

MTConnect Standard

Part 3 – Streams, Events, and Samples

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MTConnect Specification

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# Overview

MTConnect is a standard based on an open protocol for data integration. MTConnect is not intended to replace the functionality of existing products, but it strives to enhance the data acquisition capabilities of devices and applications and move toward a plug-and-play environment to reduce the cost of integration.

MTConnect is built upon the most prevalent standards in the manufacturing and software industry, maximizing the number of tools available for its implementation and providing the highest level of interoperability with other standards and tools in these industries.

To facilitate this level of interoperability, a number of objectives are being met. Foremost is the ability to transfer data via a standard protocol which includes:

* + A device identity (i.e. model number, serial number, calibration data, etc.).
  + The identity of all the independent components of the device.
  + Possibly a device’s design characteristics (i.e. axis length, maximum speeds, device thresholds, etc.).
  + Most importantly, data captured in real or near-real-time (i.e. current speed, position data, temperature data, program block, etc.) by a device that can be utilized by other devices or applications (e.g. utilized by maintenance diagnostic systems, management production information systems, CAM products, etc.).

The types of data that may need to be addressed in MTConnect could include:

* + Physical and actual device design data
  + Measurement or calibration data
  + Near-real-time data from the device

To accommodate the vast amount of different types of devices and information that may come into play, MTConnect will provide a common high-level vocabulary and structure.

The first version of MTConnect will focus on a limited set of the characteristics mentioned above that were selected based on the fact that they can have an immediate affect on the efficiency of operations.

## MTConnect Document Structure

The MTConnect specification is subdivided using the following scheme:

Part 1: Overview and Protocol

Part 2: Components and Data Items

Part 3: Streams, Events and Samples

Extensions to the standard will be made according to this scheme and new sections will be added as new areas are addressed. Documents will be named as follows: MTC\_Part\_<Number>\_<Description>.doc. All documents will be developed in Microsoft® Word format and released in Adobe® PDF format. For example, this document is MTC\_Part\_1\_Overview.doc.

# Purpose of This Document

This document is intended to:

* define the MTConnect standard;
* specify the requirements for compliance with the MTConnect standard;
* provide engineers with sufficient information to implement Agents for their devices;
* provide developers with the necessary guidelines to use the standard to develop applications.

The third part of the standard covers the data returned from a current or sample request (for more information on the requests, see Part 1). Part 2 covered what data is available; this section covers the values of the data representing the state of the machine. The values and the descriptive information are separated do reduce the amount of redundant information and reduce the network bandwidth used by the protocol.

The information is broken down into two general types. The first is events that represent information that has finite state changes like controller modes and samples that are continuously changing like axis positions. This section also covers the vocabulary and format of every piece of data that can be retrieved from the machine.

## Terminology

**Adapter** An optional software component that connects the Agent to the Device.

**Agent** A process that implements the MTConnect specification, acting as an interface to the device.

**Alarm** An alarm indicates an event that requires attention and indicates a deviation from normal operation.

**Application** A process or set of processes that access the MTConnect Agent to perform some task.

**Attribute** A part of an element that provides additional information about that element. For example, the name element of the Device is given as <Device **name=”mill-1”**>...</Device>

**CDATA** The text in a simple content element. For example, *This is some text*, in <mt:Alarm ...>This is some text</mt:Alarm>.

**Component** A part of a device that can have sub-components and data items. A component is a basic building block of a device.

**Controlled Vocabulary** The value of an element or attribute is limited to a restricted set of possibilities. Examples of controlled vocabularies are country codes: US, JP, CA, FR, DE, etc…

**Current** A snapshot request to the Agent to retrieve the current values of all the data items specified in the path parameter. If no path parameter is given, then the values for all components are provided.

**Data Item** A data item provides the descriptive information regarding something that can be collected by the Agent.

**Device** A piece of equipment capable of performing an operation. A device is composed of a set of components that provide data to the application. The device is a separate entity with at least one Controller managing its operation.

**Discovery** Discovery is a service that allows the application to locate Agents for devices in the manufacturing environment. The discovery service is also referred to as the *Name Service.*

**Element** An XML element is the central building block of any XML Document. For example, in MTConnect the Device element is specified as <**Device** >...</**Device**>

**Event** An event represents a change in state that occurs at a point in time. Note: An event does not occur at predefined frequencies.

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

**Instance** When used in software engineering, the word *instance* is used to define a single physical example of that type. In object-oriented models, there is the class that describes the thing and the instance that is an example of that thing.

