MTConnect® Standard
Part 3 – Streams, Events, Samples, and Condition
Version 1.1.0 – Final

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MTConnect Specification

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1 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.

1.1 MTConnect® Document Structure

The MTConnect® specification is subdivided using the following scheme:

- Part 1: Overview and Protocol – Version 1.1.0, Final
- Part 2: Components and Data Items – Version 1.1.0, Final
- Part 3: Streams, Events, Samples, and Condition – Version 1.1.0, Final

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.
2 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.

Part 3 of the MTConnect standard focuses on the data returned from a current or sample request (for more information on these requests, see Part 1). This section covers the data representing the state of the machine. To reduce the amount of redundant information being transmitted and the resulting impact on the communications network, the descriptive information about a data item and its actual value are separated into different communication requests.

The information is broken into three types—Events, Samples, and Condition. An Event represents the state of a data item or a message. Samples represent the point in time value of a continuously changing data item like axis position. Condition represent the health of a device or component. This section also covers the vocabulary and format for each piece of data that can be retrieved from a machine.

2.1 Terminology

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

Agent A process that implements the MTConnect® HTTP protocol, XML generation, and MTConnect protocol.

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"/>

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, Events, and Condition 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, Samples, and Condition 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 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.

XML NMTOKEN  The data type for XML identifiers. It must start with a letter, an underscore “_” or a colon “:” and then it MUST be followed by a letter, a number, or one of the following “.”, “-“,”_“,”:“. An NMTOKEN cannot have any spaces or special characters.

2.2 Terminology and Conventions

Please refer to Part 1 “Overview and Protocol” Section 2 for XML Terminology and Documentation conventions.
3 Streams, Samples, Events, and Condition

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 three parts: Samples, Events, and Condition. 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 or represents a message. 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, Execution, Message etc.

A Condition communicates the device’s health and ability to function. It can be one of Unavailable, Normal, Warning, or Fault and there can be multiple active condition at one time whereas a sample or event can only have a single value at one point in time.

3.1 Structure

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

![Figure 1: Streams Example Structure](image-url)
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.

```xml
<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>
```

### 3.2 Sequence Number and Protocol

The sequence numbers are 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, Events, and Condition are not selected or when the Agent is supporting more than one device and data from only one device is requested. Please refer to *MTConnect® Part 1, Overview and Protocol, Section 5: Protocol* for more information.

### 3.3 Streams

A Streams element is the high level container for all device streams. Its function is to contain DeviceStream sub-elements. There **MUST** be no attributes or elements within this element.
3.4 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.
3.4.1 DeviceStream Attributes

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>The device’s name. An NMTOKEN XML type.</td>
<td>1</td>
</tr>
<tr>
<td>uuid</td>
<td>The device’s unique identifier</td>
<td>1</td>
</tr>
</tbody>
</table>

3.4.2 DeviceStream Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>ComponentStream</td>
<td>One component’s stream for each component with data</td>
<td>0..INF</td>
</tr>
</tbody>
</table>
3.5 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.

3.5.1 ComponentStream Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>This component’s name within the device. An NMTOKEN XML type.</td>
<td>1</td>
</tr>
<tr>
<td>nativeName</td>
<td>The name the device manufacturer assigned to the component. If the native name is not provided it MUST be the name.</td>
<td>0..1</td>
</tr>
<tr>
<td>component</td>
<td>The element name for the component</td>
<td>1</td>
</tr>
<tr>
<td>uuid</td>
<td>The component’s unique identifier</td>
<td>0..1</td>
</tr>
</tbody>
</table>

Figure 4: ComponentStream Schema
The Elements of the ComponentStream classify the data into Events, samples, and Condition. (*The classification is discussed below*). The ComponentStream **MUST NOT** be empty. It **MUST** include an Events and/or a Samples element.

