The ATLAS Detector Control System

Dr. Stefan Schlenker
CERN Geneva

for the ATLAS DCS Community
The ATLAS Detector

- Largest of four LHC experiments
- 7000 tonnes, ~100 million read-out channels, 3000 km of cables
- Contains 11 sub-detectors of different technologies in layer structure
- Built and operated by collaboration of >3000 physicists
- Operation with collisions since end 2009
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DCS Architecture

- Facilitate management of implementation, operation and maintenance by using standard building blocks

  **Joint Controls Project**

- Controls hierarchy:
  1. Front-End (FE): detector interface
  2. Local Back-End (BE): FE connection, readout, processing
  3. Sub-detector BE: grouping different technologies, standalone operation
  4. Global BE: interfaces to operators, storage and external facilities
DCS Front-End Components

- **Industrial Power Supplies & Crates**
  (CAEN, Wiener, ISEG),
  read out and controlled via CAN/Ethernet
- Few **PLCs** read out via Mod-bus (managed by CERN infrastructure)
- Custom built low-cost I/O concentrator: **Embedded Local Monitoring Board**
  - 64 analog inputs (16-bit ADC) and 32 digital I/O channels
  - ATmega128 microcontroller (8 bits, 4 MHz)
  - CAN controller for communication over field-bus
  - Powered by custom power supply via CAN bus (or hosting board)
  - Modular, remotely upgradable firmware
  - CANopen OPC server for communication with back-end
  - Radiation hard up to 50 Gy, tolerant to magnetic field >1.4T
  - More than 5000 ELMBs in use in ATLAS (detector, counting rooms), >10k LHC-wide
DCS Back-End

Components and Usage

- Front-End interfaced to individual control stations (server PCs), Windows/Linux
- Stations run SCADA software PVSS II (Siemens), allows distribution of applications
- Data exchanged via OPC (standard), Modbus (PLCs), DIM (anything else)
- Conditions data can be streamed to relational database (Oracle)
- Low level alarm system for individual parameters crossing thresholds
Back-End Integration

**Sub-systems**
- Distributed system of >130 stations in private network
- Control applications implemented by ~50 different sub-system developers based on event driven processing of >$10^7$ data elements

**External Systems**
- Information servers dedicated to communication with external controls systems (Safety, Magnets, Cryo, Gas, Cooling,..., LHC)
- Middleware: JCOP

**Scaling Behavior**
- Hierarchy approach pays off
- PVSS scaling becomes an issue on global level (influencing next version...)

<table>
<thead>
<tr>
<th>System</th>
<th>Component</th>
<th># Servers (Appl.)</th>
<th># Archived Parameters</th>
<th>Total # Parameters</th>
<th># FSM Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Detector</td>
<td>Pixel</td>
<td>11(12)</td>
<td>57k</td>
<td>1'086k</td>
<td>9.1k</td>
</tr>
<tr>
<td></td>
<td>Silicon strips</td>
<td>11(11)</td>
<td>106k</td>
<td>1'265k</td>
<td>14.7k</td>
</tr>
<tr>
<td></td>
<td>Transit. radiation</td>
<td>11(11)</td>
<td>69k</td>
<td>123k</td>
<td>13k</td>
</tr>
<tr>
<td></td>
<td>Services</td>
<td>7(8)</td>
<td>16k</td>
<td>494k</td>
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<tr>
<td>Calorimeters</td>
<td>Liquid Argon</td>
<td>13(13)</td>
<td>27k</td>
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<tr>
<td></td>
<td>Tile</td>
<td>5(5)</td>
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<tr>
<td>Muon Spectrometer</td>
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<td>29(29)</td>
<td>214k</td>
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<td></td>
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## Back-End Integration

### Sub-systems
- Distributed system of >130 stations in private network
- Control applications implemented by ~50 different sub-system developers based on event driven processing of >10^7 data elements

### External Systems
- **Information servers** dedicated to communication with external controls systems (Safety, Magnets, Cryo, Gas, Cooling,…, LHC)
- **Middleware**: JCOP
  - **Data Interchange Protocol**

### Scaling Behavior
- **Hierarchy approach pays off**
- **PVSS scaling becomes an issue on global level** (influencing next version…)

### Table: System Components and Parameters

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**Total**: 131(139) servers, 809k parameters, 12.3M total parameters, 91.2k FSM objects
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Need for higher level architecture due to heterogeneity and complexity
State Machine Hierarchy

Reduce complexity!