**LDAP** Lightweight Directory Access Protocol, better known as Active Directory in Microsoft Windows. This protocol provides resource location and contact information in a hierarchal structure.

**MIME** Multipurpose Internet Mail Extensions. A format used for encoding multipart mail and http content with separate sections separated by a fixed boundary.

**Probe** A request to determine the configuration and reporting capabilities of the device.

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

**Results** A general term for the Samples and Events contained in a ComponentStream as a response from a sample or current request.

**Sample** A sample is a data point from within a continuous series of data points. An example of a Sample is the position of an axis.

**Socket** When used concerning interprocess communication, it refers to a connection between two end-points (usually processes). Socket communication most often uses TCP/IP as the underlying protocol.

**Stream** A collection of events and samples organized by devices and components.

**Service** An application that provides necessary functionality.

**Tag** Used to reference an instance of an XML element.

**TCP/IP** TCP/IP is the most prevalent stream-based protocol for interprocess communication. It is based on the IP stack (Internet Protocol) and provides the flow-control and reliable transmission layer on top of the IP routing infrastructure.

**URI** Universal Resource Identifier. This is the official name for a web address as seen in the address bar of a browser.

**UUID** Universally unique identifier.

**XPath** XPath is a language for addressing parts of an XML Document. See the XPath specification for more information. <http://www.w3.org/TR/xpath>

**XML** Extensible Markup Language. <http://www.w3.org/XML/>

**XML Schema** The definition of the XML structure and vocabularies used in the XML Document.

**XML Document** An instance of an XML Schema which has a single root element and conforms to the XML specification and schema.

## Terminology and Conventions

Please refer to Part 1 “Overview and Protocol” Section 2 for XML Terminology and Documentation conventions.

# Streams, Samples and Events

The MTConnect Agent collects data from various sources and delivers it to applications in response to sample or current requests. (See *Protocol* section in *Part 1*.) All the data are collected into streams and organized by device and then by component. A component stream has two parts: Samples and Events. Samples are point-in-time readings from a component reporting what the value is at that instant. For an example, refer to the Device in Figure 2 below.

An Event changes state to a limited set of values. It is assumed that an event remains at a state until the next event occurs; it cannot have any intermediate values between the reported values. Alarms are classified as events. The following are examples of Events: Block, Code, Execution, PowerStatus, etc.

If two adjacent samples for the same component and data item have the same value, the second sample **MUST NOT** be sent to the client application and does not need to be retained by the MTConnect Agent. This will greatly reduce the amount of information sent to the application. The application can always assume that if the sample is not present, it has the previous value. If the application needs the present value, it can always ask for the current values (see *Protocol).*

## Streams

A Streams element is the high level container for all device streams. It serves no other purpose than to have DeviceStream sub-elements. There **MUST** be no attributes or elements within this element.



Figure 1: Streams Schema Diagram

| **Elements** | **Description** | **Occurrence** |
| --- | --- | --- |
| DeviceStream | The stream of samples and events for each device. | 1..INF |

## Structure

The following diagram illustrates the structure of the streams with some samples and events at the lowest level:

 Figure 2: Streams Example Structure

A Stream **MUST** have at least one DeviceStream and the DeviceStream **MAY** have one or more ComponentStream elements, depending on whether there are events or samples available for the component. If there are no ComponentStream elements, then no data will be delivered for this request.

Below is an example XML Document response for an Agent with two devices, mill-1 and mill-2. The data is reported in two separate device streams. The sequence numbers is unique across the two devices. The applications **MUST NOT** assume that the event and sample sequence numbers are strictly in sequence. All sequence numbers **MAY** not be included, for example when a path argument is provided and all the Samples and Events are not selected or when the *Agent* is supporting more than one device and data from only one device is requested.

1. <?xml version="1.0" encoding="UTF-8"?>
2. <MTConnectStreams ...>
3. <Header .../>
4. <Streams>
5. <DeviceStream uuid="1" name="mill-1">
6. <ComponentStream componentId="2" name="power" component="Power">
7. <Events>
8. <PowerStatus name="power" dataItemId="9" sequence="30055111" timestamp="2008-07-07T14:27:59.591">ON</PowerStatus>
9. </Events>
10. </ComponentStream>
11. </DeviceStream>
12. <DeviceStream uuid="2" name="mill-2">
13. <ComponentStream componentId="3" name="power" component="Power">
14. <Events>
15. <PowerStatus name="power" dataItemId="10" sequence="52162" timestamp="2008-06-11T10:17:33.291">ON</PowerStatus>
16. </Events>
17. </ComponentStream>
18. </DeviceStream>
19. </Streams>
20. </MTConnectStreams>

## DeviceStream

A DeviceStream is created to hold the device-specific information so it does not need to be repeated for every event and sample. This is done to reduce the size of each event and sample so they only carry the information that is being reported. A DeviceStream **MAY** contain one or more ComponentStream elements. If the request is valid and there are no events or samples that match the criteria, an empty DeviceStream element **MUST** be created to indicate that the device exists, but there was no data available.

