THE WONDERLAND OF OPERATING THE ALICE EXPERIMENT

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Abstract

ALICE is one of the experiments at the Large Hadron Collider (LHC), CERN, Geneva, Switzerland. Composed of 18 sub-detectors each with numerous subsystems that need to be controlled and operated in a safe and efficient way. The Detector Control System (DCS) is the key to this and has been used by detector experts with success during the commissioning of the individual detectors. During the transition from commissioning to operation, more and more tasks were transferred from detector experts to central operators. By the end of the 2010 data-taking campaign, the ALICE experiment was run by a small crew of central operators, with only a single controls operator. The transition from expert to non-expert operation constituted a real challenge in terms of tools, documentation and training. A relatively high turnover and diversity in the operator crew that is specific to the HEP experiment environment (as opposed to the more stable operation crews for accelerators) made this challenge even bigger. This paper describes the original architectural choices that were made and the key components that enabled the DCS to come to an homogeneous control system that would allow for efficient centralized operation. Challenges and specific constraints that apply to the operation of a large complex experiment are described. Emphasis will be put on the tools and procedures that were implemented to allow the transition from local detector expert operation during commissioning and early operation, to efficient centralized operation by a small operator crew not necessarily consisting of experts.

INTRODUCTION

ALICE (A Large Ion Collider Experiment) is a general purpose heavy–ion detector installed on the 27 km Large Hadron Collider (LHC) at CERN. The experiment is designed to study the physics of strongly interacting matter and the quark–gluon plasma in nucleus–nucleus collisions. Data-taking during proton-proton runs provides reference data for the heavy-ion programme and addresses a number of specific strong-interaction topics for which ALICE is complementary to the other LHC experiments.

The experiment (Fig. 1) is composed of 18 sub-detectors and the collaboration currently involves over 1300 physicists, engineers and technicians from 116 institutes in 33 countries. The overall dimension of the detector is 16x16x26m3 with a total weight of approximately 10 000 tons.

The operation of the experiment relies on several independent online systems, each responsible for a specific domain of the operation:

- The Detector Control System (DCS) for the control and safety of the experiment; this paper will concentrate on this system
- The Data Acquisition (DAQ) system is responsible for the readout of the physics data, for event building and for data transport.
- The Trigger (TRG) system selects the interesting events and triggers the readout of the experiment.
- The High-Level Trigger (HLT) system performs online reconstruction of data in order to reject or tag events and to allow for data compression.

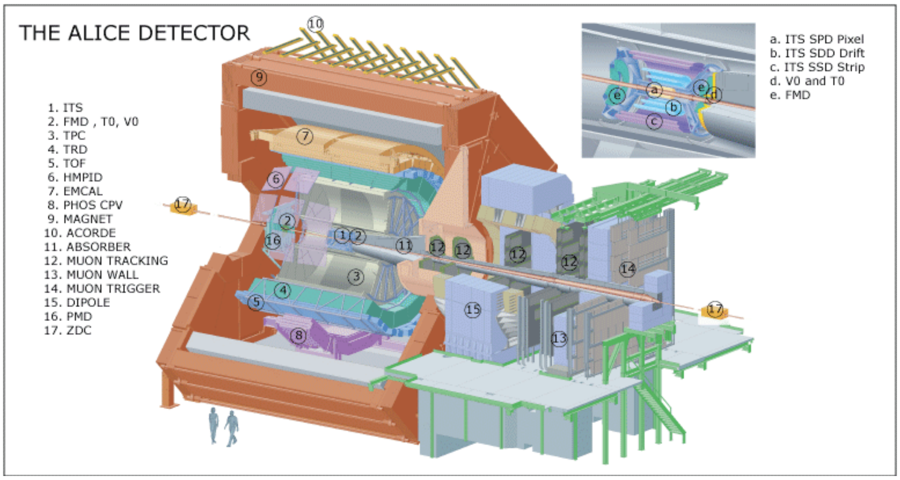


Figure 1: The ALICE detector at the LHC.

THE DCS IN ALICE

The main task of the Detector Control System in ALICE is to ensure safe and efficient operation of the experiment [1]. It provides configuration, remote control, and monitoring of all experimental equipment to allow the entire experiment to be operated from the ALICE Control Room (ACR) at LHC point 2, through a unique set of operator panels. The DCS provides the optimal operational conditions so that the physics data taken by the experiment is of the highest quality. The control system has been designed to reduce the downtime of the experiment to a minimum and hence contribute to a high running efficiency. It also aims to maximise the number of readout channels operational at any time.

The sub-detector control systems are provided by the contributing institutes; this work of over 100 developers from all around the world and from various backgrounds is coordinated by a small central controls team. The core of the controls system is a commercial Supervisory Control and Data Acquisition (SCADA) system: PVSSII [2]. It controls and monitors the detector devices, provides configuration data from the configuration database, and archives acquired values in the archival database. It allows for data exchange with external services and systems through a standardized set of interfaces.

