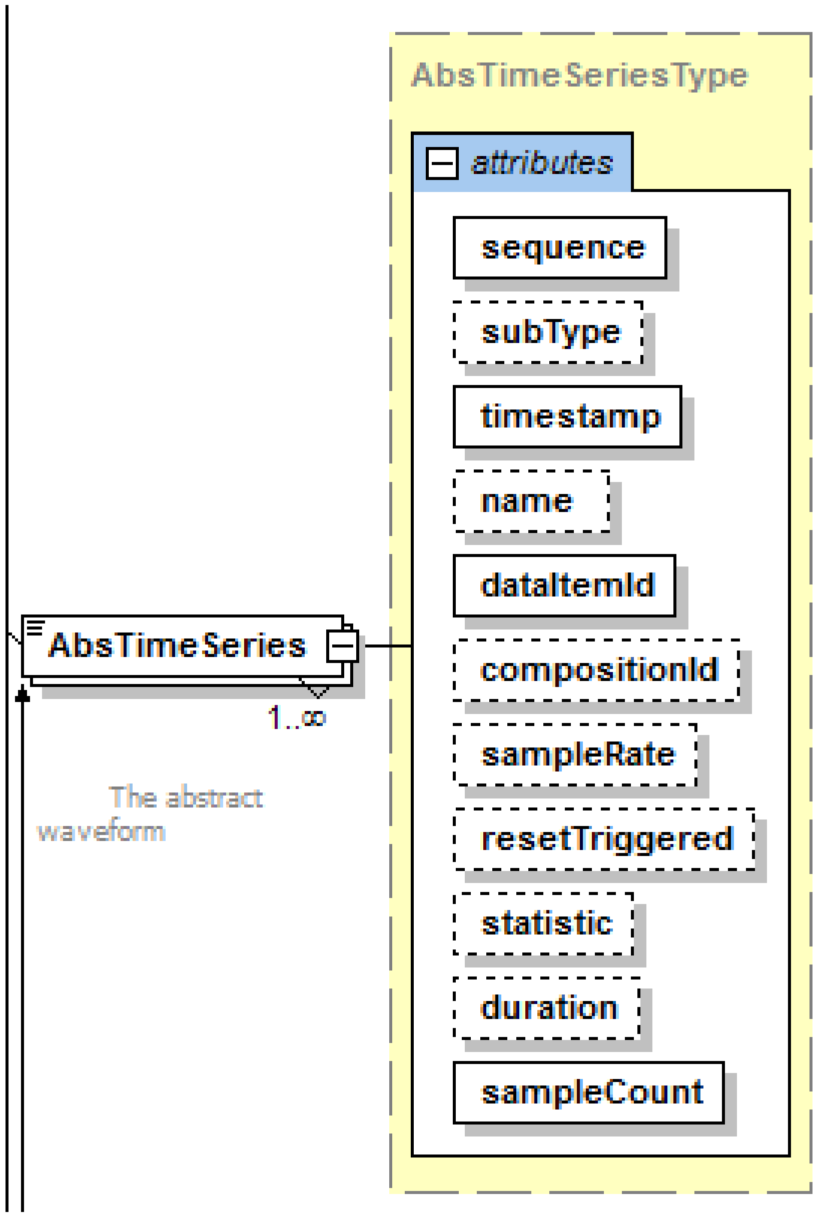

Figure 8: AbsTimeSeries Schema Diagram

5.6.1.2 Attributes for Time Series Observation

Table 14 defines the additional attribute provided for a DataItem of category SAMPLE with a representation attribute of TIME_SERIES.

Table 14: Attributes for Time Series Observation

Attribute	Description	Occurrence
sampleCount	The number of values given for the *observation*	1

5.6.2 Observations for DataItem with representation of DISCRETE (DEPRECATED)

MTConnect Version 1.5 replaced representation DISCRETE (**DEPRECATED** in *Version 1.5*) with a discrete *attribute* for DataItem.

DISCRETE (**DEPRECATED** in *Version 1.5*) **MUST** only be used with a DataItem with a category of EVENT.

Each occurrence of the *observation* **MAY** have the same value as the previous occurrence, and **MUST NOT** suppress duplicates.

Examples of DISCRETE (**DEPRECATED** in *Version 1.5*) information as follows: A PartCount reporting the completion of each part using a 1 to indicate completion of a single part, a Message that occurs each time a door opens.

5.6.3 Observations for DataItem with representation of DATA_SET

A DataItem with DATA_SET representation **MUST** have a category of SAMPLE or EVENT.

A *Data Set observation* **MUST** have a count attribute.

Data Set observation reports multiple values as a set of *key-value pairs* where each *key* **MUST** be unique. The representation of the *key-value pair* in XML is an Entry. The value of each Entry **MUST** have the same constraints and format as the *observation* defined for the VALUE representation for the DataItem type.

The meaning of each Entry **MAY** be provided as the DataItem EntryDefinition.

5.6.3.1 XML Schema for Data Set Observation

Figure 9 represents the *XML Schema* of a `DataItem` with a `representation` attribute of `DATA_SET`.

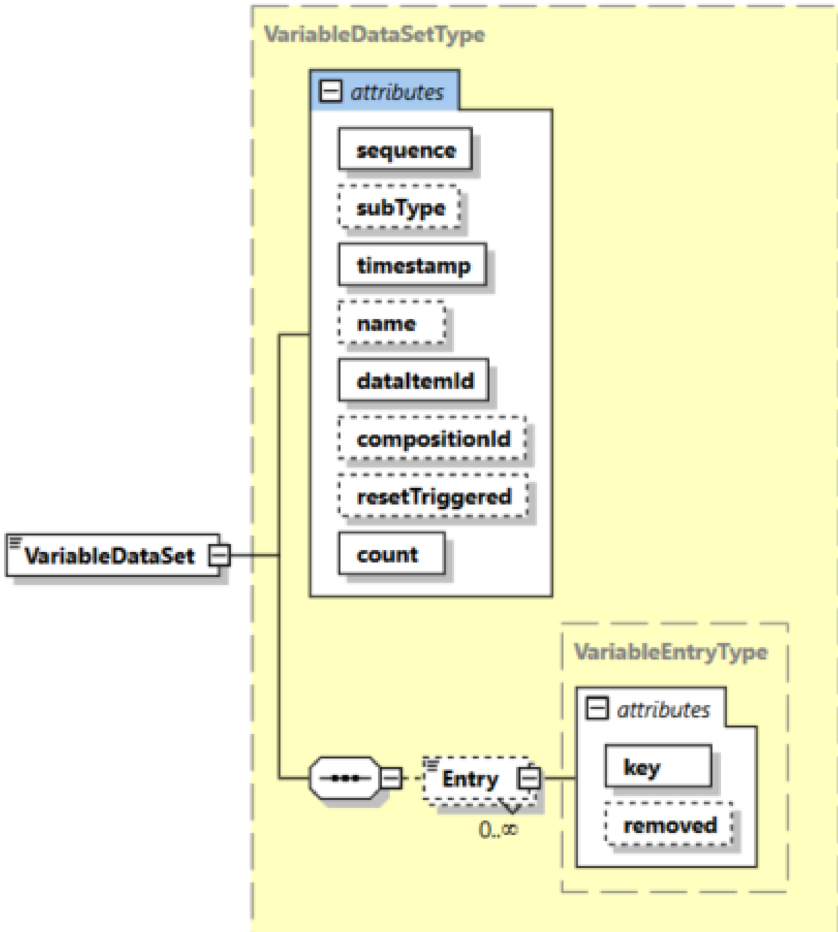

Figure 9: Sample Data Set Schema Diagram

Table 15 defines the additional attribute provided for a `DataItem` with a `representation` attribute of `DATA_SET`.

Table 15: Attributes for Data Set Observation

Attribute	Description	Occurrence
`count`	The number of `Entry` elements for the *observation*.	1

Table 16 defines the elements provided for a `DataItem` with a `representation` attribute of `DATA_SET`.

Table 16: Elements for Data Set Observation

Element	Description	Occurrence
`Entry`	A *key-value pair* published as part of a *Data Set observation*.	0..*

5.6.3.2 Entry Element for Data Set Observation

Figure 10 represents the *XML Schema* structure for a `Entry` XML element that represents the information published for a *key-value pair*. Any number of `Entry` elements **MAY** be provided for a *Data Entity* defined with a `representation` attribute of `DATA_SET`.

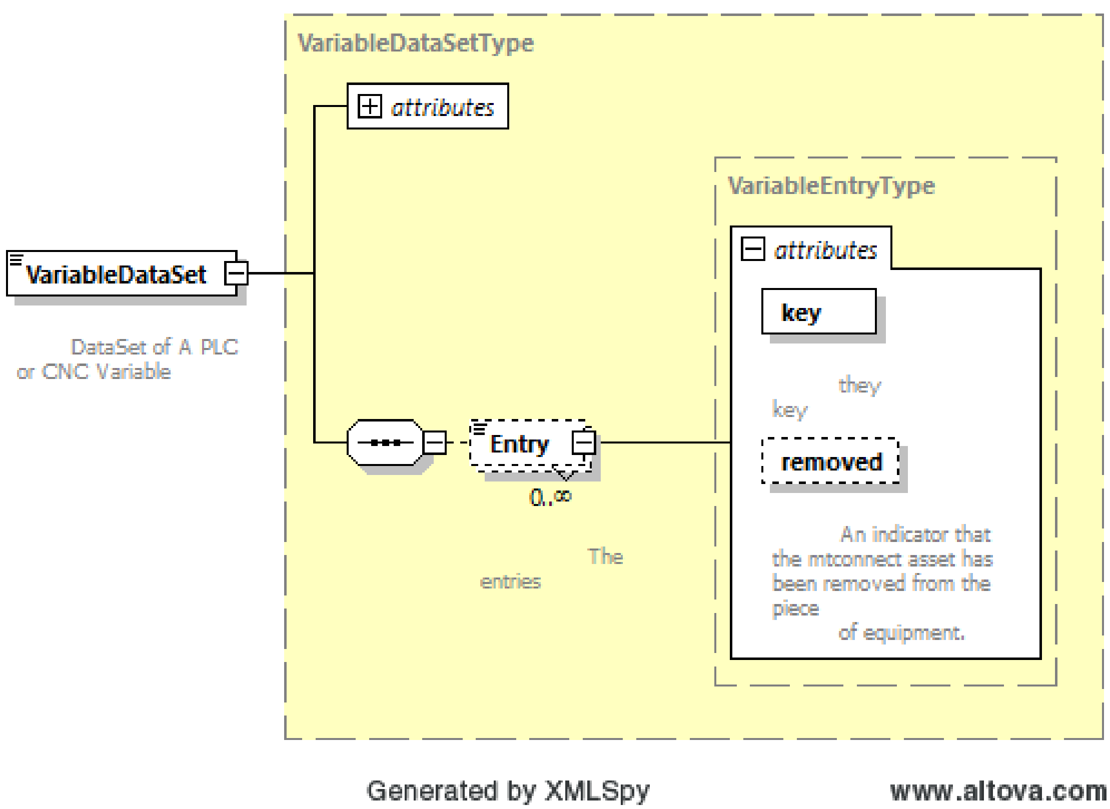

Figure 10: Entry Element Schema Diagram

Notes: The `VariableDataSet` is an example of a `DataItem` with `type` `VARIABLE` and `representation` `DATA_SET`.

The following is an example in XML of `Entry` elements for a `DataItem` with `type` `VARIABLE`:

Example 9: Example of multiple key-value pairs Reported for a Data Entity

```
<VariableDataSet timestamp="..." sequence="..." count="2">
  <Entry key="a101">100.21</Entry>
  <Entry key="a102">609</Entry>
  <Entry key="a103" removed="true" />
</VariableDataSet>
```

5.6.3.3 Attributes for Entry Element for Data Set Observation

Table 17 defines the attributes provided for a `Entry` XML element.

Table 17: Attributes for Entry

Attribute	Description	Occurrence
`key`	A unique identifier for each *key-value pair*. The value provided for `key` **MUST** be unique in a set of `Entry` elements. The value provided for `key` **MUST** be an XML NMTOKEN type.	1
`removed`	Boolean removal indicator of a *key-value pair* that **MUST** be `true` or `false`. `true` indicates the `Entry` is removed. `false` (default) indicates the `Entry` is present.	0..1

5.6.3.4 Constraints for Entry Values

The value of each `Entry` **MUST** have the same restrictions as the value of an *observation* with `representaton` of `VALUE`.

An `Entry` **MAY** be further constrained by the `DataItem` definition (see *MTConnect Standard: Part 2.0 - Devices Information Model*), for example a `VariableDataSet` having a string value **MAY** have a floating-point `Temperature` value. A restriction **MUST NOT** be broadened or removed, for example, the value "READY" **MUST NOT** occur with a `TemperatureDataSet` constrained to floating-point numbers.

The *MTConnect Standard: Part 2.0 - Devices Information Model* `DataItem` `Definition` **MAY** provide the `type` and `units` of an `Entry` for a `key`.

5.6.4 Management of Data Set Observations

An *Agent* **MUST** maintain the current state of the *Data Set* as described in *MTConnect Standard Part 1.0 - Overview and Fundamentals Section Part 1: Management of Streaming Data Storage*.

One or more *key-value pairs* **MAY** be added, removed, or changed in an *observation*. An *Agent* **MUST** publish the changes to one or more *key-value pairs* as a single *observation*. An *Agent* **MUST** indicate the removal of a *key-value pair* from a *Data Set* using the `removed` attribute equal `true`.

When the `DataItem` `discrete` attribute is `false` or is not present, an *Agent* in response to a *sample request* **MUST** only publish the changed *key-value pair* since the previous state of the *Data Set*.

When the `DataItem` `discrete` attribute is `true`, an *Agent*, in response to a *sample request*, **MUST** report all *key-value pairs* ignoring the state of the *Data Set*.

When an *Agent* responds to a *Current Request*, the *response document* **MUST** include the full set of *key-value pairs*. If the *Current Request* includes an `at` *query parameter*, the *Agent* **MUST** provide the set of *key-value pairs* at the *sequence number*.

When an *observation reset* occurs, the *Data Set* **MUST** remove all *key-value pairs* making the set empty. The *observation* **MAY** simultaneously populate the *Data Set* with new *key-value pairs*. The previous entries **MUST NOT** be included and **MUST NOT** have `removed` attribute equal `true`.

When the *observation* is `UNAVAILABLE` the *Data Set* **MUST** remove all *key-value pairs* making the set empty.

5.6.5 Observations for DataItem with representation of TABLE

A *Table* represents two-dimensional sets of *key-value pairs* where the `Entry` represents rows containing sets of *key-value pairs* given by `Cell` elements. The *Table* has the same behavior as the *Data Set* for change tracking, clearing, and history. When an `Entry` changes. All `Cell` elements update at the same time; they are not tracked separately like `Entry`.

The meaning of each `Entry` and `Cell` **MAY** be provided as the `DataItem` `EntryDefinition` and `CellDefinition`.

The `Entry` `key` attribute **MUST** be the unique identity of the `Entry` within an *observation*. The `Cell` `key` attribute **MUST** be the unique identity of the `Cell` within an `Entry`.

5.6.5.1 Structure of Table Observations

Figure 11 represents the XML schema representing `DataItem` defined in the *MTConnect Standard: Part 2.0 - Devices Information Model* with a `representation` attribute of `TABLE`.

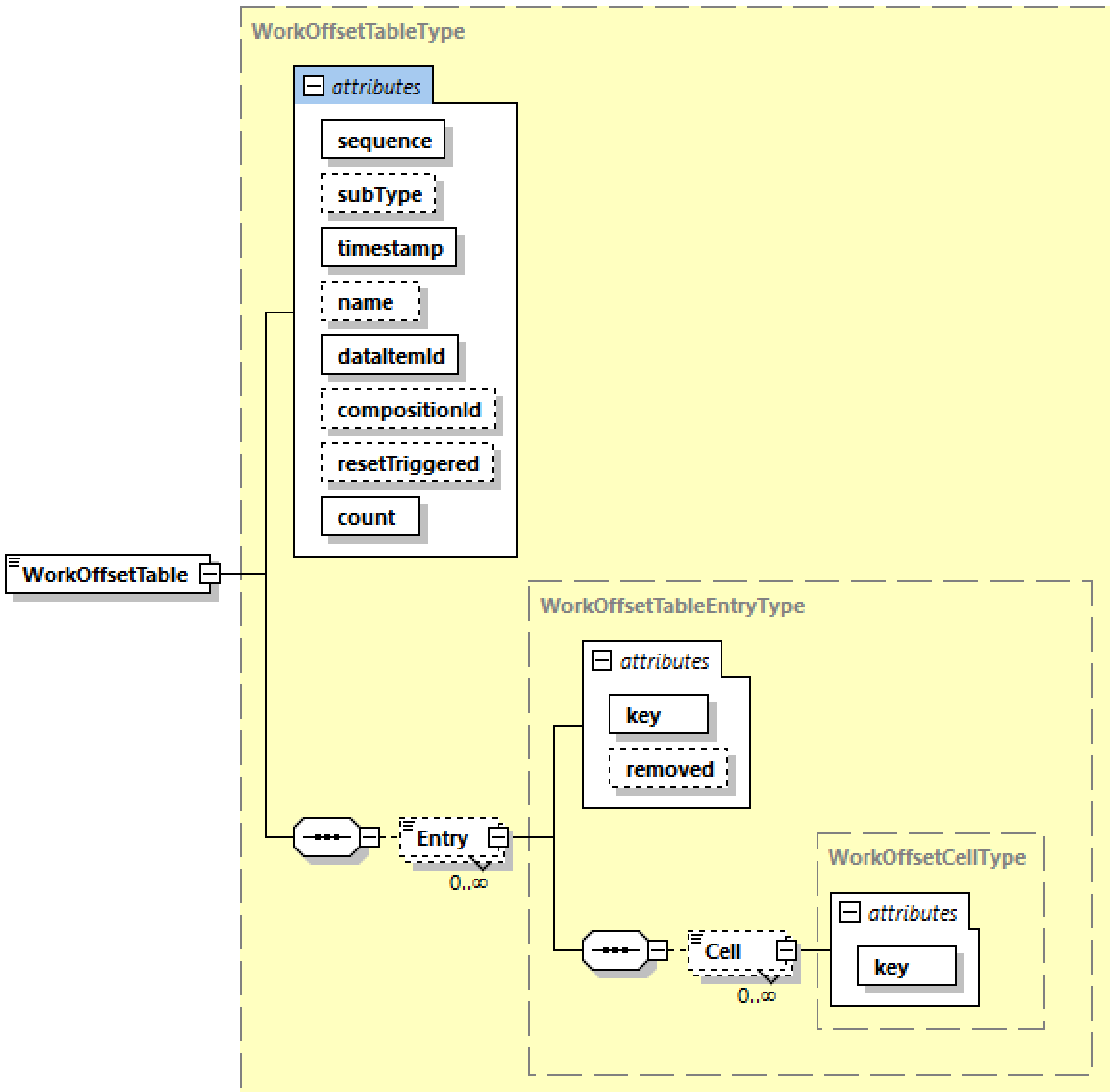

Figure 11: Table Schema Diagram

5.6.5.2 Attributes of Table Observations

Table 18: Attributes for Table

Attribute	Description	Occurrence
`count`	Represents the number of *key-value pairs* represented as `Entry` elements. `count` **MUST** be provided when the `DataItem` `representation` is `TABLE`.	1

5.6.5.3 Elements of Table Observations

Table 19 An `Entry` is the only child element that **MAY** be associated with a *Table observation*.

Table 19: Elements for Table

Element	Description	Occurrence
`Entry`	A *key-value-pair* containing a set of *key-value pairs*.	0..*

5.6.5.3.1 Structure for Table Entry for an Observation

An `Entry` represents a *Row* subdivided into `Cell` elements when representing tabular data. The meaning of an `Entry` **MAY** be given in the `DataItem` `EntryDefinition` associated with its unique `key`.

5.6.5.3.2 Attributes for Table Entry for an Observation

See *Section 5.6.3.3 - Attributes for Entry Element for Data Set Observation*.

5.6.5.3.3 Elements for Table Cell for an Observation

Table 20: Elements for Table Cell

Element	Description	Occurrence
`Cell`	An element representing a *key-value pair* published as part of an `Entry`.	0..*

5.6.5.3.4 Structure for Table Cell for an Entry

A `Cell` represents a *Column* within a *Row* of a tabular data. The `DataItem` `CellDefinition` **MAY** give the meaning of the `Cell` associated with its unique `key`.

Any number of `Cell` elements **MAY** be provided for an `Entry` for a *Table observation*.

The `type` of the `DataItem` constrains the *CDATA* of the `Cell` as specified in *MTConnect Standard: Part 2.0 - Devices Information Model*.

5.6.5.3.5 Attributes for Table Cell for an Observation

Table 21 defines the attributes provided for a `Cell` XML element for an `Entry`.

Table 21: Attributes for Table Cell

Attribute	Description	Occurrence
`key`	A unique identifier for each *key-value pair*. The value provided for `key` **MUST** be unique in a set of `Cell` elements. The value provided for `key` **MUST** be an XML NMTOKEN type.	1

5.6.5.3.6 Constraints for Cell Values

The value of each `Cell` **MUST** have the same restrictions as the value of an *observation* with `representaton` of `VALUE`.

An `Cell` **MAY** be further constrained by the `DataItem` definition (see *MTConnect Stan-*

dard: Part 2.0 - Devices Information Model), for example a VariableDataSet having a string value **MAY** have a floating-point Temperature value. A restriction **MUST NOT** be broadened or removed, for example, the value "READY" **MUST NOT** occur with a TemperatureDataSet constrained limited to floating-point numbers.

The *MTConnect Standard: Part 2.0 - Devices Information Model* DataItem Definition **MAY** provide the type and units of a Cell for a key.

5.6.5.3.7 Example Table Observation

Example 10: Example of WorkpieceOffset observation for a TABLE representation

```
<WorkpieceOffsetTable dataItemId="wp1" timestamp="TIME" name="wpo"
    sequence="15" count="3">
  <Entry key="G53.1"><Cell key="X">1</Cell><Cell key="Y">2</Cell>
      <Cell key="Z">3</Cell></Entry>
  <Entry key="G53.2"><Cell key="X">4</Cell><Cell key="Y">5</Cell>
      <Cell key="Z">6</Cell></Entry>
  <Entry key="G53.3"><Cell key="U">10</Cell><Cell key="X">7</Cell>
      <Cell key="Y">8</Cell><Cell key="Z">9</Cell></Entry>
</WorkpieceOffsetTable>
```

5.7 Condition Container

Condition is a XML container type element. Condition organizes the *Data Entities* returned in the MTConnectStreams XML document for those DataItem elements defined with a category attribute of CONDITION in the MTConnectDevices document.

A separate Condition container will be provided for the data returned for the DataItem elements associated with each *Structural Element* of a piece of equipment defined in the MTConnectDevices document.

Table 22: MTConnect Condition Element Container

Element	Description	Occurrence
`Condition`	An XML container type element that organizes the data reported in the `MTConnectStreams` document for `DataItem` elements defined in the `MTConnectDevices` document with a `category` attribute of `CONDITION`. A separate `Condition` container **MUST** be provided for each `ComponentStream` element for which data is returned for a `DataItem` element defined in the `MTConnectDevices` document with a category attribute of `CONDITION`. If provided in the document, a `Condition` XML container **MUST** contain at least one `Condition` element.	0..1

5.8 Condition Data Entity

A `Condition` XML element provides the information and data provided from a piece of equipment for those `DataItem` elements defined with a `category` attribute of `CONDITION` in the `MTConnectDevices` document.

`Condition` provides information reported by a piece of equipment describing its health and ability to function.

`Condition` is an abstract type XML element and will never appear directly in the `MTConnectStreams` XML document. As an abstract type XML element, `Condition` will be replaced in the XML document by a *Data Entity* representing the `CONDITION` category `DataItem` element defined in the `MTConnectDevices` document that this `Condition` element represents.

The *Data Entities* represented by `Condition` are structured differently than the *Data Entities* representing `Sample` and `Event`. The *Element Name* for each `Condition` element reported in the `MTConnectStreams` document defines the *Fault State* of the *Data Entity*. A `Condition` element is identified by the *Structural Element* to which it is associated, along with the `type` and `dataItemId` defined for the element. *Section 6.3 - Types of Condition Elements* provides details on the different `types` of `Condition` elements.

Table 23: MTConnect Condition Element

Element	Description	Occurrence
`Condition`	An XML element which provides the information and data reported from a piece of equipment for those `DataItem` elements defined with a `category` attribute of `CONDITION` in the `MTConnectDevices` document. `Condition` is an abstract type XML element. It is replaced in the `MTConnectStreams` document by a specific type of `Condition` element. There **MAY** be multiple types of `Condition` elements in a `Conditions` container.	1..*

`CONDITION` type `DataItem` elements defined in the `MTConnectDevices` document **MAY** report multiple simultaneous *Fault States* in the `MTConnectStreams` document. This is unlike a `SAMPLE` or `EVENT` `DataItem` element that can only report a single occurrence of a `Sample` or `Event` element in the `MTConnectStreams` document at any one point in time.

For example, a controller on a piece of equipment may detect and report multiple format errors in a motion program. Each error represents a separate *Fault State* from the controller. Each *Fault State* is represented as a separate `Condition` element in the `MTConnectStreams` document since each *Fault State* **MUST** be identified and tracked individually in the document.

5.8.1 Element Names for Condition

`Condition` elements are reported differently from other *Data Entity* `types`. The *Element Name* reported for a `Condition` element represents the *Fault State* (`Normal`, `Warning`, or `Fault`) associated with each `Condition`.

Examples of XML elements representing `Condition` elements for each of the possible *Fault States* are shown in *Example 11*:

Example 11: Example of Condition Element Fault States

```
<Normal type="MOTION_PROGRAM" dataItemId="cc2" sequence="25"
    timestamp="2010-04-06T06:19:35.153141"</Normal>
<Fault type="COMMUNICATIONS" dataItemId="cc1" sequence="26"
```

```
    nativeCode="IO1231" timestamp="2010-04-
    06T06:19:35.153141">Communications error</Fault>
<Warning type="LOGIC_PROGRAM" dataItemId="pm6" sequence="32"
    timestamp="2010-04-06T06:19:35.153141"<Warning/>
```

5.8.2 XML Schema Structure for Condition

The XML schema in *Figure 12* represents the structure of a `Condition` XML element showing the attributes defined for `Condition` elements.

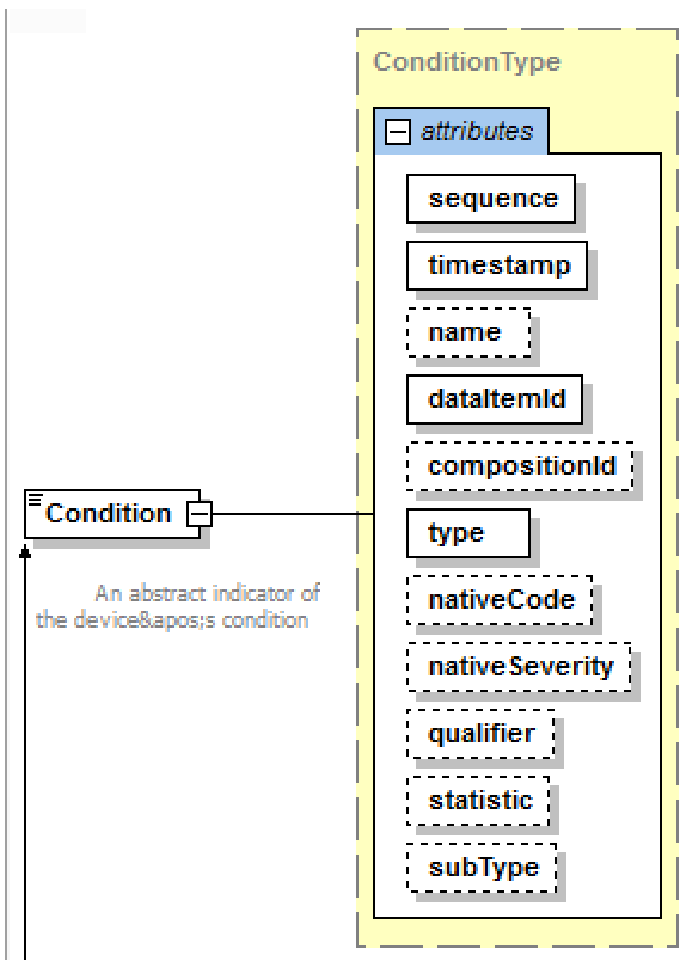

Figure 12: Condition Schema Diagram

5.8.3 Attributes for Condition

Table 24 defines the attributes used to provide additional information for a `Condition` XML element.

Table 24: Attributes for Condition

Attribute	Description	Occurrence
`sequence`	A number representing the sequential position of an occurrence of the `Condition` in the data buffer of an MTConnect Agent. `sequence` is a required attribute. `sequence` **MUST** have a value represented as an unsigned 64-bit value from 1 to $2^{64} - 1$.	1
`timestamp`	The most accurate time available to a piece of equipment that represents the point in time that the data reported for the `Condition` was measured. `timestamp` is a required attribute.	1
`name`	The name of the `Condition` element. `name` is an optional attribute. `name` **MUST** match the `name` attribute of the `DataItem` element defined in the `MTConnectDevices` document that the `Condition` element represents. An NMTOKEN XML type.	0..1
`dataItemId`	The unique identifier for the`Condition` element. `dataItemId` is a required attribute. `dataItemId` **MUST** match the id attribute of the `DataItem` element defined in the `MTConnectDevices` document that the `Condition` element represents.	1

Continuation of Table 24		
Attribute	Description	Occurrence
type	An identifier of the type of fault represented by the Condition element. type is a required attribute. type **MUST** match the type attribute of the DataItem element defined in the MTConnectDevices document that this Condition element represents.	1
nativeCode	The native code (usually an alpha-numeric value) generated by the controller of a piece of equipment providing a reference identifier for a Condition. nativeCode is an optional attribute. This is the same information an operator or maintenance personnel may see as a reference code designating a specific fault code provided by the piece of equipment.	0..1
nativeSeverity	If the piece of equipment designates a severity level to a fault, nativeSeverity reports that severity information to a client software application. nativeSeverity is an optional attribute.	0..1

Continuation of Table 24		
Attribute	Description	Occurrence
qualifier	qualifier provides additional information regarding a *Fault State* associated with the measured value of a process variable. qualifier is an optional attribute. qualifier defines whether the *Fault State* represented by the Condition indicates a measured value that is above or below an expected value of a process variable. If the *Fault State* represents a measured value that is greater than the expected value for the process variable, qualifier **MUST** report a value of HIGH. If the *Fault State* represents a measured value that is less than the expected value for the process variable, qualifier **MUST** report a value of LOW.	0..1
statistic	statistic provides additional information describing the meaning of the Condition element. statistic is an optional attribute. statistic **MUST** match the statistic attribute of the DataItem element defined in the MTConnectDevices document that this Condition element represents.	0..1
subType	subType provides additional information describing the meaning of the Condition element. subType is an optional attribute. subType **MUST** match the subType attribute of the DataItem element defined in the MTConnectDevices document that this Condition element represents.	0..1

Continuation of Table 24		
Attribute	Description	Occurrence
compositionId	The identifier of the Composition element defined in the MTConnectDevices document associated with the data reported for the Condition element. compositionId is an optional attribute.	0..1
xs:lang	An optional attribute that specifies the language of the CDATA returned for the Condition. Refer to IETF RFC 4646 (http://www.ietf.org/rfc/rfc4646.txt) or successor for a full definition of the values for this attribute. xs:lang does not appear in the schema diagram.	0..1

5.8.3.1 qualifier Attribute for Condition

Many Condition elements report the *Fault State* associated with the measured value of a process variable.

qualifier provides an indication whether the measured value is above or below an expected value of a process variable.

As an example, a Condition element with a type attribute of ~~AMPERAGE~~ may differentiate between a higher than expected amperage and a lower than expected amperage by using the qualifier attribute.

When a qualifier of either HIGH or LOW is used with Fault and Warning, the *Fault States* can be differentiated as follows:

Fault,LOW

Warning,LOW

Normal

Warning,HIGH

```
Fault,HIGH
```

Example 12 is an example of an XML element representing `Condition` using `qualifier`:

Example 12: Example of a Condition Element using qualifier

```
<Warning type="FILL_LEVEL" dataItemId="pm6"
    qualifier="HIGH" sequence="32"
    timestamp="2009-11-13T08:32:18">...</Warning>
```

5.8.4 Valid Data Value for Condition

`Condition` elements reported in an `MTConnectStreams` XML document **MAY** provide a value in the CDATA of the *Data Entity* when additional information regarding the *Fault State* is available.

A *Valid Data Value* for the CDATA included in a `Condition` element **MAY** be any text string. A *Valid Data Value* is not required to be reported for a `Condition` category *Data Entity*. The *Fault State* and the attributes provided in a `Condition` element **MAY** be sufficient to fully describe the *Data Entity*.

The *Valid Data Value* reported as CDATA for a `Condition` element **MUST** be formatted as part of the content between the element tags in the XML element representing that *Data Entity*. As an example, `Condition` elements are formatted as shown in *Example 13*:

Example 13: Example of CDATA for Condition

```
<Warning type="FILL_LEVEL" dataItemId="pm6"
    qualifier="HIGH" sequence="32" timestamp=
    "2009-11-13T08:32:18">Fill Level on Tank
    #12 is reaching a high level</Warning>
```

In this example, the “Fill Level on Tank #12 is reaching a high level" is the CDATA for the *Data Entity*.

5.9 Unavailability of Fault State for Condition

When an *Agent* cannot determine a valid *Fault State* for a `Condition` element, it **MUST** report the *Element Name* for the *Data Entity* as Unavailable.

Example 14 demonstrates how an *Agent* reports a `Condition` category *Data Entity* when it is unable to determine a valid *Fault State*:

Example 14: Example of Condition when Fault State is UNAVAILABLE

```
<Unavailable type="MOTION_PROGRAM" dataItemId="cc2"
    sequence="25" timestamp=
    "2009-11-13T08:32:18">...</Unavailable>
<Unavailable type="COMMUNICATIONS" dataItemId="cc1"
    sequence="26" timestamp=
    "2009-11-13T08:32:18">...</Unavailable>
<Unavailable type="LOGIC_PROGRAM" dataItemId="cc3"
    sequence="28" timestamp=
    "2009-11-13T08:32:18">...</Unavailable>
<Unavailable type="LOGIC_PROGRAM" dataItemId="pm6"
    sequence="32" timestamp=
    "2009-11-13T08:32:18">...</Unavailable>
```

6 Listing of Data Entities

Data Entities that report data in MTConnectStreams documents are represented by Sample, Event, or Condition elements based upon the category and type attributes defined for the corresponding DataItem XML element in the MTConnectDevices document.

Each *Data Entity* in the MTConnectStreams document has an *Element Name*, as defined in the following sections, based upon the corresponding category attribute defined for that DataItem element in the MTConnectDevices document.

6.1 Sample Element Names

Table 25 lists the XML elements that can be placed in the Samples container of the ComponentStream element.

The *Table 25* shows both the type attribute for each SAMPLE category DataItem element as defined in the MTConnectDevices document and the corresponding *Element Name* for the *Data Entity* that **MUST** be reported as a Sample element in the MTConnectStreams document.