### 3.5.2 ComponentStream Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Events</td>
<td>The events for this component stream</td>
<td>0..1</td>
</tr>
<tr>
<td>Samples</td>
<td>The samples for this component</td>
<td>0..1</td>
</tr>
<tr>
<td>Condition</td>
<td>The condition of the device.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

### 3.6 Samples and Events

All sample and event values **MUST** be able to provide **UNAVAILABLE** as a valid value when the data source is not connected or the data source is unable to retrieve information. The **UNAVAILABLE** value will persist until the connection is restored and a new value can be retrieved. This state does not imply the device is no longer operational, it only implies that the state cannot be determined.

### 3.7 Samples

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

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>The subtype of Sample for this component stream</td>
<td>1..INF</td>
</tr>
</tbody>
</table>

### 3.8 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 as a sub-element of Samples. Examples of sample sub-types are Position, Load, and Angle. Sample types **MUST** have numeric values.

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).

3.8.1 Sample attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>The name MUST match the name of the DataItem this sample is associated with. It MUST be an NMTOKEN XML type.</td>
<td>1</td>
</tr>
<tr>
<td>sequence</td>
<td>The sequence number of this event. Values from 1 to 2^63-1 must be supported.</td>
<td>1</td>
</tr>
<tr>
<td>timestamp</td>
<td>The timestamp of the sample.</td>
<td>1</td>
</tr>
<tr>
<td>dataItemID</td>
<td>The id attribute of the corresponding data retrieved in the probe request.</td>
<td>1</td>
</tr>
</tbody>
</table>

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.

3.8.2 Sample Element Tag Names

The following is a list of all the elements that can be placed in the Samples section of the ComponentStream. All samples have a numeric value as the CDATA or UNAVAILABLE if the data is in an indeterminate state.

**Acceleration** The acceleration of a linear 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 linear axis of the tool relative to the workpiece. 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.

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

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

Load The load on a component. The load MUST always be reported in NEWTON or PERCENT 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. 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.

PathPosition The program position as given in 3 dimensional space. This position MUST default to WORK coordinates, if the WORK coordinates are defined, and MUST be given as a space delimited vector of floating point numbers given in MILLIMETER_3D units. The PathPosition will be given in the following format and MUST be listed in order X, Y, and Z:

\[<\text{PathPosition \ldots}>10.123\ 55.232\ 100.981</\text{PathPosition}]\]

Where X = 10.123, Y = 55.232, and Z=100.981.

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. DEPRECATED

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. The default coordinate system for Position MUST be MACHINE_COORDINATES.

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

---

1 From ASME B5.54 - 2005
2 From ASME B5.54 - 2005
SpindleSpeed: The rate of rotation of a machine spindle \(^3\). 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 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 linear 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.

3.8.3 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.

3.9 Events

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

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event</td>
<td>The subtype of Event for this component stream</td>
<td>1..INF</td>
</tr>
</tbody>
</table>

3.10 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.
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>The name MUST match the name of the event's associated DataItem. An NMTOKEN XML type.</td>
<td>1</td>
</tr>
<tr>
<td>sequence</td>
<td>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.</td>
<td>1</td>
</tr>
<tr>
<td>timestamp</td>
<td>The time-stamp of the event</td>
<td>1</td>
</tr>
<tr>
<td>dataItemID</td>
<td>The id attribute of the corresponding data retrieved in the probe request.</td>
<td>1</td>
</tr>
</tbody>
</table>

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 Availability transitions from UNAVAILABLE to AVAILABLE, 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.

### 3.10.1 Event Element Tag Names

The Event elements represent the state of various device attributes. The following is a list of all the event elements that may be placed within the Events section of the ComponentStream.

- **ActiveAxes**
  The set of axes being controlled by a Path. The value MUST be a space delimited set of axes names. For example:
  `<ActiveAxes ...>X Y Z C</ActiveAxes>`
  If this is not provided, it MUST assumed the Path is controlling all the axes.

