MTConnect® Standard

Part 3 – Streams, Events, Samples, and Condition

Version 1.1.0 – Final

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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"`**`>...</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`, `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 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.

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:

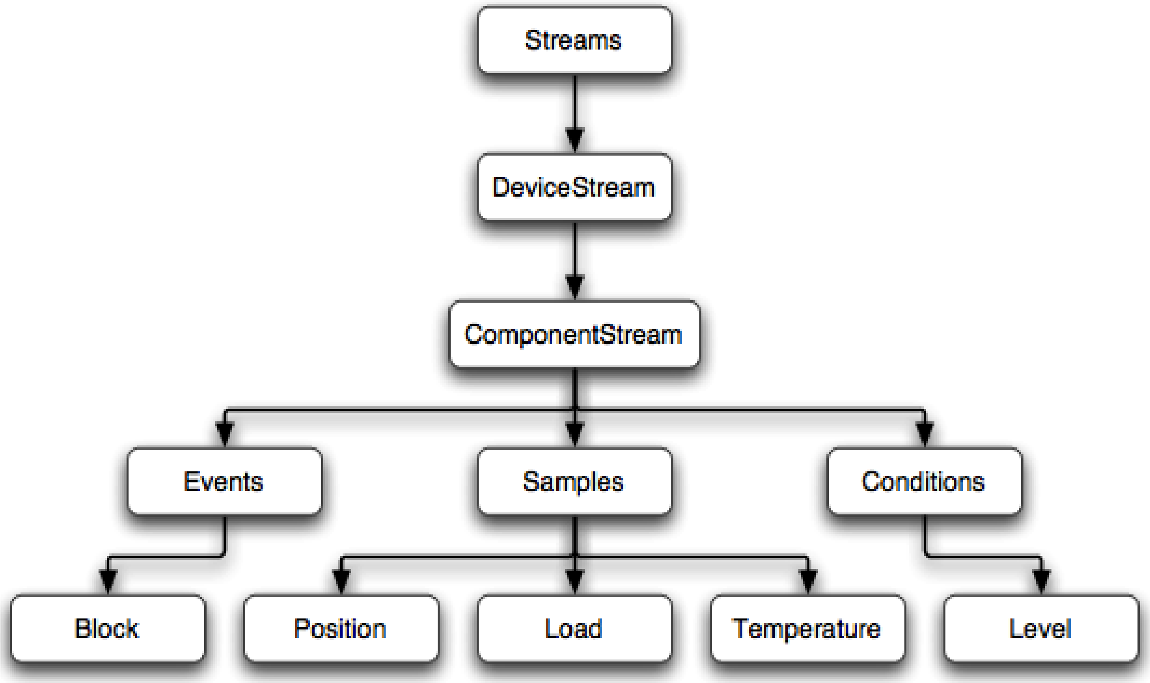

Figure 1: Streams Example Structure

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.

```
<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" time-
stamp="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" time-
stamp="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.

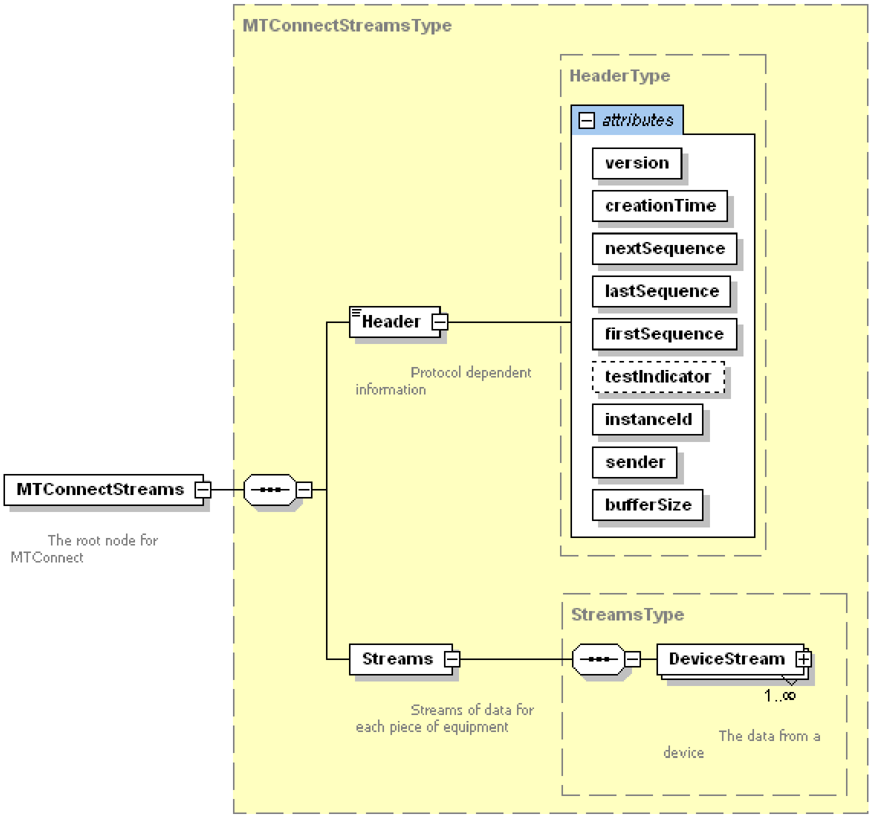

Figure 2: Streams Schema Diagram

Elements	Description	Occurrence
