# The Common Infrastructure Control of the ATLAS experiment

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*Abstract* – ATLAS is one of the experiments at the Large Hadron Collider (LHC), constructed to study proton-proton collisions at the unprecedented energy of 14 TeV. In order to guarantee efficient and safe operation of the ATLAS detector, an advanced Detector Control System (DCS) has been implemented. With more than 150 PCs, the DCS is a highly distributed system, hierarchically organized for operating the detector. An important role is played by the Common Infrastructure Control (CIC), supervising the experimental area. The CIC provides monitoring and control for all common services and for the environment in the cavern and in the counting rooms. Distributed I/O concentrators, called Embedded Local Monitor Boards (ELMB), have been developed to operate under the special conditions of the experiment such as strong magnetic field and ionizing radiation. They are used for a variety of applications and are geographically distributed over the whole experiment. The communication is handled via the Controller Area Network (CAN) fieldbus using the *CANopen* protocol. Information and high level control is available to the users by a Finite State Machine (FSM) software running in the control room and information is also displayed on the web. The technical infrastructure of ATLAS has continuously been supervised during the commissioning phase by the CIC and ensures safe operation.

## INTRODUCTION

ATLAS is a general purpose High Energy Physics (HEP) experiment, scheduled to start data taking in 2008 at the new accelerator LHC at CERN, Geneva, Switzerland. Its scale is unprecedented in HEP, in both terms of size – the detector elements are distributed over a cylindrical volume of 25m diameter and 50m length – and organization – more than 2000 people of 167 institutions in 37 countries contribute to the project [1]. To ensure safe operation of the detector and the electronics, a highly distributed control system, the Detector Control System (DCS), has been implemented [2]. The DCS enables equipment supervision using operator commands, reads, processes and archives the operational parameters of the detector, allows for error recognition and handling, manages the communication with external control systems, and provides a synchronization mechanism with the physics data acquisition system.

The Back-End (BE) of the DCS is organized as a hierarchy of Finite State Machines, with a part for each sub-detector. The DCS has also implemented the supervision of all parts of ATLAS which are not under the direct responsibility of a sub-detector. These monitoring and control applications of the Common Infrastructure Control system are grouped within a dedicated hierarchy. The Front-End (FE) is based on CAN field buses deployed over the whole experiment – in the experimental cavern and in the counting rooms – and uses ELMB boards that are insensitive to the magnetic fields and tolerant to the radiations. External control systems are also included in the DCS tree, retrieving the corresponding information from the CIC or from the DCS Information Server (IS).

Finally, the information corresponding to the supervision and the control of the infrastructure is displayed in the ATLAS Control Room (ACR). The information provided by the FSM Screen is exported to a web server in order to allow remote monitoring of the ATLAS status.

## I. THE BE OF THE DCS

The DCS has the task to permit coherent and safe operation of ATLAS and to serve as a homogenous interface to all sub-detectors and to the technical infrastructure of the experiment. The DCS must be able to bring the detector into any desired operational state, to continuously monitor and archive the operational parameters, to signal any abnormal behavior to the operator, and to allow manual or automatic actions to be taken.

The DCS uses the SCADA product PVSS II 3.6 [3], a device-oriented and event-driven control system which can be distributed over a large number of PCs running Windows or Linux as operating system. Four main concepts of PVSS make it suitable for a large scale control system implementation such as the ATLAS DCS:

• A control station (PC) runs a so-called “Project” which contains a number of processes, called “Managers”. Different types of Managers may be used depending upon the type of application the Project is being used for, therefore avoiding unnecessary overhead.

• Each PVSS Project uses a central database for all current data values, stored in objects called “Data Points” (DP). All Managers have full Oracle database access for which PVSS provides transparent synchronization. Data processing is performed in an event-based approach using multithreaded callback routines upon value changes.

• Different Projects can be connected via LAN to form a “Distributed System” allowing to remotely access the databases and events of all connected Projects. This provides scalability up to the full size of ATLAS.

• A generic API allows extending the functionality of control applications using additional software components.

Due to the enormous size and complexity of detector and the large amount of data to be monitored, the full BE hierarchy of the DCS, from the operator interface down to the level of individual devices, is represented by a distributed Finite State Machine mechanism allowing for standardized operation and error handling in each functional layer [4]. Each functional part is represented in the FSM by a “Device Unit” (DU), attributing a “State” of operation and a ”Status” reflecting an anomaly. The BE is organized in three layers (see Fig. 1): the Local Control Stations (LCS) for process control of subsystems, the Sub-detector Control Stations (SCS) for high-level control of a sub-detector allowing stand-alone operation, and the Global Control Stations (GCS) with server applications and human interfaces in the ATLAS control room for the overall operation.