### DeviceStream Attributes

| **Attributes** | **Description** | **Occurrence** |
| --- | --- | --- |
| name | The device’s name. An NMTOKEN XML type. | 1 |
| uuid | The device’s unique identifier | 1 |

### DeviceStream Elements

| **Element** | **Description** | **Occurrence** |
| --- | --- | --- |
| ComponentStream | One component’s stream for each component with data | 0..INF |

## ComponentStream

A ComponentStream is similar to the DeviceStream. It contains the information specific to the component within the Device. The uuid only needs to be specified if the Component has a uuid assigned.

### ComponentStream Attributes

| **Attribute** | **Description** | **Occurrence** |
| --- | --- | --- |
| name | This component’s name within the device. An NMTOKEN XML type. | 1 |
| component | The element name for the component | 1 |
| uuid | The component’s unique identifier | 0..1 |
| componentId | Corresponds to the id attribute of the component in the probe request (Refer to Probe in Part 1). | 1 |

The Elements of the ComponentStream classify the data into Events and Samples. *(The classification is discussed below)*. The ComponentStream **MUST NOT** be empty. It **MUST** include an Events and/or a Samples element.

### ComponentStream Elements

| **Element** | **Description** | **Occurrence** |
| --- | --- | --- |
| Events | The events for this component stream | 0..1 |
| Samples | The samples for this component | 0..1 |

## Samples

The Samples element must contain at least one Sample element. This element acts only as a container for all the Samples to provide a logical structure to the XML Document.

| **Element** | **Description** | **Occurrence** |
| --- | --- | --- |
| Sample | The subtype of Sample for this component stream | 1..INF |

## Sample

A Sample is an abstract type. This means there will never be an actual element called Sample, but any element that is a sub-type of Sample can be used in place of Sample. Examples of sample sub-types are Position, Load, and Angle. Sample types **MUST** have numeric values.

### Sample attributes:

| **Attribute** | **Description** | **Occurrence** |
| --- | --- | --- |
| name | The name **MUST** match the name of the DataItem this sample is associated with. An NMTOKEN XML type. | 1 |
| sequence | The sequence number of this sample. This value **MUST** have a maximum value of 2^63-1 and **MUST** be stored in a signed 64 bit integer. | 1 |
| timestamp | The timestamp of the sample. | 1 |
| dataItemID | The id attribute of the corresponding data retrieved in the probe request. | 1 |

A sample **MUST** contain CDATA as the content between the element tags. A position is formatted like this:

1. <Position sequence=”112” timestamp=”2007-08-09T12:32:45.1232” name=”Xabs” dataItemId=”10”>123.3333</Position>

In this example the 123.3333 is the CDATA for the position. All the CDATA in a sample is typed, meaning that it can be validated using an XML parser. This restricts the format of the values to a specific pattern.

### Sample Elements

**Acceleration** The acceleration of the component MUST always be reported in MILLIMETER/SECOND^2. An acceleration **MUST** have a numeric value.

**Amperage** The current in an electrical circuit. The amperage **MUST** have a numeric value and **MUST** be reported in AMPS.

**Angle** An angle **MUST** always be reported in DEGREE and **MUST** always have a numeric CDATA value as a floating point number.

**AngularAcceleration** The angular acceleration of the component as measured in DEGREE/SECOND^2. An acceleration **MUST** have a numeric value.

**AngularVelocity** A angular velocity represents the rate of change in angle. An angular velocity **MUST** always be reported in DEGREE/SECOND and **MUST** always have a numeric CDATA value as a floating point number.

**AxisFeedrate** Axis Feedrate is defined as the rate of motion of the feed axis of the tool relative to the workpiece[[1]](#footnote-1). An axis feedrate **MUST** always be reported in MILLIMETER/SECOND or PERCENT for override and **MUST** always have a numeric CDATA value as a floating point number.