`DeviceStream`	The stream of samples, events, and condition for each device.	1..INF

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.

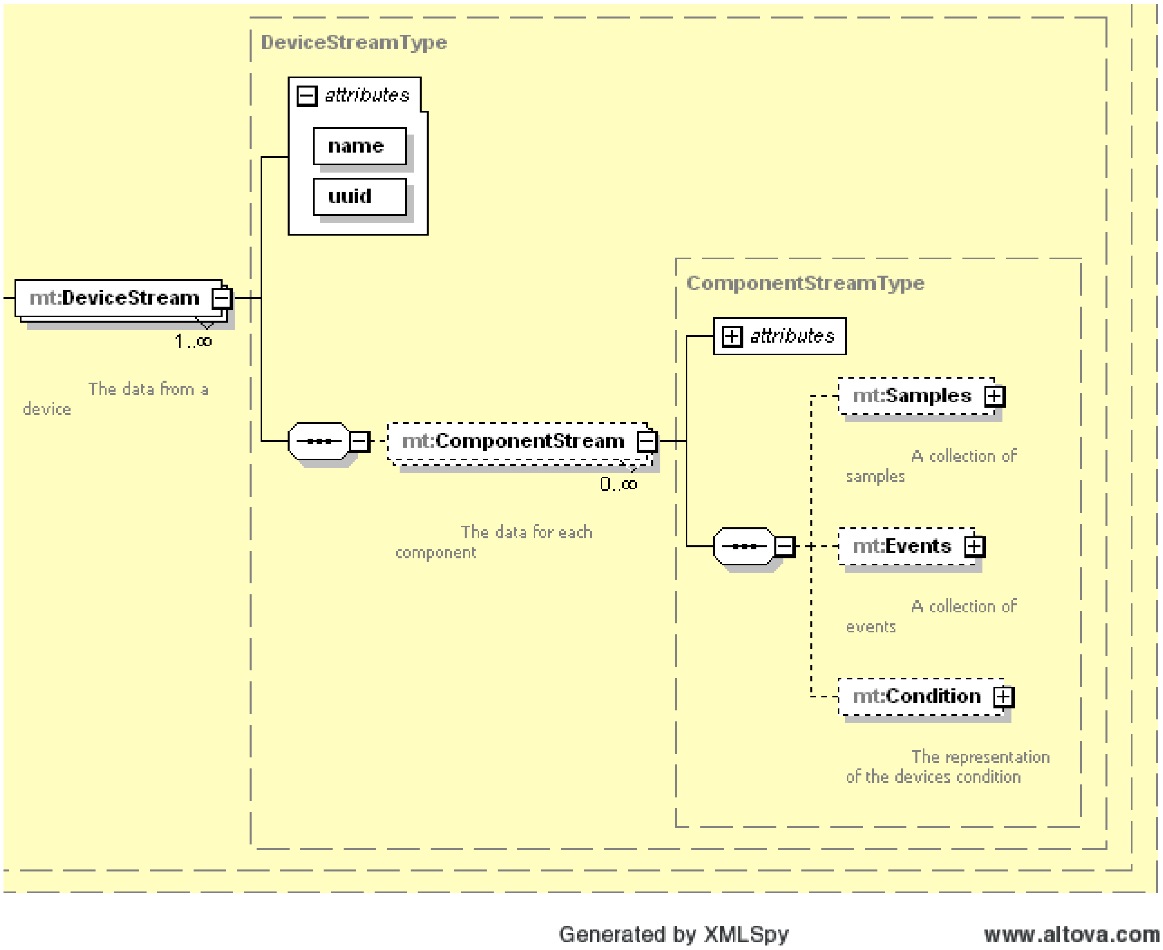

Figure 3: DeviceStream Schema

3.4.1 `DeviceStream` Attributes

Attributes	Description	Occurrence
`name`	The device's name. An NMTOKEN XML type.	1
`uuid`	The device's unique identifier	1

3.4.2 `DeviceStream` Elements

Element	Description	Occurrence
`ComponentStream`	One component's stream for each component with data	0..INF

3.5 ComponentStream

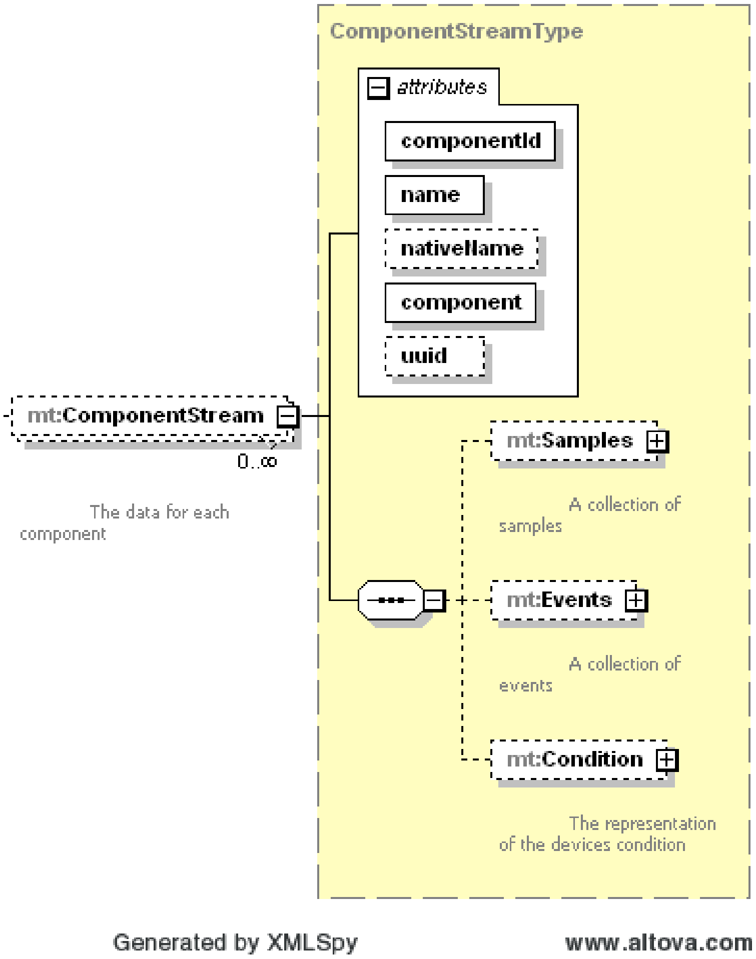

Figure 4: ComponentStream Schema

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

Attribute	Description	Occurrence
`name`	This component's name within the device. An NMTOKEN XML type.	1
`nativeName`	The name the device manufacturer assigned to the component. If the native name is not provided it **MUST** be the `name`.	0..1
`component`	The element name for the component	1
`uuid`	The component's unique identifier	0..1

Attribute	Description	Occurrence
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, 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

Element	Description	Occurrence
Events	The events for this component stream	0..1
Samples	The samples for this component	0..1
Condition	The condition of the device.	0..1

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.

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

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:

Attribute	Description	Occurrence
`name`	The name **MUST** match the name of the `DataItem` this sample is associated with. It **MUST** be an NMTOKEN XML type.	1
`sequence`	The sequence number of this event. Values from 1 to 2^63-1 must be supported.	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:

```
<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[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.

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[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.

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:
`<PathPosition …>10.123 55.232 100.981</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.

Element	Description	Occurrence
`Event`	The subtype of `Event` for this component stream	1..INF

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.

Attribute	Description	Occurrence

[3] From ASME B5.54 - 2005

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 `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.

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

Value	Description
AVAILABLE	The component is available.
UNAVAILABLE	The component is not available.

`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

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. Duplicates `Block`.

`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.
`SEMI_AUTOMATIC`	The controller is operating in a single cycle, single block, or single step mode.
`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.

`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:

Value	Description
`CLOCKWISE`	The component is rotating in a clockwise fashion using the right hand rule.
`COUNTER_CLOCKWISE`	The component is rotating in a counter clockwise fashion using the right hand rule.

DoorState A door state represents an opening that can be opened or closed. The CDATA **MUST** be as follows:

Value	Description
OPEN	The door is opened
CLOSED	The door is closed.

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.

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

Value	Description
ARMED	The circuit is complete and the device is operating.
TRIGGERED	The circuit is open and the device must cease operation.

Line 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.

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.

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`.

Value	Description
INDEPENDENT	A set of axes are operating independently and without the influence of another set of axes.
SYNCHRONOUS	The sets of axes are operating synchronously.
MIRROR	The sets of axes are mirroring each other.

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

~~Value~~	~~Description~~
~~ON~~	~~The power to the component is ON.~~
~~OFF~~	~~The power to the component is OFF.~~

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

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.

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

Value	Description
SPINDLE	The axis is operating like a spindle and spinning.
INDEX	The axis is indexing to a position.

Value	Description
CONTOUR	The axes is indexing and rotating at a programmed velocity.

ToolId This is a reference to an identifier for the current tool in use by the Path. It is a placeholder for now and can be used at the discretion of the implementation. Once mobile assets have been defined, this will refer to the corresponding asset.

WorkholdingId This is a reference to an identifier for the current workholding. It is a placeholder for now and can be used at the discretion of the implementation. Once mobile assets have been defined, this will refer to the corresponding asset.

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.

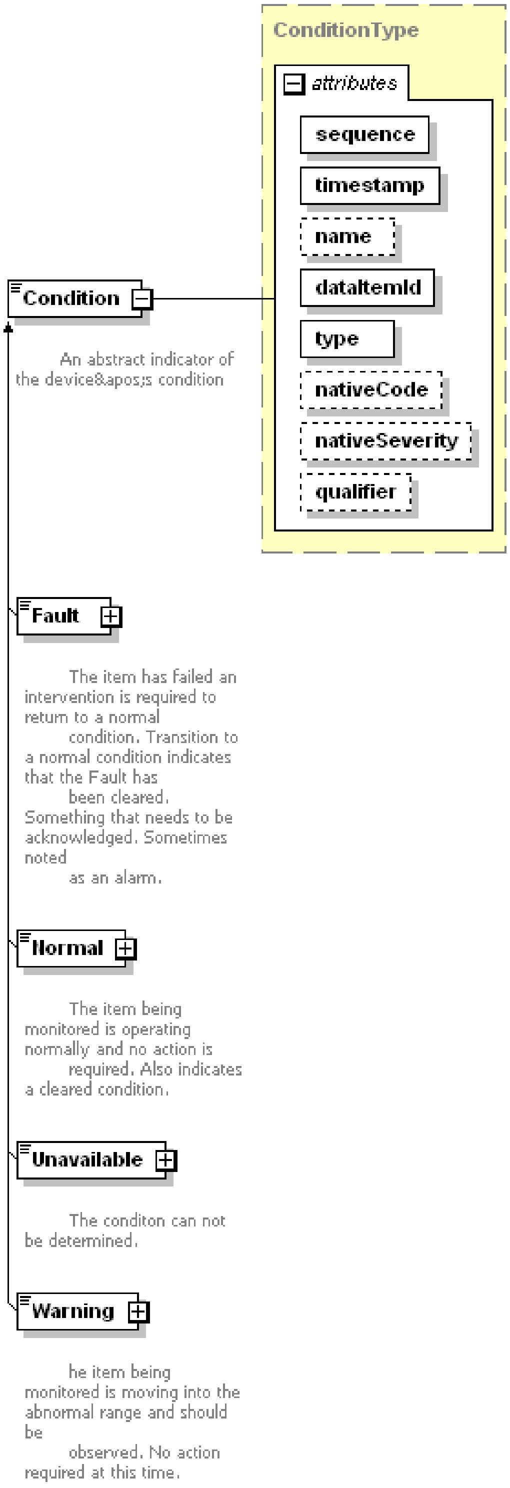
ConditionType
attributes
sequence
timestamp
name
dataItemId
type
nativeCode
nativeSeverity
qualifier
Condition
An abstract indicator of the device&apos;s condition
Fault
The item has failed an intervention is required to return to a normal condition. Transition to a normal condition indicates that the Fault has been cleared. Something that needs to be acknowledged. Sometimes noted as an alarm.
Normal
The item being monitored is operating normally and no action is required. Also indicates a cleared condition.
Unavailable
The conditon can not be determined.
Warning
he item being monitored is moving into the abnormal range and should be observed. No action required at this time.