Efficient error recognition and handling for each DP is provided by a centralized alarm system which raises alarms at the granularity of the individual FE devices and propagates these alarms within the FSM hierarchy.

In order to synchronize the state of the detector with the operation of the physics data acquisition system, bi-directional communication between DCS and run control is provided.

The Joint Controls Project (JCOP) [5] was founded in order to maximize synergy effects for the DCS of the four experiments at the LHC by using common DCS components. Within JCOP, standards for the use of DCS hardware were established and a commercial controls software product has been selected to serve as the basis for all DCS applications. This software package was substantially extended by a comprehensive framework of software components and implementation policies.

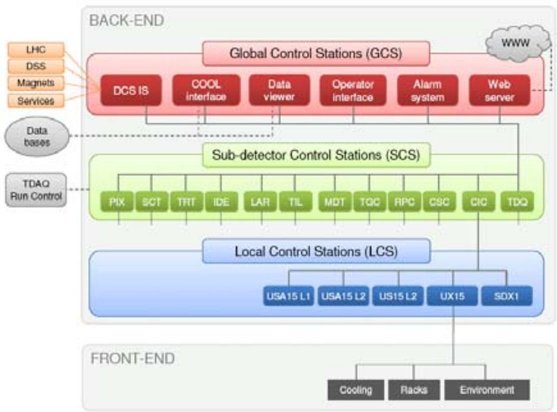


Figure 1: ATLAS DCS architecture

## II. THE CIC CONTROL SYSTEM

All parts of ATLAS which are common to the experiment are supervised by the CIC and the External Systems as shown in Fig. 2. The architecture is also reflected in the FSM.

The CIC is part of the ATLAS FSM like a sub detector and reflects the "State/Status" of the cooling, the environment and of the 5 counting rooms, for the control of the racks and the power supplies. The information is relevant for the users in the ACR and on dedicated WebPages [6], thus allowing the monitoring of the hardware equipment.

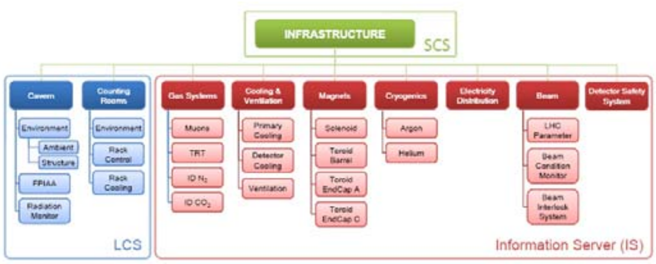


Figure 2: CIC architecture

The CIC comprises 6 Control Stations, measuring in total about 5000 Data Points Elements via CAN buses using the *CANopen* protocol [7]. A Control Station includes 2 Intel Xeon processors (3 GHz), 2 disks (250GB each), 2GB RAM, an Intelligent Platform Management Interface (IPMI) for remote control and has 3 PCI slots for CAN interface boards.

### *A. A read-out chain based on the ELMB*

There are essentially two categories of Front-End devices: commercial systems like power supplies and Embedded Local Monitor Board, which is a purpose-built flexible I/O system. The ELMB resists to the magnetic fields and is radiation tolerant. It has been developed in order to achieve as much homogeneity in the interfacing of various types of sensors and therefore to save development effort and ease maintenance.

The ELMB is separated in three powering sections. The CAN bus cables for the CIC are composed of 2 wires for the signals, 4 wires to provide 2 sources of 12V – Analog/Digital and CAN power – and 1 wire for the grounding. It has 64 analogue input channels of 16-bit resolution, 24 digital input/output lines and a serial bus to connect further I/O devices.

The front side of the ELMB motherboard is occupied by connectors for the CAN bus, digital I/O, analog inputs. The back side carries the ELMB and has sockets for signal conditioning adapters for all 64 analog input channels (see Fig. 3). Adapters for different sensors, for example NTC, 2-wire PT1000 or 4-wire PT100, are available. With these adapters sensors can be directly connected to the motherboard. More details can be found in [8].

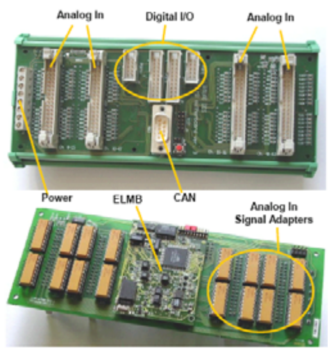


Figure 3: ELMB motherboard

The ELMB can either be integrated into more complex devices such as high or low voltage systems for their control or it can work stand-alone with sensors and actuators directly connected to it. It performs local data processing and communicates via a CAN field bus network with the Back End of the DCS. The data is archived in PVSS Oracle databases on the LCS. As the ELMB tolerates the harsh environment, it can be placed in the experimental cavern, which reduces enormously the size and complexity of cabling.