Table 25: Element Names for Sample

DataItem Type	Element Name	Description
ACCELERATION	Acceleration	The positive rate of change of velocity. If a subType is not specified, the reported value for the data **MUST** default to the subType of ACTUAL. Subtypes of Acceleration are ACTUAL, COMMANDED and PROGRAMMED. Acceleration **MUST** be reported in units of MILLIMETER/SECOND^2.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
ACCUMULATED_TIME	AccumulatedTime	The measurement of accumulated time for an activity or event. AccumulatedTime **MUST** be reported in units of SECOND. **DEPRECATION WARNING** : May be deprecated in the future. Recommend using ProcessTimer and EquipmentTimer.
~~AMPERAGE~~	~~Amperage~~	**DEPRECATED** in *Version 1.6*. Replaced by AMPERAGE_AC and AMPERAGE_DC.
AMPERAGE_AC	AmperageAC	The measurement of an electrical current that reverses direction at regular short intervals. Subtypes of AMPERAGE_AC are ACTUAL, COMMANDED and PROGRAMMED. AmperageAC is reported in units of AMPERE.
AMPERAGE_DC	AmperageDC	The measurement of an electric current flowing in one direction only. Subtypes of AMPERAGE_DC are ACTUAL, COMMANDED and PROGRAMMED. AmperageDC is reported in units of AMPERE.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
ANGLE	Angle	The measurement of angular position. Subtypes of Angle are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subType of ACTUAL. Angle **MUST** be reported in units of DEGREE.
ANGULAR_-ACCELERATION	AngularAcceleration	The positive rate of change of angular velocity. If a subType is not specified, the reported value for the data **MUST** default to the subType of ACTUAL. Subtypes of AngularAcceleration are ACTUAL, COMMANDED and PROGRAMMED. AngularAcceleration **MUST** be reported in units of DEGREE/SECOND^2.
ANGULAR_-DECELERATION	AngularDeceleration	Negative rate of change of angular velocity. Subtypes of AngularDeceleration are ACTUAL, COMMANDED and PROGRAMMED. AngularDeceleration **MUST** be reported in units of DEGREE/SECOND^2.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
ANGULAR_VELOCITY	AngularVelocity	The measurement of the rate of change of angular position. AngularVelocity **MUST** be reported in units of DEGREE/SECOND.
ASSET_UPDATE_-RATE	AssetUpdateRate	The average rate of change of values for assets in the MTConnect streams. The average is computed over a rolling window defined by the implementation. AssetUpdateRate **MUST** be reported in units of COUNT/SECOND.
AXIS_FEEDRATE	AxisFeedrate	The measurement of the feedrate of a linear axis. Subtypes of AxisFeedrate are ACTUAL, COMMANDED, JOG, PROGRAMMED, and RAPID. If a subType is not specified, the reported value for the data **MUST** default to the subType of PROGRAMMED. AxisFeedrate **MUST** be reported in units of MILLIMETER/SECOND.
CAPACITY_FLUID	CapacityFluid	The fluid capacity of an object or container. CapacityFluid **MUST** be reported in units of MILLILITER.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
CAPACITY_SPATIAL	CapacitySpatial	The geometric capacity of an object or container. CapacitySpatial **MUST** be reported in units of CUBIC_MILLIMETER.
CONCENTRATION	Concentration	The measurement of the percentage of one component within a mixture of components Concentration **MUST** be reported in units of PERCENT.
CONDUCTIVITY	Conductivity	The measurement of the ability of a material to conduct electricity. Conductivity **MUST** be reported in units of SIEMENS/METER.
CUTTING_SPEED	CuttingSpeed	The speed difference (relative velocity) between the cutting mechanism and the surface of the workpiece it is operating on. Subtypes of CUTTING_SPEED are ACTUAL, COMMANDED, and PROGRAMMED. If no subType is specified, the reported value must default to PROGRAMMED. CuttingSpeed is reported in units of MILLIMETER/SECOND.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
DECELERATION	Deceleration	Negative rate of change of velocity. Subtypes of Deceleration are ACTUAL, COMMANDED and PROGRAMMED. Deceleration **MUST** be reported in units of MILLIMETER/SECOND^2.
DENSITY	Density	The volumetric mass of a material per unit volume of that material. Density **MUST** be reported in units of MILLIGRAM/CUBIC_-MILLIMETER.
DEPOSITION_-ACCELERATION_-VOLUMETRIC	DepositionAccelera-tionVolumetric	The rate of change in spatial volume of material deposited in an additive manufacturing process. Subtypes of DepositionAccelera-tionVolumetric are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. DepositionAccelera-tionVolumetric **MUST** be reported in units of CUBIC_-MILLIMETER/SECOND^2.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
DEPOSITION_-DENSITY	DepositionDensity	The density of the material deposited in an additive manufacturing process per unit of volume. Subtypes of DepositionDensity are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. DepositionDensity **MUST** be reported in units of MILLIGRAM/CUBIC_-MILLIMETER.
DEPOSITION_MASS	DepositionMass	The mass of the material deposited in an additive manufacturing process. Subtypes of DepositionMass are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. DepositionMass **MUST** be reported in units of MILLIGRAM.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
DEPOSITION_-RATE_VOLUMETRIC	DepositionRateVolumetric	The rate at which a spatial volume of material is deposited in an additive manufacturing process. Subtypes of DepositionRateVolumetric are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. DepositionRateVolumetric **MUST** be reported in units of CUBIC_MILLIMETER/SECOND.
DEPOSITION_-VOLUME	DepositionVolume	The spatial volume of material deposited in an additive manufacturing process. Subtypes of DepositionVolume are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. DepositionVolume **MUST** be reported in units of CUBIC_MILLIMETER.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
DIAMETER	Diameter	The measured dimension of a diameter. Diameter **MUST** be reported in units of MILLIMETER.
DISPLACEMENT	Displacement	The measurement of the change in position of an object. Displacement **MUST** be reported in units of MILLIMETER.
ELECTRICAL_-ENERGY	ElectricalEnergy	The value of Wattage used or generated by a component over an interval of time. ElectricalEnergy **MUST** be reported in units of WATT_SECOND.
EQUIPMENT_TIMER	EquipmentTimer	The measurement of the amount of time a piece of equipment or a sub-part of a piece of equipment has performed specific activities. Subtypes of EquipmentTimer are LOADED, WORKING, OPERATING, POWERED, and DELAY. A subType **MUST** always be specified. EquipmentTimer **MUST** be reported in units of SECOND.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
FILL_LEVEL	FillLevel	The measurement of the amount of a substance remaining compared to the planned maximum amount of that substance. FillLevel **MUST** be reported in units of PERCENT.
FLOW	Flow	The measurement of the rate of flow of a fluid. Flow **MUST** be reported in units of LITER/SECOND.
FREQUENCY	Frequency	The measurement of the number of occurrences of a repeating event per unit time. Frequency **MUST** be reported in units of HERTZ.
~~GLOBAL_POSITION~~	~~GlobalPosition~~	**DEPRECATED** in Version 1.1
HUMIDITY_-ABSOLUTE	HumidityAbsolute	The amount of water vapor expressed in grams per cubic meter. Subtypes of HumidityAbsolute are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. HumidityAbsolute **MUST** be reported in units of GRAM/CUBIC_METER.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
HUMIDITY_-RELATIVE	HumidityRelative	The amount of water vapor present expressed as a percent to reach saturation at the same temperature. Subtypes of HumidityRelative are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. HumidityRelative **MUST** be reported in units of PERCENT.
HUMIDITY_-SPECIFIC	HumiditySpecific	The ratio of the water vapor present over the total weight of the water vapor and air present expressed as a percent. Subtypes of HumiditySpecific are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. HumiditySpecific **MUST** be reported in units of PERCENT.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
LENGTH	Length	The measurement of the length of an object. Subtypes of Length are STANDARD, REMAINING, and USEABLE. If a subType is not specified, the reported value for the data **MUST** default to the subType of REMAINING. Length **MUST** be reported in units of MILLIMETER.
~~LEVEL~~	~~Level~~	**DEPRECATED** in Version 1.2. See FILL_LEVEL
LINEAR_FORCE	LinearForce	A *Force* applied to a mass in one direction only. LinearForce **MUST** be reported in units of NEWTON.
LOAD	Load	The measurement of the actual versus the standard rating of a piece of equipment. Load **MUST** be reported in units of PERCENT.
MASS	Mass	The measurement of the mass of an object(s) or an amount of material. Mass **MUST** be reported in units of KILOGRAM.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
OBSERVATION_-UPDATE_RATE	ObservationUpdateRate	The average rate of change of values for data items in the MTConnect streams. The average is computed over a rolling window defined by the implementation. ObservationUpdateRate **MUST** be reported in units of COUNT/SECOND.
ORIENTATION	Orientation	A measured or calculated orientation of a plane or vector relative to a cartesian coordinate system The value of Orientation **MUST** be three space-delimited floating-point numbers and **MUST** be in units of DEGREE_3D. The values represent the degrees of rotation around the X, Y, and Z axes respectively as the ordered values A, B, and C. If any of the rotations is not known, it **MUST** be zero (0).

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
PATH_FEEDRATE	PathFeedrate	The measurement of the feedrate for the axes, or a single axis, associated with a Path component-a vector. Subtypes of PathFeedrate are ACTUAL, COMMANDED,JOG, PROGRAMMED, and RAPID. If a subType is not specified, the reported value for the data **MUST** default to the subType of PROGRAMMED. PathFeedrate **MUST** be reported in units of MILLIMETER/SECOND.
PATH_FEEDRATE_-PER_REVOLUTION	PathFeedratePerRev-olution	The feedrate for the axes, or a single axis. PathFeedratePerRev-olution is reported in units of MILLIME-TER/REVOLUTION. Subtypes of PathFee-dratePerRevolution are ACTUAL, COMMANDED, and PROGRAMMED.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
PATH_POSITION	PathPosition	A measured or calculated position of a control point reported by a piece of equipment expressed in WORK coordinates. The coordinate system will revert to MACHINE coordinates if WORK coordinates are not available. Subtypes of PathPosition are ACTUAL, PROGRAMMED, COMMANDED, TARGET, and PROBE. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. PathPosition **MUST** be reported as a set of space-delimited floating-point numbers representing a point in 3-D space. The position of the control point **MUST** be reported in units of MILLIMETER and listed in order of X, Y, and Z referenced to the coordinate system of the piece of equipment.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
PATH_POSITION (Continued)	PathPosition	An example of the value reported for PathPosition would be: <PathPosition ...>10.123 55.232 100.981 </PathPosition> Where X = 10.123, Y = 55.232, and Z=100.981.
PH	PH	A measure of the acidity or alkalinity of a solution. PH **MUST** be reported in units of PH.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
POSITION	Position	A measured or calculated position of a Component element as reported by a piece of equipment. Subtypes of Position are ACTUAL, COMMANDED, PROGRAMMED, and TARGET. If a subType is not specified, the reported value for the data **MUST** default to the subType of ACTUAL. When Position is provided representing a measured value for the physical axes of the piece of equipment, the data **MUST** be provided in MACHINE coordinates. When Position is provided representing a logical or calculated position, the data **MUST** be provided in WORK coordinates and is associated with a Path element of the equipment controller. Position **MUST** be reported in units of MILLIMETER.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
POWER_FACTOR	PowerFactor	The measurement of the ratio of real power flowing to a load to the apparent power in that AC circuit. PowerFactor **MUST** be reported in units of PERCENT.
PRESSURE	Pressure	The force per unit area measured relative to atmospheric pressure. Commonly referred to as gauge pressure. Pressure **MUST** be reported in units of PASCAL.
PRESSURE_-ABSOLUTE	PressureAbsolute	The force per unit area measured relative to a vacuum. PressureAbsolute **MUST** be reported in units of PASCAL.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
PROCESS_TIMER	ProcessTimer	The measurement of the amount of time a piece of equipment has performed different types of activities associated with the process being performed at that piece of equipment. Subtypes of ProcessTimer are PROCESS, and DELAY. A subType **MUST** always be specified. ProcessTimer **MUST** be reported in units of SECOND.
PRESSURIZATION_-RATE	PressurizationRate	The change of pressure per unit time. Subtypes of PressurizationRate are ACTUAL, COMMANDED and PROGRAMMED. PressurizationRate **MUST** be reported in units of PASCAL/SECOND.
RESISTANCE	Resistance	The measurement of the degree to which a substance opposes the passage of an electric current. Resistance **MUST** be reported in units of OHM.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
ROTARY_VELOCITY	RotaryVelocity	The measurement of the rotational speed of a rotary axis. Subtypes of RotaryVelocity are ACTUAL, COMMANDED and PROGRAMMED. If a subType is not specified, the reported value for the data **MUST** default to the subType of ACTUAL. RotaryVelocity **MUST** be reported in units of REVOLUTION/MINUTE.
SOUND_LEVEL	SoundLevel	The measurement of a sound level or sound pressure level relative to atmospheric pressure. Subtypes of SoundLevel are NO_SCALE, A_SCALE, B_SCALE, C_SCALE and D_SCALE. If a subType is not specified, the reported value for the data **MUST** default to the subType of NO_SCALE. SoundLevel **MUST** be reported in units of DECIBEL.
~~SPINDLE_SPEED~~	~~SpindleSpeed~~	**DEPRECATED** in Version 1.2. Replaced by ROTARY_VELOCITY

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
STRAIN	Strain	The measurement of the amount of deformation per unit length of an object when a load is applied. Strain **MUST** be reported in units of PERCENT.
TEMPERATURE	Temperature	The measurement of temperature. Subtypes of Temperature are ACTUAL and COMMANDED. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. Temperature **MUST** be reported in units of CELSIUS.
TENSION	Tension	The measurement of a force that stretches or elongates an object. Tension **MUST** be reported in units of NEWTON.
TILT	Tilt	The measurement of angular displacement. Tilt **MUST** be reported in units of MICRO_RADIAN.
TORQUE	Torque	The measurement of the turning force exerted on an object or by an object. Torque **MUST** be reported in units of NEWTON_METER.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
VELOCITY	Velocity	The measurement of the rate of change of position of a Component. When provided as the Velocity of the Axes Component, it represents the value of the velocity vector for all given axes, similar to PathFeedrate. When provided as the Velocity of an individual Axis Component, it represents the value of the velocity for that specific axis with no influence of the relative velocity of any other axes. Velocity **MUST** be reported in units of MILLIMETER/SECOND.
VISCOSITY	Viscosity	The measurement of a fluids resistance to flow. Viscosity **MUST** be reported in units of PASCAL_SECOND.
~~VOLTAGE~~	~~Voltage~~	**DEPRECATED** in *Version 1.6*. Replaced by VOLTAGE_AC and VOLTAGE_DC.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
VOLTAGE_AC	VoltageAC	The measurement of the electrical potential between two points in an electrical circuit in which the current periodically reverses direction. Subtypes of VOLTAGE_AC are ACTUAL, PROGRAMMED, and COMMANDED. VoltageAC **MUST** be in units of VOLT.
VOLTAGE_DC	VoltageDC	The measurement of the electrical potential between two points in an electrical circuit in which the current is unidirectional. Subtypes of VOLTAGE_DC are ACTUAL, PROGRAMMED, and COMMANDED. VoltageDC **MUST** be in units of VOLT.
VOLT_AMPERE	VoltAmpere	The measurement of the apparent power in an electrical circuit, equal to the product of root-mean-square (RMS) voltage and RMS current (commonly referred to as VA). VoltAmpere **MUST** be reported in units of VOLT_AMPERE.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
VOLT_AMPERE_-REACTIVE	VoltAmpereReactive	The measurement of reactive power in an AC electrical circuit (commonly referred to as VAR). VoltAmpereReactive **MUST** be reported in units of VOLT_AMPERE_-REACTIVE.
VOLUME_FLUID	VolumeFluid	The fluid volume of an object or container. Subtypes of VolumeFluid are ACTUAL, START, ENDED, CONSUMED, WASTE, and PART. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. VolumeFluid **MUST** be reported in units of MILLILITER.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
VOLUME_SPATIAL	VolumeSpatial	The geometric volume of an object or container. Subtypes of VolumeSpatial are ACTUAL, START, ENDED, CONSUMED, WASTE, and PART. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. VolumeSpatial **MUST** be reported in units of CUBIC_MILLIMETER.
WATTAGE	Wattage	The measurement of power flowing through or dissipated by an electrical circuit or piece of equipment. Subtypes of Wattage are ACTUAL and TARGET. If a subType is not specified, the reported value for the data **MUST** default to the subType of ACTUAL. Wattage **MUST** be reported in units of WATT.

Continuation of Table 25: Element Names for Sample		
DataItem Type	Element Name	Description
X_DIMENSION	XDimension	Measured dimension of an entity relative to the X direction of the referenced coordinate system. XDimension **MUST** be reported in units of MILLIMETER.
Y_DIMENSION	YDimension	Measured dimension of an entity relative to the Y direction of the referenced coordinate system. YDimension **MUST** be reported in units of MILLIMETER.
Z_DIMENSION	ZDimension	Measured dimension of an entity relative to the Z direction of the referenced coordinate system. ZDimension **MUST** be reported in units of MILLIMETER.

Note: The Sample response format **MUST** be extended when the representation attribute for the data item is TIME_SERIES. See *Section 5.6.1 - Observations for DataItem with representation of TIME_SERIES* for details on extending the response format.

6.2 Event Element Names

Table 26 lists the XML elements that can be placed in the Events container of the ComponentStream element.

The *Table 25* shows both the type for each EVENT category DataItem element defined in the MTConnectDevices document and the corresponding *Element Name* for the *Data Entity* that **MUST** be reported as an Event element in the MTConnectStreams document.

The table also defines the *Valid Data Value* for those `Event` `type` data items where the reported values are restricted to a *Controlled Vocabulary*.

Table 26: Element Names for Event

DataItem Type	Element Name	Description
`ACTIVATION_COUNT`	`ActivationCount`	Accumulation of the number of times a function has attempted to, or is planned to attempt to, activate or be performed. When the `discrete` attribute is `true`, the value represents the count since the previous occurrence of the event. Subtypes of `ActivationCount` are `ALL`, `GOOD`, `BAD`, `TARGET`, `REMAINING`, `COMPLETE`, `FAILED`, and `ABORTED`. The *Valid Data Value* **MUST** be numeric.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
ACTIVE_AXES	ActiveAxes	The set of axes currently associated with a Path or Controller *Structural Element*. The *Valid Data Value* reported **SHOULD** be a space-delimited set of axes names. The names returned **SHOULD** match the name attribute of the Linear or Rotary *Structural Elements* defined in the MTConnectDevices document that this Event element represents. If name is not available, nativeName **MUST** be returned to identify the Linear or Rotary *Structural Elements*. For example: <ActiveAxes ...>X Y Z W S</ActiveAxes> where X, Y, Z, W, and S are the nativeName attributes of the *Structural Elements*. If it is not specified elsewhere in the MTConnectDevices document, it **MUST** be assumed that all of the axes are associated with the Path component.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
ACTUATOR_-STATE	ActuatorState	Represents the operational state of an apparatus for moving or controlling a mechanism or system. *Valid Data Values*: ACTIVE: The actuator is operating INACTIVE: The actuator is not operating
ADAPTER_-SOFTWARE_-VERSION	AdapterSoftwareVersion	The originator's software version of the *Adapter*. The *Valid Data Value* **MUST** be a string.
ADAPTER_URI	AdapterURI	The URI of the *Adapter*. The *Valid Data Value* **MUST** be a string.
~~ALARM~~	~~Alarm~~	**DEPRECATED** : Replaced with CONDITION category data items in Version 1.1.0.
ALARM_LIMIT	AlarmLimit	A set of limits used to trigger warning or alarm indicators. The *Valid Data Value* **MUST** be a float. The Entry key **MUST** be one or more from the following: UPPER_LIMIT, UPPER_WARNING, LOWER_WARNING, or LOWER_LIMIT.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
APPLICATION	Application	The application on a component. Subtypes of APPLICATION are LICENSE, VERSION, RELEASE_DATE, INSTALL_DATE, and MANUFACTURER. The *Valid Data Value* **MUST** be a text string.
AVAILABILITY	Availability	Represents the *Agent*'s ability to communicate with the data source. Availability **MUST** be provided for each Device *Structural Element* and **MAY** be provided for any other *Structural Element*. *Valid Data Values*: AVAILABLE: The *Structural Element* is active and capable of providing data. UNAVAILABLE: The *Structural Element* is either inactive or not capable of providing data.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
AXIS_-COUPLING	AxisCoupling	Describes the way the axes will be associated to each other. This is used in conjunction with COUPLED_AXES to indicate the way they are interacting. The coupling of the axes **MUST** be viewed from the perspective of a specified axis. Therefore, a MASTER coupling indicates that this axis is the master for the COUPLED_AXES. AxisCoupling **MUST** be provided for each axis element associated with a set of axes defined by the COUPLED_AXES data item element defined in the MTConnectDevices document. *Valid Data Values*: TANDEM: The axes are physically connected to each other and operate as a single unit. SYNCHRONOUS: The axes are not physically connected to each other but are operating together in lockstep. MASTER: The axis is the master of the CoupledAxes SLAVE: The axis is a slave to the CoupledAxes

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
AXIS_-FEEDRATE_-OVERRIDE	AxisFeedrateOverride	The value of a signal or calculation issued to adjust the feedrate of an individual linear type axis. The value provided for AxisFeedrateOverride is expressed as a percentage of the designated feedrate for the axis. Subtypes of AxisFeedrateOverride are JOG, PROGRAMMED, and RAPID. If a subType is not specified, the reported value for the data **MUST** default to the subType of PROGRAMMED. The *Valid Data Value* **MUST** be a floating-point number.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
AXIS_-INTERLOCK	AxisInterlock	An indicator of the state of the axis lockout function when power has been removed and the axis is allowed to move freely. *Valid Data Values*: ACTIVE: The axis lockout function is activated, power has been removed from the axis, and the axis is allowed to move freely. INACTIVE: The axis lockout function has not been activated, the axis may be powered, and the axis is capable of being controlled by another component.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
AXIS_STATE	AxisState	An indicator of the controlled state of a Linear or Rotary component representing an axis. *Valid Data Values*: HOME: The axis is in its home position. TRAVEL: The axis is in motion PARKED: The axis has been moved to a fixed position and is being maintained in that position either electrically or mechanically. Action is required to release the axis from this position. STOPPED: The axis is stopped
BLOCK	Block	The line of code or command being executed by a Controller *Structural Element*. Block **MUST** include the entire expression for a line of program code, including all parameters The *Valid Data Value* **MUST** be a text string.
BLOCK_COUNT	BlockCount	The total count of the number of blocks of program code that have been executed since execution started. The *Valid Data Value* **MUST** be an integer.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
CHUCK_-INTERLOCK	ChuckInterlock	An indication of the state of an interlock function or control logic state intended to prevent the associated CHUCK component from being operated. A CHUCK component or composition element may be controlled by more than one type of ChuckInterlock function. When the ChuckInterlock function is provided by an operator controlled interlock that can inhibit the ability to initiate an unclamp action of an electronically controlled chuck, this ChuckInterlock function **SHOULD** be further characterized by specifying a subType of MANUAL_UNCLAMP. *Valid Data Values*: ACTIVE: The chuck cannot be unclamped INACTIVE: The chuck can be unclamped.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
CHUCK_STATE	ChuckState	An indication of the operating state of a mechanism that holds a part or stock material during a manufacturing process. It may also represent a mechanism that holds any other mechanism in place within a piece of equipment. *Valid Data Values*: OPEN: The CHUCK component or composition element is open to the point of a positive confirmation CLOSED: The CHUCK component or composition element is closed to the point of a positive confirmation UNLATCHED: The CHUCK component or composition element is not closed to the point of a positive confirmation and not open to the point of a positive confirmation. It is in an intermediate position.
CLOCK_TIME	ClockTime	The value provided by a timing device at a specific point in time. ClockTime **MUST** be reported in W3C ISO 8601 format.
~~CODE~~	~~Code~~	**DEPRECATED** in Version 1.1.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
COMPOSITION_-STATE	CompositionState	An indication of the operating condition of a mechanism represented by a Composition type element. Subtypes of CompositionState are ACTION, LATERAL, MOTION, SWITCHED, and VERTICAL. A subType **MUST** be provided. *Valid Data Values* for subType ACTION are: ACTIVE: The Composition element is operating INACTIVE: The Composition element is not operating. *Valid Data Values* for subType LATERAL are: RIGHT : The position of the Composition element is oriented to the right to the point of a positive confirmation LEFT : The position of the Composition element is oriented to the left to the point of a positive confirmation TRANSITIONING : The position of the Composition element is not oriented to the right to the point of a positive confirmation and is not

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
COMPOSITION_-STATE (Continued)	CompositionState	oriented to the left to the point of a positive confirmation. It is in an intermediate position. *Valid Data Values* for subType SWITCHED are: ON : The activation state of the Composition element is in an ON condition, it is operating, or it is powered. OFF : The activation state of the Composition element is in an OFF condition, it is not operating, or it is not powered. *Valid Data Values* for subType VERTICAL are: UP : The position of the Composition element is oriented in an upward direction to the point of a positive confirmation DOWN : The position of the Composition element is oriented in a downward direction to the point of a positive confirmation TRANSITIONING : The position of the Composition element is not oriented in an upward direction to the point of a positive confirmation and is not oriented in a downward direction to the point of a positive confirmation. It is in an intermediate position.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
COMPOSITION_-STATE (Continued)	CompositionState	*Valid Data Values* for subType MOTION are: OPEN: The position of the Composition element is open to the point of a positive confirmation CLOSED: The position of the Composition element is closed to the point of a positive confirmation UNLATCHED: The position of the Composition element is not open to the point of a positive confirmation and is not closed to the point of a positive confirmation. It is in an intermediate position.
CONNECTION_-STATUS	ConnectionStatus	The status of the connection between an *Adapter* and an *Agent*. *Valid Data Values*: CLOSED: represents no connection at all. LISTEN: represents the *Agent* waiting for a connection request from an *Adapter*. ESTABLISHED: represents an open connection. The normal state for the data transfer phase of the connection.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
CONTROL_-LIMIT	ControlLimit	A set of limits used to indicate whether a process variable is stable and in control. The *Valid Data Value* **MUST** be a float. The Entry key **MUST** be one or more from the following: UPPER_LIMIT, UPPER_WARNING, NOMINAL, LOWER_WARNING, or LOWER_LIMIT.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
CONTROLLER_-MODE	ControllerMode	The current operating mode of the Controller component. *Valid Data Values*: AUTOMATIC: The controller is configured to automatically execute a program. MANUAL: The controller is not executing an active program. It is capable of receiving instructions from an external source – typically an operator. The controller executes operations based on the instructions received from the external source. MANUAL_DATA_INPUT: The operator can enter a series of operations for the controller to perform. The controller will execute this specific series of operations and then stop. SEMI_AUTOMATIC: The controller is operating in a mode that restricts the active program from processing its next process step without operator intervention. EDIT: The controller is currently functioning as a programming device and is not capable of executing an active program.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
CONTROLLER_-MODE_-OVERRIDE	ControllerModeOverride	A setting or operator selection that changes the behavior of a piece of equipment. Subtypes of Controller-ModeOverride are DRY_RUN, SINGLE_BLOCK, MACHINE_AXIS_LOCK, OPTIONAL_STOP, and TOOL_CHANGE_STOP. A subType **MUST** always be specified. *Valid Data Values*: ON : The indicator of the ControllerModeOver-ride is in the ON state and the mode override is active. OFF : The indicator of the ControllerModeOver-ride is in the OFF state and the mode override is inactive

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
COUPLED_AXES	CoupledAxes	Refers to the set of associated axes. Used in conjunction with AxisCoupling to describe how the CoupledAxes relate to each other. The *Valid Data Value* reported **SHOULD** be a space-delimited set of axes names. The names returned **SHOULD** match the name attribute of the Linear or Rotary *Structural Elements* defined in the MTConnectDevices document that this Event element represents. If name is not available, nativeName **MUST** be returned to identify the Linear or Rotary *Structural Elements*. Example: <CoupledAxes ...>Y1 Y2</CoupledAxes>

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
CYCLE_COUNT	CycleCount	Accumulation of the number of times a cyclic function has attempted to, or is planned to attempt to execute. When the discrete attribute is true, the value represents the count since the previous occurrence of the event. Subtypes of CycleCount are ALL, GOOD, BAD, TARGET, REMAINING, COMPLETE, FAILED, and ABORTED. The *Valid Data Value* **MUST** be numeric.
DATE_CODE	DateCode	The time and date code associated with a material or other physical item. Subtypes of DateCode are MANUFACTURE, EXPIRATION, and FIRST_USE. A subType **MUST** always be specified. DateCode **MUST** be reported in ISO 8601 format.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
DEACTIVATION_COUNT	DeactivationCount	Accumulation of the number of times a function has attempted to, or is planned to attempt to, de-activate or cease. When the discrete attribute is true, the value represents the count since the previous occurrence of the event. Subtypes of DeactivationCount are ALL, GOOD, BAD, TARGET, REMAINING, COMPLETE, FAILED, and ABORTED. The *Valid Data Value* **MUST** be numeric.
DEVICE_ADDED	DeviceAdded	DeviceAdded is an Event that provides the UUID of a new device added to an *MTConnect Agent*. *Valid Data Value* is the value of the Device's UUID that was added to the *MTConnect Agent*.
DEVICE_-CHANGED	DeviceChanged	DeviceChanged is an Event that provides the UUID of the device whose *Metadata* has changed. *Valid Data Value* is the value of the Device's UUID for which the metadata has changed.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
DEVICE_-REMOVED	DeviceRemoved	DeviceRemoved is an Event that provides the UUID of a device removed from an *MTConnect Agent*. *Valid Data Value* is the value of the Device's UUID that was removed from the *MTConnect Agent*.
DEVICE_UUID	DeviceUuid	The identifier of another piece of equipment that is temporarily associated with a component of this piece of equipment to perform a particular function. *Valid Data Values* are the value of the UUID attribute of the associated device - a NMTOKEN XML type.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
DIRECTION	Direction	The direction of motion. Subtypes of Direction are ROTARY and LINEAR. *Valid Data Values* for subType ROTARY are as follows: CLOCKWISE: Clockwise rotation using the right-hand rule. COUNTER_CLOCKWISE: Counter-clockwise rotation using the right-hand rule. NONE: No direction. *Valid Data Values* for subType LINEAR are as follows: POSITIVE: Linear position is increasing. NEGATIVE: Linear position is decreasing. NONE: No direction.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
DOOR_STATE	DoorState	The operational state of a DOOR type component or composition element. *Valid Data Values*: OPEN: The DOOR is open to the point of a positive confirmation CLOSED: The DOOR is closed to the point of a positive confirmation UNLATCHED: The DOOR is not closed to the point of a positive confirmation and is not open to the point of a positive confirmation. It is in an intermediate position.
EMERGENCY_-STOP	EmergencyStop	The current state of the emergency stop signal for a piece of equipment, controller path, or any other component or subsystem of a piece of equipment. *Valid Data Values*: ARMED : The emergency stop circuit is complete and the piece of equipment, component, or composition element is allowed to operate. TRIGGERED : The emergency stop circuit is open and the operation of the piece of equipment, component, or composition element is inhibited.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
END_OF_BAR	EndOfBar	An indication of whether the end of a piece of bar stock being feed by a bar feeder has been reached. Subtypes of EndOfBar are PRIMARY and AUXILIARY. If a subType is not specified, the reported value for the data **MUST** default to the subType of PRIMARY. *Valid Data Values*: YES : The EndOfBar has been reached. NO : The EndOfBar has not been reached.
EQUIPMENT_-MODE	EquipmentMode	An indication that a piece of equipment, or a sub-part of a piece of equipment, is performing specific types of activities. Subtypes of EquipmentMode are DELAY, LOADED, WORKING, OPERATING, and POWERED. A subType **MUST** always be specified. *Valid Data Values*: ON : The equipment is functioning in the mode designated by the subType. OFF : The equipment is not functioning in the mode designated by the subType.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
EXECUTION	Execution	The execution status of a component. *Valid Data Values*: READY: The component is ready to execute instructions. It is currently idle. ACTIVE: The component is actively executing an instruction. INTERRUPTED: The component suspends the execution of the program due to an external signal. Action is required to resume execution. WAIT: The component suspends execution while a secondary operation executes. Execution resumes automatically once the secondary operation completes. FEED_HOLD: The motion of the active axes are commanded to stop at their current position.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
EXECUTION (continued)	Execution	STOPPED: The component program is not READY to execute. OPTIONAL_STOP: A command from the program has intentionally interrupted execution. The component **MAY** have another state that indicates if the execution is interrupted or the execution ignores the interrupt instruction. PROGRAM_STOPPED: A command from the program has intentionally interrupted execution. Action is required to resume execution. PROGRAM_COMPLETED: The program completed execution.
FIRMWARE	Firmware	The embedded software of a component. Subtypes of FIRMWARE are LICENSE, VERSION, RELEASE_DATE, INSTALL_DATE, and MANUFACTURER. The *Valid Data Value* **MUST** be a text string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
FUNCTIONAL_-MODE	FunctionalMode	The current intended production status of the device or component. Typically, the FunctionalMode **SHOULD** be associated with the Device *Structural Element*, but it **MAY** be associated with any *Structural Element* in the XML document. *Valid Data Values*: PRODUCTION : The Device element or another *Structural Element* is currently producing product, ready to produce product, or its current intended use is to be producing product. SETUP : The Device element or another *Structural Element* is not currently producing product. It is being prepared or modified to begin production of product. TEARDOWN : The Device element or another *Structural Element* is not currently producing product. Typically, it has completed the production of a product and is being modified or returned to a neutral state such that it may then be prepared to begin production of a different product.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
FUNCTIONAL_-MODE (Continued)	FunctionalMode	MAINTENANCE : The Device element or another *Structural Element* is not currently producing product. It is currently being repaired, waiting to be repaired, or has not yet been returned to a normal production status after maintenance has been performed. PROCESS_DEVELOPMENT : The Device element or another *Structural Element* is being used to prove-out a new process, testing of equipment or processes, or any other active use that does not result in the production of product.
HARDNESS	Hardness	The measurement of the hardness of a material. Subtypes of Hardness are ROCKWELL, VICKERS, SHORE, BRINELL, LEEB, and MOHS. A subType **MUST** always be specified. The *Valid Data Value* **MUST** be a floating-point number.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
HARDWARE	Hardware	The hardware of a component. Subtypes of HARDWARE are LICENSE, VERSION, RELEASE_DATE, INSTALL_DATE, and MANUFACTURER. The *Valid Data Value* **MUST** be a text string.
INTERFACE_-STATE	InterfaceState	The current functional or operational state of an Interface type element indicating whether the *Interface* is active or not currently functioning. *Valid Data Values*: ENABLED: The *Interface* is currently operational and performing as expected. DISABLED: The Interface is currently not operational. When the INTERFACE_STATE is DISABLED, the state of all data items that are specific for the *Interaction Model* associated with that *Interface* **MUST** be set to NOT_READY.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
LIBRARY	Library	The software library on a component. Subtypes of LIBRARY are LICENSE, VERSION, RELEASE_DATE, INSTALL_DATE, and MANUFACTURER. The *Valid Data Value* **MUST** be a text string.
~~LINE~~	~~Line~~	**DEPRECATED** in Version 1.4.0.
LINE_LABEL	LineLabel	An optional identifier for a BLOCK of code in a PROGRAM. The *Valid Data Value* **MUST** be any text string.
LINE_NUMBER	LineNumber	A reference to the position of a block of program code within a control program. Subtypes of LineNumber are ABSOLUTE and INCREMENTAL. A subType **MUST** always be specified. The *Valid Data Value* **MUST** be an integer.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
LOAD_COUNT	LoadCount	Accumulation of the number of times an operation has attempted to, or is planned to attempt to, load materials, parts, or other items. When the discrete attribute is true, the value represents the count since the previous occurrence of the event. Subtypes of LoadCount are ALL, GOOD, BAD, TARGET, REMAINING, COMPLETE, FAILED, and ABORTED. The *Valid Data Value* **MUST** be numeric.
LOCK_STATE	LockState	The state or operating mode of a Lock. *Valid Data Values*: LOCKED: The mechanism is engaged and preventing the associated component from being opened or operated. UNLOCKED: The mechanism is disengaged and the associated component is able to be opened or operated.
MATERIAL	Material	The identifier of a material used or consumed in the manufacturing process. The *Valid Data Value* **MUST** be any text string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
MATERIAL_-LAYER	MaterialLayer	Designates the layers of material applied to a part or product as part of an additive manufacturing process. Subtypes of MaterialLayer are ACTUAL and TARGET. If a subType is not specified, the reported value for the data **MUST** default to the subtype of ACTUAL. The *Valid Data Value* **MUST** be an integer.
MESSAGE	Message	Any text string of information to be transferred from a piece of equipment to a client software application. The *Valid Data Value* **MUST** be any text string.
MTCONNECT_-VERSION	MTConnectVersion	The reference version of the MTConnect Standard supported by the *Adapter*. The *Valid Data Value* **MUST** be a string.
NETWORK	Network	Network details of a component. Subtypes of NETWORK are IPV4_ADDRESS, IPV6_ADDRESS, GATEWAY, SUBNET_MASK, VLAN_ID, MAC_ADDRESS, and WIRELESS. The *Valid Data Value* **MUST** be a text string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
OPERATING_-SYSTEM	OperatingSystem	The Operating System of a component. Subtypes of OPERATING_SYSTEM are LICENSE, VERSION, RELEASE_DATE, INSTALL_DATE, and MANUFACTURER. The *Valid Data Value* **MUST** be a text string. When specified with no subType, use the following vocabulary or specify the name of the operating system: - WINDOWS - LINUX - MACINTOSH - PROPRIETARY
OPERATOR_ID	OperatorId	The identifier of the person currently responsible for operating the piece of equipment. The *Valid Data Value* **MAY** be any text string. **DEPRECATION WARNING** : May be deprecated in the future. See USER below.
PALLET_ID	PalletId	The identifier for a pallet. The *Valid Data Value* **MAY** be any text string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PART_COUNT	PartCount	The aggregate count of parts. When the discrete attribute is true, the value represents the number of parts since the previous occurrence of the event. Subtypes of PartCount are ALL, GOOD, BAD, TARGET, REMAINING, COMPLETE, FAILED, and ABORTED. The *Valid Data Value* **MUST** be numeric.
PART_DETECT	PartDetect	An indication designating whether a part or work piece has been detected or is present. The *Valid Data Value* **MUST** be: PRESENT: if a part or work piece has been detected or is present. NOT_PRESENT: if a part or work piece is not detected or is not present.
PART_GROUP_-ID	PartGroupId	Identifier given to a collection of individual parts. If no subType is specified, UUID is default. Subtypes of PartGroupId are UUID, LOT, BATCH, RAW_MATERIAL and HEAT_TREAT. The *Valid Data Value* **MUST** be a string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PART_ID	PartId	An identifier of a part in a manufacturing operation. The *Valid Data Value* **MAY** be any text string.
PART_KIND_ID	PartKindId	Identifier given to link the individual occurrence to a class of parts, typically distinguished by a particular part design. If no subType is specified, UUID is default. Subtypes of PartKindId are UUID, PART_NUMBER, PART_FAMILY and PART_NAME. The *Valid Data Value* **MUST** be a string.
~~PART_NUMBER~~	~~PartNumber~~	**DEPRECATED** in *Version 1.7*. PART_NUMBER is now a subType of PART_KIND_ID.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PART_ PROCESSING_ STATE	PartProcessingState	The particular condition of the part occurrence at a specific time. *Valid Data Values*: NEEDS_PROCESSING: The part occurrence is not actively being processed, but the processing has not ended. Processing requirements exist that have not yet been fulfilled. This is the default entry state when the part occurrence is originally received. In some cases, the part occurrence may return to this state while it waits for additional processing to be performed. IN_PROCESS: The part occurrence is actively being processed. PROCESSING_ENDED: The part occurrence is no longer being processed. A general state when the reason for termination is unknown. PROCESS-ING_ENDED_COMPLETE: The part occurrence has completed processing successfully. PROCESS-ING_ENDED_STOPPED: The process has been stopped during the processing. The part occurrence will require special treatment. PROCESS-ING_ENDED_ABORTED: The processing of the part occurrence has come to a premature end. PROCESS-

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PART_STATUS	PartStatus	State or condition of a part. If unique identifier is given, part status is for that individual. If group identifier is given without a unique identifier, then the status is assumed to be for the whole group. The *Valid Data Value* **MUST** be: PASS: The part does conform to given requirements. FAIL: The part does not conform to some given requirements.
PART_-UNIQUE_ID	PartUniqueId	Identifier given to a distinguishable, individual part. If no subType is specified, UUID is default. Subtypes of PartUniqueId are UUID, SERIAL_NUMBER and RAW_MATERIAL. The *Valid Data Value* **MUST** be a string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PATH_-FEEDRATE_-OVERRIDE	PathFeedrateOverride	The value of a signal or calculation issued to adjust the feedrate for the axes associated with a Path component that may represent a single axis or the coordinated movement of multiple axes. The value provided for PathFeedrateOverride is expressed as a percentage of the designated feedrate for the path. Sub-types of PathFeedrateOverride are JOG, PROGRAMMED, and RAPID. If a subType is not specified, the reported value for the data **MUST** default to the subType of PROGRAMMED. The *Valid Data Value* **MUST** be a floating-point number.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PATH_MODE	PathMode	Describes the operational relationship between a Path *Structural Element* and another Path *Structural Element* for pieces of equipment comprised of multiple logical groupings of controlled axes or other logical operations. *Valid Data Values*: INDEPENDENT : The path is operating independently and without the influence of another path. MASTER: The path provides the reference motion for a SYNCHRONOUS or MIRROR type path to follow. For non-motion type paths, the MASTER provides information or state values that influences the operation of other paths SYNCHRONOUS: The axes associated with the path are following the motion of the MASTER type path. MIRROR : The axes associated with the path are mirroring the motion of the MASTER path. When PathMode is not specified, the operational mode of the path **MUST** be interpreted as INDEPENDENT .