- **Availability**
  Represents the components ability to communicate its availability. This MUST be provided for the device and MAY be provided for all other components.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVAILABLE</td>
<td>The component is available.</td>
</tr>
<tr>
<td>UNAVAILABLE</td>
<td>The component is not available.</td>
</tr>
</tbody>
</table>

**AxisCoupling** Describes the way the axes will be associated to each other. This is used in conjunction with COUPLED_AXES to indicate the way the are interacting.
### Value | Description
---|---
TANDEM | The axes are physically connected to each other and must operate as a single unit.
SYNCHRONOUS | The axes are coupled and are operating together in lockstep.
MASTER | The axis is the master of the CoupledAxes
SLAVE | The axis is a slave of the CoupledAxes

**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. DEPRECATED.

**ControllerMode**

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

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUTOMATIC</td>
<td>The controller is configured to automatically execute a program.</td>
</tr>
<tr>
<td>SEMI_AUTOMATIC</td>
<td>The controller is operating in a single cycle, single block, or single step mode.</td>
</tr>
<tr>
<td>MANUAL</td>
<td>The controller is under manual control by the operator.</td>
</tr>
<tr>
<td>MANUAL_DATA_INPUT</td>
<td>The operator can enter operations for the controller to perform. There is no current program being executed.</td>
</tr>
</tbody>
</table>

**CoupledAxes**

As a Linear or Rotary axis data item, refers to the set of associated axes to be used in conjunction with AxisCoupling. The value will be a space delimited set of axes names. For example:

```
<CoupledAxes ...>Y2</CoupledAxes>
```

**Direction**

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

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLOCKWISE</td>
<td>The component is rotating in a clockwise fashion using the right hand rule.</td>
</tr>
<tr>
<td>COUNTER_CLOCKWISE</td>
<td>The component is rotating in a counter clockwise fashion using the right hand rule.</td>
</tr>
</tbody>
</table>
A door state represents an opening that can be opened or closed. The CDATA **MUST** be as follows:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPEN</td>
<td>The door is opened</td>
</tr>
<tr>
<td>CLOSED</td>
<td>The door is closed</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>READY</td>
<td>The controller is ready to execute. It is currently idle.</td>
</tr>
<tr>
<td>ACTIVE</td>
<td>The controller is actively executing an instruction.</td>
</tr>
<tr>
<td>INTERRUPTED</td>
<td>The operator or the program has paused execution and is waiting to be continued.</td>
</tr>
<tr>
<td>STOPPED</td>
<td>The controller has been stopped.</td>
</tr>
</tbody>
</table>

The emergency stop state of the machine. The CDATA **MUST** be one of the following:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARMED</td>
<td>The circuit is complete and the device is operating.</td>
</tr>
<tr>
<td>TRIGGERED</td>
<td>The circuit is open and the device must cease operation.</td>
</tr>
</tbody>
</table>

This event refers to the optional program line number. For example in RS274/NGC the line number begins with an N and is followed by 1 to 5 digits (0 – 99999). If there is not an assigned line number in the programming systems as in RS274, the line number will refer to the position in the executing program. The line number **MUST** be any positive integer from 0 to $2^{32} - 1$.

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

This is a reference to an identifier for the current part being machined. It is a placeholder for now and can be used at the discretion of the implementation.

**PathMode**

The Path mode is provided for devices that are controlling multiple sets of axes using one program. When PathMode is not provided it MUST be assumed to be INDEPENDENT.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDEPENDENT</td>
<td>A set of axes are operating independently and without the influence of another set of axes.</td>
</tr>
<tr>
<td>SYNCHRONOUS</td>
<td>The sets of axes are operating synchronously.</td>
</tr>
<tr>
<td>MIRROR</td>
<td>The sets of axes are mirroring each other.</td>
</tr>
</tbody>
</table>

**PowerStatus**

Power status MUST be either ON or OFF. DEPRECATED.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>The power to the component is ON.</td>
</tr>
<tr>
<td>OFF</td>
<td>The power to the component is OFF.</td>
</tr>
</tbody>
</table>