In ATLAS the order of 5000 ELMBs are used, corresponding to more than 400.000 channels. About 500 of them are used for the CIC.

### *B. The Rack Control application*

The Rack Control application monitors more than 400 racks in the 5 counting rooms and enables equipment supervision, sending commands and archiving the operational parameters for each rack. The FSM allows the supervision of the racks by attributing a "State" to reflect the state of operation and a "Status" to indicate an eventual default on one of the parameters.

For each rack at ATLAS, the "State" of the DU is determined by the electrical parameters; this information is read out, though an Ethernet connection, from a master PLC

(Premium) which control local PLCs (Twido). Commands can be sent to act on the powering of the racks.

The racks in the experimental area are equipped with a Turbine Unit to ventilate and cool the air. A special monitoring board using the ELMB has been developed and is placed in the Turbine Unit [9] to read out about 20 parameters, like Temperatures, Humidity, Dew Point, Turbine currents… Additional sensors for specific needs (i.e. temperature sensor, leak detection system…) can easily be interfaced. The turbines placed in the cavern are especially designed to tolerate magnetic field.

The racks in the TDAQ counting rooms, housing computers for data taking are cooled with fans and heat exchangers placed on the rear doors.

The FSM displays the State of operation and the Status reflecting any abnormal parameter at different levels. The operator interface allows visualizing the State/Status of a counting room up to an individual rack represented by a DU. The panel for a rack displays the parameters measured and the equipment it houses. One can also obtain the trend of a chosen parameter; an illustration in shown in Fig. 4.


Figure 4: CIC Rack Control operator screen in USA15 Level1

## C. *Cavern and Counting Room Environment*

In each of the 5 counting rooms, sensors are installed to supervise the ambient conditions (temperature, humidity and pressure) and the cooling system (see Fig. 5).

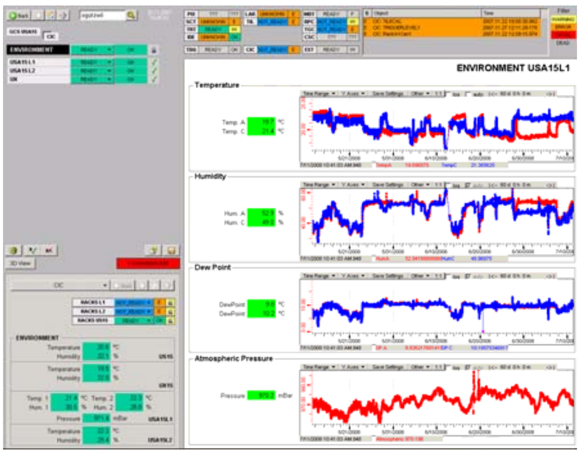


Figure 5: Ambient Environment panel in USA15 Level1

The general environment in the experimental cavern is also supervised. Ambient parameters are read out at several locations and a network of CAN buses with about 90 ELMB nodes, which covers the whole volume of the experiment, has been deployed. About one third of the 8000 channels are presently used, the rest are foreseen for future upgrades.

More than hundred PT100 probes have been placed on the aluminum structures of the detector. These sensors and their connections are designed to be able to localize and assess major accidents, e.g. a fire or a cryogenic leak.

The level of radiation inside ATLAS needs to be continuously monitored. About 60 radiation sensors [10] are installed just outside of the calorimeter and on the Muon detectors. Their FE electronics is also read out by the ELMB.

# III. The External Systems

## A. *Infrastructure Services*

The data exchange between the ATLAS DCS and external control systems is handled via the Data Interchange Protocol (DIP). This protocol is a thin layer on top of the Distributed Information Management (DIM) process communication interface [11] designed for highly reliable event-based data transfer. A DIP server publishes data items to a dedicated name server, while a client process can fetch the server publication information from the name server and can subscribe at the DIP server to selected data items, resulting in an event-triggered, pushed data transfer from the server to the client.

All external control systems are interfaced to the ATLAS DCS using a dedicated DCS Information Server in the GCS layer (see Fig. 1). Information from the external systems is transferred via DIP into the IS PVSS Project, thus made available to all DCS stations within the Distributed System, and stored in the PVSS Oracle database. A generic error handling mechanism using the DIP quality monitoring facilities has been implemented for all subscriptions on the DCS IS signaling any error condition related to the DIP communication via the PVSS alarm system.