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
POWER_STATE	PowerState	The indication of the status of the source of energy for a *Structural Element* to allow it to perform its intended function or the state of an enabling signal providing permission for the *Structural Element* to perform its functions. Subtypes of PowerState are LINE and CONTROL. When the subType is LINE, PowerState represents the primary source of energy for a *Structural Element*. When the subType is CONTROL, PowerState represents an enabling signal providing permission for the *Structural Element* to perform its function(s). If a subType is not specified, the reported value for the data **MUST** default to the subType of LINE.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
POWER_STATE (Continued)	PowerState	*Valid Data Values*: ON : The source of energy for a *Structural Element* or the enabling signal providing permission for the *Structural Element* to perform its function(s) is present and active. OFF : The source of energy for a *Structural Element* or the enabling signal providing permission for the *Structural Element* to perform its function(s) is not present or is disconnected. **DEPRECATION WARNING** : PowerState may be deprecated in the future.
~~POWER_STATUS~~	~~PowerStatus~~	**DEPRECATED** in Version 1.1.0.
PROCESS_-AGGREGATE_ID	ProcessAggregateId	Identifier given to link the individual occurrence to a group of related occurrences, such as a process step in a process plan. Subtypes of ProcessAggregateId are PROCESS_STEP, PROCESS_PLAN and ORDER_NUMBER. The *Valid Data Value* **MUST** be a string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PROCESS_-KIND_ID	ProcessKindId	Identifier given to link the individual occurrence to a class of processes or process definition. Subtypes of ProcessKindId are UUID, PROCESS_NAME and ISO_STEP_EXECUTABLE. The *Valid Data Value* **MUST** be a string.
PROCESS_-OCCURRENCE_-ID	ProcessOccurrenceId	An identifier of a process being executed by the device. The *Valid Data Value* **MUST** be a string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PROCESS_STATE	ProcessState	The particular condition of the process occurrence at a specific time. *Valid Data Values*: INITIALIZING: The device is preparing to execute the process occurrence. READY: The process occurrence is ready to be executed. ACTIVE: The process occurrence is actively executing. COMPLETE: The process occurrence is now finished. INTERRUPTED: The process occurrence has been stopped and may be resumed. ABORTED: The process occurrence has come to a premature end and cannot be resumed.
PROCESS_TIME	ProcessTime	The time and date associated with an activity or event. Subtypes of ProcessTime are START, COMPLETE, and TARGET_COMPLETION. A subType **MUST** always be specified. ProcessTime **MUST** be reported in ISO 8601 format.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PROGRAM	Program	The identity of the logic or motion program being executed. The *Valid Data Value* **MUST** be any text string. Subtypes of PROGRAM are SCHEDULE, MAIN and ACTIVE. If a subType is not specified, it is assumed to be MAIN.
PROGRAM_-COMMENT	ProgramComment	A comment or non-executable statement in the control program. The *Valid Data Value* **MUST** be any text string. Subtypes of PROGRAM_COMMENT are SCHEDULE, MAIN and ACTIVE. If a subType is not specified, it is assumed to be MAIN.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PROGRAM_EDIT	ProgramEdit	An indication of the status of the Controller components program editing mode. On many controls, a program can be edited while another program is currently being executed. ProgramEdit provides an indication of whether the controller is being used to edit programs in either case. *Valid Data Values*: ACTIVE: The controller is in the program edit mode. READY : The controller is capable of entering the program edit mode and no function is inhibiting a change to that mode. NOT_READY : A function is inhibiting the controller from entering the program edit mode.
PROGRAM_-EDIT_NAME	ProgramEditName	The name of the program being edited. This is used in conjunction with PROGRAM_EDIT when in ACTIVE state. The *Valid Data Value* **MUST** be a text string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PROGRAM_-HEADER	ProgramHeader	The non-executable header section of the control program. Subtypes of PROGRAM_HEADER are SCHEDULE, MAIN, and ACTIVE. The *Valid Data Value* **MUST** be a text string.
PROGRAM_-LOCATION	ProgramLocation	The Uniform Resource Identifier (URI) for the source file associated with PROGRAM. The *Valid Data Value* **MUST** be any text string. A subType **MUST** always be specified. Subtypes of PROGRAM_LOCATION are SCHEDULE, MAIN, and ACTIVE.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
PROGRAM_-LOCATION_-TYPE	ProgramLocationType	Defines whether the logic or motion program defined by PROGRAM is being executed from the local memory of the controller or from an outside source. A subType **MUST** always be specified. Subtypes of PROGRAM_-LOCATION_TYPE are SCHEDULE, MAIN, and ACTIVE. *Valid Data Values* are: LOCAL: Managed by the controller. EXTERNAL: Not managed by the controller.
PROGRAM_-NEST_LEVEL	ProgramNestLevel	An indication of the nesting level within a control program that is associated with the code or instructions that is currently being executed. If an initial value is not defined, the nesting level associated with the highest or initial nesting level of the program **MUST** default to zero (0). The value reported for ProgramNestLevel **MUST** be an integer.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
ROTARY_MODE	RotaryMode	The current operating mode for a Rotary type axis. *Valid Data Values*: SPINDLE: The axis is functioning as a spindle. Generally, it is configured to rotate at a defined speed. INDEX: The axis is configured to index to a set of fixed positions or to incrementally index by a fixed amount. CONTOUR: The position of the axis is being interpolated as part of the PathPosition defined by the Controller *Structural Element*.
ROTARY_-VELOCITY_-OVERRIDE	RotaryVelocityOverride	The value of a command issued to adjust the programmed velocity for a Rotary type axis. This command represents a percentage change to the velocity calculated by a logic or motion program or set by a switch for a Rotary type axis. RotaryVelocityOverride is expressed as a percentage of the programmed RotaryVelocity. The *Valid Data Value* **MUST** be a floating-point number.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
ROTATION	Rotation	A three space angular rotation relative to a coordinate system. The value **MUST** be three floating-point numbers representing rotations around the X, Y, and Z axes in degrees. The values in XML are space delimited.
SENSOR_-ATTACHMENT	SensorAttachment	A SensorAttachment is an Event defining an *Attachment* between a sensor and an entity. The *Valid Data Value* **MUST** be a string. The Entry key **MUST** be from the following: SENSOR_ID
SERIAL_-NUMBER	SerialNumber	The serial number associated with a Component, Asset, or Device. The *Valid Data Value* **MUST** be a text string.
SPECIFICATION_-LIMIT	SpecificationLimit	A set of limits defining a range of values designating acceptable performance for a variable. The *Valid Data Value* **MUST** be a float. The Entry key **MUST** be one or more from the following: UPPER_LIMIT, NOMINAL, or LOWER_LIMIT.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
SPINDLE_-INTERLOCK	SpindleInterlock	An indication of the status of the spindle for a piece of equipment when power has been removed and it is free to rotate. *Valid Data Values*: ACTIVE: Power has been removed and the spindle cannot be operated. INACTIVE: Spindle has not been deactivated.
TOOL_ASSET_-ID	ToolAssetId	The identifier of an individual tool asset.The *Valid Data Value* **MUST** be a text string.
TOOL_GROUP	ToolGroup	An identifier for the tool group associated with a specific tool. Commonly used to designate spare tools. The *Valid Data Value* **MUST** be any text string.
~~TOOL_ID~~	~~ToolId~~	**DEPRECATED** in Version 1.2.0. See TOOL_ASSET_ID. ~~The identifier of the tool currently in use for a given Path.~~
TOOL_NUMBER	ToolNumber	The identifier assigned by the Controller component to a cutting tool when in use by a piece of equipment. The *Valid Data Value* **MUST** be a text string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
TOOL_OFFSET	ToolOffset	A reference to the tool offset variables applied to the active cutting tool. Subtypes of ToolOffset are RADIAL and LENGTH. **DEPRECATED** in V1.5 ~~A subType **MUST** always be specified.~~ The *Valid Data Value* **MUST** be a text string.
TRANSFER_COUNT	TransferCount	Accumulation of the number of times an operation has attempted to, or is planned to attempt to, transfer materials, parts, or other items from one location to another. When the discrete attribute is true, the value represents the count since the previous occurrence of the event. Subtypes of TransferCount are ALL, GOOD, BAD, TARGET, REMAINING, COMPLETE, FAILED, and ABORTED. The *Valid Data Value* **MUST** be numeric.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
TRANSLATION	Translation	A three space linear translation relative to a coordinate system. The value **MUST** be three floating-point numbers translation along the X, Y, and Z axes in millimeters. The values in XML are space delimited.
UNLOAD_COUNT	UnloadCount	Accumulation of the number of times an operation has attempted to, or is planned to attempt to, unload materials, parts, or other items. When the discrete attribute is true, the value represents the count since the previous occurrence of the event. Subtypes of UnloadCount are ALL, GOOD, BAD, TARGET, REMAINING, COMPLETE, FAILED, and ABORTED. The *Valid Data Value* **MUST** be numeric.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
USER	User	The identifier of the person currently responsible for operating the piece of equipment. Subtypes of User are OPERATOR, MAINTENANCE, and SET_UP. A subType **MUST** always be specified. The *Valid Data Value* **MUST** be any text string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
VALVE_STATE	ValveState	The state of a valve that is one of open, closed, or transitioning between the states. Subtypes of ValveState are ACTUAL and PROGRAMMED. *Valid Data Values*: OPEN: ValveState where flow is allowed and the aperture is static. Note : For a binary value, OPEN indicates that the valve has the maximum possible aperture. OPENING: The VALVE is transitioning from a CLOSED state to an OPEN state. CLOSED: ValveState where flow is not possible, the aperture is static and the valve is completely shut. CLOSING: The VALVE is transitioning from an OPEN state to a CLOSED state.
VARIABLE	Variable	A data value whose meaning may change over time due to changes in the operation of a piece of equipment or the process being executed on that piece of equipment. The *Valid Data Value* **MUST** be a string.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
WAIT_STATE	WaitState	An indication of the reason that EXECUTION is reporting a value of WAIT. *Valid Data Values* are: POWERING_UP: An indication that execution is waiting while the equipment is powering up and is not currently available to begin producing parts or products. POWERING_DOWN: An indication that the execution is waiting while the equipment is powering down but has not fully reached a stopped state. PART_LOAD: An indication that the execution is waiting while one or more discrete workpieces are being loaded. PART_UNLOAD: An indication that the execution is waiting while one or more discrete workpieces are being unloaded. TOOL_LOAD: An indication that the execution is waiting while a tool or tooling is being loaded. TOOL_UNLOAD: An indication that the execution is waiting while a tool or tooling is being unloaded.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
WAIT_STATE (Continued)	WaitState	MATERIAL_LOAD: An indication that the execution is waiting while bulk material or the container for bulk material used in the production process is being loaded. Bulk material includes those materials from which multiple workpieces may be created. MATERIAL_UNLOAD: An indication that the execution is waiting while bulk material or the container for bulk material used in the production process is being unloaded. Bulk material includes those materials from which multiple workpieces may be created. SECONDARY_PROCESS: An indication that the execution is waiting while another process is completed before the execution can resume. PAUSING: An indication that the execution is waiting while the equipment is pausing but the piece of equipment has not yet reached a fully paused state. RESUMING: An indication that the execution is waiting while the equipment is resuming the production cycle but has not yet resumed execution.

Continuation of Table 26: Element Names for Event		
DataItem Type	Element Name	Description
`WIRE`	`Wire`	The identifier for the type of wire used as the cutting mechanism in Electrical Discharge Machining or similar processes. The *Valid Data Value* **MUST** be any text string.
`WORKHOLDING_ID`	`WorkholdingId`	The identifier for the current workholding or part clamp in use by a piece of equipment. The *Valid Data Value* **MUST** be a text string.
`WORK_OFFSET`	`WorkOffset`	A reference to the offset variables for a work piece or part associated with a `Path` in a `Controller` type component. The *Valid Data Value* **MUST** be a text string.

6.3 Types of Condition Elements

As described in *Section 5.8 - Condition Data Entity*, `Condition` *Data Entities* are reported differently from other data item `types`. They are reported based on the *Fault State* for each `Condition`. Unlike `Sample` and `Event` data items that are identified by their *Element Name*, `Condition` data items are defined by the `type` and `subType` (where applicable) attributes defined for each `Condition`.

The `type` and `subType` (where applicable) attributes for a `Condition` element **MAY** be any of the `type` and `subType` attributes defined for `SAMPLE` category or `EVENT` category data item listed in the *Devices Information Model*.

Table *Section 5.8.1 - Element Names for Condition* lists additional `Condition` *Data Entities* that have been defined to represent the health and fault status of *Structural Elements*. The table defines the `type` attribute for each of these additional `Condition` category

1137 elements that **MAY** be reported in the MTConnectStreams document.

Table 27: Element Names for Condition

DataItem Type	Description
ACTUATOR	An indication of a fault associated with an actuator.
CHUCK_INTERLOCK	An indication of the operational condition of the interlock function for an electronically controller chuck.
COMMUNICATIONS	An indication that the piece of equipment has experienced a communications failure.
DATA_RANGE	An indication that the value of the data associated with a measured value or a calculation is outside of an expected range.
DIRECTION	An indication of a fault associated with the direction of motion of a *Structural Element*.
END_OF_BAR	An indication that the end of a piece of bar stock has been reached.
HARDWARE	An indication of a fault associated with the hardware subsystem of the *Structural Element*.
INTERFACE_STATE	An indication of the operation condition of an Interface component.
LOGIC_PROGRAM	An indication that an error occurred in the logic program or programmable logic controller (PLC) associated with a piece of equipment.
MOTION_PROGRAM	An indication that an error occurred in the motion program associated with a piece of equipment.
SYSTEM	An indication of a fault associated with a piece of equipment or component that cannot be classified as a specific type.

Appendices

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IEEE STD 1451.4-1994, Standard for a Smart Transducer Interface for Sensors and Actuators – Mixed-Mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats, IEEE Instrumentation and Measurement Society, TC-9, The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y. 10016, SH95225, December 15, 2004.

MTConnect® Standard
Part 4.0 – Assets Information Model
Version 1.8.0

Prepared for: MTConnect Institute
Prepared on: September 6, 2021

September 6, 2021

MTConnect Specification and Materials

Table of Contents

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1 Purpose of This Document

This document, *MTConnect Standard: Part 4.0 - Assets Information Model* of the MTConnect Standard, details information that is common to all types of *MTConnect Assets*. Part 4.0 and its sub-parts of the MTConnect Standard provide semantic models for entities that are used in the manufacturing process, but are not considered to be a piece of equipment. These entities are defined as *MTConnect Assets*. These *Assets* may be removed from a piece of equipment without detriment to the function of the equipment and can be associated with other pieces of equipment during their lifecycle. The data associated with these *Assets* may be retrieved from multiple sources that are each responsible for providing their knowledge of the *Asset*.

2 Terminology and Conventions

Refer to Section 2 of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 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

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.

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.

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*.

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.

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*.

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`.

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 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*.

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*.

Equipment Metadata

See *Metadata*

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*.

Lower Level

A nested element that is below a higher level element.

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*.

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 Information Model

See *Information Model*

MTConnectDevices Response Document

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

MTConnectStreams Response Document

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

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.

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*.

Probe Request

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

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*.

Response Document

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

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*.

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*.

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*.

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*.

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*.

Top Level

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

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).

XML Schema

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

2.2 Acronyms

AMT

The Association for Manufacturing Technology

2.3 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.8.0.

[MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Streams Information Model*. Version 1.8.0.

[MTConnect Part 4.0] *MTConnect Standard: Part 4.0 - Assets Information Model*. Version 1.8.0.

3 MTConnect Assets

3.1 Overview

The MTConnect Standard supports a simple distributed storage mechanism that allows applications and equipment to share and exchange complex information models in a similar way to a distributed data store. The *Asset Information Model* associates each electronic `MTConnectAssets` document with a unique identifier and allows for some predefined mechanisms to find, create, request, updated, and delete these electronic documents in a way that provides for consistency across multiple pieces of equipment.

The protocol provides a limited mechanism of accessing *MTConnect Assets* using the following properties: `assetId`, *Asset* type (element name of *Asset* root), and the piece of equipment associated with the *Asset*. These access strategies will provide the following services and answer the following questions: What *Assets* are from a particular piece of equipment? What are the *Assets* of a particular type? What *Assets* is stored for a given `assetId`?

Although these mechanisms are provided, an *Agent* should not be considered a data store or a system of reference. The *Agent* is providing an ephemeral storage capability that will temporarily manage the data for applications wishing to communicate and manage data as need-ed by the various processes. An application cannot rely on an *Agent* for long term persistence or durability since the *Agent* is only required to temporarily store the *Asset* data and may require an-other system to provide the source data upon initialization. An *Agent* is always providing the best-known equipment centric view of the data given the limitations of that piece of equipment.

3.2 MTConnectAssets

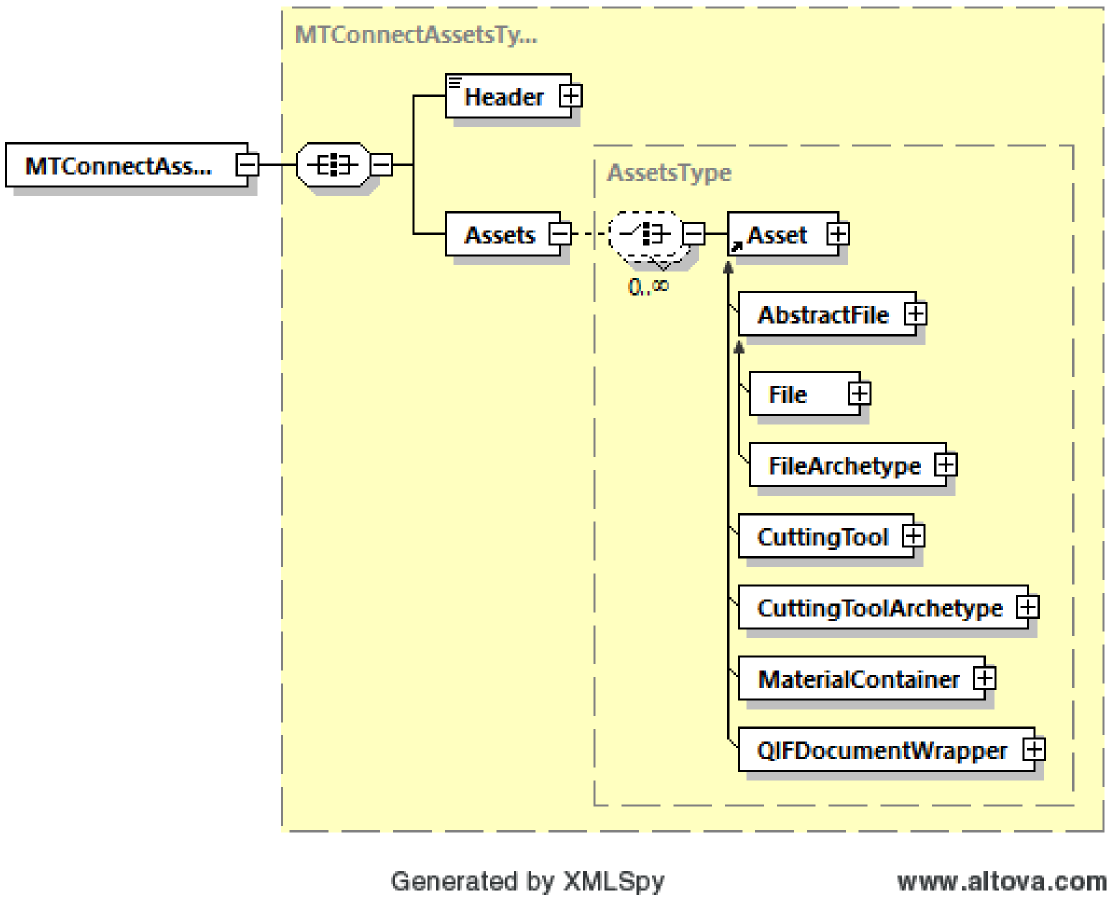

Figure 1: MTConnectAssets Schema

At the top level of the `MTConnectAssets` document is a standard header, as stated in *MTConnect Standard Part 1.0 - Overview and Fundamentals*, and one or more *MTConnect Assets*. Each *Asset* is required to have an `assetId` that serves as a unique identifier of that *Asset*. `assetId` allows an application to request the *Asset* data from an *Agent*.

In the remaining Part 4.x sub-part documents of *MTConnect Assets*, various types of *Assets* will be introduced such as cutting tools and other *Asset* types.

3.2.1 MTConnectAssets Header

The `MTConnectAssets` header is where the protocol sequence information **MUST** be provided. The *XML Schema* in *Figure 2* represents the structure of the `MTConnectAssets` header showing the attributes defined for `MTConnectAssets`.

Refer to *MTConnect Standard Part 1.0 - Overview and Fundamentals* for more information on headers.

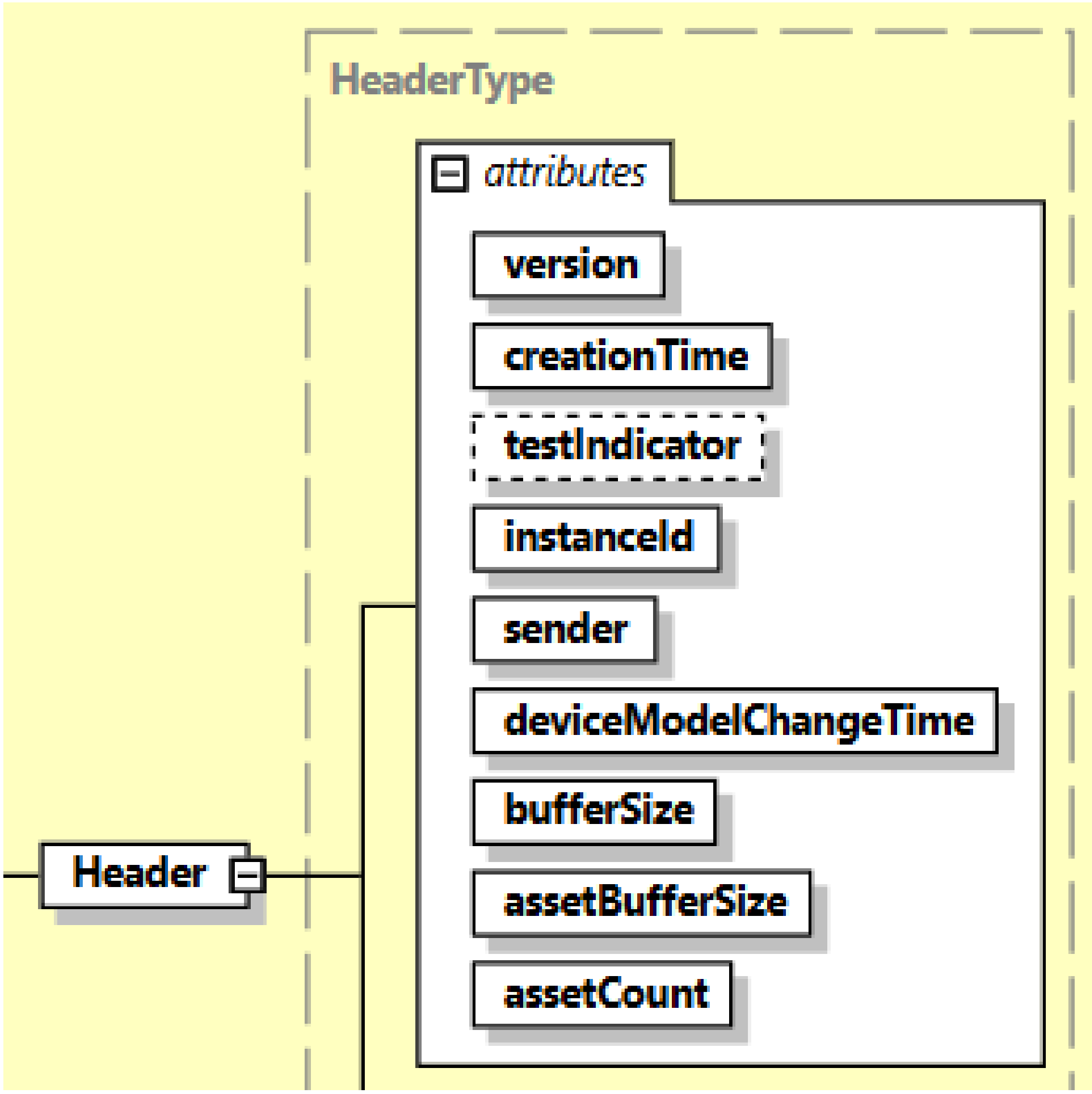

Figure 2: MTConnectAssets Header

3.2.1.1 Header Attributes

Table 1 defines the attributes used to provide information for an `MTConnectAssets` header.

Table 1: MTConnectAssets Header

Attribute	Description	Occurrence
`version`	The protocol version number. This is the *major* and *minor* version number of the MTConnect Standard being used. For example, if the version number of the Standard used is `10.21.33`, the `version` will be `10.21`. `version` is a required attribute.	1
`creationTime`	The time the response was created. `creationTime` is a required attribute.	1
`testIndicator`	Optional flag that indicates the system is operating in test mode. This data is only for testing and indicates that the data is simulated. `testIndicator` is an optional attribute.	0..1
`instanceId`	A number indicating which invocation of the *Agent*. This is used to differentiate between separate instances of the *Agent*. This value **MUST** have a maximum value of $2^{64}-1$ and **MUST** be stored in an unsigned 64-bit integer. `instanceId` is a required attribute.	1
`sender`	The *Agent* identification information. `sender` is a required attribute.	1
`assetBufferSize`	The maximum number of *MTConnect Assets* that will be retained by the *Agent*. The `assetBufferSize` **MUST** be an unsigned positive integer value with a maximum value of $2^{32}-1$. `assetBufferSize` is a required attribute.	1

Continuation of Table 1

Attribute	Description	Occurrence
`assetCount`	The total number of *MTConnect Assets* in an*Agent*. This **MUST** be an unsigned positive integer value with a maximum value of $2^{32} - 1$. This value **MUST NOT** be greater than `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 1: MTConnectAssets Header Example

```
<Header creationTime="2010-03-13T07:59:11+00:00"
        sender="localhost" instanceId="1268463594"
        assetBufferSize="1024" version="1.1"
        assetCount="12" />
```

3.2.2 Assets

`Assets` is an XML container used to group information about various *MTConnect Asset* types. `Assets` contains one or more `Asset` XML elements.

Table 2: MTConnect Assets Element

Element	Description	Occurrence
`Assets`	An XML container that consists of one or more types of `Asset` XML elements.	0..1

3.2.3 Asset

An `Asset` XML element is a container type XML element used to organize information describing an entity that is not a piece of equipment. `Asset` is an abstract type XML element and will never appear directly in the MTConnect XML document. As an abstract type XML element, `Asset` will be replaced in the XML document by specific *MTConnect Asset* type.

Table 3: MTConnect Asset Element

Element	Description	Occurrence
`Asset`	An abstract XML element. Replaced in the XML document by types of `Asset` elements representing entities that are not pieces of equipment. There can be multiple types of `Asset` XML elements in the document.	1..*

There are various types of entities or *Asset* types. Each type of *Asset* is described in sub-parts of *MTConnect Standard: Part 4.0 - Assets Information Model*. These sub-parts are designated by a Part 4.x document number.

For all *MTConnect Asset* types there are some common attributes and elements that apply to all of them. The following defines these common attributes and elements.

3.2.3.1 Common Asset Attributes

The *XML Schema* in *Figure 3* represents the structure of `Asset` showing the attributes defined for `Asset`.

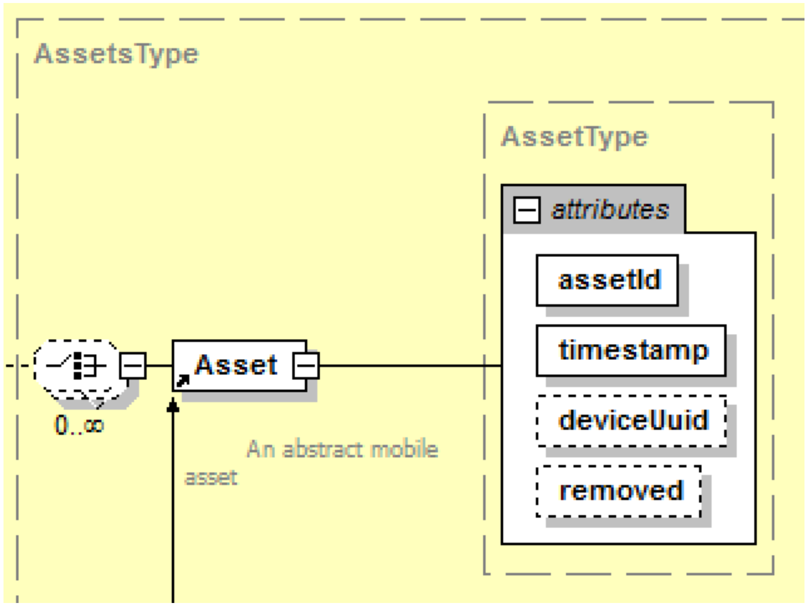

Figure 3: Asset Schema

Table 4 defines the attributes that are used to provide information for the `Asset` element.

Table 4: Attributes for Asset

Attribute	Description	Occurrence
`assetId`	The unique identifier for the *MTConnect Asset*. The identifier **MUST** be unique with respect to all other *Assets* in an MTConnect installation. The identifier **SHOULD** be globally unique with respect to all other *Assets*. `assetId` is a required attribute.	1
`timestamp`	The time this *MTConnect Asset* was last modified. Always given in UTC. The `timestamp` **MUST** be provided in UTC (Universal Time Coordinate, also known as GMT). This is the time the *Asset* data was last modified. `timestamp` is a required attribute.	1

Continuation of Table 4		
Attribute	Description	Occurrence
`deviceUuid`	The piece of equipments UUID that supplied this data. This is an optional element references to the UUID attribute given in the `Device` element. This can be any series of numbers and letters as defined by the XML type NMTOKEN.	0..1
`removed`	This is an optional attribute that is an indicator that the *MTConnect Asset* has been removed from the piece of equipment. If the *Asset* is marked as removed, it will not be visible to the client application unless the=true parameter is provided in the URL. If this attribute is not present it MUST be assumed to be false. The value is an `xsi:boolean` type and **MUST** be `true` or `false`.	0..1

All *MTConnect Assets* **MUST** have a unique value for `assetId` and it **SHOULD** be globally unique, such as a RFC 4122 UUID.

The following attributes **MUST** be provided and are common to all *MTConnect Asset* types: the `assetId` attribute providing the unique identifier for the *Asset*, and the `timestamp` providing the time the *Asset* was inserted or updated. A removed flag that if `true` indicates the *Asset* has been removed (deleted) from the equipment is optional, however the *Asset* will still be available if requested directly or a request is made that includes removed *Assets*.

An `MTConnectAssets` document contains information pertaining to something that is not a direct component of the piece of equipment and can be relocated to another piece of equipment or location during its lifecycle. The `Asset` will contain data that will be changed as a unit, meaning that at any given point in time the latest version of the complete state for this *Asset* will be provided.

Each piece of equipment or location may have a different view of this *Asset* and it is the responsibility of an application to collect and determine the aggregate information and keep a historical record if required. An *Agent* will allow any application or other equipment to request this information. The piece of equipment **MUST** supply the latest and most accurate information regarding a given *Asset*.

3.2.3.2 Common Asset Elements

The element `Description` is the only element common to all *Asset* types.

The *XML Schema* in *Figure 4* represents the structure of `Description`.

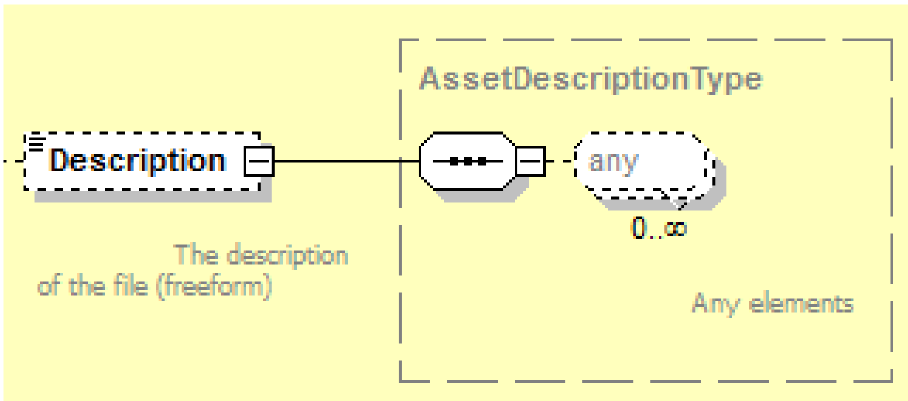

Figure 4: Description Schema

Table 5 defines the elements that are used to provide information for `Asset`.

Table 5: Elements for Asset

Elements	Description	Occurrence
`Description`	An optional element that can contain any descriptive content. This can contain configuration information and manufacturer specific details. This element is defined to contain mixed content and XML elements can be added to extend the descriptive semantics of MTConnect Standard.	0..1

4 MTConnect Assets Architecture

4.1 Agent Asset Storage

The *Agent* stores *MTConnect Assets* in a similar fashion as the *Agent* data storage described in *MTConnect Standard Part 1.0 - Overview and Fundamentals*. The storage of information is contained in the *asset buffer*. The *Agent* provides a limited number of *Assets* that can be stored at one time and uses the same method of pushing out the oldest *Asset* when the *asset buffer* is full. The *asset buffer* size for the *Asset* storage is maintained separately from the `Sample`, `Event`, and `Condition` storage.

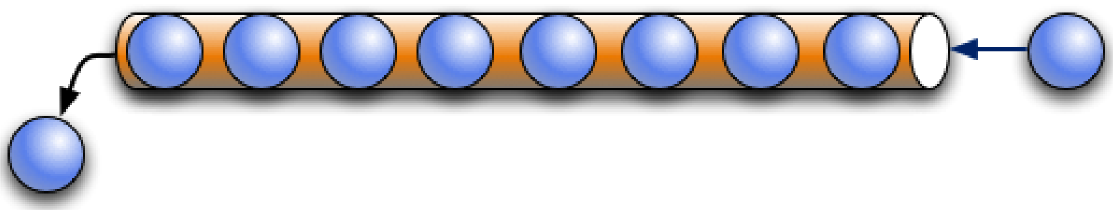

Figure 5: MTConnect Assets storage as First in First Out

MTConnect Assets also behave like a key/value in memory database. In the case of the *Asset*, the key is the `assetId` and the value is the XML document describing the *Asset*. The key can be any string of letters, punctuation or digits and represent the domain specific coding scheme for their assets. Each *Asset* type will have a recommended way to construct a unique `assetId`, for example, a cutting tool **SHOULD** be identified by the tool ID and serial number as a composed synthetic identifier.

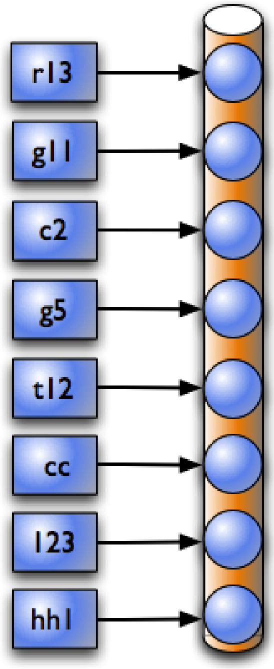

Figure 6: MTConnect Assets storage as Key/Value pairs

As in *Figure 6* , each of the *Assets* is referred to by their key. The key is independent of the order in the *asset buffer* storage.

4.2 Asset Protocol

MTConnect Standard provides methods to retrieve an *MTConnect Asset* or a set of *Assets* given various criteria. These criteria are as follows: The `assetId`, the *Asset* `type` as defined by the name of the *Asset*'s topmost element, and the originating piece of equipment.

The URL format is similar to the `probe` and `sample` structure. Reference each `assetId` directly to request an *MTConnect Asset* by `assetId`.

4.2.1 Asset by assetId

Example 2: Asset by assetId Example

```
url: http://example.com/asset/e39d23ba-ef2d-
     11e6-b12c15028cfe91a82ef
```

Example 2 returns the `MTConnectAssets` document for *Asset* `e39d23ba-ef2d-11e6-b12c-28cfe91a82ef`

Request multiple *Assets* by each `assetId`:

Example 3: Assets by assetId Example

```
url: http://example.com/asset/e39d23ba-ef2d-11e6-b12c155;
    8cfe91a82ef;e46d5256-ef2d-11e6-96aa-28cfe91a82ef
```

Example 3 returns the `MTConnectAssets` document for *Assets* `e39d23ba-ef2d-11e6-b12c-28cfe91a82ef` and `e46d5256-ef2d-11e6-96aa-28cfe91a82ef`.

Request for all the *Assets* in the *Agent*:

Example 4: Get all Assets Example

```
url: http://example.com/assets
```

Example 4 returns all available *MTConnect Assets* in the *Agent*. The *Agent* **MAY** return a limited set if there are too many *Asset* records. The *Assets* **MUST** be added to the beginning with the most recently modified *Asset*.

4.2.2 Asset for a Given Type

Example 5: Asset for a Given Type Example

```
url: http://example.com/assets?type="CuttingTool"
```

Example 5 returns all available `CuttingTool` *Assets* from the *Agent* of the type `CuttingTool`. The *Agent* **MAY** return a limited set if there are too many *Asset* records. The *Assets* **MUST** be added to the beginning with the most recently modified assets.

Request for all *Assets* of a given type in the *Agent* up to a maximum count:

Example 6: Asset for a Given Type with Maximum count Example

```
url: http://example.com/assets?type="CuttingTool"
```

Example 6 returns all available `CuttingTool` *Assets* from the *Agent*. The *Agent* **MUST** return up to 1000 *Assets* beginning with the most recently modified *Assets* if they exist.

4.2.3 Assets Including Removed Assets

Example 7: Assets Including Removed Assets Example

```
url: http://example.com/assets?type=CuttingTool&removed=true
```

Example 7 returns all available `CuttingTool` *Assets* from the *Agent*. With the removed flag, *Assets* that have been removed but are included in the result set.

4.2.4 Assets for a Piece of Equipment

If no `assetId` is provided with a general *Assets* request, it would be as shown in *Example 8*:

Example 8: Assets For a Piece of Equipment Example

```
url: http://example.com/Mill123/assets
```

All *MTConnect Assets* will be provided for that piece of equipment (`Device`) up to the *Agent*'s maximum count or as specified with the count parameter. These *Assets* will be returned starting from the newest to oldest list.

Any of the previous constraints can also be applied to the request, for example, to get all the `CuttingTool` instances for a given piece of equipment:

Example 9: Assets For a Piece of Equipment For a Given Type Example

```
url: http://example.com/Mill123/asset/
          ?type=CuttingTool&count=100
```

The request in *Example 9* will get the newest 100 Cutting Tool Instance *Assets* from the *Agent* for `Mill123`. Similarly:

Example 10: Assets For a Piece of Equipment For a Given Type Example 2

```
url: http://example.com/Mill123/asset/
          ?type=CuttingToolArchetype
```

Example 10 will provide all Cutting Tool Archetype *Assets* with the `deviceUuid` of `Mill123`.

5 Extensions to Part 2.0 - Devices Information Model

This document will add the following data item types to support change notification when an *MTConnect Asset* is added or updated. The data item **MUST** be placed in the DataItems container associated with Device. The Device **MUST** be the piece of equipment that is supplying the asset data.

5.1 Data Item Types added for EVENT Category

Table 6: DataItem Type for EVENT category

DataItem Type SubType	Description
ASSET_CHANGED	The event generated when an asset is added or changed. AssetChanged **MUST** be discrete and the value of the DataItem's discrete attribute **MUST** be true.
ASSET_REMOVED	The value of the CDATA for the event **MUST** be the assetId of the asset that has been removed. The asset will still be visible if requested with the includeRemoved parameter as described in the protocol section. When assets are removed they are not moved to the beginning of the most recently modified list.

