A Standard Model for Machine to Supervisory Systems Data Exchange

Rainer Beudert - Schneider Electric
Ludwig Leurs - Bosch Rexroth
Steve Zuponcic - Rockwell Automation

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Machine to Supervisory Communication
• **Importance of a standardization of machine states**
Base Machine Object – State Model

- State of the machine is important to operator and supervisory systems
- Shown at operator panel, traffic light on top of machine
- Difference state versus status
  - Status just indicates the state of a machine without any transient states
  - State is shown in a model with events leading via transient states to a changed state
  - State changes can be triggered by commands
- Machine State models are specific to the industry branch
- A simple Machine Status can be generalized for a common view by all systems
PackML machine state diagram

**Internal Condition**
- IDLE
- STARTING
- EXECUTE
- COMPLETING
- COMPLETE
- SUSPENDED
- SUSPENDING
- CLEARING
- ABORTED
- ABORTING

**External Condition**
- IDLE
- STARTING
- EXECUTE
- COMPLETING
- COMPLETE

**States**
- SC = State Complete
- IDLE = Wait State
- ABORTED = Acting State
- EXECUTE = Dual State

**Transitions**
- Start
- Un-Hold
- Hold
- Suspend
- Resume
- Clear
- Abort
# Machine state comparison matrix

<table>
<thead>
<tr>
<th>ANSI/ISA 88</th>
<th>PackML</th>
<th>Weihenstephan</th>
<th>GEM</th>
<th>MTConnect</th>
<th>Base Machine Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Machine States</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>execute</td>
<td>execute (6)</td>
<td>operating (128)</td>
<td>executing</td>
<td>active</td>
<td>green (execute)</td>
</tr>
<tr>
<td>pausing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>green (execute)</td>
</tr>
<tr>
<td>paused</td>
<td>paused (4)</td>
<td>paused (1)</td>
<td></td>
<td></td>
<td>orange (stopped)</td>
</tr>
<tr>
<td>idle</td>
<td>idle (4)</td>
<td>idle (32768)</td>
<td></td>
<td></td>
<td>yellow (idle)</td>
</tr>
<tr>
<td>stopped</td>
<td>stopped (2)</td>
<td>stopped (1)</td>
<td></td>
<td></td>
<td>orange (stopped)</td>
</tr>
<tr>
<td>starting</td>
<td>starting (3)</td>
<td>starting (2)</td>
<td></td>
<td></td>
<td>yellow (idle)</td>
</tr>
<tr>
<td>suspending</td>
<td>suspending (13)</td>
<td></td>
<td></td>
<td></td>
<td>green (execute)</td>
</tr>
<tr>
<td>suspended</td>
<td>suspended (5)</td>
<td>prepared (4)</td>
<td>pausing</td>
<td>interrupted</td>
<td>orange (stopped)</td>
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<tr>
<td></td>
<td></td>
<td>lack (8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>tailback (16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>lack in branch line (32)</td>
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<td></td>
<td></td>
<td>tailback in branch line (64)</td>
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<tr>
<td>un-suspending</td>
<td>un-suspending (14)</td>
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<td></td>
<td>orange (stopped)</td>
</tr>
<tr>
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<td>stopping (7)</td>
<td>stopping (2)</td>
<td></td>
<td></td>
<td>orange (stopped)</td>
</tr>
<tr>
<td>aborting</td>
<td>aborting (8)</td>
<td>aborting (9)</td>
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<td></td>
<td>red (aborted)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>equipment failure (1024)</td>
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<td></td>
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</tr>
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<td>external failure (2048)</td>
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<td></td>
<td></td>
<td>emergency stop (4096)</td>
<td>emergency</td>
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<td>red (aborted)</td>
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<tr>
<td>held</td>
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<td>held (16384)</td>
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<td></td>
<td>green (execute)</td>
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<td>un-holding</td>
<td>un-holding (12)</td>
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<td>orange (stopped)</td>
</tr>
<tr>
<td>completing</td>
<td>completing (16)</td>
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<td></td>
<td>green (execute)</td>
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<td>complete</td>
<td>complete (17)</td>
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<td></td>
<td>orange (stopped)</td>
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<tr>
<td>resetting</td>
<td>resetting (15)</td>
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<td></td>
<td>orange (stopped)</td>
</tr>
<tr>
<td>clearing</td>
<td>clearing (1)</td>
<td></td>
<td></td>
<td></td>
<td>red (aborted)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>setting up</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Basic machine state model

idle (yellow) → execute (green) → stopped (orange)

start → resume → stop

reset → abort

aborted (red) → reset → abort

Simplified model for status

Start stop
abort
abort reset
reset
Basic machine state model

idle (yellow)
execute (green)
stopped (orange)
aborted (red)
## Targeted Machine Types