The external systems are:

### 1) *Cooling and Ventilation (CaV)*

Cooling and ventilation is an infrastructure service provided by CERN. A primary water cooling plant is installed at the ATLAS site on the surface. It provides cooling to secondary plants underground, which cool the racks, equipment like vacuum pumps, cables or sub-detector specific equipments. The operational parameters of each of these secondary plants are read out by the respective sub-detector. In addition, the CIC monitors the overall status of the primary and all secondary cooling plants. The ventilation system for the underground rooms and the cavern is operated autonomously and its status will be transmitted to the DCS IS.

### 2) *Electricity Distribution*

The electricity distribution system as part of the CERN infrastructure is supervised by a dedicated control system. The part relevant for ATLAS (e.g. distribution cabinets, switch boards, UPS systems) is also monitored by the DCS.

*3) Gas systems*

Each of the gas systems of the different sub-detectors is controlled by a dedicated PLC. All PLCs are supervised by one PVSS system, which is not part of the ATLAS distributed control system. The operational parameters are published by DIP and the DCS IS transfers them into PVSS data points for further distribution to the sub-detectors. The relevant sub-detector control project sets up a FSM hierarchy for its gas system and includes it in its sub-detector tree.

*4) Magnets and Cryogenics*

The ATLAS magnets and cryogenics systems are also controlled by dedicated PLCs and monitored by a stand-alone PVSS station and information is retrieved via DIP to the DCS. The systems are represented in the CIC FSM hierarchy including corresponding status panels. All infrastructure parameters are available to the sub-detector applications.

*5) LHC parameters*

The interaction by software between ATLAS and the LHC is handled by DCS. Dedicated instrumentation on both sides provides detailed information about luminosity and backgrounds via the DIP protocol. The state of the LHC accelerator is presented to the ATLAS operator by the DCS.

A Beam Interlock System (BIS) combines signals in ATLAS indicating high backgrounds, and in case of danger for the detector sends a hardware interlock signal to LHC in order to dump the beams. The status of the BIS is presented by the CIC as an FSM unit.

## *B. The FPIAA system*

The experimental area is accessible in periods without beam. As the volumes are often quite small, confined and interconnected in a very complex way, a dedicated system called Finding Persons Inside ATLAS Area (FPIAA) [12] has been developed in order to be able to track people inside the ATLAS cavern, e.g. during detector maintenance periods.

It is based on 800 passive infrared sensors that detect the movement of people. These signals are analyzed in real time and in a case of an abnormal situation of a person not moving for a too long time, a PVSS alarm is generated. The synoptic panel of the FPIAA system (Fig. 6) allows the operator in the control room to know if and where people are in the cavern.

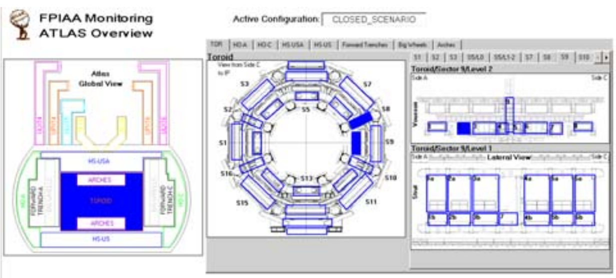


Figure 6: Synoptic panel of the FPIAA application

## *C. The Detector Safety System*

The Detector Safety System (DSS) [13] has the task to detect possibly dangerous situations for the detector e.g. due to overheating, failure of services, etc. and to shut down the relevant detector automatically. It is based on redundant PLCs which drive hardware interlocks and is supervised by a stand-alone PVSS system. All alarms of DSS are transmitted to DCS. DSS actions can be delayed in order to enable DCS to execute shut-down procedures in a controlled way before DSS switches off the equipment.

## CONCLUSIONS

During the ongoing commissioning, it was proven that the Common Infrastructure Control system, with notably the Rack Control application, is able to continuously provide stable control and supervision of the experimental area.

The use of the standardized read-out chain based on ELMB and PVSS has the advantage to facilitate long-term maintainability. The monitoring and control of the common infrastructure is provided by a Finite State Machine mechanism, which effectively reduces the complex set of FE component states to a single overall state.

Information is displayed in the ACR on the main FSM and on the Alert Screen. There are permanently a DCS shifter and a Shift Leader in Matters of Safety (SLIMOS) in the control room in charge of the supervision of the infrastructure.

To have remotely an overview of the state of the ATLAS Infrastructure and to give access to this data to everyone, Web pages are displaying the main information on the Internet.

At the time of writing this paper, the control of the common Infrastructure is integrated within the overall DCS and is ready for the start-up of the LHC.

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