5.1.1 ASSET_CHANGED Data Item Type

When an *MTConnect Asset* is added or modified, an AssetChanged event **MUST** be published to inform an application that new asset data is available. The application can request the new asset data from the piece of equipment at that time. Every time the asset data is modified an AssetChanged event will be published. Since the asset data is a complete electronic document, the system will publish a single AssetChanged event for the entire set of changes.

The asset data **MUST** remain constant until the AssetChanged event is published. Once it is published the data **MUST** change to reflect the new content at that instant. The timestamp of the asset will reflect the time the last change was made to the asset data.

5.1.2 ASSET_REMOVED Data Item Type

When an *MTConnect Asset* has been removed from an *Agent*, or marked as removed, an `AssetRemoved` event **MUST** be generated in a similar way to the `AssetChanged` event. The CDATA of the `AssetRemoved` event **MUST** contain the `assetId` that was just removed.

Every time an *MTConnect Asset* is modified or added it will be moved to the beginning of the *asset buffer* and become the newest *Asset*. As the *asset buffer* fills up, the oldest *Asset* will be pushed out and its information will be removed. The MTConnect Standard does not specify the maximum size of the *asset buffer*, and if the implementation desires, permanent storage **MAY** be used to store the *Assets*. A value of 4,294,967,296 or 2^{32} can be given to indicate unlimited storage.

There is no requirement for persistent *Asset* storage. If the *Agent* fails, all existing *MTConnect Assets* **MAY** be lost. It is the responsibility of the implementation to restore the lost *Asset* data and it is the responsibility of the application to persist the *Asset* data. The *Agent* **MAY** make no guarantees about availability of *Asset* data after the *Agent* stops.

6 Extensions to Part 3.0 - Streams Information Model

The associated modifications **MUST** be added to *MTConnect Standard: Part 3.0 - Streams Information Model* to add the following event to the `Events` in the streams.

6.1 AssetChanged Extension to Events

The `AssetChanged` element extends the base `Event` type XML data element defined in *MTConnect Standard: Part 3.0 - Streams Information Model* and adds the `assetType` attribute to the base `Event`. This new `Event` will signal whenever a new *MTConnect Asset* is added or the existing definition of an *Asset* is updated. The `assetId` is provided as the CDATA value and can be used to request the *Asset* data from the *Agent*.

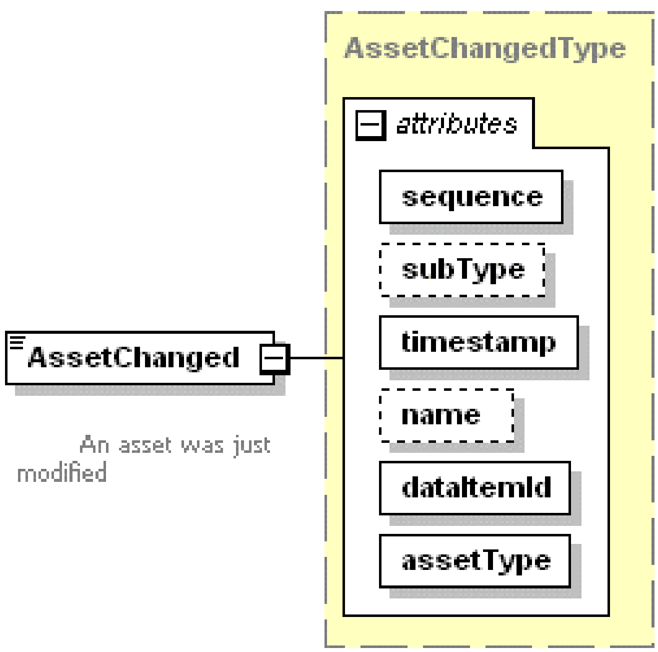

Figure 7: AssetChanged Schema

`AssetChanged`: An *MTConnect Asset* has been added or modified. The CDATA for the `AssetChanged` element **MUST** be the `assetId` of the *Asset* that has been modified.

6.1.1 AssetChanged event Attributes

Table 7: Attributes for AssetChanged

Attribute	Description	Occurrence

`assetType`	The type of asset changed.
	`assetType` is a required attribute.
	Valid Data Values:
	`CuttingTool`
	`File`
	`QIFDocumentWrapper`
	`MaterialContainer`
		1

6.2 AssetRemoved Extension to Events

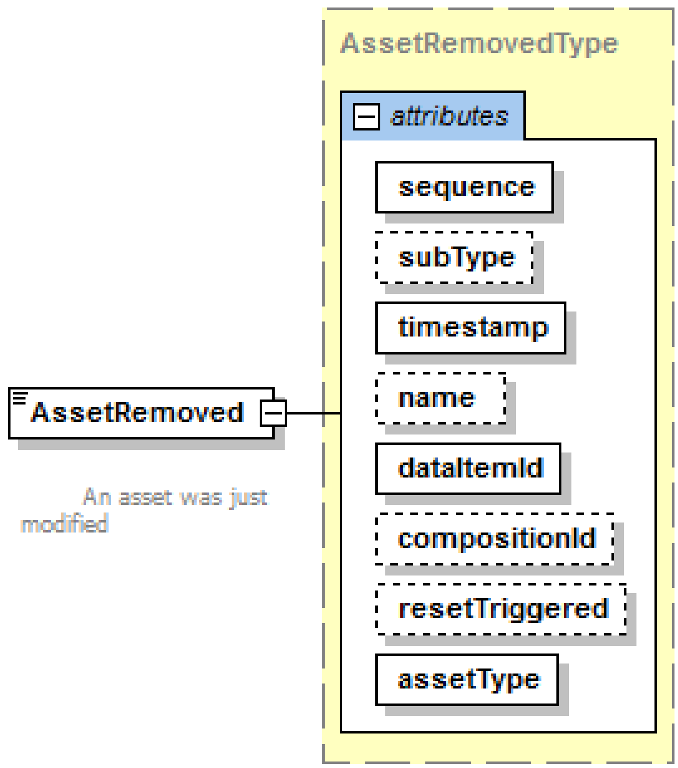

Figure 8: AssetRemoved Schema

`AssetRemoved`: An *MTConnect Asset* has been removed. The CDATA for the `AssetRemoved` element **MUST** be the `assetId` of the *Asset* that has been removed.

6.2.1 AssetRemoved Attributes

Table 8: Attributes for AssetRemoved

Attribute	Description	Occurrence

`assetType`	The type of asset that was removed.
	`assetType` is a required attribute.
	Valid Data Values:
	`CuttingTool`
	`File`
	`QIFDocumentWrapper`
	`MaterialContainer`
		1

The *MTConnect Asset* will still be available if requested if the removed=true argument is supplied. The `assetId` is provide as the CDATA value and can be used to request the *Asset* data from the *Agent*.

Appendices

A Bibliography

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MTConnect® Standard

Part 4.1 – Cutting Tools

Version 1.8.0

Prepared for: MTConnect Institute
Prepared on: September 6, 2021

MTConnect Specification and Materials

Table of Contents

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1 Purpose of This Document

This document, *MTConnect Standard: Part 4.1 - Cutting Tools* of the MTConnect Standard, establishes the rules and terminology to be used by designers to describe the function and operation of cutting tools used within manufacturing and to define the data that is provided by an *Agent* from a piece of equipment. This part of the Standard also defines the structure for the XML document that is returned from an *Agent* in response to a `probe` request.

The data associated with these cutting tools will be retrieved from multiple sources that are responsible for providing their knowledge of an *MTConnect Asset*.

2 Terminology and Conventions

Refer to Section 2 of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 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

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.

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.

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*.

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.

Attribute

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

Appears in the documents in the following form: attribute.

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*.

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`.

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 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*.

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*.

Equipment Metadata

See *Metadata*

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*.

Lower Level

A nested element that is below a higher level element.

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*.

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 Information Model

See *Information Model*

MTConnectDevices Response Document

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

MTConnectStreams Response Document

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

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.

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*.

Probe Request

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

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*.

Response Document

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

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*.

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*.

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*.

Spindle

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

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

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*.

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*.

Top Level

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

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).

XML Schema

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

2.2 Acronyms

AMT

The Association for Manufacturing Technology

2.3 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.8.0.

[MTConnect Part 2.0] *MTConnect Standard: Part 2.0 - Devices Information Model*. Version 1.8.0.

[MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Streams Information Model*. Version 1.8.0.

[MTConnect Part 4.1] *MTConnect Standard: Part 4.1 - Cutting Tools*. Version 1.8.0.

3 Cutting Tool and Cutting Tool Archetype

There are two *Information Models* used to represent a cutting tool, `CuttingToolArchetype` and `CuttingTool`. The `CuttingToolArchetype` represent the static cutting tool geometries and nominal values as one would expect from a tool catalog and the `CuttingTool` represents the use or application of the tool on the shop floor with actual measured values and process data. In Version 1.3.0 of the MTConnect Standard it was decided to separate out these two concerns since not all pieces of equipment will have access to both sets of information. In this way, a generic definition of the cutting tool can coexist with a specific assembly *Information Model* with minimal redundancy of data.

3.1 XML Schema Structure for CuttingTool and CuttingToolArchetype

The *Figure 1* shows the *XML Schema* that applies to both the `CuttingTool` *Information Model* and the `CuttingToolArchetype` *Information Model*.

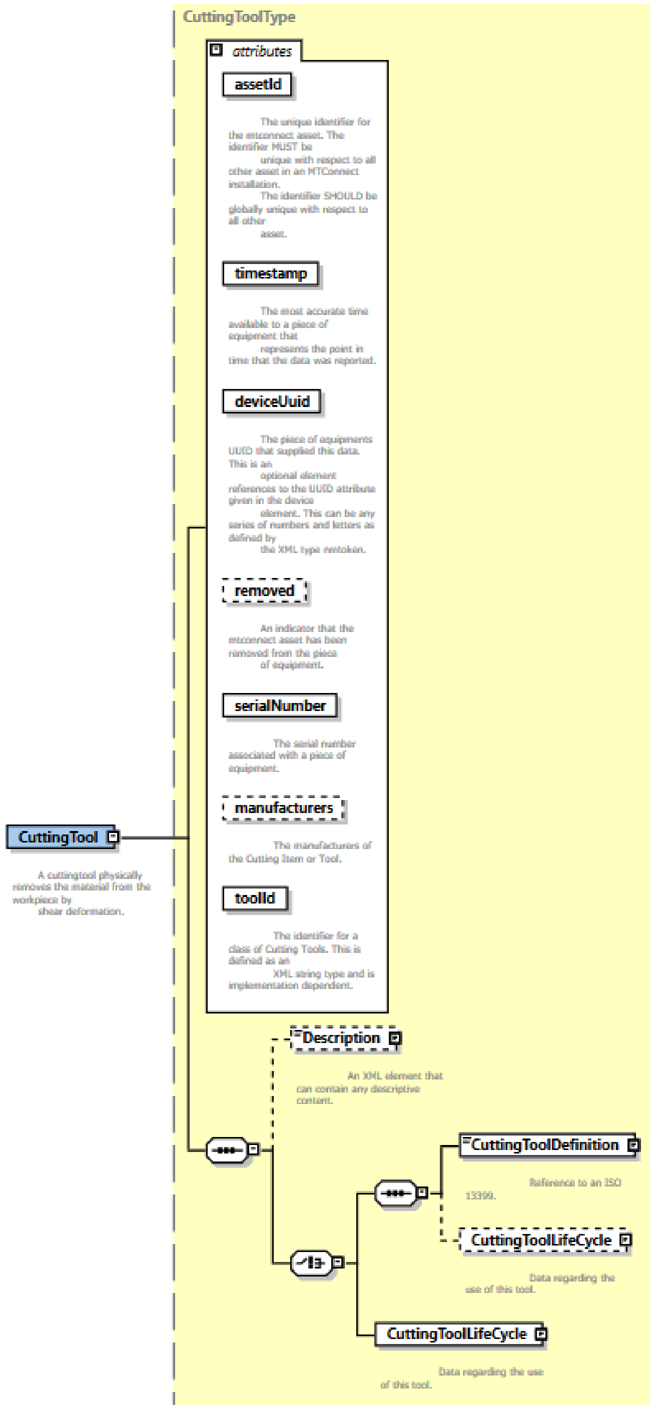

Figure 1: Cutting Tool Schema

Note: The use of the XML element `CuttingToolDefinition` has been **DEPRECATED** in the `CuttingTool` schema, but remains in the `CuttingToolArchetype` schema.

The following sections contain the definitions of `CuttingTool` and `CuttingToolArchetype` and describe their unique components. The following are the common entities for both elements.

3.2 Common Attributes for CuttingTool and CuttingToolArchetype

Table 1: Attributes for CuttingTool and CuttingToolArchetype

Attribute	Description	Occurrence
`timestamp`	The time this *MTConnect Asset* was last modified. Always given in UTC. The `timestamp` **MUST** be provided in UTC (Universal Time Coordinate, also known as GMT). This is the time the *Asset* data was last modified. `timestamp` is a required attribute.	1
`assetId`	The unique identifier of the instance of this tool. This will be the same as the `toolId` and `serialNumber` in most cases. The `assetId` **SHOULD** be the combination of the `toolId` and `serialNumber` as in `toolId`. `serialNumber` or an equivalent implementation dependent identification scheme. `assetId` is a required attribute. `assetId` is a permanent identifier that will be associated with an *MTConnect Asset* for its entire life.	1
`serialNumber`	The unique identifier for this assembly. This is defined as an XML string type and is implementation dependent. `serialNumber` is a required attribute.	1

Continuation of Table 1		
Attribute	Description	Occurrence
toolId	The identifier for a class of Cutting Tools. This is defined as an XML string type and is implementation dependent. toolId is a required attribute.	1
deviceUuid	A reference to the Device's uuid that created the Asset information. The deviceUuid **MUST** be an NMTOKEN XML type.	1
manufacturers	An optional attribute referring to the manufacturer(s) of this Cutting Tool, for this element, this will reference the Tool Item and Adaptive Items specifically. The Cutting Items manufacturers' will be an attribute of the CuttingItem elements. The representation will be a comma (,) delimited list of manufacturer names. This can be any series of numbers and letters as defined by the XML type string.	0..1
removed	This is an indicator that the Cutting Tool has been removed from the piece of equipment. removed is a required attribute. If the *MTConnect Asset* is marked as removed, it will not be visible to the client application unless the includeRemoved=true parameter is provided in the URL. If this attribute is not present it **MUST** be assumed to be false. The value is an xsi:boolean type and **MUST** be true or false.	0..1

3.3 Common Elements for CuttingTool and CuttingToolArchetype

Table 2: Common Elements for CuttingTool and CuttingToolArchetype

Element	Description	Occurrence
`Description`	An element that can contain any descriptive content. This can contain configuration information and manufacturer specific details. This element is defined to contain mixed content and XML elements can be added to extend the descriptive semantics of MTConnect Standard.	0..1

3.3.1 Description Element for CuttingTool and CuttingToolArchetype

`Description` **MAY** contain mixed content, meaning that an additional XML element or plain text may be provided as part of the content of the description tag. Currently `Description` contains no attributes.

4 CuttingToolArchetype Information Model

The `CuttingToolArchetype` *Information Model* will have the identical structure as the `CuttingTool` *Information Model* illustrated in *Figure 1* , except for a few entities. The `CuttingTool` will no longer carry the `CuttingToolDefinition`, this **MUST** only appear in the `CuttingToolArchetype`. The `CuttingToolArchetype` **MUST NOT** have measured values and **MUST NOT** have any of the following items: `CutterStatus`, `ToolLife` values, `Location`, or a `ReconditionCount`.

MTConnect Standard will adopt the ISO 13399 structure when formulating the vocabulary for Cutting Tool geometries and structure to be represented in the `CuttingToolArchetype`. The nominal values provided in the `CuttingToolLifeCycle` section are only concerned with two aspects of the Cutting Tool, the Cutting Tool and the Cutting Item. The Tool Item, Adaptive Item, and Assembly Item will only be covered in the `CuttingToolDefinition` section of this document since this section contains the full ISO 13399 information about a Cutting Tool.

Figure 2: Cutting Tool Parts

The *Figure 2* illustrates the parts of a Cutting Tool. The Cutting Tool is the aggregate of all the components and the Cutting Item is the part of the tool that removes the material from the workpiece. These are the primary focus of the MTConnect Standard.

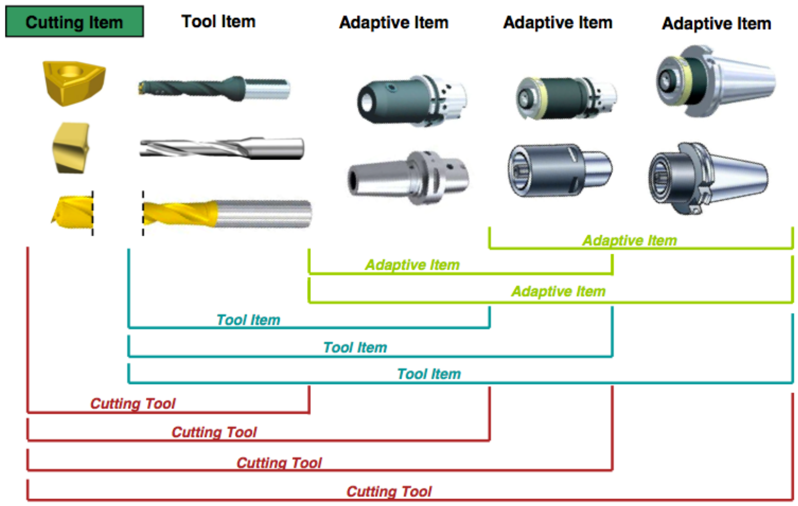

Figure 3: Cutting Tool Composition

Figure 3 provides another view of the composition of a Cutting Tool. The Adaptive Items and Tool Items will be used for measurements, but will not be modeled as separate entities. When we are referencing the Cutting Tool we are referring to the entirety of the assembly and when we provide data regarding the Cutting Item we are referencing each individual item as illustrated on the left of the previous diagram.

Figure 4 and *Figure 5* further illustrates the components of the Cutting Tool. As we compose the Tool Item, Cutting Item, Adaptive Item, we get a Cutting Tool. The Tool Item, Adaptive Item, and Assembly Item will only be in the `CuttingToolDefinition` section that will contain the full ISO 13399 information.

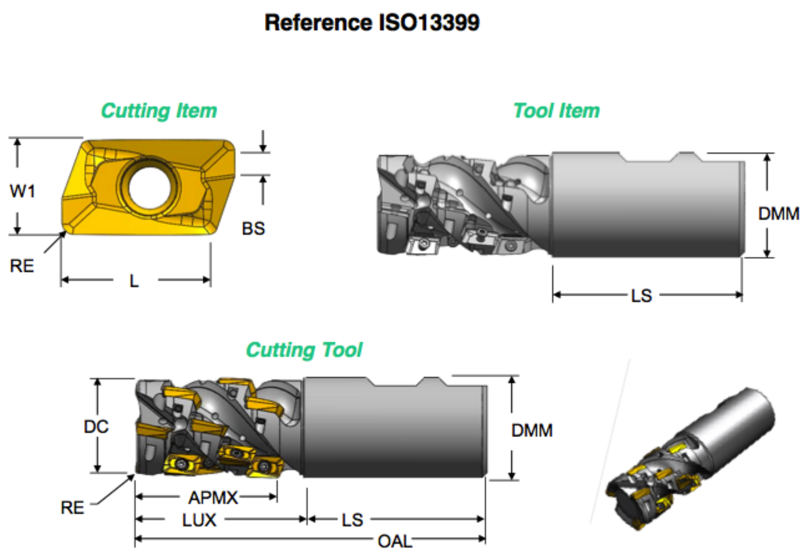

Figure 4: Cutting Tool, Tool Item, and Cutting Item

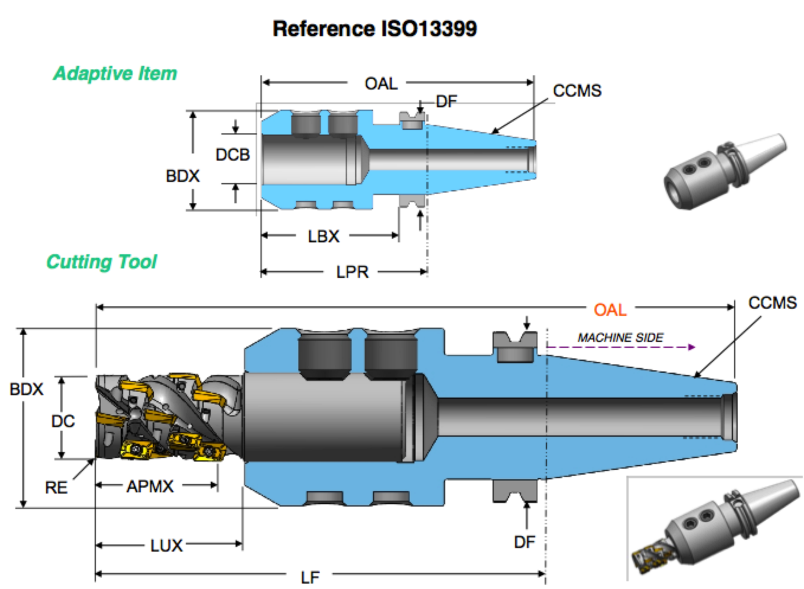

Figure 5: Cutting Tool, Tool Item, and Cutting Item 2

Figure 4 and *Figure 5* use the ISO 13399 codes for each of the measurements. These codes will be translated into the MTConnect Standard vocabulary as illustrated below. The measurements will have a maximum, minimum, and nominal value representing the tolerance of allowable values for this dimension. See below for a full discussion.

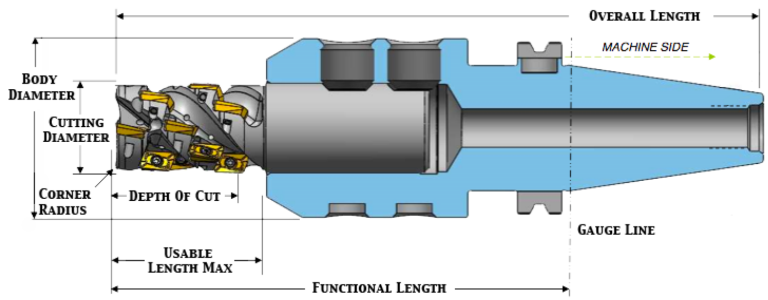

Figure 6: Cutting Tool Measurements

The MTConnect Standard will not define the entire geometry of the Cutting Tool, but will provide the information necessary to use the tool in the manufacturing process. Additional information can be added to the definition of the Cutting Tool by means of schema extensions.

Additional diagrams will reference these dimensions by their codes that will be defined in the measurement tables. The codes are consistent with the codes used in ISO 13399 and have been standardized. MTConnect Standard will use the full text name for clarity in the XML document.

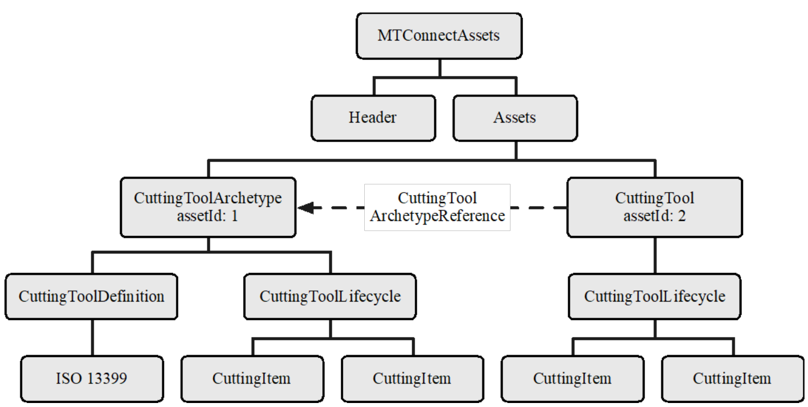

Figure 7: Cutting Tool Asset Structure

The structure of the `MTConnectAssets` header is defined in *MTConnect Standard Part 1.0 - Overview and Fundamentals* of the Standard. A finite number of *MTConnect Assets* will be stored in the *Agent*. This finite number is implementation specific and will depend on memory and storage constraints. The standard will not prescribe the number or capacity requirements for an implementation.

4.1 Attributes for CuttingToolArchetype

Refer to *Section 3.2 - Common Attributes for CuttingTool and CuttingToolArchetype* for a full description of the attributes for `CuttingToolArchetype` *Information Model*.

4.2 Elements for CuttingToolArchetype

The elements associated with `CuttingToolArchetype` are given in *Table 3*. Each element will be described in more detail below and any possible values will be presented with full definitions. The elements **MUST** be provided in the following order as prescribed by XML. At least one of `CuttingToolDefinition` or `CuttingToolLifeCycle` **MUST** be supplied.

Table 3: Elements for CuttingToolArchetype

Element	Description	Occurrence
`Description`	An element that can contain any descriptive content. This can contain configuration information and manufacturer specific details. This element is defined to contain mixed content and XML elements can be added to extend the descriptive semantics of MTConnect Standard.	0..1
`CuttingToolDefinition`	Reference to an ISO 13399.	0..1
`CuttingToolLifeCycle`	Data regarding the use of this tool. The archetype will only contain nominal values.	0..1

4.2.1 CuttingToolDefinition Element for CuttingToolArchetype

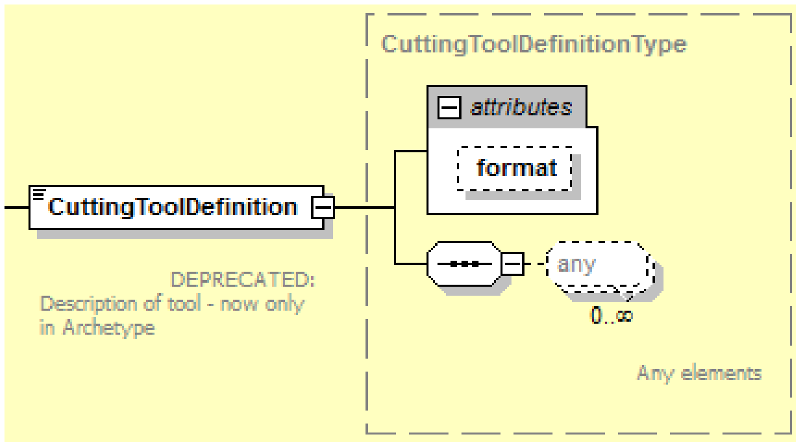

Figure 8: CuttingToolDefinition Schema

The `CuttingToolDefinition` contains the detailed structure of the Cutting Tool. The information contained in this element will be static during its lifecycle. Currently we are referring to the external ISO 13399 standard to provide the complete definition and composition of the Cutting Tool as defined in *Section 6.1 - CuttingToolLifeCycle*.

4.2.1.1 Attributes for CuttingToolDefinition

Table 4: Attributes for CuttingToolDefinition

Attribute	Description	Occurrence
`format`	Identifies the expected representation of the enclosed data. `format` is an optional attribute. Valid values of `format` are – `XML`, `EXPRESS`, `TEXT`, or `UNDEFINED`. If `format` is not specified, the assumed format is `XML`.	0..1

4.2.1.1.1 format Attribute for CuttingToolDefnition

The `format` attribute describes the expected representation of the enclosed data. If no value is given, the assumed format will be `XML`.

Table 5: Values for format attribute of CuttingToolDefinition

Value	Description
`XML`	The default value for the definition. The content will be an XML document.
`EXPRESS`	The document will confirm to the ISO 10303 Part 21 standard.
`TEXT`	The document will be a text representation of the tool data.
`UNDEFINED`	The document will be provided in an undefined format.

4.2.1.2 Elements for CuttingToolDefinition

The only acceptable Cutting Tool definition at present is defined by the ISO 13399 standard. Additional formats **MAY** be considered in the future.

4.2.1.3 ISO13399 Standard

The ISO 13399 data **MUST** be presented in either XML (ISO 10303-28) or EXPRESS format (ISO 10303-21). An *XML Schema* will be preferred as this will allow for easier integration with the MTConnect Standard XML tools. EXPRESS will also be supported, but software tools will need to be provided or made available for handling this data representation.

There will be the root element of the ISO13399 document when XML is used. When EXPRESS is used the XML element will be replaced by the text representation.

4.2.2 CuttingToolLifeCycle Element for CuttingToolArchetype

Refer to *Section 6 - Common Entity CuttingToolLifeCycle* for a complete description of `CuttingToolLifeCycle` element.

5 CuttingTool Information model

The `CuttingTool` *Information Model* illustrated in *Figure 1* has the identical structure as the `CuttingToolArchetype` *Information Model* except for the XML element `CuttingToolDefinition` that has been **DEPRECATED** in the `CuttingTool` schema.

5.1 Attributes for CuttingTool

Refer to *Section 3.2 - Common Attributes for CuttingTool and CuttingToolArchetype* for a full description of the *Attributes* for `CuttingTool` *Information Model*.

5.2 Elements for CuttingTool

The elements associated with `CuttingTool` are given below. The elements **MUST** be provided in the order shown in *Table 6* as prescribed by XML.

Table 6: Elements for CuttingTool

Element	Description	Occurrence
`Description`	An element that can contain any descriptive content. This can contain configuration information and manufacturer specific details. This element is defined to contain mixed content and XML elements can be added to extend the descriptive semantics of MTConnect Standard.	0..1
~~`CuttingToolDefinition`~~	**DEPRECATED** for `CuttingTool` in Version 1.3.0. ~~Reference to an ISO 13399.~~	~~0..1~~

Continuation of Table 6		
Element	Description	Occurrence
`CuttingToolLifeCycle`	Data regarding the use of this tool.	0..1
`CuttingToolArchetypeReference`	The content of this XML element is the `assetId` of the `CuttingToolArchetype` document. It **MAY** also contain a `source` attribute that gives the URL of the archetype data as well.	0..1

5.2.1 CuttingToolLifeCycle Elements for CuttingTool Only

The following `CuttingToolLifeCycle` elements are used only in the `CuttingTool` *Information Model* and are not part of the `CuttingToolArchetype` *Information Model*. Refer to *Section 6 - Common Entity CuttingToolLifeCycle* for a complete description of the remaining elements for `CuttingToolLifeCycle` that are common in both *Information Models*. Refer also to the `CuttingToolLifeCycle` schema illustrated in *Figure 14* .

5.2.1.1 CutterStatus Element for CuttingToolLifeCycle

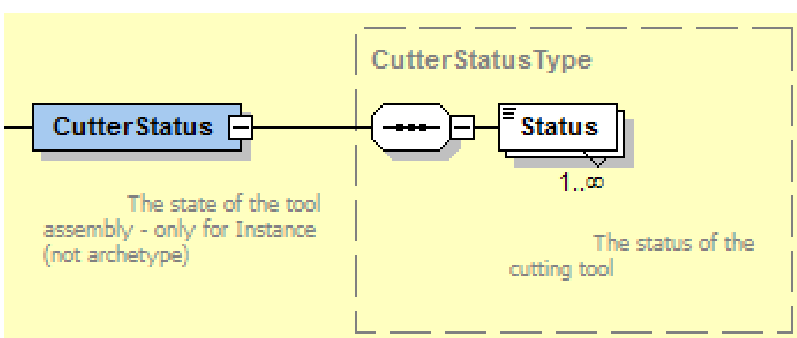

Figure 9: CutterStatus Schema

The elements of the `CutterStatus` element can be a combined set of `Status` elements. The *MTConnect Standard* allows any set of statuses to be combined, but only certain combinations make sense. A `CuttingTool` **SHOULD** not be both `NEW` and

USED at the same time. There are no rules in the schema to enforce this, but this is left to the implementer. The following combinations **MUST NOT** occur:

- NEW **MUST NOT** be used with USED, RECONDITIONED, or EXPIRED.
- UNKNOWN **MUST NOT** be used with any other status.
- ALLOCATED and UNALLOCATED **MUST NOT** be used together.
- AVAILABLE and UNAVAILABLE **MUST NOT** be used together.
- If the tool is EXPIRED, BROKEN, or NOT_REGISTERED it **MUST NOT** be AVAILABLE.
- All other combinations are allowed.

Table 7: Elements for CutterStatus

Element	Description	Occurrence
Status	The status of the Cutting Tool. There can be multiple Status elements.	1..*

5.2.1.1.1 Status Element for CutterStatus

One of the values for the status of the CuttingTool.

Table 8: Values for Status Element of CutterStatus

Value	Description
NEW	A new tool that has not been used or first use. Marks the start of the tool history.
AVAILABLE	Indicates the tool is available for use. If this is not present, the tool is currently not ready to be used.
UNAVAILABLE	Indicates the tool is unavailable for use in metal removal. If this is not present, the tool is currently not ready to be used.

Continuation of Table 8	
Value	Description
ALLOCATED	Indicates if this tool is has been committed to a piece of equipment for use and is not available for use in any other piece of equipment. If this is not present, this tool has not been allocated for this piece of equipment and can be used by another piece of equipment.
UNALLOCATED	Indicates this Cutting Tool has not been committed to a process and can be allocated.
MEASURED	The tool has been measured.
RECONDITIONED	The Cutting Tool has been reconditioned. See ReconditionCount for the number of times this cutter has been reconditioned.
USED	The Cutting Tool is in process and has remaining tool life.
EXPIRED	The Cutting Tool has reached the end of its useful life.
BROKEN	Premature tool failure.
NOT_REGISTERED	This Cutting Tool cannot be used until it is entered into the system.
UNKNOWN	The Cutting Tool is an indeterminate state. This is the default value.

5.2.1.2 ToolLife Element for CuttingToolLifeCycle

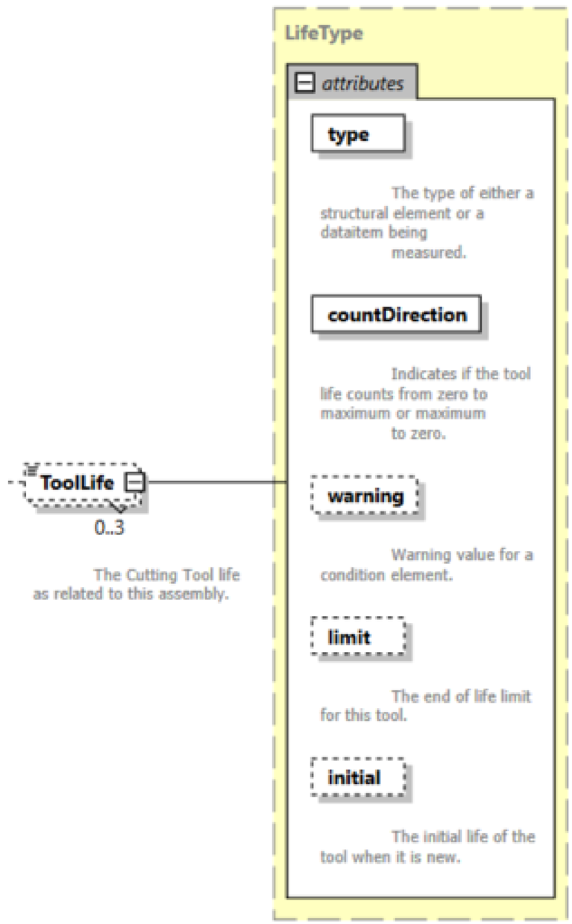

Figure 10: ToolLife Schema

The value is the current value for the `ToolLife`. The value **MUST** be numeric. `ToolLife` is an option element which can have three types, either minutes for time based, part count for parts based, or wear based using a distance measure. One `ToolLife` element can appear for each type, but there cannot be two entries of the same type. Additional types can be added in the future.

5.2.1.2.1 Attributes for ToolLife

ToolLife has the following attributes that can be used to indicate the behavior of the tool life management mechanism.

Table 9: Attributes for ToolLife

Attribute	Description	Occurrence
type	The type of tool life being accumulated. MINUTES, PART_COUNT, or WEAR. type is a required attribute.	1
countDirection	Indicates if the tool life counts from zero to maximum or maximum to zero. The value **MUST** be one of UP or DOWN. countDirection is a required attribute.	1
warning	The point at which a tool life warning will be raised. warning is an optional attribute.	0..1
limit	The end of life limit for this tool. If the countDirection is DOWN, the point at which this tool should be expired, usually zero. If the countDirection is UP, this is the upper limit for which this tool should be expired. limit is an optional attribute.	0..1
initial	The initial life of the tool when it is new. initial is an optional attribute.	0..1

5.2.1.2.2 type Attribute for ToolLife

The value of type must be one of the following:

Table 10: Values for type of ToolLife

Value	Description
MINUTES	The tool life measured in minutes. All units for minimum, maximum, and nominal **MUST** be provided in minutes.
PART_COUNT	The tool life measured in parts. All units for minimum, maximum, and nominal **MUST** be provided as the number of parts.
WEAR	The tool life measured in tool wear. Wear **MUST** be provided in millimeters as an offset to nominal. All units for minimum, maximum, and nominal **MUST** be given as millimeter offsets as well. The standard will only consider dimensional wear at this time.

5.2.1.2.3 countDirection Attribute for ToolLife

The value of `countDirection` must be one of the following:

Table 11: Values for countDirection

Value	Description
UP	The tool life counts up from zero to the maximum.
DOWN	The tool life counts down from the maximum to zero.

5.2.1.3 Location Element for CuttingToolLifeCycle

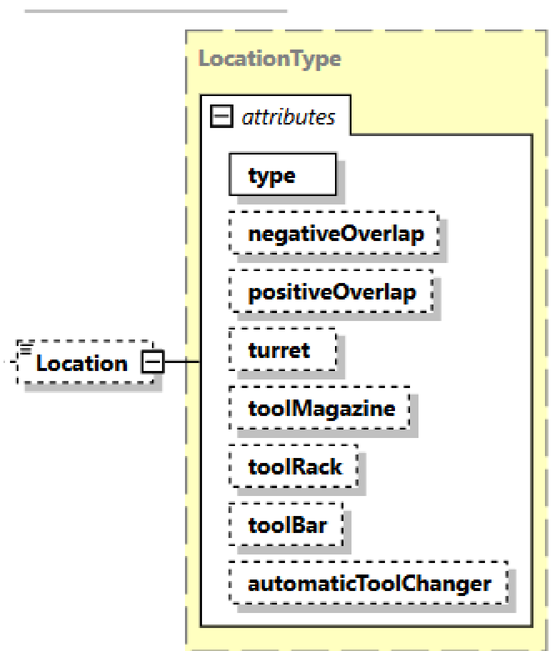

Figure 11: Location Schema

`Location` element identifies the specific location where a tool resides in a piece of equipment tool storage or in a tool crib. This can be any series of numbers and letters as defined by the XML type NMTOKEN. When a `POT` or `STATION` type is used, the value **MUST** be a numeric value. If a `negativeOverlap` or the `positiveOverlap` is provided, the tool reserves additional locations on either side, otherwise if they are not given, no additional locations are required for this tool. If the pot occupies the first or last location, a rollover to the beginning or the end of the index-able values may occur. For example, if there are 64 pots and the tool is in pot 64 with a `positiveOverlap` of 1, the first pot **MAY** be occupied as well.