**PowerState**

Power state MUST be either ON or OFF. DEPRECATION WARNING: MAY be deprecated in the future.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>The power to the component is ON.</td>
</tr>
<tr>
<td>OFF</td>
<td>The power to the component is OFF.</td>
</tr>
</tbody>
</table>

**Program**

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

**RotaryMode**

The mode the rotary axis is currently operating. The CDATA MUST be one of the following:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPINDLE</td>
<td>The axis is operating like a spindle and spinning.</td>
</tr>
<tr>
<td>INDEX</td>
<td>The axis is indexing to a position.</td>
</tr>
</tbody>
</table>
### Value Description

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTOUR</td>
<td>The axes is indexing and rotating at a programmed velocity.</td>
</tr>
</tbody>
</table>

#### 3.11 Condition

Condition items provide a channel by which the machine can communicate its health and ability to function. A condition can be one of **Normal**, **Warning**, **Fault**, or **Unavailable**. A Component **MAY** have multiple active condition at one time whereas a Sample or Event can only have a single value at a point in time.

##### 3.11.1 Types of Condition

- **Normal**
  
  The item being monitored is operating normally and no action is required. Normal also indicates a Fault has been cleared if the item was previously identified with Fault.

- **Warning**
  
  The item being monitored is moving into the abnormal range and should be observed. No action is required at this time.

- **Fault**
  
  The item has failed and intervention is required to return to a normal condition. Transition to a normal condition indicates that the Fault has been cleared. A fault is something that always needs to be acknowledged before operation can continue. Faults are sometimes noted as an alarm.

- **Unavailable**
  
  The condition is in an indeterminate state since the data source is no longer providing data. This will also be the initial state of the condition before a connection is established with the data source. The condition **MUST** be **Unavailable** when the value is unknown.
Figure 5: Condition Schema
### 3.11.2 Attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>sequence</td>
<td>The sequence number of this event. Values from 1 to 2^63-1 must be supported.</td>
<td>1</td>
</tr>
<tr>
<td>timestamp</td>
<td>The timestamp of the sample.</td>
<td>1</td>
</tr>
<tr>
<td>dataItemID</td>
<td>The id attribute of the corresponding data retrieved in the probe request.</td>
<td>1</td>
</tr>
<tr>
<td>name</td>
<td>The name <strong>MUST</strong> match the name of the event’s associated DataItem. An NMTOKEN XML type.</td>
<td>0..1</td>
</tr>
<tr>
<td>type</td>
<td>The data item type this condition refers to.</td>
<td>1</td>
</tr>
<tr>
<td>qualifier</td>
<td>Qualifies the condition and adds context or additional clarification. This optional attribute can be used to convey information like HIGH, LOW, ...</td>
<td>0..1</td>
</tr>
<tr>
<td>nativeCode</td>
<td>The native code for the piece of equipment. This is the way the alarm is represented on the component.</td>
<td>0..1</td>
</tr>
<tr>
<td>nativeSeverity</td>
<td>The pass thru severity from the device manufacturer.</td>
<td>0..1</td>
</tr>
<tr>
<td>xs:lang</td>
<td>An optional attribute that specifies language of the alarm text. Refer to IETF RFC 4646 (<a href="http://www.ietf.org/rfc/rfc4646.txt">http://www.ietf.org/rfc/rfc4646.txt</a>) or successor for a full definition of the values for this attribute.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

### 3.11.3 Condition Contents - CDATA

The contents are the optional text from the data source in the un-interpreted form. The text is provided for informational purpose only for interpretation by the application or other client software.

### 3.11.4 Condition Types

All existing Data Item types **MAY** be used as types for the Condition types. There are some additional types that have been added that represent logical parts of the device architecture and allow for better association and representation of the device's health. The following are the types specifically added for the Condition.