Machine Classes classified by NAICS

<table>
<thead>
<tr>
<th>Machinery classes</th>
<th>NAICS Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Product Machinery Manufacturing</td>
<td>333294</td>
</tr>
<tr>
<td>Packaging Machinery Manufacturing</td>
<td>333993</td>
</tr>
<tr>
<td>Plastics and Rubber Industry Machinery Manufacturing</td>
<td>333220</td>
</tr>
<tr>
<td>Machine Tool (Metal Cutting Types) Manufacturing</td>
<td>333512</td>
</tr>
<tr>
<td>Oil and Gas Field Machinery and Equipment Manufacturing</td>
<td>333132</td>
</tr>
<tr>
<td>Engine, Turbine, and Power Transmission Equipment Manufacturing</td>
<td>33361</td>
</tr>
<tr>
<td>Conveyor and Conveying Equipment Manufacturing</td>
<td>333922</td>
</tr>
<tr>
<td>Paper Industry Machinery Manufacturing</td>
<td>333291</td>
</tr>
<tr>
<td>Semiconductor Machinery Manufacturing</td>
<td>333295</td>
</tr>
<tr>
<td>Mining Machinery and Equipment Manufacturing</td>
<td>333131</td>
</tr>
<tr>
<td>Printing Machinery and Equipment Manufacturing</td>
<td>333293</td>
</tr>
<tr>
<td>Mounting and Handling Machines</td>
<td>not classified</td>
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</tbody>
</table>
Applications for Data Use

• Administration
• Alarms & Events
• ANDON
• Batch/recipe management
• Condition Monitoring
• Data Exchange
• Energy Management
• Laboratory Management
• Machine Data Access (MDA)
• Maintenance Management

• Material Management
• Order Management
• Performance Management
• Process Data Access (PDA)
• Quality management
• Time-series data (historian)
• Tool Management
• Traceability & genealogy
• Version Management
• …and many more
Base Machine Data Structure
Base Machine Data Structure
- Machinery Configuration
- Input Data
  - Commands
  - Tracking ID
  - Material
- Output Data
  - Machine Identifier
  - Mode, Status
  - Material
  - Tracking ID
  - Events
Machinery Configuration Data

- AssetID
- EquipmentType
- MachineVendorId
- EndUserDescription
- VendorName
- VendorModel
- VendorMachineSerialNumber
- VendorContact
- VendorInstallDate
- VendorDescription
- Utilities
Machinery Configuration Data

- AssetID
- EquipmentType
- MachineVendorId
- EndUserDescription
- VendorName
- VendorModel
- VendorMachineSerialNumber
- VendorContact
- VendorInstallDate
- VendorDescription
- Utilities

EUDescript[xx]
- Country
- State/Province
- City
- Facility
- Level
- Cell/Quadrant/Zone
- Machine ID
- User Defined
- User Defined
- User Defined
Machinery **Configuration** Data

- AssetID
- EquipmentType
- MachineVendorId
- EndUserDescription
- VendorName
- VendorModel
- VendorMachineSerialNumber
- **VendorContact**
- VendorInstallDate
- VendorDescription
- Utilities

**VendContact[xx]**
- Street number
- Street Name
- City
- State/Province
- Country
- ZIP/Postal Code
- Contact Name
- Phone number
- Phone extension
- Email address
Machinery Configuration Data

- AssetID
- EquipmentType
- MachineVendorId
- EndUserDescription
- VendorName
- VendorModel
- VendorMachineSerialNumber
- VendorContact
- VendorInstallDate
- VendorDescription
- Utilities
  - ID
  - Name
  - Value
  - Units
  - ScalerValue
  - ScalerUnits
Machinery **Input** Data

- **State**
- **CommandRate**
- **CommandRateUnit**
- **TrackingID**
- **ResetCounts**
- **Material**
Machinery **Input** Data