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Figure 5: `Condition` Schema

3.11.2 Attributes

Attribute	Description	Occurrence
sequence	The sequence number of this event. Values from 1 to 2^63-1 must be supported.	1
timestamp	The timestamp of the sample.	1
dataItemID	The id attribute of the corresponding data retrieved in the probe request.	1
name	The name **MUST** match the name of the event's associated DataItem. An NMTOKEN XML type.	0..1
type	The data item type this condition refers to.	1
qualifier	Qualifies the condition and adds context or additional clarification. This optional attribute can be used to convey information like HIGH, LOW, …	0..1
nativeCode	The native code for the piece of equipment. This is the way the alarm is represented on the component.	0..1
nativeSeverity	The pass thru severity from the device manufacturer.	0..1
xs: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

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 devices health. The following are the types specifically added for the Condition.

Data Item type/ qualifier	Description
AMPERAGE	Indicates the electric current of a component is within operating limits.
HIGH	The amperage is too high.
LOW	The amperage is too low.

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

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`.

```
...
<Linear id="y" name="Y">
  <DataItems>
    <DataItem type="POSITION" subType="ACTUAL" id="yp" category="SAMPLE"
name="Yact" units="MILLIMETER" nativeUnits="MILLIMETER" coordinateSys-
tem="MACHINE"/>

    <DataItem type="POSITION" id="ylc" category="CONDITION" />
    <DataItem type="LOAD" id="ylc" category="CONDITION" />
    <DataItem type="TEMPERATURE" id="ytc" category="CONDITION" />
  </DataItems>
</Linear>
...

<Controller id="cont" name="controller">
  <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" coordina-
teSystem="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>
</Controller >

```

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:

```
<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>
    </Samples>
    <Condition>
      <Normal type="TEMPERATURE" id="ytmp" sequence="25" timestamp="..."/>
      <Normal type="LOAD" id="ylc" sequence="26" timestamp="..."/>
      <Normal type="POSITION" id="ypc" sequence="26" timestamp="..."/>
    </Condition>
  </ComponentStream>
</DeviceStream>
  <ComponentStream component="Controller" name="cont" componentId="cont">
    <Events>
       ...
    </Events>
    <Condition>
```

```
        <Normal type="MOTION_PROGRAM" id="cc2" sequence="25" timestamp="..."/>
        <Normal type="COMMUNICATIONS" id="cc1" sequence="26" timestamp="..."/>
        <Normal type="LOGIC_PROGRAM" id="cc3" sequence="26" timestamp="..."/>
      </Condition>
    </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.

```
<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>
    </Samples>
    <Condition>
      <Normal type="TEMPERATURE" id="ytmp" sequence="25" timestamp="..."/>
      <Normal type="LOAD" id="ylc" sequence="26" timestamp="..."/>
      <Normal type="POSITION" id="ypc" sequence="26" timestamp="..."/>
    </Condition>
  </ComponentStream>
</DeviceStream>
  <ComponentStream component="Controller" name="cont" componentId="cont">
    <Events>
       ...
    </Events>
    <Condition>
      <Normal type="MOTION_PROGRAM" id="cc2" sequence="25" timestamp="..."/>
      <Fault type="COMMUNICATIONS" id="cc1" sequence="26" nativeCode="IO1231"
timestamp="...">Communications error</Fault>
      <Normal type="LOGIC_PROGRAM" id="cc3" sequence="26" timestamp="..."/>
    </Condition>
  </ComponentStream>
</DeviceStream>
```

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 `Fault`s on the same condition can exist.