**PathFeedrate** Path Feedrate is defined as the rate of motion of the feed path of the tool relative to the workpiece[[2]](#footnote-2). A path feedrate **MUST** always be reported in MILLIMETER/SECOND or PERCENT for override and **MUST** always have a numeric CDATA value as a floating point number.

**Frequency** The rate at which a component is vibrating. The frequency **MUST** have a numeric value and **MUST** be reported in HERTZ.

**Displacement** The displacement as measured from zero to peak. The displacement **MUST** have a value reported in MILLIMETER.

**GlobalPosition** The global position is the three space coordinate of the tool. A global position **MUST** always be reported in MILLIMETER and **MUST** always have a numeric CDATA value as three floating point numbers (x, y, and z). Position **MUST** always be given in absolute coordinates.

**Load** The load on a component. The load **MUST** always be reported in NEWTON and **MUST** always have a numeric CDATA value as a floating point number.

**Position** A position represents the location along a linear axis. A position **MUST** always be reported in MILLIMETER and **MUST** always have a numeric CDATA value as a floating point number. Position **MUST** always be given in absolute coordinates.

**Pressure** The pressure on a component. The pressure **MUST** be a numeric value and **MUST** be provided in PASCALS.

**SpindleSpeed** The rate of rotation of a machine spindle [[3]](#footnote-3). A spindle speed **MUST** always be reported in REVOLUTION/MINUTE and **MUST** always have a numeric CDATA value as a floating point number.

**Temperature** Temperature **MUST** always be reported in degrees CELSIUS and **MUST** always have a numeric CDATA value as a floating point number.

**Torque** The torque of the component **MUST** be reported in SI units of NEWTON\_METER and **MUST** have a numeric CDATA value as a floating point number.

**Velocity** A velocity represents the rate of change in position along one or more axis. When given as a Sample for the Axes component, it represents the magnitude of the velocity vector for all given axis, similar to a path feedrate. A velocity **MUST** always be reported in MILLIMETER/SECOND and **MUST** always have a numeric CDATA value as a floating point number.

**Volts** The potential difference as measured across an electrical circuit. The voltage **MUST** have a numeric value and **MUST** be reported in VOLTS.

**Watts** The electrical power (volt-amps) of an electrical circuit. The watts **MUST** have a numeric value and **MUST** be reported in WATTS.

### Extensibility

Additional sample types can be added by extending the Sample type in the XML schema. The samples presented here are the official sample types that will be supported by all MTConnect *Agents*. Any non-sanctioned extensions will not be guaranteed to have consistency across implementations.

## Events

The Events element must contain at least one Event element. This element acts only as a container for all the Events to provide a logical structure to the XML Document.

| **Element** | **Description** | **Occurrence** |
| --- | --- | --- |
| Event | The subtype of Event for this component stream | 1..INF |

## Event

A Event is an abstract type. This means there will never be an actual element called Event, but any element that is a sub-type of Event can be used in place of Sample. Examples of event sub-types are Block, Execution, and Line. Events types have values in any format.

| **Attribute** | **Description** | **Occurrence** |
| --- | --- | --- |
| name | The name **MUST** match the name of the event's associated DataItem. An NMTOKEN XML type. | 1 |
| sequence | The sequence number of this event. This value **MUST** have a maximum value of 2^63-1 and **MUST** be stored in a signed 64 bit integer. | 1 |
| timestamp | The time-stamp of the event | 1 |
| dataItemID | The id attribute of the corresponding data retrieved in the probe request. | 1 |

An event is similar to a sample, but its values are going to be changing with unpredictable frequency. Events do not have intermediate values. When a power status transitions from OFF to ON, there is no intermediate state that can be inferred. Therefore, most events have a controlled vocabulary as their content.

An event does not add any additional attributes or elements to the Sample. It is a placeholder in the schema type hierarchy for elements that are events. This relationship will be enforced by the schema.

### Event Elements

**Block** A Block of code is a command being executed by the Controller. The Block **MUST** include the entire command with all the parameters.

**Code** The code is just the G, M, or NC code being executed. The Code **MUST** only contain the simplest form of the executing command.

