

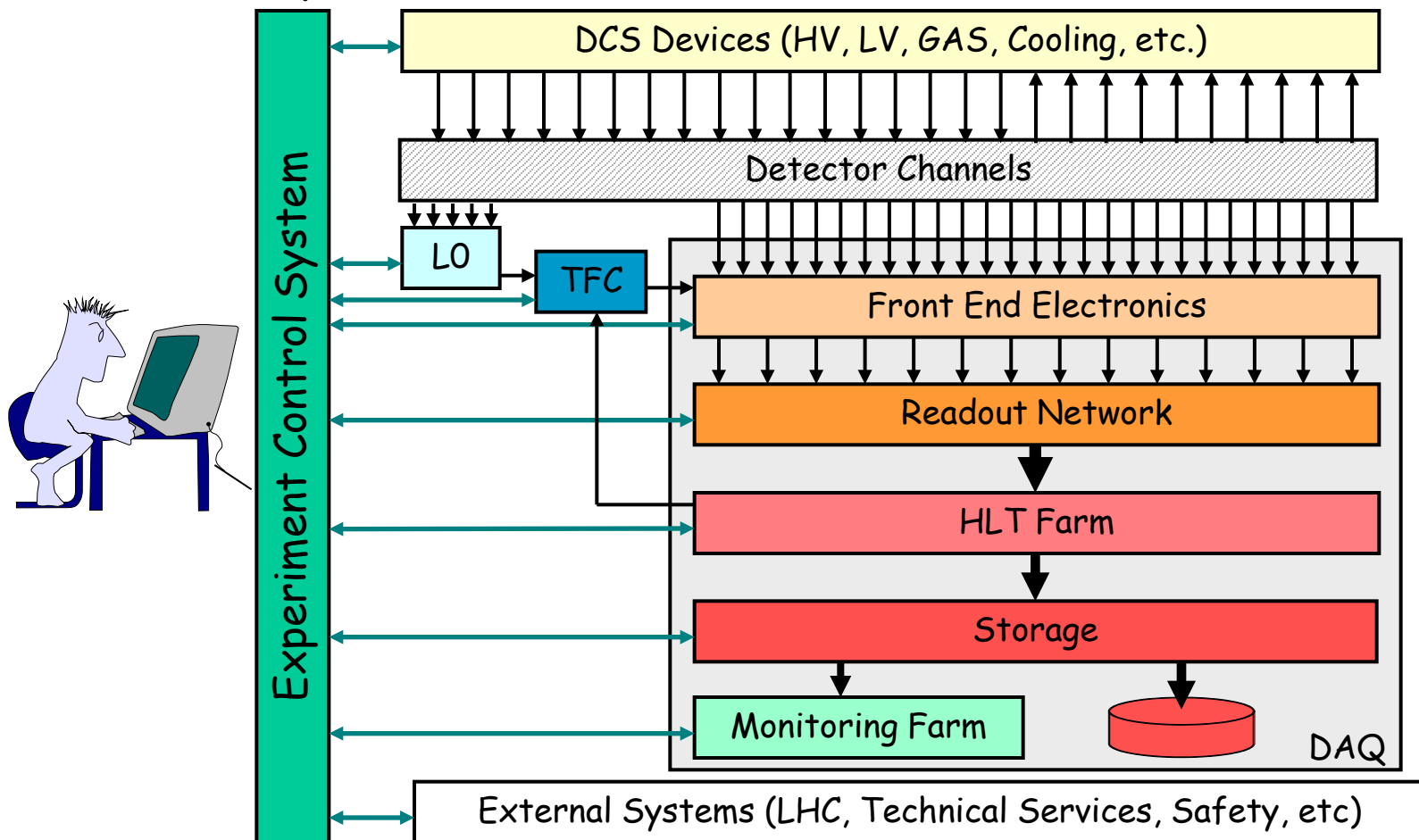
The LHCb Experiment Control System:

On the path to full automation

Clara Gaspar, October 2011

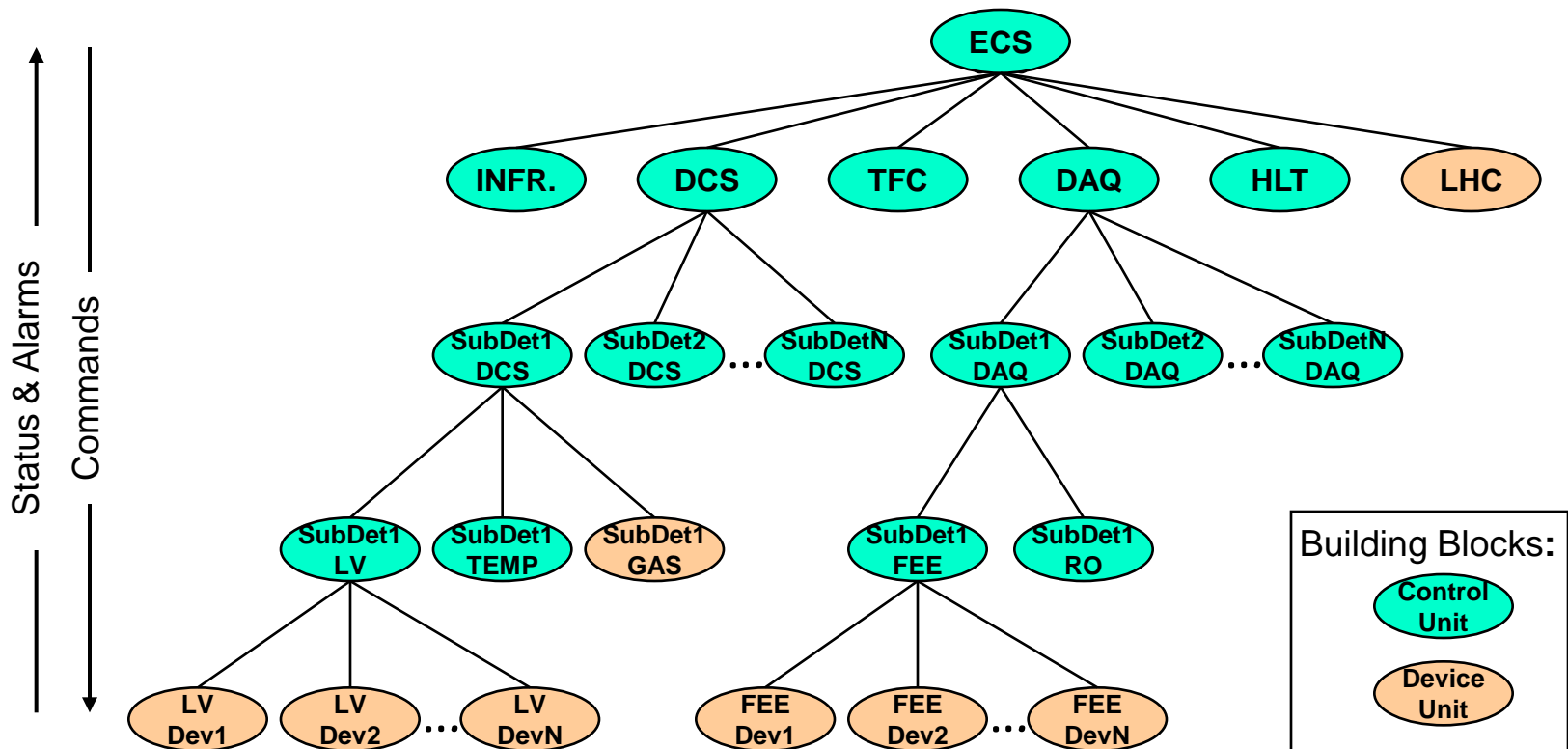
The Experiment Control System

- Is in charge of the Control and Monitoring of all areas of the experiment



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- Same architecture and same tools used throughout the Control System.
- Generic Architecture:



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The Control Framework

- The JCOP* Framework is based on:

- SCADA System - PVSSII for:

- | Device Description (Run-time Database)
 - | Device Access (OPC, Profibus, drivers) +DIM
 - | Alarm Handling (Generation, Filtering, Masking, etc)
 - | Archiving, Logging, Scripting, Trending
 - | User Interface Builder
 - | Alarm Display, Access Control, etc.