5.2.1.3.1 Attributes for Location

Table 12: Attributes for Location

Attribute	Description	Occurrence
type	The type of location being identified. type **MUST** be one of POT, STATION, CRIB, SPINDLE, TRANSFER_POT, RETURN_POT, STAGING_POT, REMOVAL_POT, EXPIRED_POT, or END_EFFECTOR. type is a required attribute.	1
positiveOverlap	The number of locations at higher index value from this location. positiveOverlap is a optional attribute.	0..1
negativeOverlap	The number of location at lower index values from this location. negativeOverlap is an optional attribute.	0..1
turret	The turret associated with a tool. turret **MUST** be an XML NMTOKEN type.	0..1
toolMagazine	The tool magazine associated with a tool. toolMagazine **MUST** be an XML NMTOKEN type.	0..1
toolBar	The tool bar associated with a tool. toolBar **MUST** be an XML NMTOKEN type.	0..1
toolRack	The tool rack associated with a tool. toolRack **MUST** be an XML NMTOKEN type.	0..1
automaticToolChanger	The automatic tool changer associated with a tool. automaticToolChanger **MUST** be an XML NMTOKEN type.	0..1

5.2.1.3.2 type Attribute for Location

The type of location being identified.

Table 13: Values for type of Location

Value	Description
POT	A location in a tool magazine.
STATION	A location in a turret, tool bar, or tool rack.
CRIB	A location within a tool crib.
SPINDLE	A location associated with a *Spindle*.
TRANSFER_POT	A location for a tool awaiting transfer from a tool magazine to spindle or a turret.
RETURN_POT	A location for a tool removed from a *Spindle* or turret and awaiting return to a tool magazine.
STAGING_POT	A location for a tool awaiting transfer to a tool magazine or turret from outside of the piece of equipment.
REMOVAL_POT	A location for a tool removed from a tool magazine or turret awaiting transfer to a location outside of the piece of equipment.
EXPIRED_POT	A location for a tool that is no longer useable and is awaiting removal from a tool magazine or turret.
END_EFFECTOR	A location associated with an end effector.

5.2.1.3.3 postiveOverlap Attribute for Location

The number of locations at higher index values that the `CuttingTool` occupies due to interference. The value **MUST** be an integer. If not provided it is assumed to be 0.

5.2.1.3.4 negativeOverlap Attribute for Location

The number of locations at lower index values that the `CuttingTool` occupies due to interference. The value **MUST** be an integer. If not provided it is not assumed to be 0.

The tool number assigned in the part program and is used for cross referencing this tool information with the process parameters. The value **MUST** be an integer.

5.2.1.4 ReconditionCount Element for CuttingToolLifeCycle

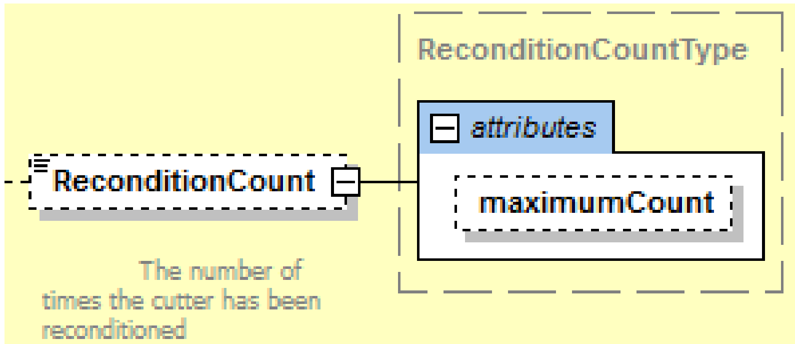

Figure 12: ReconditionCount Schema

This element **MUST** contain an integer value as the CDATA that represents the number of times the cutter has been reconditioned.

5.2.1.4.1 Attributes for ReconditionCount

Table 14: Attributes for ReconditionCount

Attribute	Description	Occurrence
`maximumCount`	The maximum number of times this tool may be reconditioned. `maximumCount` is a optional attribute.	0..1

5.2.2 CuttingToolArchetypeReference Element for Cutting Tool

Figure 13: CuttingToolArcheTypeReference Schema

This optional element references another *MTConnect Asset* document providing the static geometries and nominal values for all the measurements. This reduces the amount of data duplication as well as providing a mechanism for asset definitions to be provided before complete measurement has occurred.

5.2.2.1 source Attribute for CuttingToolArcheTypeReference

Table 15: Attributes for CuttingToolArchetypeReference

Attribute	Description	Occurrence
`source`	The URL of the `CuttingToolArchetype` *Information Model*. This **MUST** be a fully qualified URL as in http://example.com/asset/A213155	0..1

6 Common Entity CuttingToolLifeCycle

6.1 CuttingToolLifeCycle

The life cycle refers to the data pertaining to the application or the use of the tool. This data is provided by various pieces of equipment (i.e. machine tool, presetter) and statistical process control applications. Life cycle data will not remain static, but will change periodically when a tool is used or measured. The life cycle has three conceptual parts; `CuttingTool` and `CuttingItem` identity, properties, and measurements. A measurement is defined as a constrained value that is reported in defined units and as a W3C floating point format.

The `CuttingToolLifeCycle` contains data for the entire tool assembly. The specific `CuttingItems` that are part of the `CuttingToolLifeCycle` are contained in the `CuttingItems` element. Each Cutting Item has similar properties as the assembly; identity, properties, and `Measurements`.

The units for all `Measurements` have been predefined in the *MTConnect Standard* and will be consistent with *MTConnect Standard: Part 2.0 - Devices Information Model* and *MTConnect Standard: Part 3.0 - Streams Information Model*. This means that all lengths and distances will be given in millimeters and all angular measures will be given in degrees. Quantities like `ProcessSpindleSpeed` will be given in RPM, the same as the `ROTARY_VELOCITY` in *MTConnect Standard: Part 3.0 - Streams Information Model*.

6.1.1 XML Schema Structure for CuttingToolLifeCycle

The `CuttingToolLifeCycle` schema shown in *Figure 14* is used in both the `CuttingToolArchetype` and `CuttingTool` *Information Models*. The only difference is that the elements `CutterStatus`, `ToolLife`, `Location`, and `ReconditionCount` are used only in the `CuttingTool` *Information Model*.

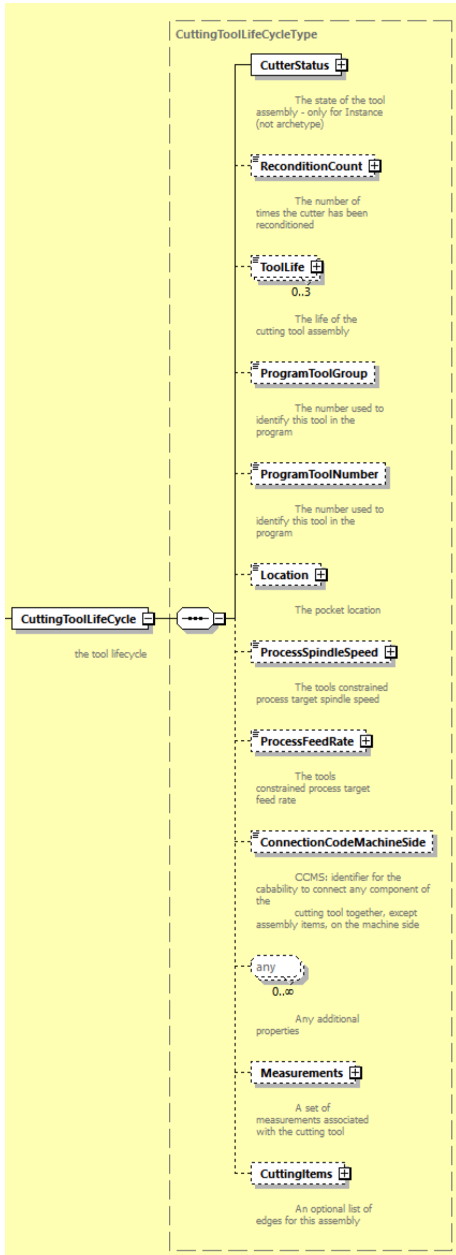

Figure 14: CuttingToolLifeCycle Schema

6.2 Elements for CuttingToolLifeCycle

The elements associated with this Cutting Tool are given in *Table 16*. The elements **MUST** be provided in the following order as prescribed by XML.

Table 16: Elements for CuttingToolLifeCycle

Element	Description	Occurrence
`CutterStatus`	The status of this assembly. `CutterStatus` can be one of the following values: `NEW`, `AVAILABLE`, `UNAVAILABLE`, `ALLOCATED`, `UNALLOCATED`, `MEASURED`, `RECONDITIONED`, `NOT_REGISTERED`, `USED`, `EXPIRED`, `BROKEN`, or `UNKNOWN`. **MUST** only be used in the `CuttingTool` *Information Model*.	1
`ReconditionCount`	The number of times this cutter has been reconditioned. **MUST** only be used in the `CuttingTool` *Information Model*.	0..1
`ToolLife`	The Cutting Tool life as related to this assembly. **MUST** only be used in the `CuttingTool` *Information Model*.	0..1
`Location`	The Pot or Spindle this tool currently resides in. **MUST** only be used in the `CuttingTool` *Information Model*.	0..1

Continuation of Table 16

Element	Description	Occurrence
`ProgramToolGroup`	The tool group this tool is assigned in the part program.	0..1
`ProgramToolNumber`	The number of the tool as referenced in the part program.	0..1
`ProcessSpindleSpeed`	The constrained process spindle speed for this tool.	0..1
`ProcessFeedRate`	The constrained process feed rate for this tool in mm/s.	0..1
`ConnectionCodeMachineSide`	Identifier for the capability to connect any component of the Cutting Tool together, except Assembly Items, on the machine side. Code: `CCMS`	0..1
`Measurements`	A collection of measurements for the tool assembly.	0..1
`CuttingItems`	An optional set of individual Cutting Items.	0..1
`xs:any`	Any additional properties not in the current document model. **MUST** be in separate XML namespace.	0..n

6.2.1 ProgramToolGroup Element for CuttingToolLifeCycle

The optional identifier for the group of Cutting Tools when multiple tools can be used interchangeably. This is defined as an XML string type and is implementation dependent.

6.2.2 ProgramToolNumber Element for CuttingToolLifeCycle

The tool number assigned in the part program and is used for cross referencing this tool information with the process parameters. The value **MUST** be a string.

6.2.3 ProcessSpindleSpeed Element for CuttingToolLifeCycle

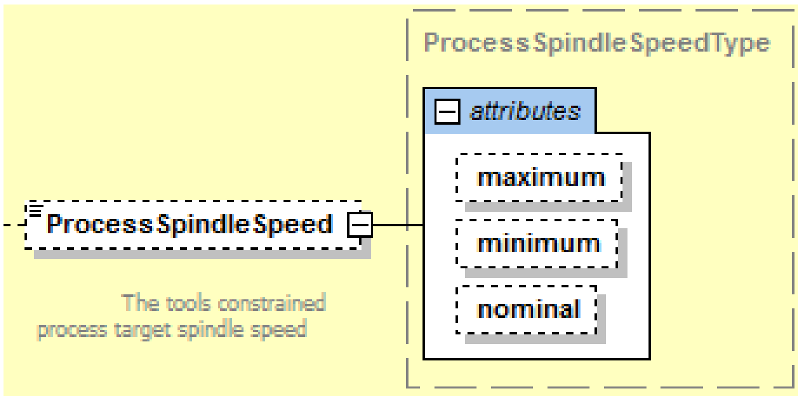

Figure 15: ProcessSpindleSpeed Schema

The `ProcessSpindleSpeed` **MUST** be specified in revolutions/minute (RPM). The CDATA **MAY** contain the nominal process target spindle speed if available. The maximum and minimum speeds **MAY** be provided as attributes. If `ProcessSpindleSpeed` is provided, at least one value of `maximum`, `nominal`, or `minimum` **MUST** be specified.

6.2.3.1 Attributes for ProcessSpindleSpeed

Table 17: Attributes for ProcessSpindleSpeed

Attribute	Description	Occurrence
`maximum`	The upper bound for the tool's target spindle speed. `maximum` is an optional attribute.	0..1
`minimum`	The lower bound for the tools spindle speed. `minimum` is a optional attribute.	0..1
`nominal`	The nominal speed the tool is designed to operate at. `nominal` is an optional attribute.	0..1

6.2.4 ProcessFeedRate Element for CuttingToolLifeCycle

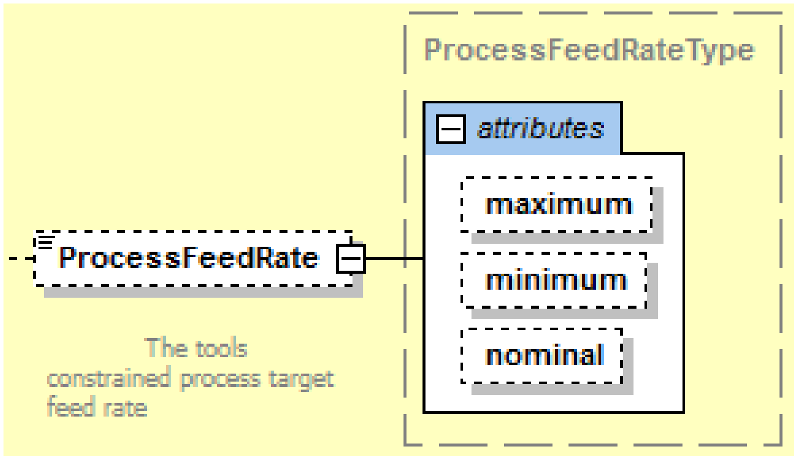

Figure 16: ProcessFeedRate Schema

The `ProcessFeedRate` **MUST** be specified in millimeters/second (mm/s). The CDATA **MAY** contain the nominal process target feed rate if available. The maximum and minimum rates MAY be provided as attributes. If `ProcessFeedRate` is provided, at least one value of `maximum`, `nominal`, or `minimum` **MUST** be specified.

6.2.4.1 Attributes for ProcessFeedRate

Table 18: Attributes for ProcessFeedRate

Attribute	Description	Occurrence
`maximum`	The upper bound for the tool's process target feedrate. `maximum` is an optional attribute.	0..1
`minimum`	The lower bound for the tools feedrate. `minimum` is a optional attribute.	0..1
`nominal`	The nominal feedrate the tool is designed to operate at. `nominal` is an optional attribute.	0..1

6.2.5 ConnectionCodeMachineSide Element for CuttingToolLifeCycle

This is an optional identifier for implementation specific connection component of the Cutting Tool on the machine side. Code: `CCMS`. The CDATA **MAY** be any valid string according to the referenced connection code standards.

6.2.6 xs:any Element for CuttingToolLifeCycle

Utilizing *XML Schema* 1.1, extension points are available where an additional element can be added to the document without being part of a substitution group. The new elements **MUST NOT** be part of the *MTConnect namespace* and **MUST NOT** be one of the predefined elements mentioned above.

This allows additional properties to be defined for `CuttingTool` without having to change the definition of the definition of the `CuttingTool` or modify the standard, but requires *XML Schema* Version 1.1.

6.2.7 Measurements Element for CuttingToolLifeCycle

The `Measurements` element is a collection of one or more constrained scalar values associated with this Cutting Tool. The XML element **MUST** be a type extension of the base types `CommonMeasurement` or `AssemblyMeasurement`. The following section defines the abstract `Measurement` type used in both `CuttingToolLifeCycle` and `CuttingItem`. This subsequent sections describe the `AssemblyMeasurement` types followed by the `CuttingItemMeasurement` types.

A `Measurement` is specific to the tool management policy at a particular shop. The tool zero reference point or gauge line will be different depending on the particular implementation and will be assumed to be consistent within the shop. *MTConnect Standard* does not standardize the manufacturing process or the definition of the zero point.

6.2.8 Measurement

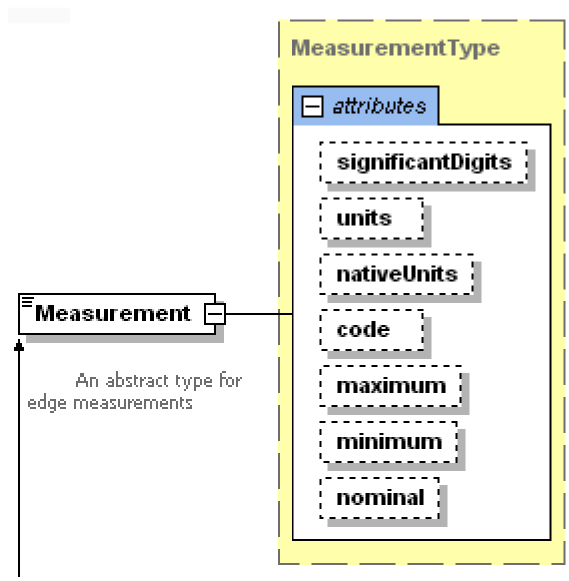

Figure 17: Measurement Schema

A `Measurement` **MUST** be a scalar floating-point value that **MAY** be constrained to a maximum and minimum value. Since the `CuttingToolLifeCycle`'s main responsibility is to track aspects of the tool that change over its use in the shop, *MTConnect* represents the current value of the `Measurement` **MUST** be in the CDATA (text between the start and end element) as the most current valid value.

The `minimum` and `maximum` **MAY** be supplied if they are known or relevant to the `Measurement`. A `nominal` value **MAY** be provided to show the reference value for this `Measurement`.

There are three abstract subtypes of `Measurement`: `CommonMeasurement`, `AssemblyMeasurement`, and `CuttingItemMeasurement`. These abstract types **MUST NOT** appear in an `MTConnectAssets` document, but are used in the schema as a way to separate which measurements **MAY** appear in the different sections of the document. Only subtypes that have extended these types **MAY** appear in the `MTConnectAssets` XML.

`Measurements` in the `CuttingToolLifeCycle` section **MUST** refer to the entire assembly and not to an individual `CuttingItem`. `CuttingItem` measurements **MUST** be located in the measurements associated with the individual `CuttingItem`.

`Measurements` **MAY** provide an optional `units` attribute to reinforce the given units. The units **MUST** always be given in the predefined MTConnect units. If `units` are provided, they are only for documentation purposes. nativeUnits **MAY** optionally be provided to indicate the original units provided for the measurements.

6.2.8.1 Attributes for Measurement

Table 19: Attributes for Measurement

Attribute	Description	Occurrence
code	A shop specific code for this measurement. ISO 13399 codes **MAY** be used for these codes as well. code is a optional attribute.	0..1
maximum	The maximum value for this measurement. Exceeding this value would indicate the tool is not usable. maximum is a optional attribute.	0..1
minimum	The minimum value for this measurement. Exceeding this value would indicate the tool is not usable. minimum is a optional attribute.	0..1
nominal	The as advertised value for this measurement. nominal is a optional attribute.	0..1
significantDigits	The number of significant digits in the reported value. This is used by applications to determine accuracy of values. This **MAY** be specified for all numeric values. significantDigits is a optional attribute.	0..1

Continuation of Table 19		
Attribute	Description	Occurrence
`units`	The units for the measurements. MTConnect Standard defines all the units for each measurement, so this is mainly for documentation sake. See MTConnect *MTConnect Standard: Part 2.0 - Devices Information Model* 7.2.2.5 for the full list of units. `units` is a optional attribute.	0..1
`nativeUnits`	The units the measurement was originally recorded in. This is only necessary if they differ from units. See *MTConnect Standard: Part 2.0 - Devices Information Model* Section 7.2.2.6 for the full list of units. `nativeUnits` is a optional attribute.	0..1

6.2.8.2 Measurement Subtypes for CuttingToolLifeCycle

These `Measurements` for `CuttingTool` are specific to the entire assembly and **MUST NOT** be used for the `Measurement` pertaining to a `CuttingItem`. *Figure 18* and *Figure 19* will be used to reference the assembly specific `Measurements`.

The Code in *Table 20* will refer to the acronyms in the diagrams. We will be referring to many diagrams to disambiguate all measurements of the `CuttingTool` and `CuttingItem`.

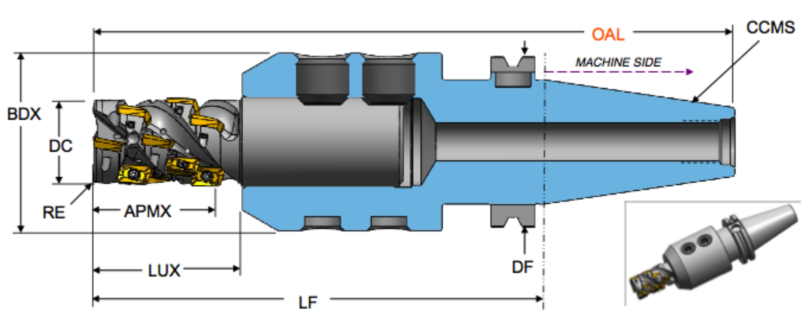

Figure 18: Cutting Tool Measurement Diagram 1

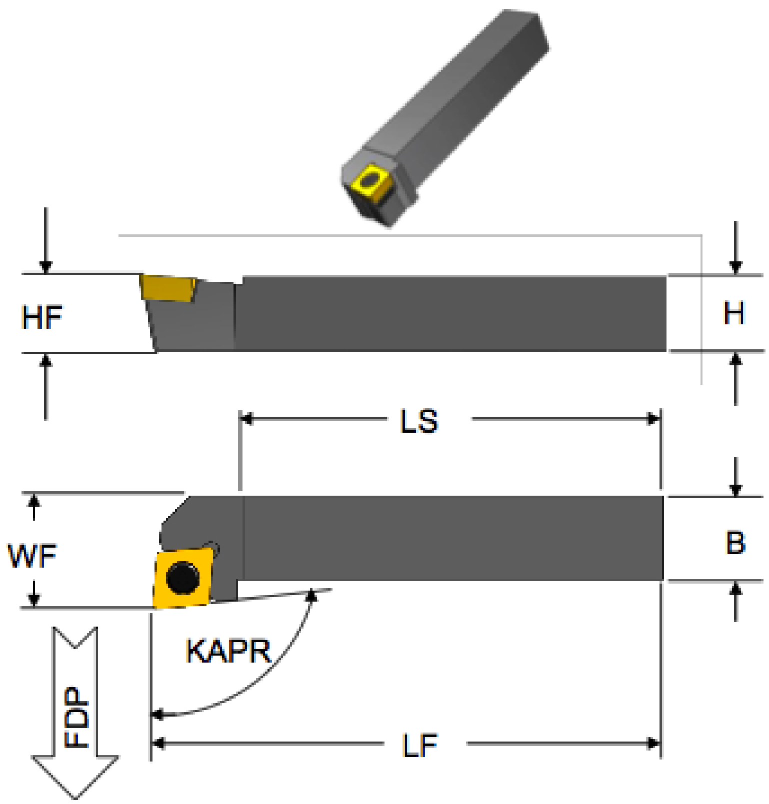

Figure 19: Cutting Tool Measurement Diagram 2

Table 20: Measurement Subtypes for CuttingTool

Measurement Subtype	Code	Description	Units
`BodyDiameterMax`	`BDX`	The largest diameter of the body of a Tool Item.	`MILLIMETER`

Continuation of Table 20			
Measurement Subtype	Code	Description	Units
BodyLengthMax	LBX	The distance measured along the X axis from that point of the item closest to the workpiece, including the Cutting Item for a Tool Item but excluding a protruding locking mechanism for an Adaptive Item, to either the front of the flange on a flanged body or the beginning of the connection interface feature on the machine side for cylindrical or prismatic shanks.	MILLIMETER
DepthOfCutMax	APMX	The maximum engagement of the cutting edge or edges with the workpiece measured perpendicular to the feed motion.	MILLIMETER
CuttingDiameterMax	DC	The maximum diameter of a circle on which the defined point Pk of each of the master inserts is located on a Tool Item. The normal of the machined peripheral surface points towards the axis of the Cutting Tool.	MILLIMETER
FlangeDiameterMax	DF	The dimension between two parallel tangents on the outside edge of a flange.	MILLIMETER
OverallToolLength	OAL	The largest length dimension of the Cutting Tool including the master insert where applicable.	MILLIMETER

Continuation of Table 20			
Measurement Subtype	Code	Description	Units
`ShankDiameter`	`DMM`	The dimension of the diameter of a cylindrical portion of a Tool Item or an Adaptive Item that can participate in a connection.	`MILLIMETER`
`ShankHeight`	`H`	The dimension of the height of the shank.	`MILLIMETER`
`ShankLength`	`LS`	The dimension of the length of the shank.	`MILLIMETER`
`UsableLengthMax`	`LUX`	Maximum length of a Cutting Tool that can be used in a particular cutting operation including the non-cutting portions of the tool.	`MILLIMETER`
`ProtrudingLength`	`LPR`	The dimension from the yz-plane to the furthest point of the Tool Item or Adaptive Item measured in the -X direction.	`MILLIMETER`
`Weight`	`WT`	The total weight of the Cutting Tool in grams. The force exerted by the mass of the Cutting Tool.	`GRAM`

Continuation of Table 20			
Measurement Subtype	Code	Description	Units
FunctionalLength	LF	The distance from the gauge plane or from the end of the shank to the furthest point on the tool, if a gauge plane does not exist, to the cutting reference point determined by the main function of the tool. The CuttingTool functional length will be the length of the entire tool, not a single Cutting Item. Each CuttingItem can have an independent FunctionalLength represented in its measurements.	MILLIMETER

6.2.9 CuttingItems Element for CuttingToolLifeCycle

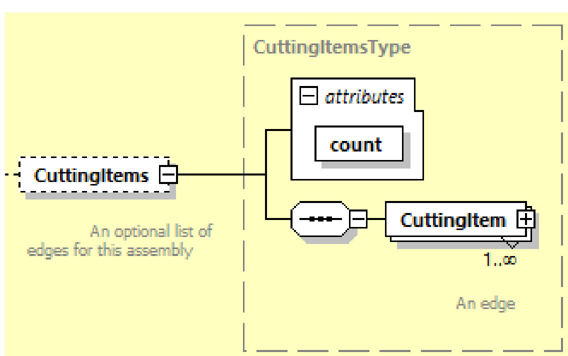

Figure 20: CuttingItems Schema

An optional collection of CuttingItems that **SHOULD** be provided for each independent edge or insert. If the CuttingItems are not present; it indicates there is no specific information with respect to each of the CuttingItems. This does not imply there are no CuttingItems – there **MUST** be at least one CuttingItem – but there is no specific information.

6.2.9.1 Attributes for CuttingItems

Table 21: Attributes for CuttingItems

Attribute	Description	Occurrence
`count`	The number of Cutting Item. `count` is a required attribute.	1

6.2.10 CuttingItem

A `CuttingItem` is the portion of the tool that physically removes the material from the workpiece by shear deformation. The Cutting Item can be either a single piece of material attached to the `CuttingItem` or it can be one or more separate pieces of material attached to the `CuttingItem` using a permanent or removable attachment. A `CuttingItem` can be comprised of one or more cutting edges. `CuttingItems` include: replaceable inserts, brazed tips and the cutting portions of solid `CuttingTools`.

MTConnect Standard considers `CuttingItems` as part of the `CuttingTool`. A `CuttingItems` **MUST NOT** exist in MTConnect unless it is attached to a `CuttingTool`. Some of the measurements, such as `FunctionalLength`, **MUST** be made with reference to the entire `CuttingTool` to be meaningful.

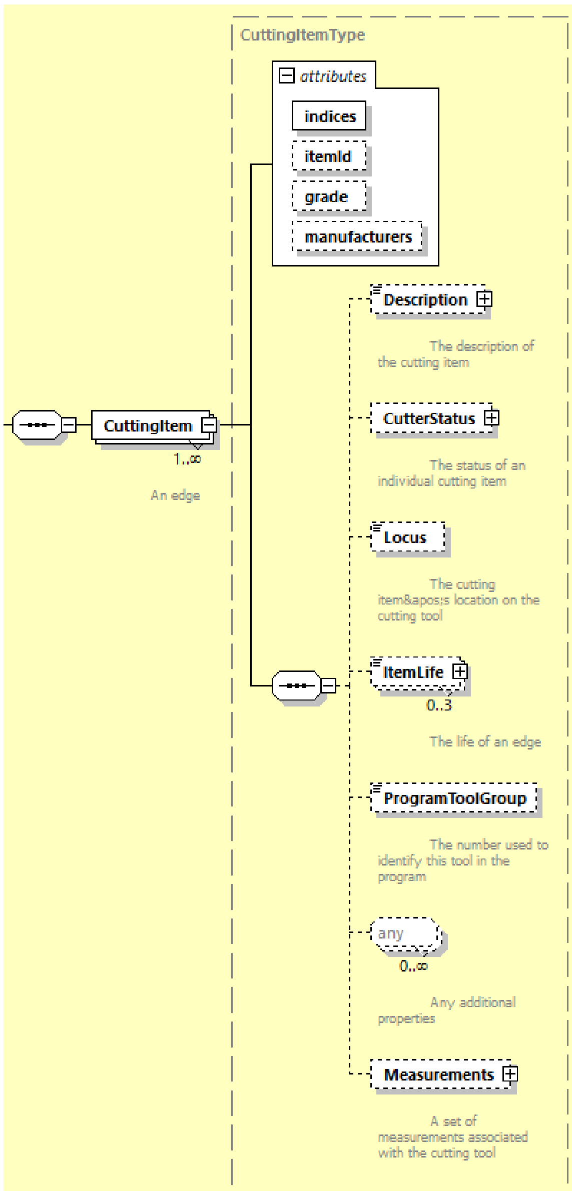

Figure 21: CuttingItem Schema

6.2.10.1 Attributes for CuttingItem

Table 22: Attributes for CuttingItem

Attribute	Description	Occurrence
`indices`	The number or numbers representing the individual Cutting Item or items on the tool. `indices` is a required attribute.	1
`itemId`	The manufacturer identifier of this Cutting Item. `itemId` is an optional attribute.	0..1
`manufacturers`	The manufacturers of the Cutting Item or Tool. `manufacturers` is an optional attribute.	0..1
`grade`	The material composition for this Cutting Item. `grade` is an optional attribute.	0..1

6.2.10.1.1 indices Attribute for CuttingItem

An identifier that indicates the `CuttingItem` or `CuttingItems` these data are associated with. The value **MUST** be a single number ("1") or a comma separated set of individual elements ("1,2,3,4"), or as a inclusive range of values as in ("1-10") or any combination of ranges and numbers as in "1-4,6-10,22". There **MUST NOT** be spaces or non-integer values in the text representation.

Indices **SHOULD** start numbering with the inserts or `CuttingItem` furthest from the gauge line and increasing in value as the items get closer to the gauge line. Items at the same distance **MAY** be arbitrarily numbered.

6.2.10.1.2 itemId Attribute for CuttingItem

The manufactures' identifier for this `CuttingItem` that **MAY** be its catalog or reference number. The value **MUST** be an XML NMTOKEN value of numbers and letters.

6.2.10.1.3 manufacturers Attribute for CuttingItem

This optional element references the manufacturers of this tool. At this level the manufacturers will reference the CuttingItem specifically. The representation will be a comma (,) delimited list of manufacturer names. This can be any series of numbers and letters as defined by the XML type string.

6.2.10.1.4 grade Attribute for CuttingItem

This provides an implementation specific designation for the material composition of this CuttingItem.

6.2.10.2 Elements for CuttingItem

Table 23: Elements for CuttingItem

Element	Description	Occurrence
Description	A free-form description of the Cutting Item.	0..1
Locus	A free form description of the location on the Cutting Tool.	0..1
ItemLife	The life of this Cutting Item.	0..3
Measurements	A collection of measurements relating to this Cutting Item.	0..1
CutterStatus	The status of this item. CutterStatus **MUST** one of the following values: NEW, AVAILABLE, UNAVAILABLE, ALLOCATED, UNALLOCATED, MEASURED, RECONDITIONED, NOT_REGISTERED, USED, EXPIRED, BROKEN, or UNKNOWN.	0..1
ProgramToolGroup	The tool group the part program assigned this item.	0..1

6.2.10.2.1 Description Element for CuttingItem

An optional free form text description of this CuttingItem.

6.2.10.2.2 Locus Element for CuttingItem

Locus represents the location of the CuttingItem with respect to the Cutting Tool. For clarity, the words FLUTE, INSERT, and CARTRIDGE **SHOULD** be used to assist in noting the location of a CuttingItem. The Locus **MAY** be any free form text, but **SHOULD** adhere to the following rules:

- The location numbering **SHOULD** start at the furthest CuttingItem (#1) and work it's way back to the Cutting Item closest to the gauge line.
- Flutes **SHOULD** be identified as such using the word FLUTE:. For example: FLUTE: 1, INSERT: 2 - would indicate the first flute and the second furthest insert from the end of the tool on that flute.
- Other designations such as CARTRIDGE **MAY** be included, but should be identified using upper case and followed by a colon (:).

6.2.10.2.3 ItemLife Element for CuttingItem

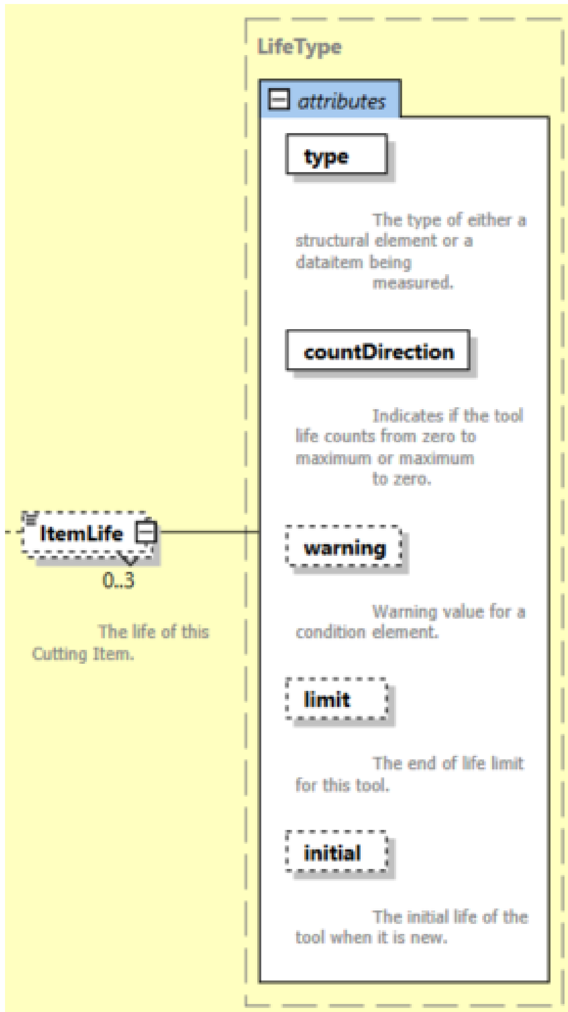

Figure 22: ItemLife Schema

The value is the current value for the `ItemLife`. The value **MUST** be numeric. `ItemLife` is an option element which can have three types, either minutes for time based, part count for parts based, or wear based using a distance measure. One `ItemLife` can appear for each type, but there cannot be two entries of the same type. Additional types can be added in the future.

6.2.10.2.4 Attributes for ItemLife

These is an optional attribute that can be used to further classify the operation type.

Table 24: Attributes for ItemLife

Attribute	Description	Occurrence
`type`	The type of tool life being accumulated. *Valid Data Values*: `MINUTES`, `PART_COUNT`, or `WEAR`. `type` is a required attribute.	1
`countDirection`	Indicates if the tool life counts from zero to maximum or maximum to zero. The value **MUST** be one of `UP` or `DOWN`. `countDirection` is a required attribute.	1
`warning`	The point at which a tool life warning will be raised. `warning` is an optional attribute.	0..1
`limit`	The end of life limit for this tool. If the `countDirection` is `DOWN`, the point at which this tool should be expired, usually zero. If the `countDirection` is `UP`, this is the upper limit for which this tool should be expired. `limit` is an optional attribute.	0..1
`initial`	The initial life of the tool when it is new. `initial` is an optional attribute.	0..1

6.2.10.2.5 type Attribute for ItemLife

The value of type must be one of the following:

Table 25: Values for type of ItemLife

Value	Description
`MINUTES`	The tool life measured in minutes. All units for minimum, maximum, and nominal **MUST** be provided in minutes.
`PART_COUNT`	The tool life measured in parts. All units for minimum, maximum, and nominal **MUST** be provided as the number of parts.
`WEAR`	The tool life measured in tool wear. Wear **MUST** be provided in millimeters as an offset to nominal. All units for minimum, maximum, and nominal **MUST** be given as millimeter offsets as well.

6.2.10.2.6 countDirection Attribute for ItemLife

The value of type must be one of the following:

Table 26: Values for countDirection

Value	Description
`UP`	The tool life counts up from zero to the maximum.
`DOWN`	The tool life counts down from the maximum to zero.

6.2.10.3 Measurement Subtypes for CuttingItem

These `Measurements` for `CuttingItem` are specific to an individual `CuttingItem` and **MUST NOT** be used for the `Measurements` pertaining to an assembly. The *Figure 23* , *Figure 24* , *Figure 25* and *Figure 26* will be used to for reference for the `CuttingItem` specific `Measurements` .

The Code in *Table 27* will refer to the acronym in the diagram. We will be referring to many diagrams to disambiguate all `Measurements` of the `CuttingTools` and `CuttingItems`. We will present a few here; please refer to Appendix B for additional reference material.