<table>
<thead>
<tr>
<th>Data Item type/ qualifier</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPERAGE</td>
<td>Indicates the electric current of a component is within operating limits.</td>
</tr>
<tr>
<td>HIGH</td>
<td>The amperage is too high.</td>
</tr>
<tr>
<td>LOW</td>
<td>The amperage is too low.</td>
</tr>
</tbody>
</table>
### Data Item type/qualifier

<table>
<thead>
<tr>
<th>Data Item type/qualifier</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTUATOR</td>
<td>A condition with the motion drive, servo, or actuator.</td>
</tr>
<tr>
<td>COMMUNICATIONS</td>
<td>A communications failure indicator.</td>
</tr>
<tr>
<td>HARDWARE</td>
<td>The operational condition of the hardware subsystem of the component.</td>
</tr>
<tr>
<td>LEVEL</td>
<td>Indicates the level of a component is within operating limits.</td>
</tr>
<tr>
<td></td>
<td><strong>HIGH</strong> The level is too high.</td>
</tr>
<tr>
<td></td>
<td><strong>LOW</strong> The level is too low.</td>
</tr>
<tr>
<td>LOAD</td>
<td>Indicates the load of a component is within operating limits.</td>
</tr>
<tr>
<td></td>
<td><strong>HIGH</strong> The load is too high.</td>
</tr>
<tr>
<td></td>
<td><strong>LOW</strong> The load is too low.</td>
</tr>
<tr>
<td>LOGIC_PROGRAM</td>
<td>An error occurred in the logic program or PLC (programmable logic controller).</td>
</tr>
<tr>
<td>MOTION_PROGRAM</td>
<td>An error occurred in the motion program.</td>
</tr>
<tr>
<td>PH</td>
<td>Indicates the pH of a component is within operating limits.</td>
</tr>
<tr>
<td></td>
<td><strong>HIGH</strong> The pH is too high.</td>
</tr>
<tr>
<td></td>
<td><strong>LOW</strong> The pH is too low.</td>
</tr>
<tr>
<td>PRESSURE</td>
<td>Indicates the pressure of a component is within operating limits.</td>
</tr>
<tr>
<td></td>
<td><strong>HIGH</strong> The pressure is too high.</td>
</tr>
<tr>
<td></td>
<td><strong>LOW</strong> The pressure is too low.</td>
</tr>
<tr>
<td>POSITION</td>
<td>The component’s position is within operational limits.</td>
</tr>
<tr>
<td>SYSTEM</td>
<td>A condition representing something that is not the operator, program, or hardware. This is often used for operating system issues.</td>
</tr>
<tr>
<td></td>
<td><strong>HIGH</strong></td>
</tr>
<tr>
<td></td>
<td><strong>LOW</strong></td>
</tr>
<tr>
<td>TEMPERATURE</td>
<td>Indicates the temperature of a component is within operating limits.</td>
</tr>
<tr>
<td></td>
<td><strong>HIGH</strong> The temperature is too high.</td>
</tr>
<tr>
<td></td>
<td><strong>LOW</strong> The temperature is too low.</td>
</tr>
<tr>
<td>VELOCITY</td>
<td>Indicates the velocity of a component is within operating limits.</td>
</tr>
<tr>
<td></td>
<td><strong>HIGH</strong> The velocity is too high.</td>
</tr>
<tr>
<td></td>
<td><strong>LOW</strong> The velocity is too low.</td>
</tr>
<tr>
<td>VOLTAGE</td>
<td>Indicates the voltage of a component is within operating limits.</td>
</tr>
<tr>
<td></td>
<td><strong>HIGH</strong> The voltage is too high.</td>
</tr>
<tr>
<td></td>
<td><strong>LOW</strong> The voltage is too low.</td>
</tr>
</tbody>
</table>

### 3.11.5 Condition Examples

The following are abbreviated examples of the use of the Condition elements in XML. The condition has additional restrictions which are different form the Event and Sample. The following will demonstrate the differences and usage of the Condition.
In the previous example we have focused on two components, a Linear Y axis and a controller. They both have condition associated with them. The axis has a temperature sensor and a load sensor that will alert when the temperature or load goes out of range. The controller also has a few condition data items associated with the program and communications.