Device Units

Control Units

- SMI++ providing:

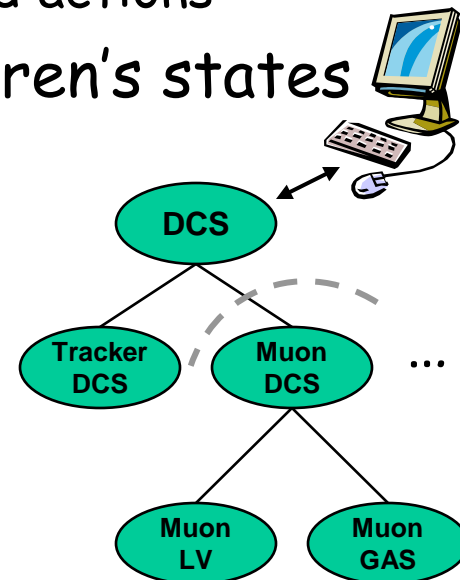
- | Abstract behavior modeling (Finite State Machines)
 - | Automation & Error Recovery (Rule based system)

* - The Joint COnTrols Project (between the 4 LHC exp. and the CERN Control Group)

- Provide access to “real” devices:
 - The FW provides interfaces to all necessary types of devices:
 - | LHCb devices: HV channels, Read Out boards, Trigger processes running in the HLT farm or Monitoring tasks for data quality, etc.
 - | External devices: the LHC, a gas system, etc.
 - Each device is modeled as a Finite State Machine:
 - | It's main interface to the outside world is a “State” and a (small) set of “Actions”.

Each Control Unit:

- Is defined as one or more Finite State Machines
 - It's interface to outside is also a state and actions
- Can implement rules based on its children's states
- In general it is able to:
 - Include/Exclude children (Partitioning)
 - Excluded nodes can run is stand-alone
 - Implement specific behaviour & Take local decisions
 - Sequence & Automate operations
 - Recover errors
 - User Interfacing
 - Present information and receive commands



FW - Graphical Editor

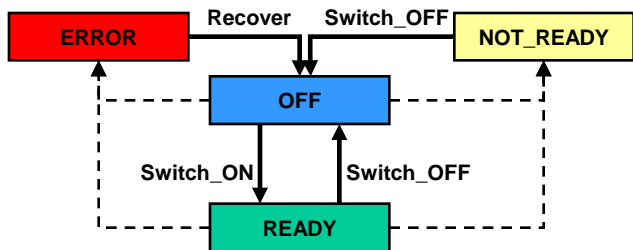
■ **SMI++**
Objects
States &
Actions

- Parallelism, Synchronization
- Asynchronous Rules

Operation Domains

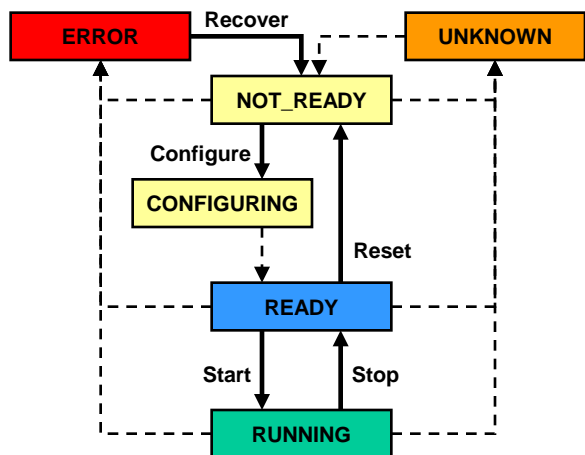
DCS Domain

Equipment operation related to a running period (Ex: GAS, Cooling)



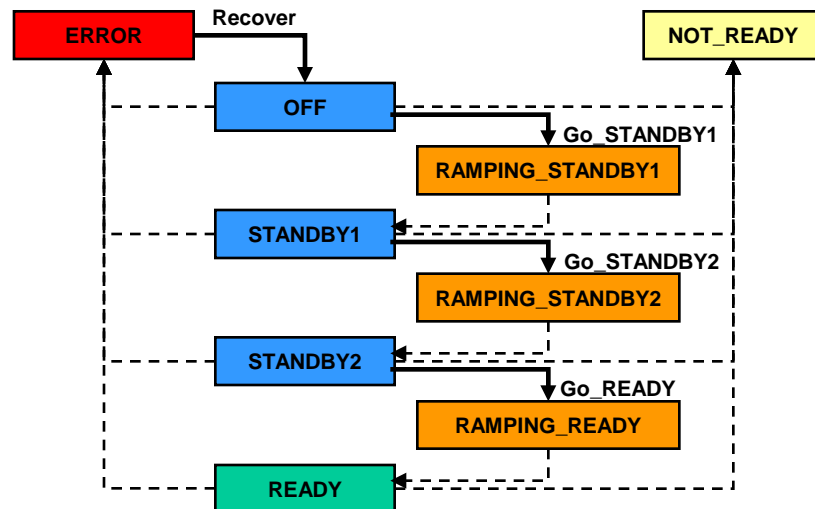
DAQ Domain

Equipment operation related to a "RUN" (Ex: RO board, HLT process)