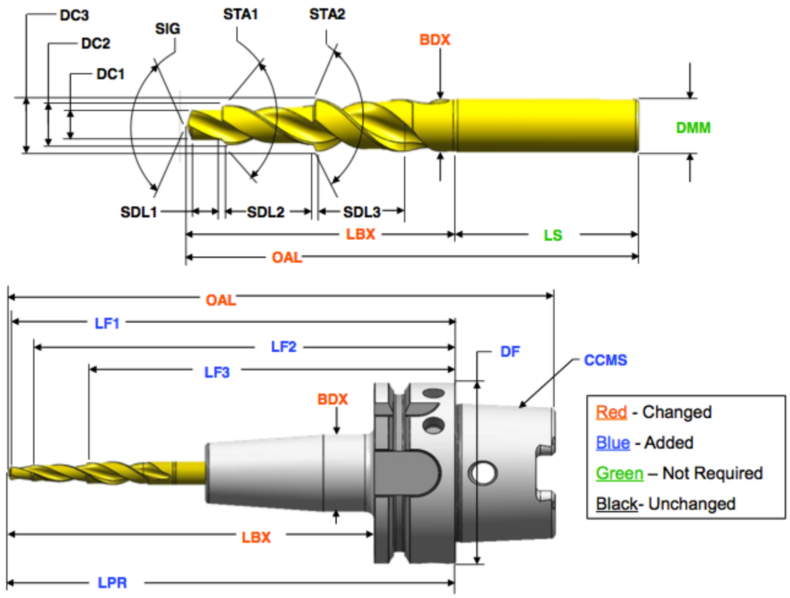

Figure 23: Cutting Tool

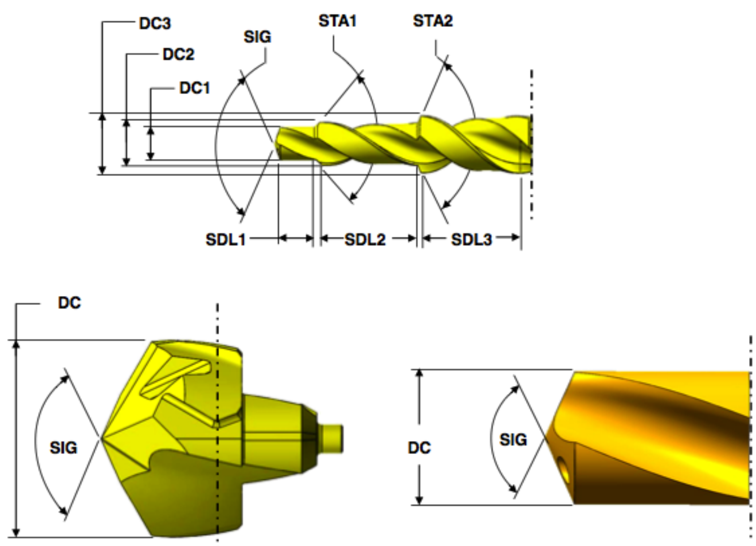

Figure 24: Cutting Item

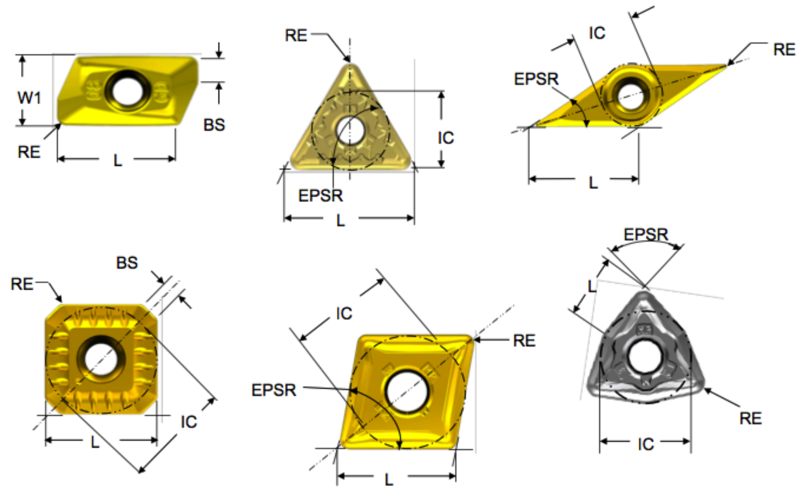

Figure 25: Cutting Item Measurement Diagram 3

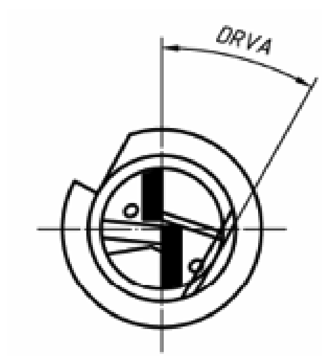

Figure 26: Cutting Item Drive Angle

The `CuttingItem` `Measurements` in *Table 27* will refer the *Figure 23* , *Figure 24* , *Figure 25* and *Figure 26* .

Table 27: Measurement Subtypes for CuttingItem

Measurement Subtype	Code	Description	Units
`CuttingReferencePoint`	`CRP`	The theoretical sharp point of the Cutting Tool from which the major functional dimensions are taken.	`MILLIMETER`

Continuation of Table 27			
Measurement Subtype	Code	Description	Units
CuttingEdgeLength	L	The theoretical length of the cutting edge of a Cutting Item over sharp corners.	MILLIMETER
DriveAngle	DRVA	Angle between the driving mechanism locator on a Tool Item and the main cutting edge.	DEGREE
FlangeDiameter	DF	The dimension between two parallel tangents on the outside edge of a flange.	MILLIMETER
FunctionalWidth	WF	The distance between the cutting reference point and the rear backing surface of a turning tool or the axis of a boring bar.	MILLIMETER
IncribedCircleDiameter	IC	The diameter of a circle to which all edges of a equilateral and round regular insert are tangential.	MILLIMETER
PointAngle	SIG	The angle between the major cutting edge and the same cutting edge rotated by 180 degrees about the tool axis.	DEGREE
ToolCuttingEdgeAngle	KAPR	The angle between the tool cutting edge plane and the tool feed plane measured in a plane parallel the xy-plane.	DEGREE

Continuation of Table 27			
Measurement Subtype	Code	Description	Units
ToolLeadAngle	PSIR	The angle between the tool cutting edge plane and a plane perpendicular to the tool feed plane measured in a plane parallel the xy-plane.	DEGREE
ToolOrientation	N/A	The angle of the tool with respect to the workpiece for a given process. The value is application specific.	DEGREE
WiperEdgeLength	BS	The measure of the length of a wiper edge of a Cutting Item.	MILLIMETER
StepDiameterLength	SDLx	The length of a portion of a stepped tool that is related to a corresponding cutting diameter measured from the cutting reference point of that cutting diameter to the point on the next cutting edge at which the diameter starts to change.	MILLIMETER
StepIncludedAngle	STAx	The angle between a major edge on a step of a stepped tool and the same cutting edge rotated 180 degrees about its tool axis.	DEGREE

Continuation of Table 27			
Measurement Subtype	Code	Description	Units
CuttingDiameter	DCx	The diameter of a circle on which the defined point Pk located on this Cutting Tool. The normal of the machined peripheral surface points towards the axis of the Cutting Tool.	MILLIMETER
CuttingHeight	HF	The distance from the basal plane of the Tool Item to the cutting point.	MILLIMETER
CornerRadius	RE	The nominal radius of a rounded corner measured in the X Y-plane.	MILLIMETER
Weight	WT	The total weight of the Cutting Tool in grams. The force exerted by the mass of the Cutting Tool.	GRAM
FunctionalLength	LFx	The distance from the gauge plane or from the end of the shank of the Cutting Tool, if a gauge plane does not exist, to the cutting reference point determined by the main function of the tool. This measurement will be with reference to the Cutting Tool and **MUST NOT** exist without a Cutting Tool.	MILLIMETER
ChamferFlatLength	BCH	The flat length of a chamfer.	MILLIMETER
ChamferWidth	CHW	The width of the chamfer.	MILLIMETER

Continuation of Table 27			
Measurement Subtype	Code	Description	Units
InsertWidth	W1	W1 is used for the insert width when an inscribed circle diameter is not practical.	MILLIMETER

Appendices

A Bibliography

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H.L. Horton, F.D. Jones, and E. Oberg. *Machinery's Handbook*. Industrial Press, Inc.

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B Additional Illustrations

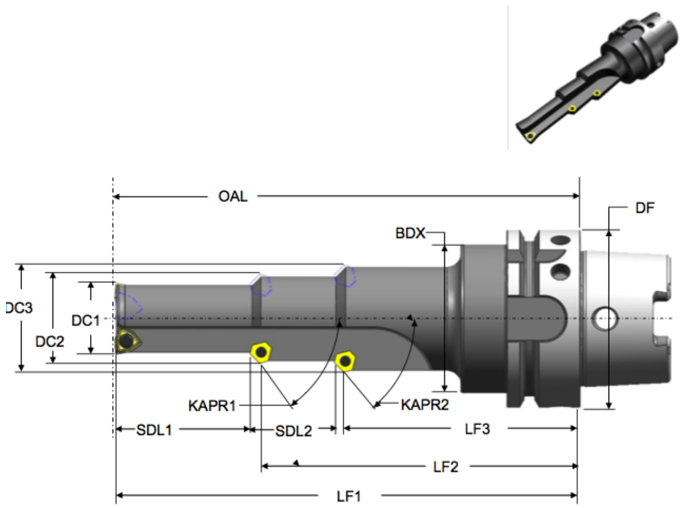

Figure 27: Cutting Tool Measurement Diagram 1
(Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)

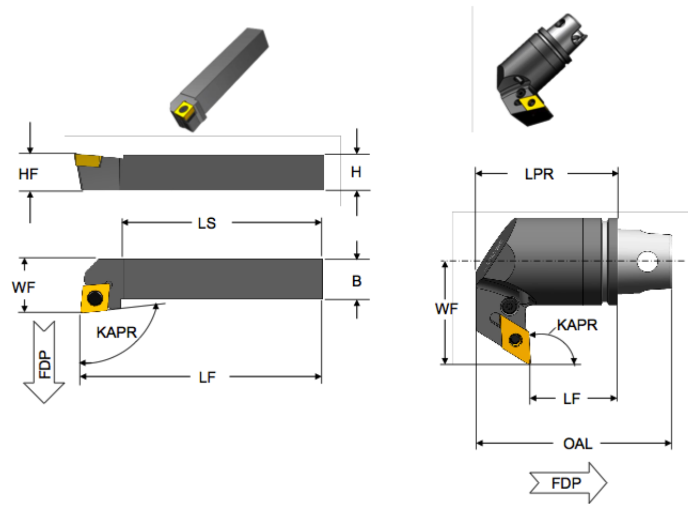

Figure 28: Cutting Tool Measurement Diagram 2
(Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)

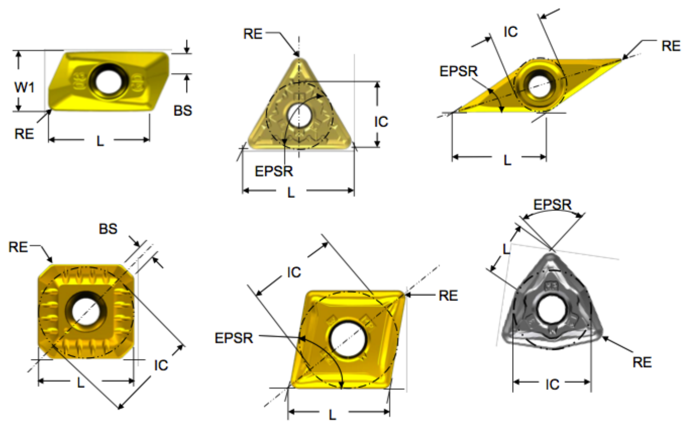

Figure 29: Cutting Tool Measurement Diagram 3
(Cutting Item – ISO 13399)

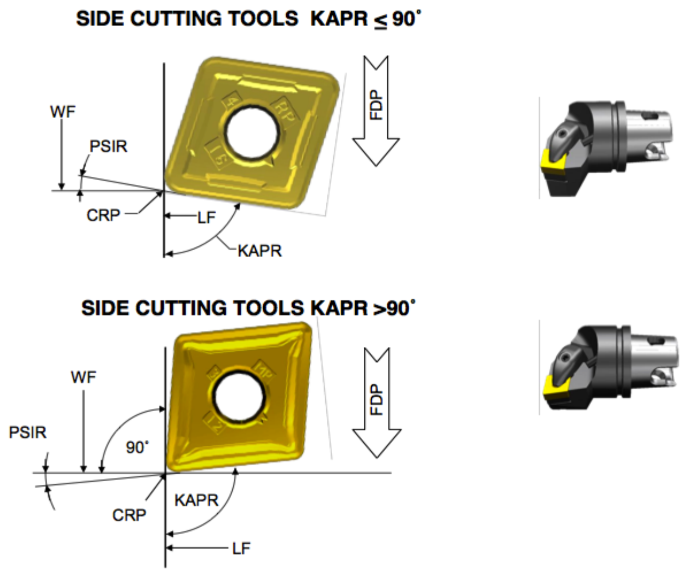

Figure 30: Cutting Tool Measurement Diagram 4
(Cutting Item – ISO 13399)

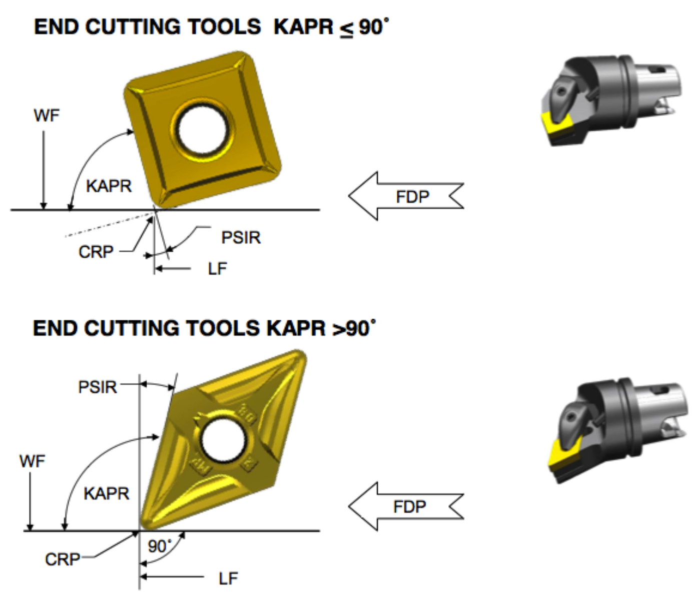

Figure 31: Cutting Tool Measurement Diagram 5
(Cutting Item – ISO 13399)

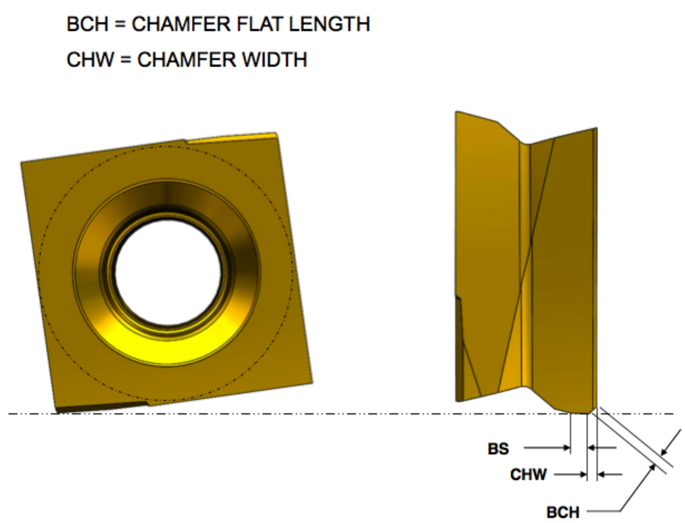

Figure 32: Cutting Tool Measurement Diagram 6
(Cutting Item – ISO 13399)

C Cutting Tool Example

C.1 Shell Mill

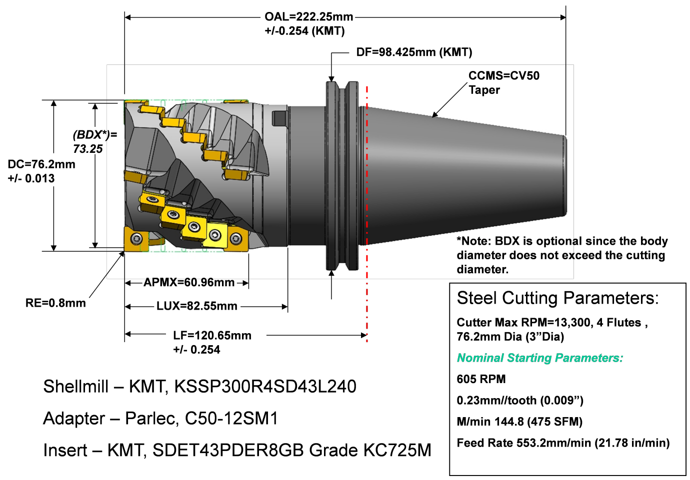

Figure 33: Shell Mill Side View

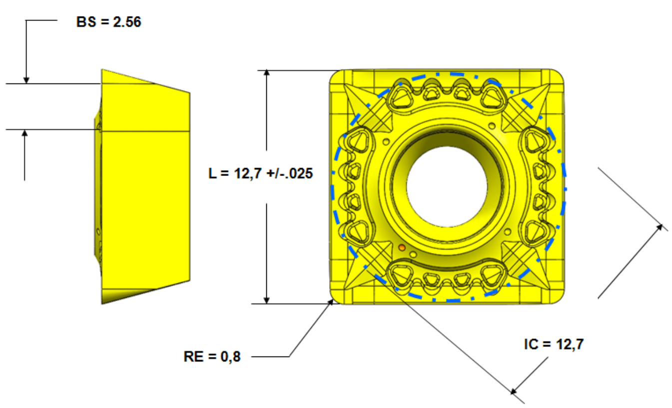

Figure 34: Indexable Insert Measurements

Example 1: Example for Indexable Insert Measurements

```
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets
xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\_1.2.xsd">
  <Header creationTime="2011-05-11T13:55:22"
  assetBufferSize="1024" sender="localhost"
```

```
assetCount="2" version="1.2" instanceId="1234"/>
<Assets>
<CuttingTool serialNumber="1" toolId="KSSP300R4SD43L240"
timestamp="2011-05-11T13:55:22" assetId="KSSP300R4SD43L240.1"
manufacturers="KMT,Parlec">
  <CuttingToolLifeCycle>
  <CutterStatus><Status>NEW</Status></CutterStatus>
  <ProcessSpindleSpeed maximum="13300"
  nominal="605">10000</ProcessSpindleSpeed>
  <ProcessFeedRate
  nominal="9.22">9.22</ProcessSpindleSpeed>
  <ConnectionCodeMachineSide>CV50
  </ConnectionCodeMachineSide>
  <Measurements>
    <BodyDiameterMax code="BDX">73.25
    </BodyDiameterMax>
    <OverallToolLength nominal="222.25"
      minimum="221.996" maximum="222.504"
      code="OAL">222.25</OverallToolLength>
    <UsableLengthMax code="LUX" nominal="82.55">82.55
    </UsableLengthMax>
    <CuttingDiameterMax code="DC" nominal="76.2"
      maximum="76.213" minimum="76.187">76.2
    </CuttingDiameterMax>
    <BodyLengthMax code="LF" nominal="120.65"
      maximum="120.904" minimum="120.404">120.65
    </BodyLengthMax>
    <DepthOfCutMax code="APMX"
    nominal="60.96">60.95</DepthOfCutMax>
    <FlangeDiameterMax code="DF"
      nominal="98.425">98.425</FlangeDiameterMax>
  </Measurements>
  <CuttingItems count="24">
    <CuttingItem indices="1-24" itemId="SDET43PDER8GB"
      manufacturers="KMT" grade="KC725M">
      <Measurements>
        <CuttingEdgeLength code="L" nominal="12.7"
          minimum="12.675" maximum="12.725">12.7
        </CuttingEdgeLength>
      <WiperEdgeLength code="BS" nominal=
        "2.56">2.56</WiperEdgeLength>
      <IncribedCircleDiameter code="IC"
        nominal="12.7">12.7
      </IncribedCircleDiameter>
      <CornerRadius code="RE" nominal="0.8">
        0.8</CornerRadius>
    </Measurements>
    </CuttingItem>
  </CuttingItems>
  </CuttingToolLifeCycle>
  </CuttingTool>
```

```xml
  </Assets>
</MTConnectAssets>
```

C.2 Step Drill

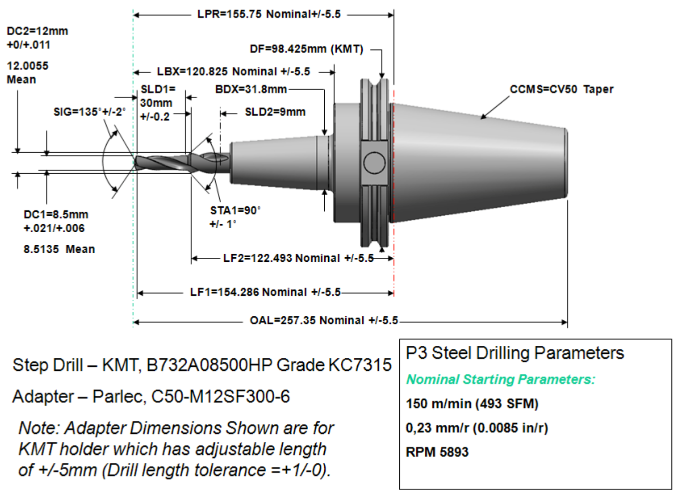

Figure 35: Step Mill Side View

Example 2: Example for Step Mill Side View

```xml
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\_1.2.xsd">
  <Header creationTime="2011-05-
␣␣11T13:55:22" assetBufferSize="1024"
  sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
  <Assets>
    <CuttingTool serialNumber="1␣" toolId="B732A08500HP"
    timestamp="2011-05-11T13:55:22" assetId="B732A08500HP␣"
    manufacturers="KMT,Parlec">
      <Description>
        Step Drill - KMT, B732A08500HP Grade KC7315
        Adapter - Parlec, C50-M12SF300-6
      </Description>
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
        <ProcessSpindleSpeed nominal="5893">5893</ProcessSpindleSpeed>
        <ProcessFeedRate nominal="2.5">2.5</ProcessFeedRate>
        <ConnectionCodeMachineSide>CV50 Taper</ConnectionCodeMachineSide>
        <Measurements>
          <BodyDiameterMax code="BDX">31.8</BodyDiameterMax>
          <BodyLengthMax code="LBX" nominal="120.825" maximum="126.325"
          minimum="115.325">120.825</BodyLengthMax>
          <ProtrudingLength code="LPR" nominal="155.75" maximum="161.25"
          minimum="150.26">155.75</ProtrudingLength>
```

```
            <FlangeDiameterMax code="DF"
            nominal="98.425">98.425</FlangeDiameterMax>
            <OverallToolLength nominal="257.35" minimum="251.85"
            maximum="262.85" code="OAL">257.35</OverallToolLength>
          </Measurements>
          <CuttingItems count="2">
            <CuttingItem indices="1" manufacturers="KMT" grade="KC7315">>
              <Measurements>
                <CuttingDiameter code="DC1" nominal="8.5" maximum="8.521"
                minimum="8.506">8.5135</CuttingDiameter>
                <StepIncludedAngle code="STA1" nominal="90" maximum="91"
                minimum="89">90</StepIncludedAngle>
                <FunctionalLength code="LF1" nominal="154.286"
                minimum="148.786"
                maximum="159.786">154.286</FunctionalLength>
                <StepDiameterLength code="SDL1"
                nominal="9">9</StepDiameterLength>
                <PointAngle code="SIG" nominal="135" minimum="133"
                maximum="137">135</PointAngle>
              </Measurements>
            </CuttingItem>
            <CuttingItem indices="2" manufacturers="KMT" grade="KC7315">>
              <Measurements>
                <CuttingDiameter code="DC2" nominal="12" maximum="12.011"
                minimum="12">12</CuttingDiameter>
                <FunctionalLength code="LF2" nominal="122.493"
                maximum="127.993"
                minimum="116.993">122.493</FunctionalLength>
                <StepDiameterLength code="SDL2"
                nominal="9">9</StepDiameterLength>
              </Measurements>
            </CuttingItem>
          </CuttingItems>
        </CuttingToolLifeCycle>
      </CuttingTool>
    </Assets>
  </MTConnectAssets>
```

C.3 Shell Mill with Individual Loci

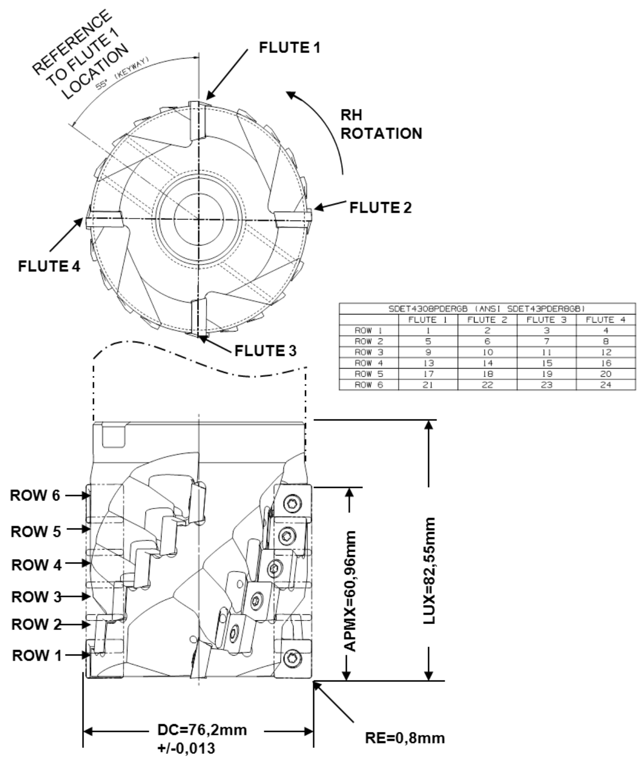

Figure 36: Shell Mill with Explicate Loci

Example 3: Example for Shell Mill with Explicate Loci

```xml
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\_1.2.xsd">
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
  sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
  <Assets>
    <CuttingTool serialNumber="1" toolId="KSSP300R4SD43L240"
    timestamp="2011-05-11T13:55:22" assetId="KSSP300R4SD43L240.1"
    manufacturers="KMT,Parlec">
      <Description>Keyway: 55 degrees</Description>
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
        <Measurements>
          <UsableLengthMax code="LUX"
          nominal="82.55">82.55</UsableLengthMax>
          <CuttingDiameterMax code="DC" nominal="76.2" maximum="76.213"
```

```
          minimum="76.187">76.2</CuttingDiameterMax>
          <DepthOfCutMax code="APMX" nominal="60.96">60.95</DepthOfCutMax>
        </Measurements>
        <CuttingItems count="24">
          <CuttingItem indices="1" itemId="SDET43PDER8GB"
          manufacturers="KMT">
            <Locus>FLUTE: 1, ROW: 1</Locus>
            <Measurements>
             <DriveAngle code="DRVA" nominal="55">55</DriveAngle>
           </Measurements>
          </CuttingItem>
          <CuttingItem indices="2-24" itemId="SDET43PDER8GB"
          manufacturers="KMT">
            <Locus>FLUTE: 2-4, ROW: 1; FLUTE: 1-4, ROW 2-6</Locus>
          </CuttingItem>
        </CuttingItems>
      </CuttingToolLifeCycle>
    </CuttingTool>
  </Assets>
</MTConnectAssets>
```

C.4 Drill with Individual Loci

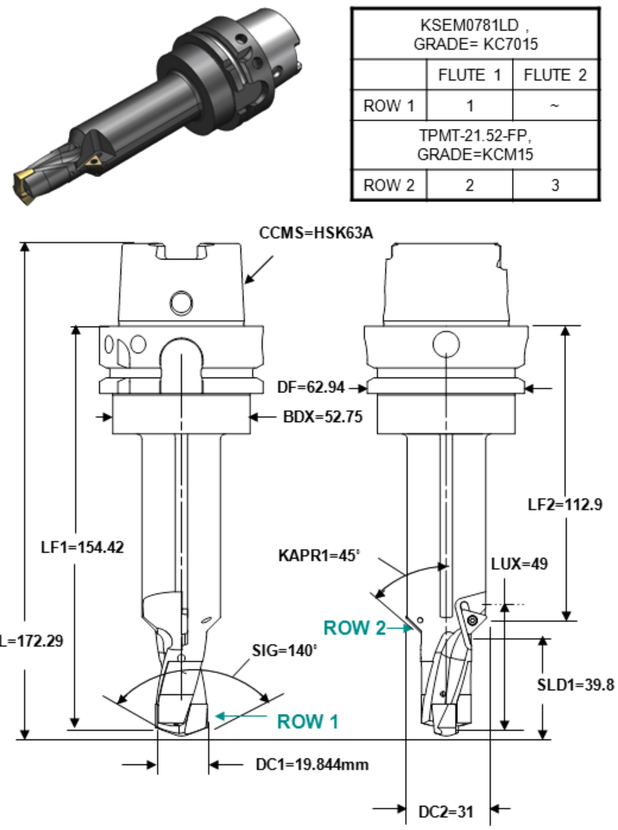

Figure 37: Step Drill with Explicate Loci

Example 4: Example for Step Drill with Explicate Loci

```xml
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\_1.2.xsd">
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
  sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
  <Assets>
    <CuttingTool serialNumber="1" toolId="KSEM0781LD"
    timestamp="2011-05-11T13:55:22" assetId="KSEM0781LD.1" manufacturers="KMT">
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
        <ConnectionCodeMachineSide>HSK63A</ConnectionCodeMachineSide>
        <Measurements>
          <BodyDiameterMax code="BDX">52.75</BodyDiameterMax>
          <OverallToolLength nominal="172.29"
```

```xml
          code="OAL">172.29</OverallToolLength>
          <UsableLengthMax code="LUX" nominal="49">49</UsableLengthMax>
          <FlangeDiameterMax code="DF"
          nominal="62.94">62.94</FlangeDiameterMax>
        </Measurements>
        <CuttingItems count="3">
          <CuttingItem indices="1" itemId="KSEM0781LD" manufacturers="KMT"
          grade="KC7015">
            <Locus>FLUTE: 1, ROW: 1</Locus>
            <Measurements>
         <FunctionalLength code="LF1" nominal="154.42">154.42</FunctionalLength>
         <CuttingDiameter code="DC1" nominal="19.844">19.844</CuttingDiameter>
         <PointAngle code="SIG" nominal="140">140</PointAngle>
         <ToolCuttingEdgeAngle code="KAPR1" nominal="45">45</ToolCuttingEdgeAngle>
         <StepDiameterLength code="SLD1" nominal="39.8">39.8</StepDiameterLength>
            </Measurements>
          </CuttingItem>
          <CuttingItem indices="2-3" itemId="TPMT-21.52-FP"
          manufacturers="KMT" grade="KCM15">
            <Locus>FLUTE: 1-2, ROW: 2</Locus>
            <Measurements>
         <FunctionalLength code="LF2" nominal="112.9">119.2</FunctionalLength>
         <CuttingDiameter code="DC2" nominal="31">31</CuttingDiameter>
            </Measurements>
          </CuttingItem>
        </CuttingItems>
      </CuttingToolLifeCycle>
    </CuttingTool>
  </Assets>
</MTConnectAssets>
```

C.5 Shell Mill with Different Inserts on First Row

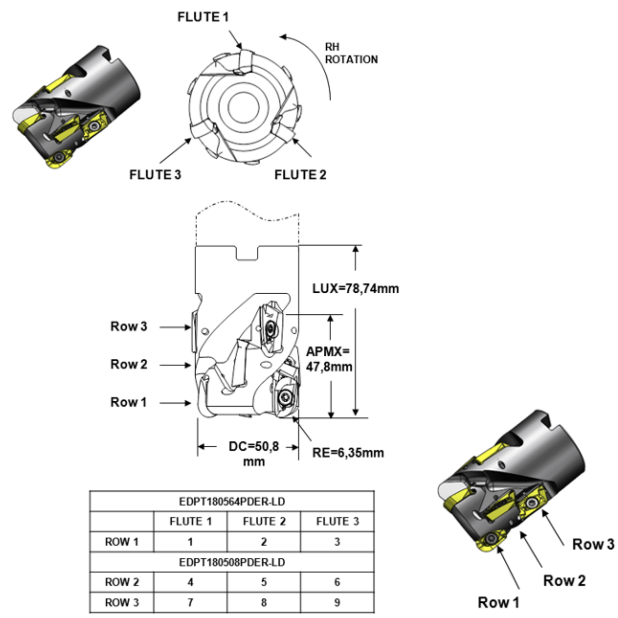

Figure 38: Shell Mill with Different Inserts on First Row

Example 5: Example for Shell Mill with Different Inserts on First Row

```xml
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\_1.2.xsd">
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
  sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
  <Assets>
    <CuttingTool serialNumber="1" toolId="XXX" timestamp="2011-05-11T13:55:22"
    assetId="XXX.1" manufacturers="KMT">
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
        <Measurements>
          <DepthOfCutMax code="APMX" nominal="47.8">47.8</DepthOfCutMax>
          <CuttingDiameterMax code="DC"
          nominal="50.8">50.8</CuttingDiameterMax>
          <UsableLengthMax code="LUX"
          nominal="78.74">78.74</UsableLengthMax>
        </Measurements>
        <CuttingItems count="9">
          <CuttingItem indices="1-3" itemId="EDPT180564PDER-LD"
          manufacturers="KMT">
            <Locus>FLUTE: 1-3, ROW: 1</Locus>
```

```xml
            <Measurements>
              <CornerRadius code="RE" nominal="6.25">6.35</CornerRadius>
            </Measurements>
          </CuttingItem>
          <CuttingItem indices="4-9" itemId="EDPT180508PDER-LD"
          manufacturers="KMT">
            <Locus>FLANGE: 1-4, ROW: 2-3</Locus>
          </CuttingItem>
        </CuttingItems>
      </CuttingToolLifeCycle>
    </CuttingTool>
  </Assets>
</MTConnectAssets>
```

MTConnect® Standard

Part 4.2 – File Asset Information Model

Version 1.8.0

Prepared for: MTConnect Institute
Prepared on: September 6, 2021

MTConnect Specification and Materials

Table of Contents

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List of Tables

1 Purpose of This Document

This document, *MTConnect Standard: Part 4.2 - File Asset Information Model* of the MTConnect Standard, establishes the rules and terminology to be used by designers to describe the function and operation of files used within manufacturing and to define the data that is provided by an *Agent* from a piece of equipment. This part of the Standard also defines the structure for the XML document that is returned from an *Agent* in response to a `probe` request.

The data associated with these files will be retrieved from multiple sources that are responsible for providing their knowledge of an *MTConnect Asset*.

2 Terminology and Conventions

Refer to Section 2 of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 Glossary

URL

Stands for Uniform Resource Locator.

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

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/*.

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*.

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.

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*.

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`.

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 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*.

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*.

Equipment Metadata

See *Metadata*

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*.

Lower Level

A nested element that is below a higher level element.

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*.

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 Information Model

See *Information Model*

MTConnectDevices Response Document

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

MTConnectStreams Response Document

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

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.

organize

The act of containing and owning one or more elements.

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*.

Probe Request

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

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*.

Response Document

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

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*.

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*.

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*.

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*.

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*.

Top Level

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

2.2 Acronyms

AMT

The Association for Manufacturing Technology

2.3 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.8.0.

[MTConnect Part 4.2] *MTConnect Standard: Part 4.2 - File Asset Information Model*. Version 1.8.0.

3 Files Information Model

Manufacturing processes require various documents, programs, setup sheets, and digital media available at the device for a given process. The `File` and `FileArchetype` `Assets` provide a mechanism to communicate specific "Files" that are relevant to a process where the media is located on a server and represented by a Universal Resource Locator (URL).

The `FileArchetype` contains metadata common to all `File Assets` for a certain purpose. The `File Asset` references the file specific to a given device or set of devices. The `File Asset` does not hold the contents of the file, it contains a reference to the location (URL) used to access the information. The metadata associated with the `File` provides semantic information about the representation (mime-type) and the application associated with the `File`. The application of the file is an extensible controlled vocabulary with common manufacturing uses provided.

3.1 AbstractFile

An `AbstractFile` is an abstract `Asset` type model that contains the common properties of the `File` and `FileArchetype` types.

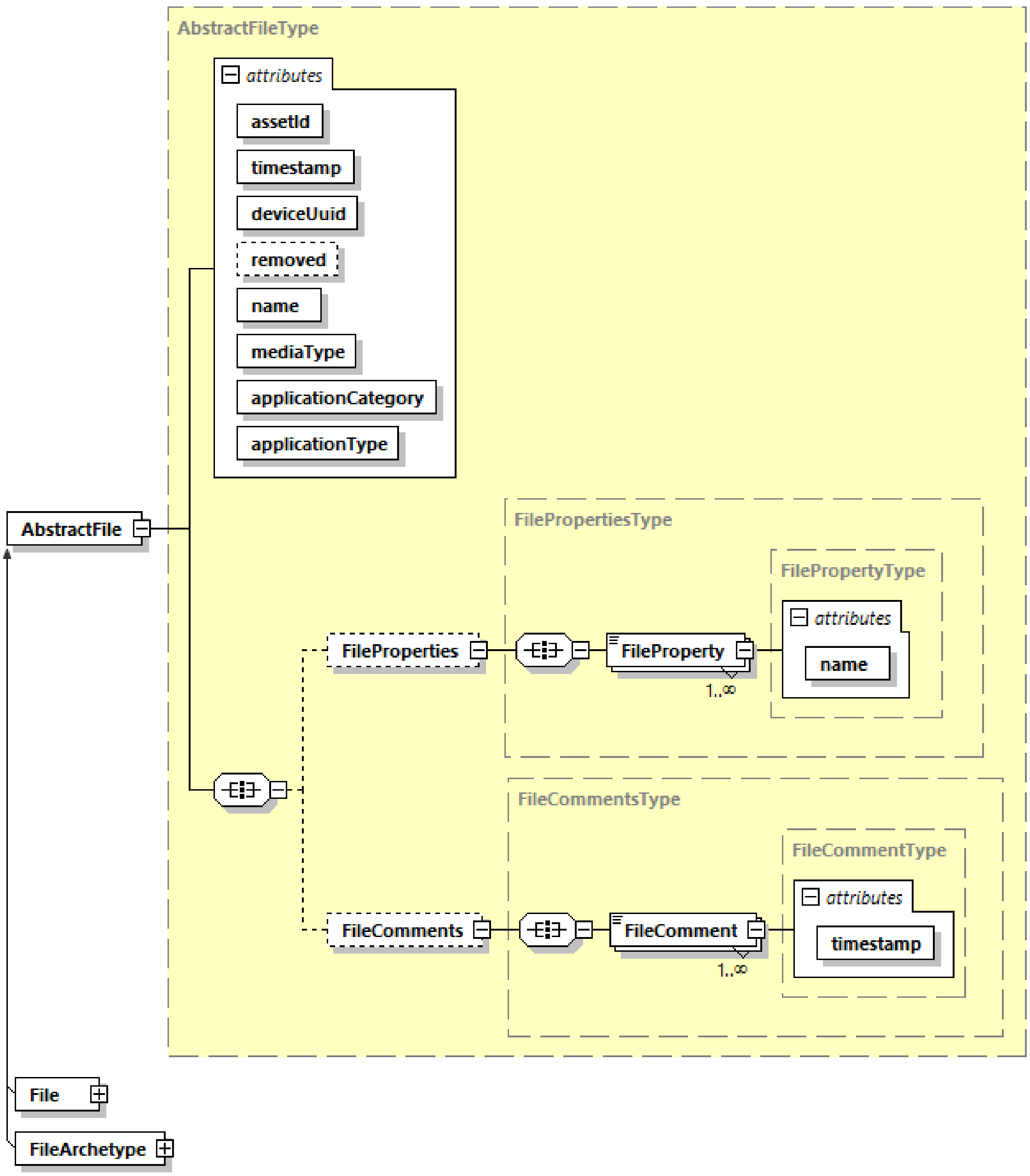

Figure 1: AbstractFile Diagram

3.1.1 Attributes for AbstractFile

Table 1 lists the attributes for an `AbstractFile` element in addition to attributes inherited from `Asset` element.

Table 1: Attributes for AbstractFile

Attribute	Description	Occurrence
`name`	The name of the file. The value of `name` **MUST** be a string.	1
`mediaType`	The mime type of the file. The value of `mediaType` **MUST** be a string.	1
`applicationCategory`	The category of application that will use this file.	1
`applicationType`	The type of application that will use this file.	1

3.1.1.1 AbstractFile applicationCategory types

Table 2 lists the types for `applicationCategory` attribute of `AbstractFile` element.