When everything is working properly, a current request will deliver the following XML:

```xml
<DeviceStream uuid="HM1" name="HMC_3Axis">
  <ComponentStream component="Linear" name="Y" componentId="y">
    <Samples>
      <Position dataItemId="yp" name="Yact" subType="ACTUAL" sequence="23" timestamp="2009-11-13T08:00:00">213.1232</Position>
      <Condition>
        <Normal type="TEMPERATURE" id="ytmp" sequence="25" timestamp="..."/>
        <Normal type="LOAD" id="ylc" sequence="26" timestamp="..."/>
      </Condition>
    </Samples>
    <Events>
      ...<Events>
  </ComponentStream>
  <ComponentStream component="Controller" name="controller" componentId="cont">
    <DataItems>
      <DataItem type="PROGRAM" id="pgm" category="EVENT" name="program"/>
      <DataItem type="BLOCK" id="blk" category="EVENT" name="block"/>
      <DataItem type="LINE" id="ln" category="EVENT" name="line"/>
      <DataItem type="PATH_FEEDRATE" id="pf" category="SAMPLE" name="Fact" units="MILLIMETER/SECOND" nativeUnits="FOOT/MINUTE" subType="ACTUAL" coordinateSystem="WORK"/>
      <DataItem type="PATH_FEEDRATE" id="pfo" category="SAMPLE" name="Fovr" units="PERCENT" nativeUnits="PERCENT" subType="OVERRIDE"/>
      <DataItem type="PATH_POSITION" id="pp" category="SAMPLE" name="Ppos" units="MILLIMETER" nativeUnits="MILLIMETER" coordinateSystem="WORK"/>
      <DataItem type="TOOL_ID" id="tid" category="EVENT" name="Tid"/>
      <DataItem type="PART_ID" id="pid" category="EVENT" name="Pid"/>
      <DataItem type="EXECUTION" id="exec" category="EVENT" name="execution"/>
      <DataItem type="CONTROLLER_MODE" id="cm" category="EVENT" name="mode"/>
      <DataItem type="COMMUNICATIONS" id="cc1" category="CONDITION"/>
      <DataItem type="MOTION_PROGRAM" id="cc2" category="CONDITION"/>
      <DataItem type="LOGIC_PROGRAM" id="cc3" category="CONDITION"/>
    </DataItems>
  </ComponentStream>
</DeviceStream>
```
The example below shows all of the condition items reporting that everything is normal for the linear axis Y and that the Controller has two conditions that are normal, but there is a communications fault on the device.

When a failure occurs the item **MUST** be reported as a **Fault**. This indicates that intervention is required to fix the problem and reset the state of the machine. In the following example we show how multiple **Faults** on the same condition can exist.

In this case a bad motion program was loaded and multiple errors were reported. When this occurs all errors **MUST** be provided and classified accordingly. The only exception to having
multiple values per condition is Normal. If the condition is Normal, there MUST only be one condition with that type present. There MUST NOT be more than one Normal and a Normal MUST NOT occur with a Fault or Warning of the same type.

A sample MUST treat condition items the same way it does Events, Samples, and Condition and only return those that are in the current select window.

### 3.12 - Alarms - DEPRECATED: See Condition instead

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

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>code</td>
<td>The type of alarm. This is a high level classification for all codes.</td>
<td>↓</td>
</tr>
<tr>
<td>severity</td>
<td>The severity of the alarm, currently we have CRITICAL, ERROR, WARNING, or INFORMATION.</td>
<td>↓</td>
</tr>
<tr>
<td>nativeCode</td>
<td>The native code for the piece of equipment. This is the way the alarm is represented on the component.</td>
<td>↓</td>
</tr>
<tr>
<td>state</td>
<td>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.</td>
<td>↓</td>
</tr>
<tr>
<td>lang</td>
<td>An optional attribute that specifies language of the alarm text. Refer to IETF RFC 4646 (<a href="http://www.ietf.org/rfc/rfc4646.txt">http://www.ietf.org/rfc/rfc4646.txt</a>) or successor for a full definition of the values for this attribute.</td>
<td>0..↓</td>
</tr>
</tbody>
</table>