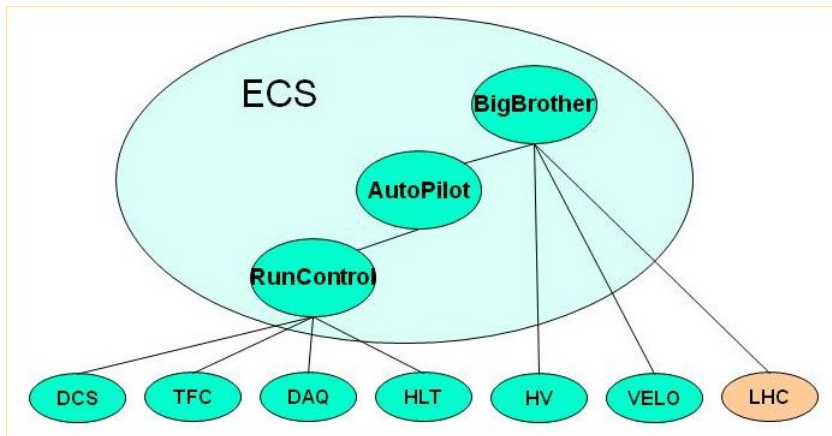
HV Domain

Equipment operation related to the LHC State (Ex: High Voltages)



- FSM templates distributed to all Sub-detectors
- All Devices and Sub-Systems have been implemented using one of these templates

ECS - Automation



Some Examples:

HLT Control (~1500 PCs)

- | Automatically excludes misbehaving PCs (within limits)
- | Can (re)include PCs at run-time (they get automatically configured and started)

RunControl

- | Automatically detects and recovers SubDetector desynchronizations
- | Can Reset SDs when problems detected by monitoring

AutoPilot

- | Knows how to start and keep a run going from any state.

BigBrother

- | Based on the LHC state:
 - | Controls SD Voltages
 - | VELO Closure
 - | RunControl

LHCb Run Control

Matrix
Domain
X
Sub-Detector

Activity
Used for
Configuring all
Sub-Systems

The screenshot displays the LHCb Run Control interface. On the left, a 'Select Node' tree shows the system hierarchy, with 'LHCb' selected. The main window is titled 'LHCb: TOP' and shows the overall system state as 'ERROR'. Below this, a table lists sub-systems and their states: DCS (READY), DAI (READY), DAQ (ERROR), RunInfo (RUNNING), TFC (RUNNING), HLT (RUNNING), Storage (RUNNING), Monitoring (RUNNING), Reconstruction (RUNNING), and Calibration (RUNNING). The interface also includes an 'Auto Pilot' section set to 'ON', a 'Run Number' of 102088, and a 'Run Start Time' of 20-Sep-2011 15:50:22. Two gauges show the L0 Rate at 812092.82 Hz and the HLT Rate at 5365.67 Hz. A 'Dead Time' gauge shows 5.37%. The 'Sub-Detectors' section shows the status of various detectors, with 'OTA' in an 'ERROR' state. The 'Trigger Components' section shows the status of various trigger elements, all in a 'RUNNING' state. A 'Messages' window at the bottom displays system logs.

System State
 System: Big Brother | State: READY

Sub-System State

Sub-System	State
LHC	PHYSICS
BCM	READY
Magnet	READY
LHCb Clock	EXTERNAL

Handshakes

Com	LHC	LHCb
STANDBY	STANDBY	VETO

Voltages

Sub-Detector	State	Req. HV	%Ok	HV State (A/C)
VELO_LHC_HV	OK	READY	100.00	READY
TT_LHC_HV	OK	READY	100.00	READY
IT_LHC_HV	OK	READY	100.00	READY
OT_LHC_HV	OK	READY	100.00	READY
RICH1_LHC_HV	OK	READY	100.00	READY
RICH2_LHC_HV	OK	READY	100.00	READY
PRS_LHC_HV	OK	READY	100.00	READY
ECAL_LHC_HV	OK	READY	100.00	READY
HCAL_LHC_HV	OK	READY	100.00	READY
MUON_LHC_HV	OK	READY	99.54	READY

Sub-Detector LV

Sub-Detector	State	Requested LV	LV State (A/C)
VELO_LHC_LV	OK	READY	READY
TT_LHC_LV	OK	READY	READY
IT_LHC_LV	OK	READY	READY
RICH1_LHC_LV	OK	READY	READY
RICH2_LHC_LV	OK	READY	READY