**ControllerMode** The Mode of the Controller. The CDATA **MUST** be one of the following:

| **Value** | **Description** |
| --- | --- |
| AUTOMATIC | The controller is configured to automatically execute a program. |
| MANUAL | The controller is under manual control by the operator. |
| MANUAL\_DATA\_INPUT | The operator can enter operations for the controller to perform. There is no current program being executed. |

**Direction** A Direction indicates the direction of rotation. The CDATA **MUST** be as follows:

| **Value** | **Description** |
| --- | --- |
| CLOCKWISE | The component is rotating in a clockwise fashion using the right hand rule. |
| COUNTER\_CLOCKWISE | The component is rotating in a clockwise fashion using the right hand rule. |

**Execution** The Execution state of the Controller. The CDATA **MUST** be one of the following:

| **Value** | **Description** |
| --- | --- |
| READY | The controller is ready to execute. It is currently idle. |
| ACTIVE | The controller is actively executing an instruction. |
| INTERRUPTED | The operator or the program has paused execution and is waiting to be continued. |
| STOPPED | The controller has been stopped. |

**Line** The current line number of the program being executed. The CDATA **MUST** be an integer numeric value from 0 to 2^31.

**PartCount** The number of parts produced. This will not be counted by the agent and **MUST** only be supplied if the controller provides the count.

**PowerStatus** Power status **MUST** be either ON or OFF.

| **Value** | **Description** |
| --- | --- |
| ON | The power to the component is ON. |
| OFF | The power to the component is OFF. |

**Program** The name of the program executing in the controller. This is usually the name of the file containing the program instructions.

## Alarms

The Alarm event adds some additional fields to the standard Event schema. The following additional attributes are used for the alarm:

| **Attribute** | **Description** | **Occurrence** |
| --- | --- | --- |
| code | The type of alarm. This is a high level classification for all codes. | 1 |
| severity | The severity of the alarm, currently we have CRITICAL, ERROR, WARNING, or INFORMATION. | 1 |
| nativeCode | The native code for the piece of equipment. This is the way the alarm is represented on the component. | 1 |
| state | Either INSTANT, ACTIVE or CLEARED. When the Alarm occurs, it will be created with an ACTIVE state. Once it has been addressed, the state will be changed to CLEARED. An INSTANT alarm does not need to be cleared. | 1 |
| lang | An optional attribute that specifies language of the alarm text. Refer to IETF RFC 4646 (http://www.ietf.org/rfc/rfc4646.txt) or successor for a full definition of the values for this attribute. | 0..1 |

The code can have one of the following values:

| **Enumeration** | **Description** |
| --- | --- |
| CRASH | A spindle crashed |
| JAM | A component jammed. |
| FAILURE | The component failed. |
| FAULT | A fault occurred on the component. |
| STALLED | The component has stalled and cannot move. |
| OVERLOAD | The component is overloaded. |
| ESTOP | The ESTOP button was pressed. |
| MATERIAL | There is a problem with the material. |
| MESSAGE | A system message. |
| OTHER | The alarm is not in any of the above categories. |

The CDATA of the Alarm is the human-readable text from the component that raised the alarm. The device should specify this text so it can be logged.

# Annotated XML Examples

## Example of a current Request

The sample was generated with the following request:

http://10.1.23.5/LinuxCNC/sample?path=//Controller|//Power

The response is as follows:

1. <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" xsi:schemaLocation="urn:mtconnect.com:MTConnectStreams:1.1” http://www.mtconnect.org/schemas/MTConnectStreams.xsd">
2. <Header sender="10.1.23.5" bufferSize="100000" creationTime="2008-07-07T23:22:40-07:00" nextSequence="31088439" version="1.1" instanceId="1214527986"/>
3. <Streams>

Events are grouped by equipment:

1. <DeviceStream uuid="linux-01" name="LinuxCNC">

All the events are then grouped by components. The path includes the most relevant parts of the xpath with only the Components containers removed here for brevity. The only element that **MUST** be removed is Components. The name selector makes the component unique within the path:

1. <ComponentStream componentId="2" name="power" component="Power">
2. <Events>
3. <PowerStatus name="power" dataItemId="9" sequence="30055111" timestamp="2008-07-10T10:27:59.591">ON</PowerStatus>
4. </Events>
5. </ComponentStream>

The control execution is now idle:

1. <ComponentStream componentId="8" name="Controller" component="Controller">
2. <Events>
3. <Execution name="execution" dataItemId="22" sequence="38148653" timestamp="2008-07-10T12:34:00.615">IDLE</Execution>

The execution unit is now running:

1. <Execution name="execution" dataItemId="22" sequence="38148753" timestamp="2008-07-10T12:35:00.615">EXECUTING </Execution>
2. </Events>
3. </ComponentStream>
4. </DeviceStream>
5. </Streams>
6. </MTConnectStreams>

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