Table 2: AbstractFile applicationCategory types

type	Description
`ASSEMBLY`	Files regarding the fully assembled product.
`DEVICE`	Device related files.
`HANDLING`	Files relating to the handling of material.
`MAINTENANCE`	File relating to equipment maintenance.
`PART`	Files relating to a part.
`PROCESS`	Files related to the manufacturing process.
`INSPECTION`	Files related to the quality inspection.
`SETUP`	Files related to the setup of a process.

3.1.1.2 AbstractFile applicationType types

Table 3 lists the types for `applicationType` attribute of `AbstractFile` element.

Table 3: AbstractFile applicationType types

type	Description
`DESIGN`	Computer aided design files or drawings.
`DATA`	Generic data.
`DOCUMENTATION`	Documentation regarding a category of file.
`INSTRUCTIONS`	User instructions regarding the execution of a task.
`LOG`	The data related to the history of a machine or process.
`PRODUCTION_PROGRAM`	Machine instructions to perform a process.

3.1.2 Elements for AbstractFile

Table 4 lists the elements for an `AbstractFile` element.

Table 4: Elements for AbstractFile

Element	Description	Occurrence
`FileProperties`	`FileProperties` *organizes* one or more `FileProperty` entities for `Files`.	0..1
`FileComments`	`FileComments` *organizes* one or more `FileComment` entities for `Files`.	0..1

3.1.3 FileProperty

A key-value pair providing additional metadata about a `File`.

The value for `FileProperty` **MUST** be a string.

3.1.3.1 Attributes for FileProperty

Table 5 lists the attributes for a `FileProperty` element.

Table 5: Attributes for FileProperty

Attribute	Description	Occurrence
`name`	The name of the `FileProperty`	1

3.1.4 FileComment

A remark or interpretation for human interpretation associated with a `File` or `FileArchetype`.

The value for `FileComment` **MUST** be a string.

3.1.4.1 Attributes for FileComment

Table 6 lists the attributes for a `FileComment` element.

Table 6: Attributes for FileComment

Attribute	Description	Occurrence
`timestamp`	The time the comment was made. The value for `timestamp` **MUST** be reported in ISO 8601 format.	1

3.2 File

The `File Asset` is an `AbstractFile` with information about the `File` instance and its URL.

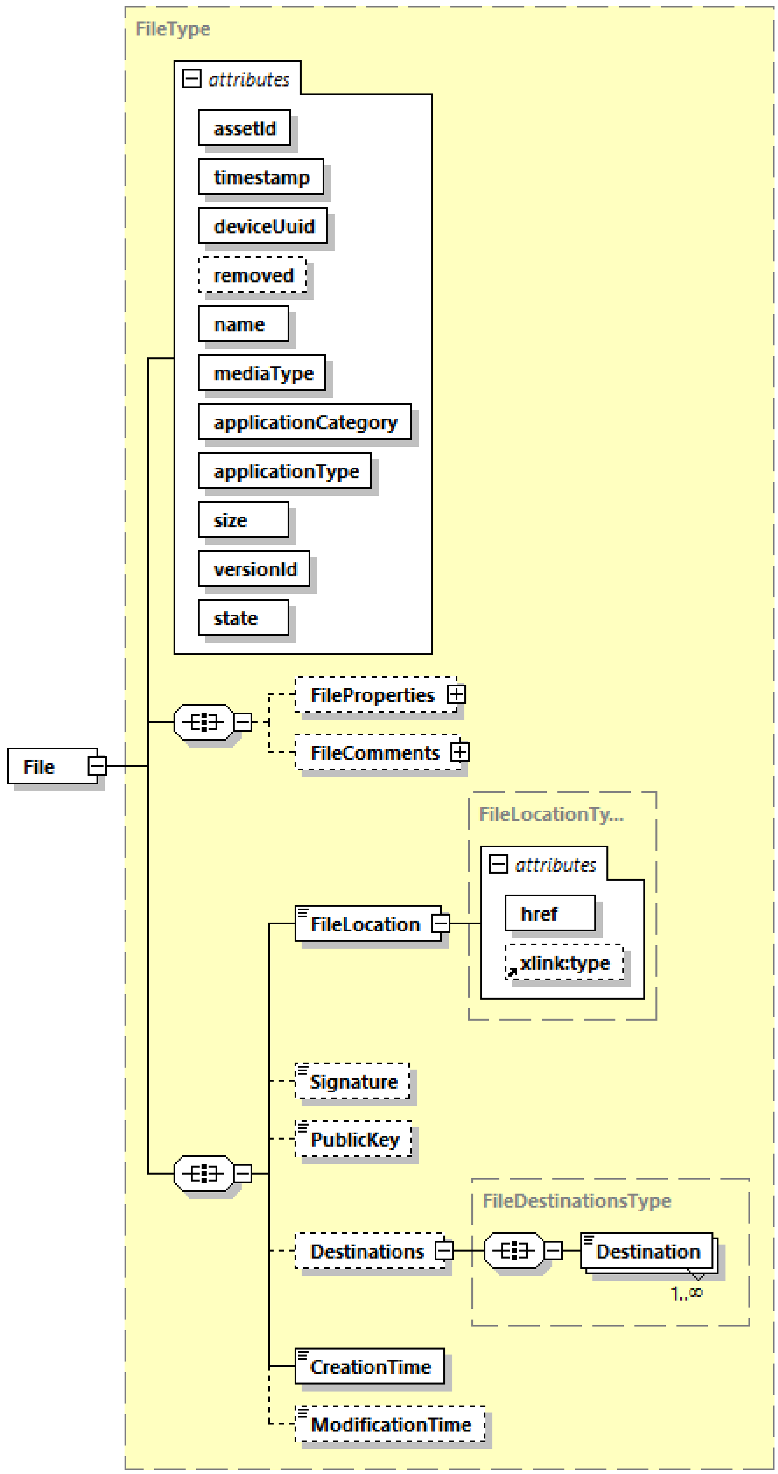

Figure 2: File Diagram

3.2.1 Attributes for File

Table 7 lists the attributes for a `File` element in addition to attributes inherited from `AbstractFile` (See *Section 3.1 - AbstractFile*).

Table 7: Attributes for File

Attribute	Description	Occurrence
`size`	The size of the file in bytes. The value of `size` **MUST** be an integer.	1
`versionId`	The version identifier of the file. The value of `versionId` **MUST** be a string.	1
`state`	The state of the file.	1

3.2.1.1 File states

Table 8 lists the values for `state` attribute of `File` element.

Table 8: File states

type	Description
`EXPERIMENTAL`	Used for processes other than production or otherwise defined.
`PRODUCTION`	Used for production processes.
`REVISION`	The content is modified from `PRODUCTION` or `EXPERIMENTAL`.

3.2.2 Elements for File

Table 9 lists the elements for a `File` element.

Table 9: Elements for File

Element	Description	Occurrence
Signature	A secure hash of the file. The value for Signature **MUST** be an x509 data block.	0..1
PublicKey	The public key used to verify the signature. The value for PublicKey **MUST** be an x509 data block.	0..1
CreationTime	The time the file was created. The value for CreationTime **MUST** be reported in ISO 8601 format.	1
ModificationTime	The time the file was modified. The value for ModificationTime **MUST** be reported in ISO 8601 format.	0..1
FileLocation	The URL reference to the file location.	1
Destinations	Destinations *organizes* one or more Destination elements.	0..1

3.2.3 FileLocation

The URL reference to the file location.

3.2.3.1 Attributes for FileLocation

Table 10 lists the attributes for a FileLocation element.

Table 10: Attributes for FileLocation

Attribute	Description	Occurrence
href	A URL reference to the file. href is of type xlink:href from the W3C XLink specification.	1

Continuation of Table 10		
Attribute	Description	Occurrence
`xlink:type`	The type of href for the xlink href type. **MUST** be `locator` referring to a URL.	0..1

3.2.4 Destination

The `Destination` is a reference to the target `Device` for this `File`.

3.2.4.1 Attributes for Destination

Table 11 lists the attributes for a `Destination` element.

Table 11: Attributes for Destination

Attribute	Description	Occurrence
`deviceUuid`	`uuid` of the target device or application.	1

3.3 FileArchetype

`FileArchetype` `Asset` is an `AbstractFile` providing information common to all versions of a file.

See *Section 3.1 - AbstractFile* for details on the `FileArchetype` model.

Appendices

A Bibliography

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MTConnect® Standard

Part 4.3 – Raw Material Asset Information Model

Version 1.8.0

Prepared for: MTConnect Institute
Prepared on: September 6, 2021

MTConnect Specification and Materials

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List of Tables

1 Purpose of This Document

This document, *MTConnect Standard: Part 4.3 - Raw Material Asset Information Model* of the MTConnect Standard, establishes the rules and terminology to be used by designers to describe the function and operation of *raw material* used within manufacturing and to define the data that is provided by an *Agent* from a piece of equipment.

The data associated with these *raw material* will be retrieved from multiple sources that are responsible for providing their knowledge of an *MTConnect Asset*.

2 Terminology and Conventions

Refer to Section 2 of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 Glossary

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*.

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.

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*.

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`.

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 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*.

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*.

Equipment Metadata

See *Metadata*

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*.

Lower Level

A nested element that is below a higher level element.

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*.

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 Information Model

See *Information Model*

MTConnectDevices Response Document

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

MTConnectStreams Response Document

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

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.

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*.

Probe Request

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

raw material

Crude or processed material that can be converted by manufacture, processing, or combination into a new and useful product.

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*.

Response Document

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

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*.

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*.

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*.

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*.

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*.

Top Level

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

2.2 Acronyms

AMT

The Association for Manufacturing Technology

ASTM

American Society for Testing and Materials

2.3 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.8.0.

[MTConnect Part 4.3] *MTConnect Standard: Part 4.3 - Raw Material Asset Information Model*. Version 1.8.0.

3 Raw Material Information Model

Raw material represents the source of material for immediate use and sources of material that may or may not be used during the manufacturing process.

The `RawMaterial` `Asset` holds the references to the content stored in the actual `RawMaterial` container or derived about the `RawMaterial` by the system during operation.

3.1 RawMaterial

`RawMaterial` is an `Asset` that represents *raw material*.

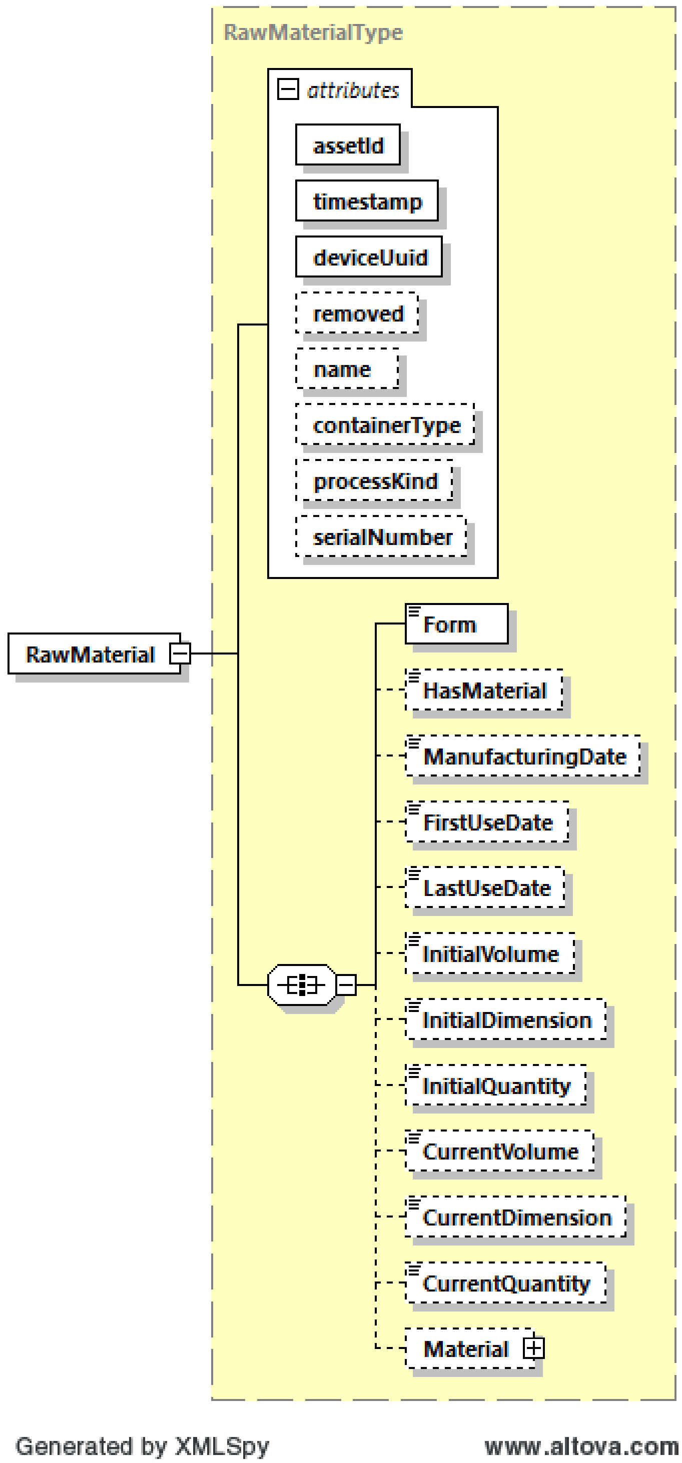

Figure 1: RawMaterial Diagram

3.1.1 Attributes for RawMaterial

Table 1 lists the attributes for a `RawMaterial` element in addition to attributes inherited from `Asset` element.

Table 1: Attributes for RawMaterial

Attribute	Description	Occurrence
`name`	The *raw material* name. Examples: `Container1` and `AcrylicContainer`. The value of `name` **MUST** be a string.	0..1
`containerType`	The type of container holding the *raw material*. Examples: `Pallet`, `Canister`, `Cartridge`, `Tank`, `Bin`, `Roll` and `Spool`. The value of `type` **MUST** be a string.	0..1
`processKind`	The ISO process type supported by this *raw material*. Examples include: `VAT_POLYMERIZATION`, `BINDER_JETTING`, `MATERIAL_EXTRUSION`, `MATERIAL_JETTING`, `SHEET_LAMINATION`, `POWDER_BED_FUSION`, or `DIRECTED_ENERGY_DEPOSITION`. *Ref: ASTM F2792-12a* The value of `processId` **MUST** be a string.	0..1
`serialNumber`	The serial number of the *raw material*. The value of `serialNumber` **MUST** be a string.	0..1

3.1.2 Elements for RawMaterial

Table 2 lists the elements for a `RawMaterial` element.

Table 2: Elements for RawMaterial

Element	Description	Occurrence
Form	The form of the *raw material*. The value **MUST** be BAR, SHEET, BLOCK, CASTING, POWDER, LIQUID, GEL, FILAMENT, or GAS.	1
HasMaterial	Material has existing usable volume. The value of HasMaterial **MUST** be boolean.	0..1
ManufacturingDate	The date the *raw material* was created. The value of ManufacturingDate **MUST** be reported in ISO 8601 format.	0..1
FirstUseDate	The date *raw material* was first used. The value of FirstUseDate **MUST** be reported in ISO 8601 format.	0..1
LastUseDate	The date *raw material* was last used. The value of LastUseDate **MUST** be reported in ISO 8601 format.	0..1
InitialVolume	The amount of material initially placed in *raw material* when manufactured. The value of InitialVolume **MUST** be reported in CUBIC_MILLIMETER.	0..1
InitialDimension	The dimension of material initially placed in *raw material* when manufactured. The value of InitialDimension **MUST** be reported in MILLIMETER_3D.	0..1
InitialQuantity	The quantity of material initially placed in *raw material* when manufactured. The value **MUST** be an integer.	0..1

Continuation of Table 2		
Element	Description	Occurrence
CurrentVolume	The amount of material currently in *raw material*. The value of CurrentVolume **MUST** be reported in CUBIC_MILLIMETER.	0..1
CurrentDimension	The dimension of material currently in *raw material*. The value of CurrentDimension **MUST** be reported in MILLIMETER_3D.	0..1
CurrentQuantity	The quantity of material currently in *raw material*. The value **MUST** be an integer.	0..1
Material	Material used as the *raw material*. See *Section 3.2 - Material* for details.	0..1

3.2 Material

Material used as the *raw material*.

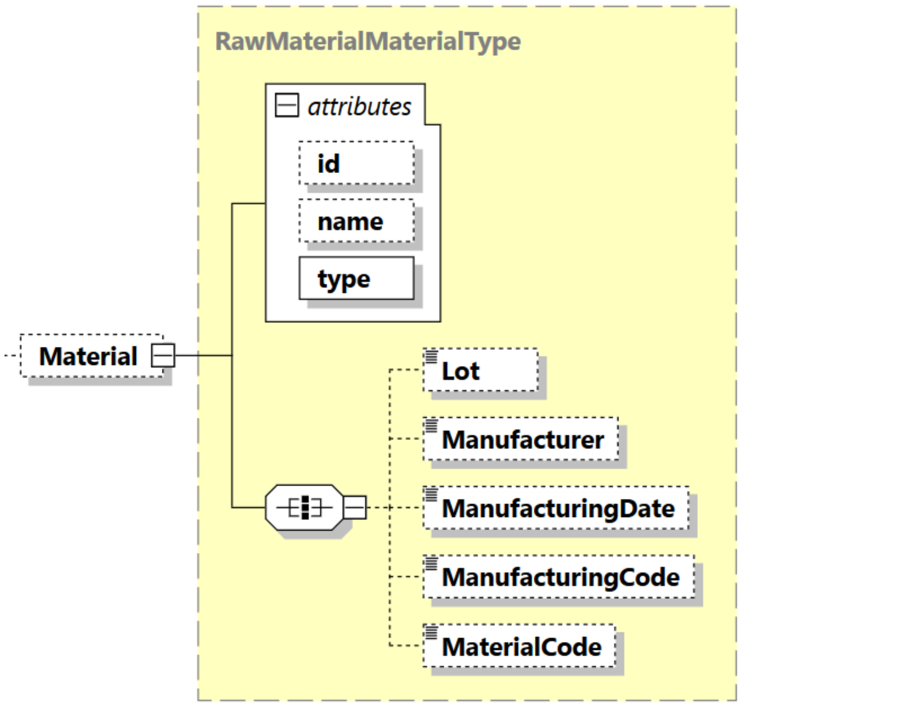

Figure 2: Material Diagram

3.2.1 Attributes for Material

Table 3 lists the attributes for a `Material` element.

Table 3: Attributes for Material

Attribute	Description	Occurrence
`id`	The unique identifier for the material. The value for `id` **MUST** be a string.	0..1
`name`	The name of the material. Examples: `ULTM9085`, `ABS`, `4140`. The value for `name` **MUST** be a string.	0..1

Continuation of Table 3		
Attribute	Description	Occurrence
`type`	The type of material. Examples: `Metal`, `Polymer`, `Wood`, `4140`, `Recycled`, `Prestine` and `Used`. The value for `type` **MUST** be a string.	1

3.2.2 Elements for Material

Table 4 lists the elements for a `Material` element.

Table 4: Elements for Material

Element	Description	Occurrence
`Lot`	The manufacturer's lot code of the material. The value for `Lot` **MUST** be a string.	0..1
`Manufacturer`	The name of the material manufacturer. The value for `Manufacturer` **MUST** be a string.	0..1
`ManufacturingDate`	The manufacturing date of the material from the material manufacturer. The value for `ManufacturingDate` **MUST** be reported in ISO 8601 format.	0..1
`ManufacturingCode`	The lot code of the raw feed stock for the material, from the feed stock manufacturer. The value for `ManufacturingCode` **MUST** be a string.	0..1
`MaterialCode`	The ASTM standard code that the material complies with. The value for `MaterialCode` **MUST** be a string.	0..1

Appendices

A Bibliography

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MTConnect® Standard

Part 4.4 – QIF Asset Information Model

Version 1.8.0

Prepared for: MTConnect Institute
Prepared on: September 6, 2021

MTConnect Specification and Materials

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1 Purpose of This Document

This document, *MTConnect Standard: Part 4.4 - QIF Asset Information Model* of the MTConnect Standard, establishes the rules and terminology to be used by designers to parse a QIF Document as an *MTConnect Asset* that is provided by an *Agent* from a piece of equipment.

The data associated with the QIF Document will be retrieved from multiple sources that are responsible for providing their knowledge of an *MTConnect Asset*.

2 Terminology and Conventions

Refer to Section 2 of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 Glossary

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*.

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.

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`.

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*.

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*.

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*.

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 Information Model

See *Information Model*

MTConnectDevices Response Document

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

MTConnectStreams Response Document

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

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.

Probe Request

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

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*.

Response Document

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

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*.

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*.

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*.

2.2 Acronyms

AMT

The Association for Manufacturing Technology

2.3 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.8.0.

[MTConnect Part 4.4] *MTConnect Standard: Part 4.4 - QIF Asset Information Model*. Version 1.8.0.

3 QIF Asset Information Model

The Quality Information Framework (QIF) is an American National Standards Institute (ANSI) accredited standard developed by the Digital Metrology Standards Consortium (DMCS) standards development organization and an A-liaison to the International Standards Organization (ISO) Technical Committee (TC) 184. QIF addresses the needs of the metrology community to have a semantic information model for the exchange of metrology data throughout the verification lifecycle from product design to execution, analysis, and reporting.

The MTConnect QIF Asset Model provides a wrapper around the QIF Information model in its native XML representation utilizing the QIF XML Schema Definition Language (XSDL) references in the wrapper to validate the document. The MTConnect standard does not alter or extend the QIF standard and regards the QIF standard as a pass-through.

Information about the QIF standards is at the following location: https://qifstandards.org

3.1 QIFDocumentWrapper

`QIFDocumentWrapper` is an `Asset` that carries the Quality Information Framework (QIF) Document.

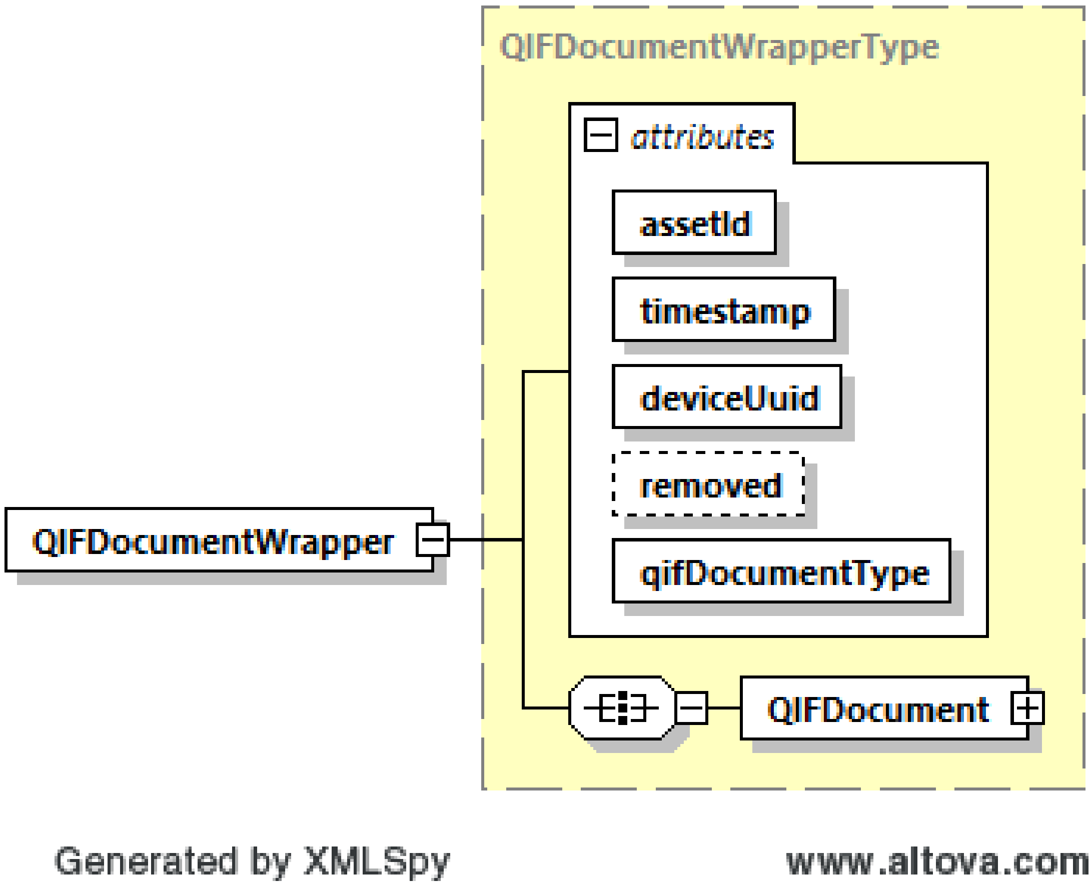

Figure 1: QIFDocumentWrapper Diagram

3.1.1 Attributes for QIFDocumentWrapper

Table 1 lists the attributes for an `QIFDocumentWrapper` element in addition to attributes inherited from `Asset` element.

Table 1: Attributes for QIFDocumentWrapper

Attribute	Description	Occurrence
`qifDocumentType`	The contained QIF Document type as defined in the QIF Standard. The value of `qifDocumentType` **MUST** be one of the current documents types as per QIF: `MEASUREMENT_RESOURCE`, `PLAN`, `PRODUCT`, `RESULTS`, `RULES` or `STATISTICS`.	0..1

3.1.2 Elements for QIFDocumentWrapper

Table 2 lists the elements for an `QIFDocumentWrapper` element.

Table 2: Elements for QIFDocumentWrapper

Element	Description	Occurrence
`QIFDocument`	The QIF Document as defined by the QIF standard.	1

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A Bibliography

Engineering Industries Association. *EIA Standard - EIA-274-D*, Interchangeable Variable, Block Data Format for Positioning, Contouring, and Contouring/Positioning Numerically Controlled Machines. Washington, D.C. 1979.

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ASME/ANSI B5.54: Methods for Performance Evaluation of Computer Numerically Controlled Machining Centers. 2005.

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MTConnect® Standard

Part 5 – Interfaces

Version 1.8.0

Prepared for: MTConnect Institute
Prepared on: September 6, 2021

MTConnect Specification and Materials

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1 Purpose of This Document

This document, *MTConnect Standard: Part 5.0 - Interfaces* of the MTConnect® Standard, defines a structured data model used to organize information required to coordinate inter-operations between pieces of equipment.

This data model is based on an *Interaction Model* that defines the exchange of information between pieces of equipment and is organized in the MTConnect Standard as the XML element `Interfaces`.

Interfaces is modeled as an extension to the `MTConnectDevices` and `MTConnectStreams` XML documents. `Interfaces` leverages similar rules and terminology as those used to describe a component in the `MTConnectDevices` XML document. `Interfaces` also uses similar methods for reporting data to those used in the `MTConnectStreams` XML document.

As defined in *MTConnect Standard: Part 2.0 - Devices Information Model*, `Interfaces` is modeled as a *Top Level* component in the `MTConnectDevices` document (see *Figure 3*). Each individual `Interface` XML element is modeled as a *Lower Level* component of `Interfaces`. The data associated with each *Interface* is modeled within each *Lower Level* component.

> Note: See *MTConnect Standard: Part 2.0 - Devices Information Model* and *MTConnect Standard: Part 3.0 - Streams Information Model* of the MTConnect Standard for information on how *Interfaces* is structured in the XML documents which are returned from an *Agent* in response to a `probe`, `sample`, or `current` request.

2 Terminology and Conventions

Refer to Section 2 of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 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

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.

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*.

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*.

Component

<u>General meaning</u>:

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*.

<u>Used in *Information Models*</u>:

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`.

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 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 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*.

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*.

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*.

Equipment Metadata

See *Metadata*

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*.

Interaction Model

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

Interface

The means by which communication is achieved between independent systems.

Lower Level

A nested element that is below a higher level element.

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*.

MTConnect Agent

See definition for *Agent*.

MTConnectDevices Response Document

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

MTConnectStreams Response Document

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

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.

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*.

Probe Request

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

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*.

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*.

Requester

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

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

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*.

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*.

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*.

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*.

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*.

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*.

Top Level

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

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).

2.2 Acronyms

AMT

The Association for Manufacturing Technology

2.3 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Version 1.8.0.

[MTConnect Part 2.0] *MTConnect Standard: Part 2.0 - Devices Information Model*. Version 1.8.0.

[MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Streams Information Model*. Version 1.8.0.

[MTConnect Part 5.0] *MTConnect Standard: Part 5.0 - Interfaces*. Version 1.8.0.

3 Interfaces Overview

In many manufacturing processes, multiple pieces of equipment must work together to perform a task. The traditional method for coordinating the activities between individual pieces of equipment is to connect them using a series of wires to communicate equipment states and demands for action. These interactions use simple binary ON/OFF signals to accomplished their intention.

In the MTConnect Standard, *Interfaces* provides a means to replace this traditional method for interconnecting pieces of equipment with a structured *Interaction Model* that provides a rich set of information used to coordinate the actions between pieces of equipment. Implementers may utilize the information provided by this data model to (1) realize the interaction between pieces of equipment and (2) to extend the functionality of the equipment to improve the overall performance of the manufacturing process.

The *Interaction Model* used to implement *Interfaces* provides a lightweight and efficient protocol, simplifies failure recovery scenarios, and defines a structure for implementing a Plug-And-Play relationship between pieces of equipment. By standardizing the information exchange using this higher-level semantic information model, an implementer may more readily replace a piece of equipment in a manufacturing system with any other piece of equipment capable of providing similar *Interaction Model* functions.

Two primary functions are required to implement the *Interaction Model* for an *Interfaces* and manage the flow of information between pieces of equipment. Each piece of equipment needs to have the following:

- An *Agent* which provides:

  - The data required to implement the *Interaction Model*.

  - Any other data from a piece of equipment needed to implement the *Interface* – operating states of the equipment, position information, execution modes, process information, etc.

- A client software application that enables the piece of equipment to acquire and interpret information from another piece of equipment.

3.1 Interfaces Architecture

MTConnect Standard is based on a communications method that provides no direct way for one piece of equipment to change the state of or cause an action to occur in another piece of equipment. The *Interaction Model* used to implement *Interfaces* is based on a *Publish/Subscribe* type of communications as described in *MTConnect Standard Part 1.0 - Overview and Fundamentals* and utilizes a *Request* and *Response* information exchange mechanism. For *Interfaces*, pieces of equipment must perform both the publish (*Agent*) and subscribe (client) functions.

Note: The current definition of *Interfaces* addresses the interaction between two pieces of equipment. Future releases of the MTConnect Standard may address the interaction between multiple (more than two) pieces of equipment.

Figure 1 provides a high-level overview of a typical system architecture used to implement *Interfaces*.

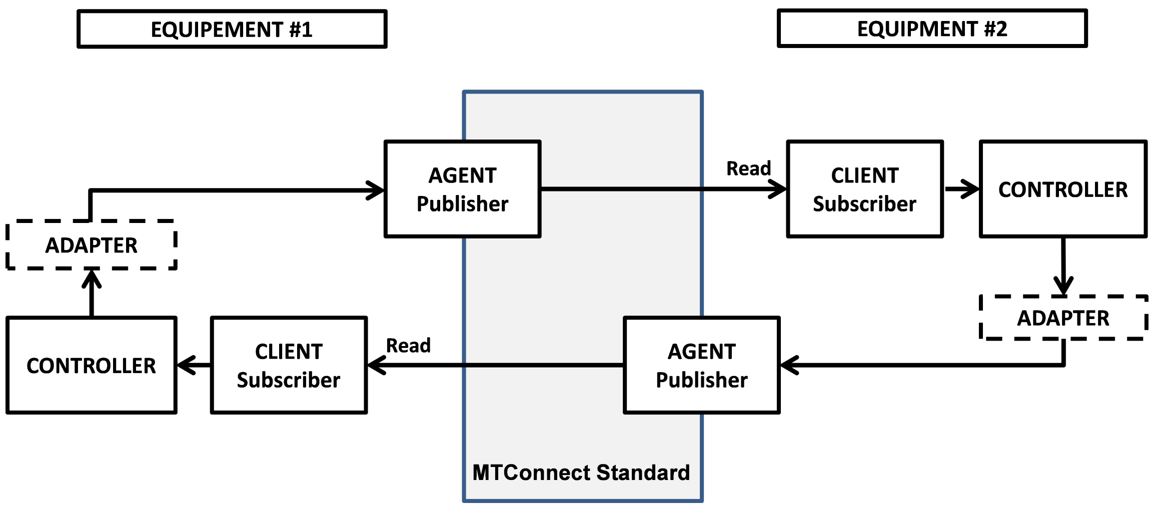

Figure 1: Data Flow Architecture for Interfaces

Note: The data flow architecture illustrated in *Figure 1* was historically referred to in the MTConnect Standard as a read-read concept.

In the implementation of the *Interaction Model* for *Interfaces*, two pieces of equipment can exchange information in the following manner. One piece of equipment indicates a *Request* for service by publishing a type of *Request* using a data item provided through an *Agent* as defined in *Section 4 - Interfaces for Devices and Streams Information Models*. The client associated with the second piece of equipment, which is subscribing to data from the first machine, detects and interprets that *Request*. If the second machine chooses to take any action to fulfill this *Request*, it can indicate its acceptance by publishing a *Response* using a data item provided through its *Agent*. The client on the first piece of equipment continues to monitor information from the second piece of equipment until it detects an indication that the *Response* to the *Request* has been completed or has failed.

An example of this type of interaction between pieces of equipment can be represented by a machine tool that wants the material to be loaded by a robot. In this example, the machine tool is the *Requester*, and the robot is the *Responder*. On the other hand, if the robot wants the machine tool to open a door, the robot becomes the *Requester* and the machine tool the *Responder*.

3.2 Request and Response Information Exchange

The concept of a *Request* and *Response* information exchange is not unique to MTConnect *Interfaces*. This style of communication is used in many different types of environments and technologies.

An early version of a *Request* and *Response* information exchange was used by early sailors. When it was necessary to communicate between two ships before radio communications were available, or when secrecy was required, a sailor on each ship could communicate with the other using flags as a signaling device to request information or actions. The responding ship could acknowledge those requests for action and identify when the requested actions were completed.

The same basic *Request* and *Response* concept is implemented by MTConnect *Interfaces* using the `EVENT` data items defined in *Section 4 - Interfaces for Devices and Streams Information Models*.

The `DataItem` elements defined by the *Interaction Model* each have a *Request* and *Response* subtype. These subtypes identify if the data item represents a *Request* or a *Response*. Using these data items, a piece of equipment changes the state of its *Request* or *Response* to indicate information that can be read by the other piece of equipment. To aid in understanding how the *Interaction Model* functions, one can view this *Interaction Model* as a simple state machine.

The interaction between two pieces of equipment can be described as follows. When the *Requester* wants an activity to be performed, it transitions its *Request* state from a `READY` state to an `ACTIVE` state. In turn, when the client on the *Responder* reads this information and interprets the *Request*, the *Responder* announces that it is performing the requested task by changing its response state to `ACTIVE`. When the action is finished, the *Responder* changes its response state to `COMPLETE`. This pattern of *Request* and *Response* provides the basis for the coordination of actions between pieces of equipment. These actions are implemented using `EVENT` category data items. (See *Section 4 - Interfaces for Devices and Streams Information Models* for details on the `Event` type data items defined for *Interfaces*.)

> Note: The implementation details of how the *Responder* piece of equipment reacts to the *Request* and then completes the requested task are up to the implementer.

Figure 2 provides an example of the *Request* and *Response* state machine:

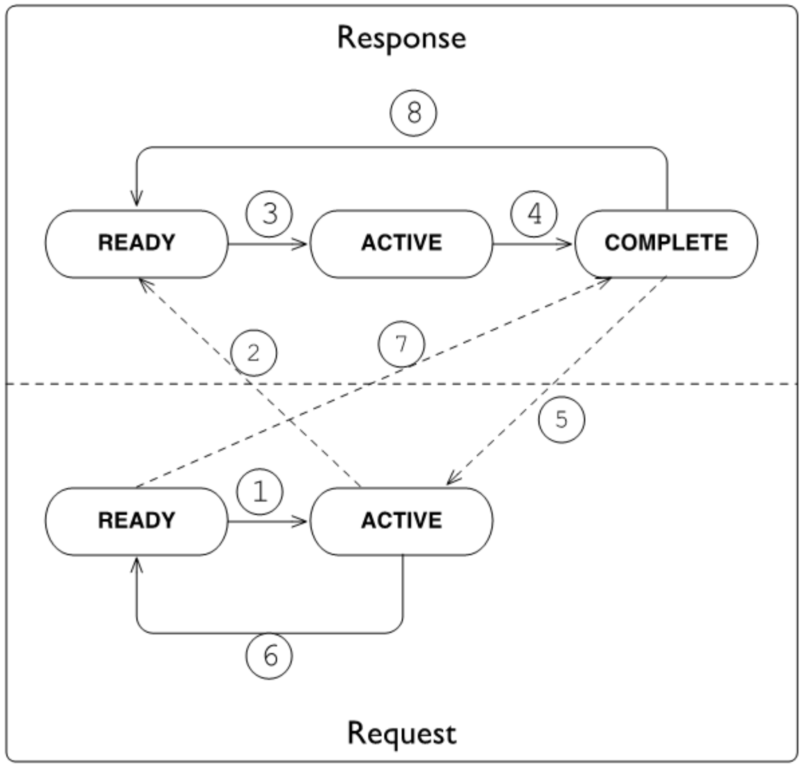

Figure 2: Request and Response Overview

The initial condition of both the *Request* and *Response* states on both pieces of equipment is `READY`. The dotted lines indicate the on-going communications that occur to monitor the progress of the interactions between the pieces of equipment.

The interaction between the pieces of equipment as illustrated in *Figure 2* progresses through the sequence in *Table 1*.

Table 1: Sequence of interaction between pieces of equipment

Step	Description
1	The *Request* transitions from `READY` to `ACTIVE` signaling that a service is needed.
2	The *Response* detects the transition of the *Request*.
3	The *Response* transitions from `READY` to `ACTIVE` indicating that it is performing the action.
4	Once the action has been performed, the *Response* transitions to `COMPLETE`.

Continuation of Table 1	
Step	Description
5	The *Request* detects the action is `COMPLETE`.
6	The *Request* transitions back to `READY` acknowledging that the service has been performed.
7	The *Response* detects the *Request* has returned to `READY`.
8	In recognition of this acknowledgement, the *Response* transitions back to `READY`.

After the final action has been completed, both pieces of equipment are back in the `READY` state indicating that they are able to perform another action.

4 Interfaces for Devices and Streams Information Models

The *Interaction Model* for implementing *Interfaces* is defined in the MTConnect Standard as an extension to the `MTConnectDevices` and `MTConnectStreams` XML documents.