```
</DeviceStream>
  <ComponentStream component="Controller" name="cont" componentId="cont">
    <Events>
       ...
    </Events>
    <Condition>
      <Fault type="MOTION_PROGRAM" id="cc2" sequence="25" nativeCode="PR1123"
timestamp="...">Syntax error on line 107</Fault>
      <Fault type="MOTION_PROGRAM" id="cc2" sequence="28" nativeCode="PR1123"
timestamp="...">Syntax error on line 112</Fault>
      <Fault type="MOTION_PROGRAM" id="cc2" sequence="30" nativeCode="PR1123"
timestamp="...">Syntax error on line 122</Fault>
      <Normal type="COMMUNICATIONS" id="cc1" sequence="26" timestamp="..."/>
<Normal type="LOGIC_PROGRAM" id="cc3" sequence="26" timestamp="..."/>
    </Condition>
  </ComponentStream>
</DeviceStream>
```

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:~~

~~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.~~

~~Enumeration~~	~~Description~~
~~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.~~

Appendices

A. Bibliography

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B. Annotated XML Examples

B.1. Example of a `current` Request

```
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectStreams xmlns:m="urn:mtconnect.org:MTConnectStreams:1.1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns="urn:mtconnect.org:MTConnectStreams:1.1"
xsi:schemaLocation="urn:mtconnect.org:MTConnectStreams:1.1
http://www.mtconnect.org/schemas/MTConnectStreams_1.1.xsd">
  <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="000">
      <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>
```

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>
        <Events>
          <RotaryMode dataItemId="cm" name="Cmode" sequence="2"
timestamp="2010-03-05T00:09:22.457383">SPINDLE</RotaryMode>
        </Events>
        <Condition>
          <Normal dataItemId="Cload" sequence="738968524" timestamp="2010-04-
16T21:09:58.356100" type="LOAD" />
        </Condition>
      </ComponentStream>
```

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.

```
      <ComponentStream component="Linear" name="X" componentId="x1">
        <Samples>
          <Position dataItemId="x2" name="Xact" sequence="739103504"
subType="ACTUAL" timestamp="2010-04-
16T21:19:05.795297">0.0019900000</Position>
          <Position dataItemId="x3" name="Xcom" sequence="739103489"
subType="COMMANDED" timestamp="2010-04-
16T21:19:05.751294">0.0019900000</Position>
        </Samples>
        <Condition>
          <Normal dataItemId="Xload" sequence="738968525" timestamp="2010-04-
16T21:09:58.356100" type="LOAD" />
        </Condition>
      </ComponentStream>
```

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.

```
      <ComponentStream component="Linear" name="Y" componentId="y1">
        <Samples>
          <Position dataItemId="y2" name="Yact" sequence="739103500"
subType="ACTUAL" timestamp="2010-04-
16T21:19:05.783296">0.0002004431</Position>
          <Position dataItemId="y3" name="Ycom" sequence="739103490"
subType="COMMANDED" timestamp="2010-04-
16T21:19:05.751294">0.0002000000</Position>
        </Samples>
        <Condition>
          <Normal dataItemId="Yload" sequence="738968526" timestamp="2010-04-
16T21:09:58.356100" type="LOAD" />
        </Condition>
      </ComponentStream>
      <ComponentStream component="Linear" name="Z" componentId="z1">
        <Samples>
          <Position dataItemId="z2" name="Zact" sequence="739103690"
subType="ACTUAL" timestamp="2010-04-
16T21:19:07.063369">1.0000000000</Position>
          <Position dataItemId="z3" name="Zcom" sequence="739103684"
subType="COMMANDED" timestamp="2010-04-
16T21:19:07.019367">1.0000000000</Position>
        </Samples>
        <Condition>
          <Normal dataItemId="Zload" sequence="738968527" timestamp="2010-04-
16T21:09:58.356100" type="LOAD" />
```

```
        </Condition>
      </ComponentStream>
      <ComponentStream component="Controller" name="controller"
componentId="cn1">
        <Events>
          <EmergencyStop dataItemId="estop" sequence="738968519"
timestamp="2010-04-16T21:09:58.356100">RESET</EmergencyStop>
        </Events>
        <Condition>
          <Normal dataItemId="clp" sequence="738968528" timestamp="2010-04-
16T21:09:58.356100" type="LOGIC_PROGRAM" />
        </Condition>
      </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="2010-03-
05T00:09:22.457383">AVAILABLE</Message>
          <Message dataItemId="msg" sequence="29" timestamp="2010-03-
05T00:09:22.457383">UNAVAILABLE</Message>
        </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" />
          <Normal dataItemId="htemp" nativeCode="HTEMP" qualifier="HIGH"
sequence="739051314" timestamp="2010-04-16T21:15:42.835731"
type="TEMPERATURE" />
        </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.

```
    </DeviceStream>
  </Streams>
</MTConnectStreams>
```