- Detector control mapped to state machine hierarchy above SCADA layer

- Using J COP FSM software framework (C. GASPAR ET AL. 2006)

- Device States are propagated upwards using state rules, Commands propagated downwards

- Error handling upwards using parallel tree of Status objects linked to device alarms

- Allows for single operator
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Operator Control

Human-Machine-Interfaces

► Alarm Screen enabling quick recognition and response to problems

► Homogeneous navigation through state machine hierarchy for operator with custom HMI

► Each state machine object has associated panel (synoptics, trends etc.)

► Access control mechanism fully synched with LDAP and shift management

► Web monitoring, no load on Back-End, history mode
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Data Management

Data Handling
- Use of Oracle databases (CERN IT services)
- Configuration DB: 1.6 GB
- Conditions DB: 6.6 GB/day, replicated for offline use
- Non-negligible maintenance

Data Access
- Directly from PVSS (trends, script-based) via OnlineDB
- Implemented dedicated web-based DCS Data Viewer (DDV)
  - DCS data access world-wide, can be embedded in any web-page
  - Generic approach allows use in other experiments (done in COMPASS)

![Diagram showing data management architecture]
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Example: Synchronization of DCS with LHC operation and physics run control

- Detector safety requires lower voltage levels during unstable beam conditions
- Communication with LHC control room using semi-automatic handshake procedure
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ATLAS data taking efficiency 94%

DCS incredibly reliable so far
Maintenance & Operations

Tasks

► Operations-driven consolidation (problem recovery automation etc.)
► Building documentation: direct access from UIs to generic TWiki
► Routine hardware replacements (PCs, FE-BE interfaces)
  ► Replace PCI based solutions to USB/Ethernet
► Software maintenance (OS, security patches, PVSS, drivers etc.)
► Migration to Linux:
  ► Windows needs high administration effort, high security constraints
  ► Need to replace OPC standard: OPC Unified Architecture (under development for CANopen/ELMB, vendors interested)
► Development on test systems, production updates only in technical stops
  ► Large scale production mirror (software only)
  ► Small scale hardware setups
► Software organized in repository, versioning essential (SVN)
► Reduced manpower requires merging of expertise and responsibilities, time consuming!
Future Upgrades

Upgrade Constraints

► Higher luminosity need to increase radiation tolerance for cavern equipment by factor ~10

► ELMB successor: ELMB++, still in conception stage
  - Radiation hardness!
  - Backwards compatibility
  - Fix bugs, support new connectivity (Ethernet?) and users

► Phase I:
  - new Pixel Inner B-Layer (new powering, Cooling)
  - Fast Track Trigger (electronics)

► Phase II: Replace complete inner detector, needs at least complete new design of DCS Front-End

LHC Upgrade Schedule

2013
E = 6.5-7 TeV
L = 10^{34} cm^{-2}s^{-1}

2017
E = 7 TeV
L = 2 \times 10^{34} cm^{-2}s^{-1}

2021
E = 7 TeV
L = 5 \times 10^{34} cm^{-2}s^{-1}

CONSOLIDATION

MOPMS021, S. Kersten et al.
Summary

- Highly distributed control system using SCADA software PVSS scales well ($10^7$ parameters)
- Reducing complexity using hierarchical structure and state machine logic
- System proven to manage routine detector operation well
- Continuous consolidation and automation
- Preparation of future upgrade
Run Number: 152221, Event Number: 383185
Date: 2010-04-01 00:31:22 CEST

\[ p_T(\mu^+) = 29 \text{ GeV} \]
\[ \eta(\mu^+) = 0.66 \]
\[ E_T^{\text{miss}} = 24 \text{ GeV} \]
\[ M_T = 53 \text{ GeV} \]

**W→μν candidate in 7 TeV collisions**
It works!

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