- **State**
- **CommandRate**
- **CommandRateUnit**
- **TrackingID**
- **ResetCounts**
- **Material**

**Material_In[xx]**
- **ID**
- **Name**
- **TrackingID**
- **Scaler**
Machinery **Output** Data

- **RemoteEnabled**
- **Mode**
- **State**
- **Status**
- **TrackingID**
- **Consumed**
- **InProcess**
- **Produced**
- **Waste**
- **EventActive**
- **EventDescription**
- **EventID**
- **ResetCountsDone**
Machinery Output Data

- RemoteEnabled
- Mode
- State
- Status
- TrackingID
- Consumed
- InProcess
- Produced
- Waste
- EventActive
- EventDescription
- EventID
- ResetCountsDone

Material_Out[xx]
- ID
- Name
- TrackingID
- Available
- IdealRate
- RawTotal
- Scaler
- Total
Extended Machine Data Structure
General Machine Information STRUCTURE

- Machine Name Plate (minimum ident)
  - Static
  - Dynamic

- Basic Machine Data (COMMON)
  - Static
  - Dynamic

- Optional Feature Description A
  - Static
  - Dynamic

- Optional Feature Description B
  - Static
  - Dynamic

- Optional Feature Description ...
  - Static
  - Dynamic

- Base Modes / States
  - Static
  - Dynamic

- Exhaustive details per request / (Local/Remote)

- Extensible Structure

- Benefits

Mandatory feature set

- e.g. Energy

- *Data structure is known

- e.g. Condition

- **Data structure is unknown
Basic ID / Name: UUID

Each object (structure) needs a unique identifier.

In case of a machine the Universally Unique Identifier (UUID) would be the combination of the

- OEM Machine Serial Number and the
- End User Asset Number
Definition Static and Dynamic Data

**Static Data**
Static data does not change over time and therefore can be stored outside the device. The minimum data set would be the identification data set that enables any client to uniquely identify the device. All other information could be stored outside and represented by a link.

**Dynamic Data**
Dynamic data are subject to changing over time. This makes it likely that this data will be stored in the device. The minimum set of dynamic data needs to be stored locally. Additional data can be stored remotely. The mandatory set of dynamic data (Common) should be stored locally.
Extensible structures are structures that can be extended from a predefined data set and offer a very flexible way to fulfill varying and future requirements.

Some reasons to introduce these are:

• Enable low cost devices to offer full information support. This works by reducing the info to be kept in the device to the mandatory data set.

• Other data may be stored outside the device and referenced by a link.

• Common data does not need to be stored in the device and inconsistent copies cannot occur.
Mandatory Features are ...
- are listed in the mandatory set of machine information.
- Only supported features are listed.
- Predefined features can reference a public available description. (PackML)
- Worldwide available on a public server (e.g. B2MML or Javascript styles).

Optional Features are ...
- described by a unique tag name
- in XML file either local or pointed to by URL
- static or dynamic
- local or remote
Local / Remote: Linked Information

Linked Information would reside on a server in an XML data file (e.g. //Server/dir/machine/uuid/ODVA.desc.xml). relative path names and permalinks are permitted.

URI to server

- //Server/DIR/Machine/UUID/ODVADESC.xml

This file contains all the non local informations

- Concept of Local / Remote
- see car registration in Europe

OVADESC.xml contains list of known features

- As Tag e.g. ODVA_energy: <supported>
  d.h. supports odva energy management
- General: just list things which are supported
XML files

- contain syntax and semantics, but also pure text readable by humans, not by machines

OVADESC.xml

- contains list of extended known / unknown features

```xml
<EXT feature: A> "Name"
<URI struct>
  "Description"
  ...
  ...
  </URI struct>
<Data>
  "Data"
  "Dynamic or static"
  "Local or remote"
</Data>
```
Benefits of a Standard Method for Machinery-to-Supervisory Information Exchange

• For machine builders, optimization of machinery integration (OMI™) will create additional value through simplified communication from machines to supervisory systems such as SCADA and MES.
• By transforming data into information, OMI will:
  – Provide tools for dynamic decision-making to maximize machine productivity and improve machine performance
  – Enhance maintainability of machinery assets
  – Create more value from machines

OMI will Emerge as a natural sweet spot to help manufacturers meet their overall business objectives, including workforce, profitability and sustainability goals.
Thank you!