The code can have one of the following values:

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

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.
A. Bibliography


B. Annotated XML Examples

B.1. Example of a current Request

```xml
<?xml version="1.0" encoding="UTF-8"?>
  <Header creationTime="2010-04-16T21:19:35+00:00" sender="localhost" instanceId="1267747762" bufferSize="131072" version="1.1" nextSequence="739103692" firstSequence="738972620" lastSequence="739103691" />

  The above is a standard header. The buffer size is 131072 entries. The first sequence number is 738972620 and the last sequence number is 739103691, if you subtract and add one, gives 131072 entries; this means the buffer is full. For the next streaming request, you would request with from set to 739103692.

  <Streams>
    <DeviceStream name="VMC-3Axis" uuid="0000">
      <ComponentStream component="Path" name="path" componentId="pth">
        <Samples>
          <PathFeedrate dataItemId="Fovr" sequence="738968517" timestamp="2010-04-16T21:09:58.356100">100.0000000000</PathFeedrate>
          <PathFeedrate dataItemId="Frt" sequence="739103685" timestamp="2010-04-16T21:19:07.019367">0</PathFeedrate>
        </Samples>
        <Events>
          <Block dataItemId="cn2" name="block" sequence="739103493" timestamp="2010-04-16T21:19:05.751294">G0Z1</Block>
          <ControllerMode dataItemId="cn3" name="mode" sequence="738968515" timestamp="2010-04-16T21:09:58.356100">AUTOMATIC</ControllerMode>
          <Line dataItemId="cn4" name="line" sequence="739103687" timestamp="2010-04-16T21:19:07.051368">0</Line>
          <Program dataItemId="cn5" name="program" sequence="738968514" timestamp="2010-04-16T21:09:58.356100">FLANGE_CAM.NGC</Program>
          <Execution dataItemId="cn6" name="execution" sequence="739103689" timestamp="2010-04-16T21:19:07.063369">READY</Execution>
        </Events>
      </ComponentStream>
    </DeviceStream>

  The Path component has both Samples and Events. The information regarding the path feedrate and feedrate override are considered sampled information in the Path. The events are related to the execution of the program for this Path.

    <ComponentStream component="Rotary" name="C" componentId="c1">
      <Samples>
        <SpindleSpeed dataItemId="c2" name="Sspeed" sequence="739103691" subtype="ACTUAL" timestamp="2010-04-16T21:19:07.063369">0.0000000000</SpindleSpeed>
        <SpindleSpeed dataItemId="c3" name="Sovr" sequence="738968518" subtype="OVERRIDE" timestamp="2010-04-16T21:09:58.356100">100.0000000000</SpindleSpeed>
      </Samples>
    </ComponentStream>
  </DeviceStream>
</MTConnectStreams>
```
The rotary C axis is the spindle and can be seen by checking the RotaryMode. In this case it is constrained to the value SPINDLE and will probably have a native name of “S”. There is also a condition which is monitoring the spindle load and is currently Normal.

Each of the linear axes has an actual and commanded position that is represented as samples as well as a condition monitoring the load. This is the same pattern for all the linear axes.
MTConnect Part 3

Streams

ComponentStream component="Controller" name="controller"
componentId="cn1">
  <Events>
    <EmergencyStop dataItemId="estop" sequence="738968519" timestamp="2010-04-16T21:09:58.356100"/>
    <Condition>
      <Normal dataItemId="clp" sequence="738968528" timestamp="2010-04-16T21:09:58.356100" type="LOGIC_PROGRAM"/>
    </Condition>
  </Events>
</ComponentStream>

Since the Path has subsumed the execution and program state, the Controller now contains mainly conditions about the hardware and the state of the device.