Messages

```

20-Sep-2011 10:05:27 - LHC_STATE in state PHYSICS
20-Sep-2011 10:05:28 - *** INFO - Confirm Prepare PHYSICS
20-Sep-2011 10:05:39 - *** INFO - Action Confirmed
  
```

LHC Parameters

Mode: PROTON PHYSICS | Fill Number: 2129 | Energy: 3500 GeV

Magnet: Set Current: 5850 A | Measured Current: 5850.0 A | Polarity: DOWN

DB Interfaces

Run DB Server: | Cond DB Server: | PVSS Archive:

VELO Closing Manager

Motion: ALLOWED | State: CLOSED

Beam Position: X: 0.45 mm, Y: -0.02 mm | XA: 0.45 mm, XC: 0.45 mm, Y: -0.01 mm

Status: 20-Sep 13:09:49 - Report: conditions OK
 20-Sep 13:09:49 - Current BPM values frozen.
 20-Sep 14:09:54 - Report: conditions OK
 20-Sep 14:09:54 - Current BPM values frozen.
 20-Sep 15:09:59 - Report: conditions OK
 20-Sep 15:09:59 - Current BPM values frozen.

Safety

Sub-Detector	State
TT_Safety	READY
IT_Safety	READY
OT_Safety	DEAD
RICH_Safety	READY
MUON_Safety	READY

Two operators on shift:

- Data Manager
- Shift Leader has 2 views of the System:

- Run Control
- Big Brother

Big Brother

- Manages LHC dependencies:
- SubDetector Voltages
- VELO Closing
- Run Control

ECS: Some numbers

Size of the Control Tree:

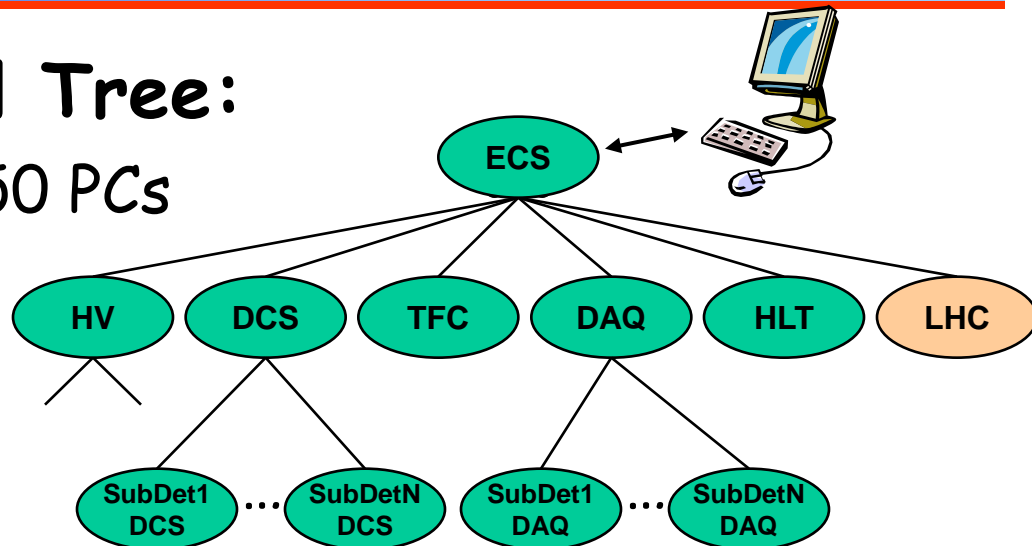
- Distributed over ~150 PCs

- ~100 Linux (50 for the HLT)

- ~ 50 Windows

- >2000 Control Units

- >50000 Device Units



Run Control Timing

- Cold Start to Running: 4 minutes

- Configure all Sub-detectors, Start & Configure ~40000 HLT processes (always done well before PHYSICS)

- Stop/Start Run: 6 seconds

- LHCb has designed and implemented a coherent and homogeneous control system
- The Experiment Control System allows to:
 - Configure, Monitor and Operate the Full Experiment
 - Run any combination of sub-detectors in parallel in standalone
- **Some of its main features:**
 - Partitioning, Sequencing, Error recovery, Automation
 - ➔ Come from the usage of SMI++ (integrated with PVSS)
- **LHCb operations now almost completely automated**
 - Operator task is easier (basically only confirmations)
 - DAQ Efficiency improved to ~98%