A piece of equipment **MAY** support multiple different *Interfaces*. Each piece of equipment supporting *Interfaces* **MUST** organize the information associated with each *Interface* in a *Top Level* component called *Interfaces*. Each individual *Interface* is modeled as a *Lower Level* component called `Interface`. `Interface` is an abstract type XML element and will be replaced in the XML documents by specific `Interface` types defined below. The data associated with each *Interface* is modeled as data items within each of these *Lower Level* `Interface` components.

The XML tree in *Figure 3* illustrates where *Interfaces* is modeled in the *Devices Information Model* for a piece of equipment.

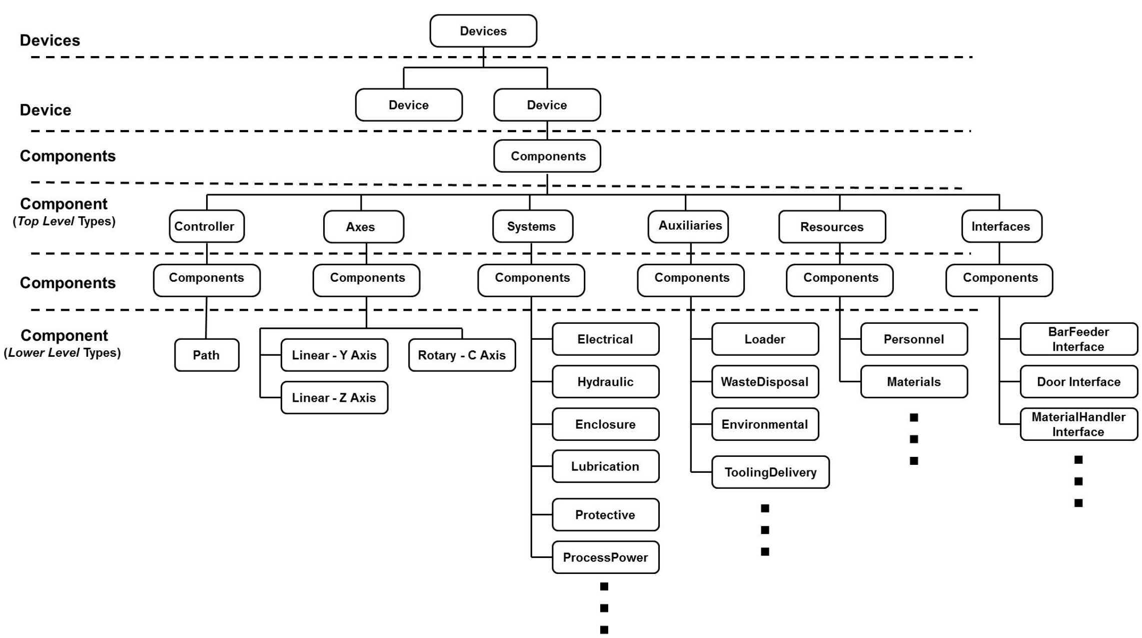

Figure 3: Interfaces as a Structural Element

4.1 Interfaces

Interfaces is an XML *Structural Element* in the `MTConnectDevices` XML document. *Interfaces* is a container type XML element. *Interfaces* is used to group information describing *Lower Level* `Interface` XML elements, which each provide information for an individual *Interface*.

If the *Interfaces* container appears in the XML document, it **MUST** contain one or more `Interface` type XML elements.

4.2 Interface

`Interface` is the next level of *Structural Element* in the `MTConnectDevices` XML document. As an abstract type XML element, `Interface` will be replaced in the XML documents by specific `Interface` types defined below.

Each `Interface` is also a container type element. As a container, the `Interface` XML element is used to organize information required to implement the *Interaction Model* for an *Interface*. It also provides structure for describing the *Lower Level Structural Elements* associated with the `Interface`. Each `Interface` contains *Data Entities* available from the piece of equipment that may be needed to coordinate activities with associated pieces of equipment.

The information provided by a piece of equipment for each *Interface* is returned in a `ComponentStream` container of an `MTConnectStreams` document in the same manner as all other types of components.

4.2.1 XML Schema Structure for Interface

The XML schema in *Figure 4* represents the structure of an `Interface` XML element.

The schema for an `Interface` element is the same as defined for `Component` elements described in Section 4.4 in *MTConnect Standard: Part 2.0 - Devices Information Model* of the MTConnect Standard. The *Figure 4* shows the attributes defined for `Interface` and the elements that may be associated with `Interface`.

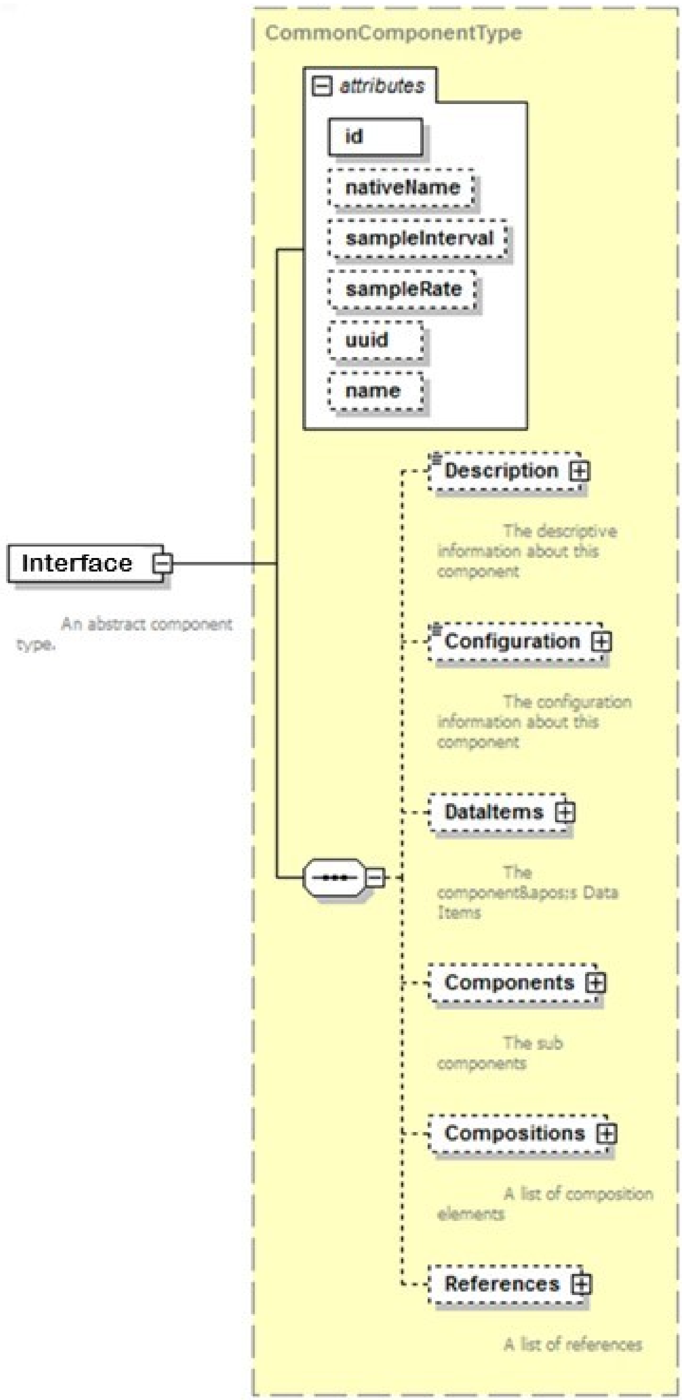

Figure 4: Interface Schema

Refer to *MTConnect Standard: Part 2.0 - Devices Information Model*, Section 4.4 for complete descriptions of the attributes and elements that are illustrated in the *Figure 4* for `Interface`.

4.2.2 Interface Types

As an abstract type XML element, `Interface` is replaced in the `MTConnectDevices` document with a XML element representing a specific type of *Interface*. An initial list of `Interface` types is defined in the *Table 2*.

Table 2: Interface types

Interface	Description
`BarFeederInterface`	`BarFeederInterface` provides the set of information used to coordinate the operations between a Bar Feeder and another piece of equipment. Bar Feeder is a piece of equipment that pushes bar stock (i.e., long pieces of material of various shapes) into an associated piece of equipment – most typically a lathe or turning center.

Continuation of Table 2	
Interface	Description
MaterialHandlerInterface	MaterialHandlerInterface provides the set of information used to coordinate the operations between a piece of equipment and another associated piece of equipment used to automatically handle various types of materials or services associated with the original piece of equipment. A material handler is a piece of equipment capable of providing any one, or more, of a variety of support services for another piece of equipment or a process: Loading/unloading material or tooling Part inspection Testing Cleaning Etc. A robot is a common example of a material handler.
DoorInterface	DoorInterface provides the set of information used to coordinate the operations between two pieces of equipment, one of which controls the operation of a door. The piece of equipment that is controlling the door **MUST** provide the data item DOOR_STATE as part of the set of information provided.

Continuation of Table 2

Interface	Description
`ChuckInterface`	`ChuckInterface` provides the set of information used to coordinate the operations between two pieces of equipment, one of which controls the operation of a chuck. The piece of equipment that is controlling the chuck **MUST** provide the data item `CHUCK_STATE` as part of the set of information provided.

Note: Additional `Interface` types may be defined in future releases of the MTConnect Standard.

In order to implement the *Interaction Model* for *Interfaces*, each piece of equipment associated with an *Interface* **MUST** provide an `Interface` XML element for that type of *Interface*. A piece of equipment **MAY** support any number of unique *Interfaces*.

4.2.3 Data for Interface

Each *Interface* **MUST** provide (1) the data associated with the specific *Interface* to implement the *Interaction Model* and (2) any additional data that may be needed by another piece of equipment to understand the operating states and conditions of the first piece of equipment as it applies to the *Interface*.

Details on data items specific to the *Interaction Model* for each type of *Interface* are provided in *Section 4.2.4 - Data Items for Interface*.

An implementer may choose any other data available from a piece of equipment to describe the operating states and other information needed to support an *Interface*.

4.2.3.1 References for Interface

Some of the data items needed to support a specific *Interface* may already be defined elsewhere in the XML document for a piece of equipment. However, the implementer may not be able to directly associate this data with the *Interface* since the MTConnect Standard does not permit multiple occurrences of a piece of data to be configured in a XML document. `References` provides a mechanism for associating information defined elsewhere in the *Information Model* for a piece of equipment with a specific *Interface*.

References is an XML container that organizes pointers to information defined elsewhere in the XML document for a piece of equipment. References **MAY** contain one or more Reference XML elements.

Reference is an XML element that provides an individual pointer to information that is associated with another *Structural Element* or *Data Entity* defined elsewhere in the XML document that is also required for an *Interface*.

References is an economical syntax for providing interface specific information without directly duplicating the occurrence of the data. It provides a mechanism to include all necessary information required for interaction and deterministic information flow between pieces of equipment.

For more information on the definition for References and Reference, see Section 4.7 and 4.8 of *MTConnect Standard: Part 2.0 - Devices Information Model*.

4.2.4 Data Items for Interface

Each Interface XML element contains data items which are used to communicate information required to execute the *Interface*. When these data items are read by another piece of equipment, that piece of equipment can then determine the actions that it may take based upon that data.

Some data items **MAY** be directly associated with the Interface element and others will be organized in a *Lower Level* References XML element.

It is up to an implementer to determine which additional data items are required for a particular *Interface*.

The data items that have been specifically defined to support the implementation of an *Interface* are provided below.

4.2.4.1 INTERFACE_STATE for Interface

INTERFACE_STATE is a data item specifically defined for *Interfaces*. It defines the operational state of the *Interface*. This is an indicator identifying whether the *Interface* is functioning or not.

An INTERFACE_STATE data item **MUST** be defined for every Interface XML element.

INTERFACE_STATE is reported in the MTConnectStreams XML document as InterfaceState. InterfaceState reports one of two states – ENABLED or DISABLED, which are provided in the CDATA for InterfaceState.

The *Table 3* shows both the INTERFACE_STATE data item as defined in the MTConnectDevices document and the corresponding *Element Name* that **MUST** be reported in the MTConnectStreams document.

Table 3: InterfaceState Event

DataItem Type	Element Name	Description
INTERFACE_STATE	InterfaceState	The current functional or operational state of an Interface type element indicating whether the *Interface* is active or not currently functioning. *Valid Data Values*: ENABLED: The *Interface* is currently operational and performing as expected. DISABLED: The *Interface* is currently not operational. When the INTERFACE_STATE is DISABLED, the state of all data items that are specific for the *Interaction Model* associated with that *Interface* **MUST** be set to NOT_READY.

4.2.4.2 Specific Data Items for the Interaction Model for Interface

A special set of data items have been defined to be used in conjunction with Interface type elements. When modeled in the MTConnectDevices document, these data items are all *Data Entities* in the EVENT category (See *MTConnect Standard: Part 3.0 - Streams Information Model* for details on how the corresponding data items are reported in the MTConnectStreams document). They provide information from a piece of equipment to *Request* a service to be performed by another associated piece of equipment; and for the associated piece of equipment to indicate its progress in performing its *Response* to the *Request* for service.

Many of the data items describing the services associated with an *Interface* are paired to describe two distinct actions – one to *Request* an action to be performed and a second to reverse the action or to return to an original state. For example, a `DoorInterface` will have two actions `OPEN_DOOR` and `CLOSE_DOOR`. An example of an implementation of this would be a robot that indicates to a machine that it would like to have a door opened so that the robot could extract a part from the machine and then asks the machine to close that door once the part has been removed.

When these data items are used to describe a service associated with an *Interface*, they **MUST** have one of the following two subType elements: `REQUEST` or `RESPONSE`. These subType elements **MUST** be specified to define whether the piece of equipment is functioning as the *Requester* or *Responder* for the service to be performed. The *Requester* **MUST** specify the `REQUEST` subType for the data item and the *Responder* **MUST** specify a corresponding `RESPONSE` subType for the data item to enable the coordination between the two pieces of equipment.

These data items and their associated subType provide the basic structure for implementing the *Interaction Model* for an *Interface*.

Table 4 provides a list of the data items that have been defined to identify the services to be performed for or by a piece of equipment associated with an *Interface*.

The *Table 4* also provides the corresponding transformed *Element Name* for each data item that **MAY** be returned by an *Agent* as an `Event` type XML *Data Entity* in the `MTConnectStreams` XML document. The *Controlled Vocabulary* for each of these data items are defined in *Section 4.2.4.3 - Event States for Interfaces*.

Table 4: Event Data Item types for Interface

DataItem Type	Element Name	Description
`MATERIAL_FEED`	`MaterialFeed`	Service to advance material or feed product to a piece of equipment from a continuous or bulk source.
`MATERIAL_CHANGE`	`MaterialChange`	Service to change the type of material or product being loaded or fed to a piece of equipment.
`MATERIAL_RETRACT`	`MaterialRetract`	Service to remove or retract material or product.

Continuation of Table 4		
DataItem Type	Element Name	Description
PART_CHANGE	PartChange	Service to change the part or product associated with a piece of equipment to a different part or product.
MATERIAL_LOAD	MaterialLoad	Service to load a piece of material or product.
MATERIAL_UNLOAD	MaterialUnload	Service to unload a piece of material or product.
OPEN_DOOR	OpenDoor	Service to open a door.
CLOSE_DOOR	CloseDoor	Service to close a door.
OPEN_CHUCK	OpenChuck	Service to open a chuck.
CLOSE_CHUCK	CloseChuck	Service to close a chuck.

4.2.4.3 Event States for Interfaces

For each of the data items above, the *Valid Data Values* for the CDATA that is returned for these data items in the MTConnectStreams document is defined by a *Controlled Vocabulary*. This *Controlled Vocabulary* represents the state information to be communicated by a piece of equipment for the data items defined in the *Table 4*.

The *Request* portion of the *Interaction Model* for *Interfaces* has four states as defined in the *Table 5*.

Table 5: Request States

Request State	Description
NOT_READY	The *Requester* is not ready to make a *Request*.
READY	The *Requester* is prepared to make a *Request*, but no *Request* for service is required. The *Requester* will transition to ACTIVE when it needs a service to be performed.
ACTIVE	The *Requester* has initiated a *Request* for a service and the service has not yet been completed by the *Responder*.

Continuation of Table 5	
Request State	Description
`FAIL`	CONDITION 1: When the *Requester* has detected a failure condition, it indicates to the *Responder* to either not initiate an action or stop its action before it completes by changing its state to `FAIL`. CONDITION 2: If the *Responder* changes its state to `FAIL`, the *Requester* **MUST** change its state to `FAIL`. ACTIONS: After detecting a failure, the *Requester* SHOULD NOT change its state to any other value until the *Responder* has acknowledged the `FAIL` state by changing its state to `FAIL`. Once the `FAIL` state has been acknowledged by the *Responder*, the *Requester* may attempt to clear its `FAIL` state. As part of the attempt to clear the `FAIL` state, the *Requester* **MUST** reset any partial actions that were initiated and attempt to return to a condition where it is again ready to perform a service. If the recovery is successful, the *Requester* changes its *Request* state from `FAIL` to `READY`. If for some reason the *Requester* is not again prepared to perform a service, it transitions its state from `FAIL` to `NOT_READY`.

444 *Figure 5* shows a graphical representation of the possible state transitions for a *Request*.

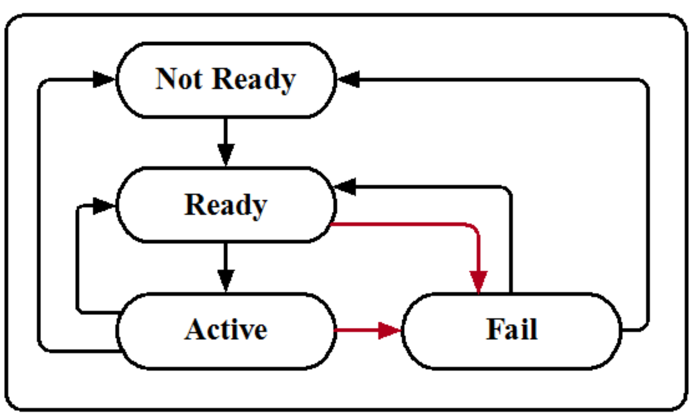

Figure 5: Request State Diagram

The *Response* portion of the *Interaction Model* for *Interfaces* has five states as defined in the *Table 6*.

Table 6: Response States

Response State	Description
`NOT_READY`	The *Responder* is not ready to perform a service.
`READY`	The *Responder* is prepared to react to a Request, but no Request for service has been detected. The *Responder* **MUST** transition to `ACTIVE` to inform the *Requester* that it has detected and accepted the Request and is in the process of performing the requested service. If the *Responder* is not ready to perform a Request, it **MUST** transition to a `NOT_READY` state.
`ACTIVE`	The *Responder* has detected and accepted a Request for a service and is in the process of performing the service, but the service has not yet been completed. In normal operation, the *Responder* **MUST NOT** change its state to `ACTIVE` unless the *Requester* state is `ACTIVE`.

Continuation of Table 6	
Response State	Description
FAIL	CONDITION 1: The *Responder* has failed while executing the actions required to perform a service and the service has not yet been completed or the *Responder* has detected that the *Requester* has unexpectedly changed state. CONDITION 2: If the *Requester* changes its state to FAIL, the *Responder* **MUST** change its state to FAIL. ACTIONS: After entering a FAIL state, the *Responder* SHOULD NOT change its state to any other value until the *Requester* has acknowledged the FAIL state by changing its state to FAIL. Once the FAIL state has been acknowledged by the *Requester*, the *Responder* may attempt to clear its FAIL state. As part of the attempt to clear the FAIL state, the *Responder* **MUST** reset any partial actions that were initiated and attempt to return to a condition where it is again ready to perform a service. If the recovery is successful, the *Responder* changes its *Response* state from FAIL to READY. If for some reason the *Responder* is not again prepared to perform a service, it transitions its state from FAIL to NOT_READY.
COMPLETE	The *Responder* has completed the actions required to perform the service. The *Responder* **MUST** remain in the COMPLETE state until the *Requester* acknowledges that the service is complete by changing its state to READY. At that point, the *Responder* **MUST** change its state to either READY if it is again prepared to perform a service or NOT_READY if it is not prepared to perform a service.

The state values described in the *Table 6* and *Table 6* **MUST** be provided in the CDATA for each of the *Interface* specific data items provided in the MTConnectStreams document.

Figure 6 shows a graphical representation of the possible state transitions for a *Response*:

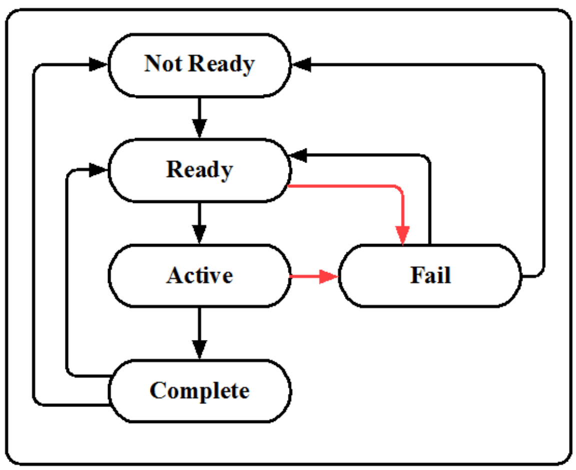

Figure 6: Response State Diagram

5 Operation and Error Recovery

The *Request/Response* state model implemented for *Interfaces* may also be represented by a graphical model. The scenario in *Figure 7* demonstrates the state transitions that occur during a successful *Request* for service and the resulting *Response* to fulfill that service *Request*.

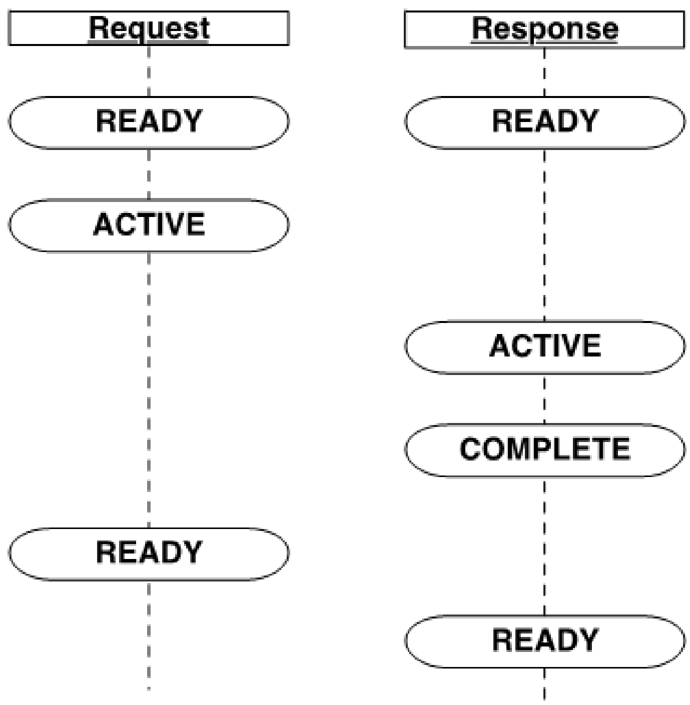

Figure 7: Success Scenario

5.1 Request/Response Failure Handling and Recovery

A significant feature of the *Request/Response Interaction Model* is the ability for either piece of equipment to detect a failure associated with either the *Request* or *Response* actions. When either a failure or unexpected action occurs, the *Request* and the *Response* portion of the *Interaction Model* can announce a `FAIL` state upon detecting a problem. The following are graphical models describing multiple scenarios where either the *Requester* or *Responder* detects and reacts to a failure. In these examples, either the *Requester* or *Responder* announces the detection of a failure by setting either the *Request* or the *Response* state to `FAIL`.

Once a failure is detected, the *Interaction Model* provides information from each piece of equipment as they attempt to recover from a failure, reset all of their functions associated with the *Interface* to their original state, and return to normal operation.

The following are scenarios that describe how pieces of equipment may react to different types of failures and how they indicate when they are again ready to request a service or respond to a request for service after recovering from those failures:

Scenario #1 – *Responder* Fails Immediately

In this scenario, a failure is detected by the *Responder* immediately after a *Request* for service has been initiated by the *Requester*.

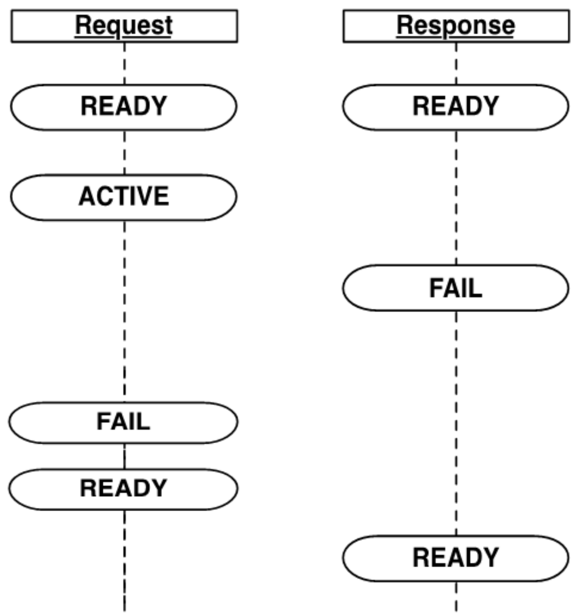

Figure 8: Responder - Immediate Failure

In this case, the *Request* transitions to `ACTIVE` and the *Responder* immediately detects a failure before it can transition the *Response* state to `ACTIVE`. When this occurs, the *Responder* transitions the *Response* state to `FAIL`.

After detecting that the *Responder* has transitioned its state to `FAIL`, the *Requester* **MUST** change its state to `FAIL`.

The *Requester*, as part of clearing a failure, resets any partial actions that were initiated and attempts to return to a condition where it is again ready to request a service. If the recovery is successful, the *Requester* changes its state from `FAIL` to `READY`. If for some reason the *Requester* cannot return to a condition where it is again ready to request a service, it transitions its state from `FAIL` to `NOT_READY`.

The *Responder*, as part of clearing a failure, resets any partial actions that were initiated and attempts to return to a condition where it is again ready to perform a service. If the recovery is successful, the *Responder* changes its *Response* state from `FAIL` to `READY`. If for some reason the *Responder* is not again prepared to perform a service, it transitions its state from `FAIL` to `NOT_READY`.

Scenario #2 – *Responder* Fails While Providing a Service

This is the most common failure scenario. In this case, the *Responder* will begin the actions required to provide a service. During these actions, the *Responder* detects a failure and transitions its *Response* state to `FAIL`.

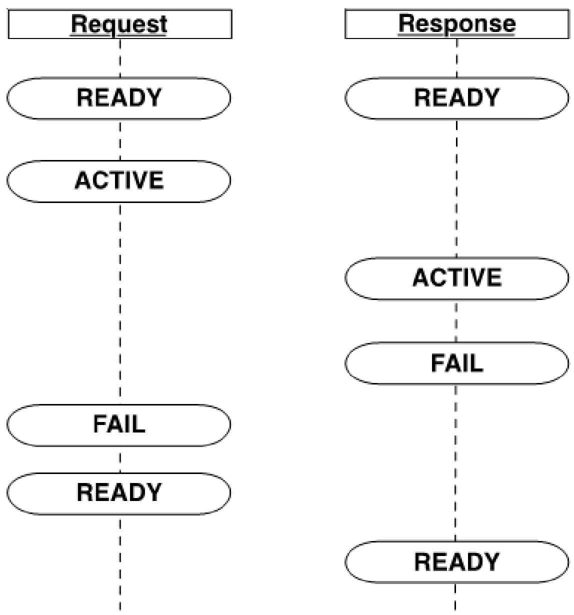

Figure 9: Responder Fails While Providing a Service

When a *Requester* detects a failure of a *Responder*, it transitions it state from `ACTIVE` to `FAIL`.

The *Requester* resets any partial actions that were initiated and attempts to return to a condition where it is again ready to request a service. If the recovery is successful, the *Requester* changes its state from `FAIL` to `READY` if the failure has been cleared and it is again prepared to request another service. If for some reason the *Requester* cannot return to a condition where it is again ready to request a service, it transitions its state from `FAIL` to `NOT_READY`.

The *Responder*, as part of clearing a failure, resets any partial actions that were initiated and attempts to return to a condition where it is again ready to perform a service. If the recovery is successful, the *Responder* changes its *Response* state from `FAIL` to `READY` if it is again prepared to perform a service. If for some reason the *Responder* is not again prepared to perform a service, it transitions its state from `FAIL` to `NOT_READY`.

Scenario #3 – *Requester* Failure During a Service *Request*

In this scenario, the *Responder* will begin the actions required to provide a service. During these actions, the *Requester* detects a failure and transitions its *Request* state to `FAIL`.

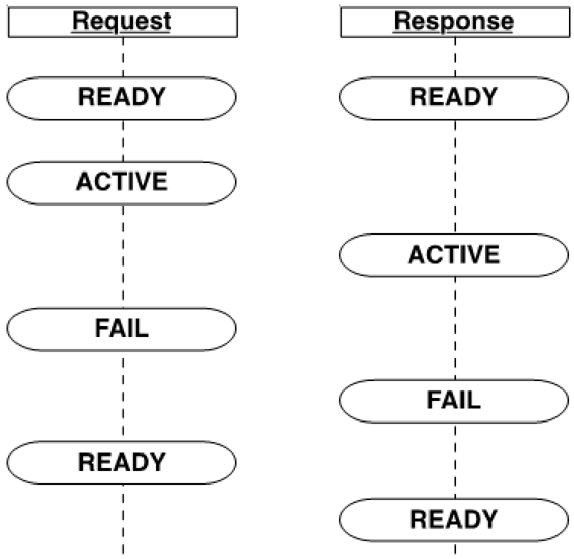

Figure 10: Requester Fails During a Service Request

When the *Responder* detects that the *Requester* has transitioned its *Request* state to `FAIL`, the *Responder* also transitions its *Response* state to `FAIL`.

The *Requester*, as part of clearing a failure, resets any partial actions that were initiated and attempts to return to a condition where it is again ready to request a service. If the recovery is successful, the *Requester* changes its state from `FAIL` to `READY`. If for some reason the *Requester* cannot return to a condition where it is again ready to request a service, it transitions its state from `FAIL` to `NOT_READY`.

The *Responder*, as part of clearing a failure, resets any partial actions that were initiated and attempts to return to a condition where it is again ready to perform a service. If the recovery is successful, the *Responder* changes its *Response* state from `FAIL` to `READY`. If for some reason the *Responder* is not again prepared to perform a service, it transitions its state from `FAIL` to `NOT_READY`.

Scenario #4 – *Requester* Changes to an Unexpected State While *Responder* is Providing a Service

In some cases, a *Requester* may transition to an unexpected state after it has initiated a

Request for service.

As demonstrated in *Figure 11* , the *Requester* has initiated a *Request* for service and its *Request* state has been changed to `ACTIVE`. The *Responder* begins the actions required to provide the service. During these actions, the *Requester* transitions its *Request* state back to `READY` before the *Responder* can complete its actions. This **SHOULD** be regarded as a failure of the *Requester*.

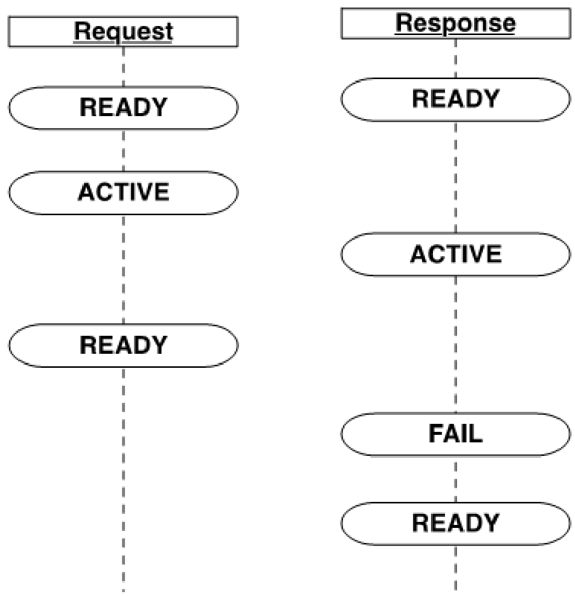

Figure 11: Requester Makes Unexpected State Change

In this case, the *Responder* reacts to this change of state of the *Requester* in the same way as though the *Requester* had transitioned its *Request* state to `FAIL` (i.e., the same as in Scenario #3 above).

At this point, the *Responder* then transitions its *Response* state to `FAIL`.

The *Responder* resets any partial actions that were initiated and attempts to return to its original condition where it is again ready to perform a service. If the recovery is successful, the *Responder* changes its *Response* state from `FAIL` to `READY`. If for some reason the *Responder* is not again prepared to perform a service, it transitions its state from `FAIL` to `NOT_READY`.

> Note: The same scenario exists if the *Requester* transitions its *Request* state to `NOT_READY`. However, in this case, the *Requester* then transitions its *Request* state to `READY` after it resets all of its functions back to a condition where it is again prepared to make a *Request* for service.

Scenario #5 – *Responder* Changes to an Unexpected State While Providing a Service

Similar to Scenario #5, a *Responder* may transition to an unexpected state while providing a service.

As demonstrated in *Figure 12* , the *Responder* is performing the actions to provide a service and the *Response* state is `ACTIVE`. During these actions, the *Responder* transitions its state to `NOT_READY` before completing its actions. This should be regarded as a failure of the *Responder*.

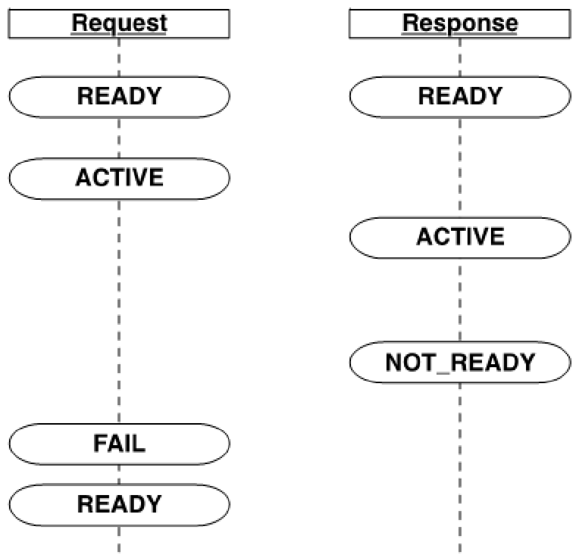

Figure 12: Responder Makes Unexpected State Change

Upon detecting an unexpected state change of the *Responder*, the *Requester* transitions its state to `FAIL`.

The *Requester* resets any partial actions that were initiated and attempts to return to a condition where it is again ready to request a service. If the recovery is successful, the *Requester* changes its state from `FAIL` to `READY`. If for some reason the *Requester* cannot return to a condition where it is again ready to request a service, it transitions its state from `FAIL` to `NOT_READY`.

Since the *Responder* has failed to an invalid state, the condition of the *Responder* is unknown. Where possible, the *Responder* should try to reset to an initial state.

The *Responder*, as part of clearing the cause for the change to the unexpected state, should attempt to reset any partial actions that were initiated and then return to a condition where it is again ready to perform a service. If the recovery is successful, the *Responder* changes its *Response* state from the unexpected state to `READY`. If for some reason the *Responder* is not again prepared to perform a service, it maintains its state as `NOT_READY`.

<u>Scenario #6 – *Responder* or *Requester* Become `UNAVAILABLE` or Experience a Loss of Communications</u>

In this scenario, a failure occurs in the communications connection between the *Responder* and *Requester*. This failure may result from the `InterfaceState` from either piece of equipment returning a value of `UNAVAILABLE` or one of the pieces of equipment does not provide a heartbeat within the desired amount of time (See *MTConnect Standard Part 1.0 - Overview and Fundamentals* for details on heartbeat).

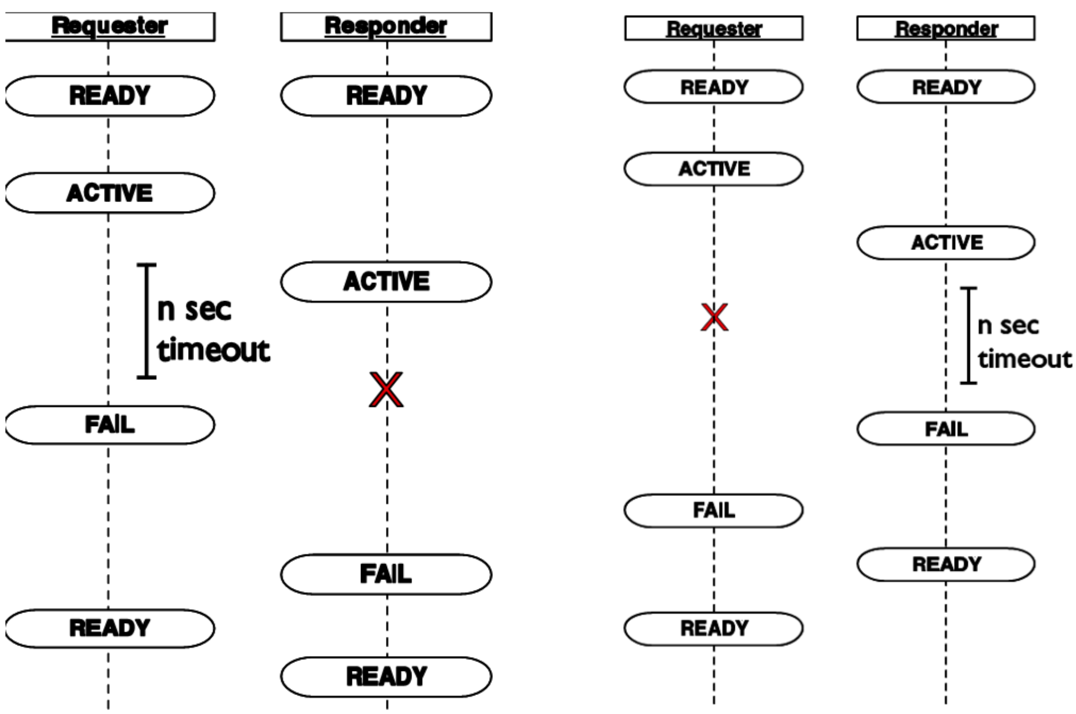

Figure 13: Requester/Responder Communication Failures

When one of these situations occurs, each piece of equipment assumes that there has been a failure of the other piece of equipment.

When normal communications are re-established, neither piece of equipment should assume that the *Request/Response* state of the other piece of equipment remains valid. Both pieces of equipment should set their state to `FAIL`.

The *Requester*, as part of clearing its `FAIL` state, resets any partial actions that were initiated and attempts to return to a condition where it is again ready to request a service. If the recovery is successful, the *Requester* changes its state from `FAIL` to `READY`. If for some reason the *Requester* cannot return to a condition where it is again ready to request a service, it transitions its state from FAIL to NOT_READY.

The *Responder*, as part of clearing its FAIL state, resets any partial actions that were initiated and attempts to return to a condition where it is again ready to perform a service. If the recovery is successful, the *Responder* changes its *Response* state from FAIL to READY. If for some reason the *Responder* is not again prepared to perform a service, it transitions its state from FAIL to NOT_READY.

Appendices

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