DØ Control System
Tutorial

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Outline

- Terminology
- Control System Components
- Alarm States
- Process Variable Naming Convention
- Significant Event System
- Detector Configuration Management
- Operator Displays
Terminology

- **Process Variable (PV)**
  - Smallest unit of control data associated with the detector
    - status, readback, setpoint, parameter, …
  - Referenced by name
  - The primary object of the Channel Access Protocol

- **Record**
  - The mechanism by which a Process Variable is defined in an IOC
    - Data structure that realizes an instance of a PV
  - Composed of fields with a type (behavior), access rules, and value(s)
    - Scan rate, timestamp, value, alarm severity, …

- **IOC (Input/Output Controller)**
  - A computer running a set of EPICS routines used to define process variables and implement real-time control algorithms
**Terminology**

- **Channel Access (CA)**
  - The communication protocol used by EPICS

- **Channel Access Server**
  - Software that provides access to a Process Variable using the Channel Access Protocol
  - Usually, an IOC

- **Channel Access Client**
  - Software that requests access to a Process Variable using the Channel Access Protocol
  - Usually, a host-level computer

- **Field bus**
  - The electrical medium by which a detector element is connected to an IOC
Terminology

- Device
  - A component of the detector, often an entire module in a crate, that performs a unified, high-level function
  - Can have 1 to more than 30 associated PV’s
Control System Components

- Process control sub-system
  - EPICS (Experimental Physics and Industrial Control System)
  - Open source
  - Maintained by HEP community
  - Scalable architecture
  - Provides tools and building blocks for constructing a control system
  - Based upon a transport protocol (Channel Access)
  - Extensive collection of host-level support applications

- DØ-specific extensions to EPICS
  - New drivers
    - MIL/STD1553B field bus
  - New record types
    - HV channel state machine
  - New device support
    - Rack monitor
    - AFE boards
Control System Components

- **Field buses**
  - VME
  - MIL/STD1553B
  - CANBUS (Run IIB)

- **Application processes**
  - Channel Access clients
  - Significant Event System
    - Alarms
  - Comics
    - Configuration management
  - Graphical resource displays
  - Data archivers
Control System Components

- **Size**
  - ~15 host-level processors
  - ~150 IOCs (Input/Output Controllers)
  - ~7000 high-level devices
  - ~150000 process variables

- ~20 major detector sub-systems

- Host-Level processes written in Python

- Source management - CVS
Control System Components

- **Operating systems**
  - Host processors - Linux
  - IOC processors - vxWorks

- **Controls staff**
  - Core system – 2 ½ FTEs (3 people)
  - Detector-specific components - ~2 FTEs
    - Primarily from other institutions
Control System Components

Host – Linux Servers
IOC – MVME162, MVME23XX, MVME5500
Field Bus – VME, MIL/STD1553B, CanBus

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Control System
Components

- Accelerator System Gateway
  - Gateway link to ACNET system
  - Bidirectional
  - *Data access only (no control)*

- Cryogenics and Gas Gateway
  - Gateway link to DMACS system
  - Read-only
  - *Data access only (no control)*

- Gateways appear as CA servers (IOC’s) to EPICS
Alarm States

- Process variables (EPICS records) exist in one of four alarm states
  - No Alarm [GREEN]
    - Value within normal range
  - Minor [YELLOW]
    - Value outside of normal range but not data corrupting
  - Major [RED]
    - Value outside of normal range and potentially data corrupting
  - Invalid [PURPLE]
    - Value returned by the device is not meaningful
    - Field bus error
    - Network connection lost

- Host-level processes add an additional state
  - Undefined [GREY]
    - Unable to find (connect to) the process variable

- In GUI display fields the background colors indicate the alarm state
Process Variable Naming Convention

Template
<det>[<sub>]<dev><loc>/<attr>[::<io>][. <field>]