ComponentStream component="Device" name="VMC-3Axis" componentId="dev">
  <Events>
    <Availability dataItemId="avail" sequence="9" timestamp="2010-04-05T00:09:22.457383" AVAILABLE/>
    <Message dataItemId="msg" sequence="29" timestamp="2010-04-05T00:09:22.457383" UNAVAILABLE/>
  </Events>
</ComponentStream>

Availability is the one required event for the device and it is currently available. If the machine is powered off then this will become UNAVAILABLE. There have been no messages on this machine, so the message state is currently UNAVAILABLE.

ComponentStream component="Coolant" name="coolant" componentId="cool">
  <Condition>
    <Normal dataItemId="clow" sequence="738968520" timestamp="2010-04-16T21:09:58.356100" type="LEVEL"/>
  </Condition>
</ComponentStream>

ComponentStream component="Hydraulic" name="hydrolic"
componentId="hsys">
  <Condition>
    <Normal dataItemId="hlow" sequence="738968521" timestamp="2010-04-16T21:09:58.356100" type="LEVEL"/>
    <Normal dataItemId="hpres" sequence="738968522" timestamp="2010-04-16T21:09:58.356100" type="PRESSURE"/>
  </Condition>
</ComponentStream>

The previous two components are systems. Systems will usually report on the condition of the components, as can be seen here it is reporting on the temperature and the pressure in the Hydraulic and the coolant level. If the level can’t be read, it will report on just the coolant related alarms.

ComponentStream component="Controller" name="controller"
componentId="cn1">
  <Events>
    <EmergencyStop dataItemId="estop" sequence="738968519" timestamp="2010-04-16T21:09:58.356100"/>
    <Condition>
      <Normal dataItemId="clp" sequence="738968528" timestamp="2010-04-16T21:09:58.356100" type="LOGIC_PROGRAM"/>
    </Condition>
  </Events>
</ComponentStream>

ComponentStream component="Device" name="VMC-3Axis" componentId="dev">
  <Events>
    <Availability dataItemId="avail" sequence="9" timestamp="2010-04-05T00:09:22.457383" AVAILABLE/>
    <Message dataItemId="msg" sequence="29" timestamp="2010-04-05T00:09:22.457383" UNAVAILABLE/>
  </Events>
</ComponentStream>

Availability is the one required event for the device and it is currently available. If the machine is powered off then this will become UNAVAILABLE. There have been no messages on this machine, so the message state is currently UNAVAILABLE.

ComponentStream component="Coolant" name="coolant" componentId="cool">
  <Condition>
    <Normal dataItemId="clow" sequence="738968520" timestamp="2010-04-16T21:09:58.356100" type="LEVEL"/>
  </Condition>
</ComponentStream>

ComponentStream component="Hydraulic" name="hydrolic"
componentId="hsys">
  <Condition>
    <Normal dataItemId="hlow" sequence="738968521" timestamp="2010-04-16T21:09:58.356100" type="LEVEL"/>
    <Normal dataItemId="hpres" sequence="738968522" timestamp="2010-04-16T21:09:58.356100" type="PRESSURE"/>
  </Condition>
</ComponentStream>

The previous two components are systems. Systems will usually report on the condition of the components, as can be seen here it is reporting on the temperature and the pressure in the Hydraulic and the coolant level. If the level can’t be read, it will report on just the coolant related alarms.

ComponentStream component="Controller" name="controller"
componentId="cn1">
  <Events>
    <EmergencyStop dataItemId="estop" sequence="738968519" timestamp="2010-04-16T21:09:58.356100"/>
    <Condition>
      <Normal dataItemId="clp" sequence="738968528" timestamp="2010-04-16T21:09:58.356100" type="LOGIC_PROGRAM"/>
    </Condition>
  </Events>
</ComponentStream>