Name Elements

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Symbol</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector</td>
<td>&lt;det&gt;</td>
<td>CAL</td>
</tr>
<tr>
<td>Sub-det</td>
<td>&lt;sub&gt;</td>
<td>N</td>
</tr>
<tr>
<td>Device Type</td>
<td>&lt;dev&gt;</td>
<td>VBD</td>
</tr>
<tr>
<td>Locator</td>
<td>&lt;loc&gt;</td>
<td>01</td>
</tr>
<tr>
<td>Attribute</td>
<td>&lt;attr&gt;</td>
<td>STATUS</td>
</tr>
<tr>
<td>I/O</td>
<td>&lt;io&gt;</td>
<td>W</td>
</tr>
<tr>
<td>Field</td>
<td>&lt;field&gt;</td>
<td>SCAN</td>
</tr>
</tbody>
</table>

Example

CALN_VBD_01/STATUS:W.SCAN
Significant Event System

- The significant event philosophy
  - Alarms are a only a sub-set of the significant events
  - The control system does not generate all of the significant events
  - Alarm utilities enhance reliability
    - Detect impending failures and fix them *before* they fail
    - Minimize the time to correct failures
  - Why look at detailed displays until they have something interesting to show?
    - The alarm display shows which detector elements should be viewed in detail
    - No comfort displays, they only clutter the screen
  - Archive all event transitions
    - The archive is a history of the state transitions of the experiment
    - Tools provided to search the event archive
Significant Event System

- A server-based event (alarm) system:
  - IOC's and user processes connect to and send alarm transitions to the server
    - Pushed by sources not pulled by the server
  - Server holds the current experiment (alarm) state
  - Server has a filter for each receiving client
    - Makes use of name structure
  - Rapid display startup of receiving clients
  - User processes may also declare events via API (C, C++, Python)
  - Written in Python
Significant Event System

Filter
SE Message
Filtered Message

EPICS IOC
Process
Process Watcher
Periodic Heartbeat

Significant Event Server

F F F
Alarm Display
Alarm Watcher
Run Control (COOR)
Run Suspend

seLogger
seBrowser

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Significant Event System

Alarm Table Display

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Significant Event System

Alarm Matrix Display

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Detector Configuration Management

- The COMICS system manages the configuration of the detector
- Configuration map is a tree
  - Directed acyclic graph – no loops
- Tree Nodes
  - Root Node
    - Origin of the configuration tree
  - Intermediate node
    - Establishes a layered hierarchy
    - Establishes an execution order
      - Depth first, left to right
  - Action node (leaf)
    - Performs all control functions (EPICS)
- Constructed on the server model with multiple clients sending commands
Detector Configuration Management

- **Root Node**: DØ
- **Intermediate Node**: SMT, MUO, CFT
- **Sector Level Node**: S0, S1, S2
- **Action Node**: uses EPICS Channel Access

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Detector Configuration Management

- Receives sector execution requests from the Run Control Process (COOR)
  - A geographical sector – usually a readout crate -- is the smallest detector component directly managed by COOR

- Server may be activated independently for configuring detector components
  - API (Python only)
  - Shell script (ComicsTalk)
  - Expert Interface (ComicsExpertGui)
Detector Configuration Management

Comics Expert GUI

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Operator Displays

- Standard, process flow (synoptic) displays do not adapt well to the monitoring most of the detector components
  - Not related in a serial or sequential fashion like, for instance, a cryogenic plant
- Tabular (spread-sheet designs) are more natural
  - Similar properties for different devices are easily compared
  - Deviations are apparent
- DØ has developed a graphics support library consisting of a series of Python display classes for building tabular displays that collect and display information from EPICS process variables
Operator Displays

Resource Display
## Operator Displays

### HV Channel Display

#### Table:

<table>
<thead>
<tr>
<th>CAL North</th>
<th>CAL South</th>
<th>CAL Argon Mon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>Value</td>
<td>Value</td>
</tr>
<tr>
<td>00N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>02N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>04N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>06N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>08N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>10N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>12N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>14N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>16N</td>
<td>2000</td>
<td>2002</td>
</tr>
<tr>
<td>18N</td>
<td>2000</td>
<td>2002</td>
</tr>
</tbody>
</table>

#### Diagram:

- **Standby Entry**
- **Right-Click For Limits**
- **Paging Tabs**
- **State Change Buttons**
Operator Displays

Global HV Display

- Crate
- Module
- Channel Alarm
- Channel State
- Left-Click for HV Channel Display
- State Change Buttons

- Left-Click for HV Channel Display
- State Change Buttons

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