In order to complement the PVSSII functionalities, a software framework has been built around PVSSII. It provides tools and guidelines for simplified implementation of the detector control systems. The core of this framework is built as a common effort between the LHC experiments, in the context of the Joint COntrols Project (JCOP) [3]. The main tools cover Finite State Machine (FSM), alarm handling, configuration, archiving, access control, user interfaces, data exchange, and communication. To cater for specific ALICE needs, the JCOP framework is complemented by components specific to ALICE. The complete ALICE framework is used by the sub-detector experts to build their own control applications, such as high voltage control, front-end electronics control, etc. Well over 100 such applications are finally integrated for a large and global ALICE control system.

FROM INSTALLATION TO ROUTINE OPERATION

After a long design, R&D and construction phase, installation of the first sub-detectors at the experiment site started in 2006. With this also the installation of the DCS infrastructure started, allowing the sub-detector groups to install their control systems.

From this moment, the time up to 2008 was heavily used to test and commission all sub-detectors to prepare for the first collisions in the autumn of 2008.

The year before resuming operation, late 2009 was used to install and commission more sub-detector modules, with the associated equipment and controls. This time was also used to gain experience in all aspects of running the experiment. The experiment collected cosmic ray data during several months, gearing up for the restart in October 2009.

After the end of year stop, operation resumed early 2010 to finish with a dedicated heavy-ion run. The last end of year stop saw again major installation work, notably the installation of a complete sub-detector (EM calorimeter).

Early this year, 2011, operation resumed, and in parallel, the commissioning of the newly installed detector equipment commenced.

Up to and including the start of 2009, the operation of the experiment was in the hands of the numerous sub-detector experts. It was only after several months of operation in 2010 that operation started to become more centralized. The transition to a fully centralized operation, where the whole experiment was run with a handful of people in a shift crew, took nearly 1 year. From early summer this year, the experiment is routinely run with a shift crew of 5.

It is clear that the evolution of the experiment has an impact on the DCS. The DCS has to follow the evolution to be able to fulfil its task of ensuring safe and efficient operation. The following sections will describe some of the challenges.

THE EVOLUTION CHALLENGE

Evolution in the Use and Users of the DCS

The early years of operation concentrated on detector debugging and commissioning. The DCS was used, and still developed, locally by the various sub-detector groups, providing all the functionality needed by the experts to operate their equipment for their test programs. The main task of the DCS at that moment was remote control of equipment, with only little emphasis on protection (e.g. from operator errors) since the system was exclusively used by system experts. The user interfaces used in this phase give access to the level of single channel operation of the equipment, and give the user a very detailed view of the system.

With the start of data-taking, the emphasis shifted more on operational aspects than pure remote control. Rather than manipulating individual channels, the simultaneous operation of groups of channels or whole sub-systems became important. Although several sub-detectors were operated at the same time, the actual operation was performed locally by the various sub-detector operators. These operators usually had a good knowledge of their sub-detector, but were not necessarily experts. Due to this, the need arose to present these operators with dedicated interfaces that would allow grouped operation and present information in a more concise form. At this point the protection against operation errors also became more important.

With the transition to more centralized operation, the tasks previously executed locally by the sub-detector operator were now carried out by a central operator.

Because of the large number of sub-detectors, it was obvious that the central operator would need additional tools to efficiently operate all sub-detectors. In addition, these operators usually have very little experience in sub-detector operation, so the tools shall also hide any complexity in sub-detector operation.

DCS Follows the Evolution of the Experiment

Another challenge for the DCS is that it has to cope with a continuously evolving experiment.

- Regularly, additional detector modules are installed that need to be integrated into the existing controls.
- Existing equipment is exchanged or upgraded. The DCS will have to be able to integrate this with minimal effort.
- While gaining experience in operation, the DCS might have to adapt to the newly gained insights.

The architecture of the DCS allows for meeting these challenges. The system was built with scalability in mind; new systems can easily be added. The notion of partitioning (taking control of a sub-tree in the controls hierarchy) was a key feature of the system to allow concurrent independent operation of sub-detectors.

THE SINGLE OPERATOR CHALLENGE

With the transition to a central operation of the experiment DCS, there were several challenges. Up to this point each detector was operated by a sub-detector operator; people with good knowledge of their sub-detector. This mode of operation required a shift crew of 25, which is not sustainable for the collaboration in the long term. More and more operation responsibilities were transferred to the central shift crew and currently a crew of 5 is running the experiment.

Unlike the accelerator sector, where shifts are usually covered by a reduced team of professionals, large HEP experiments face a specific challenge. It is common practice to encourage a maximum number of people to experience the operation of an experiment. In this way, people that will analyse physics data gain a better understanding of how operational issues can influence data quality. Nowadays large experiments are collaborations of a large number of institutes, and covering experiment shift duties are expected to be fairly shared between the collaborating institutes. This is the reason that the experiment is run with a relatively large pool of people that will only cover a small number of shifts. To illustrate, for 2011, the 926 8 hour ALICE DCS operator shifts are covered by about 80 different operators. So, an average operator will not do more than 11-12 shifts, making it difficult to gain solid experience.

This fact has a clear impact on the experiment DCS.

Training

The large number of new operators that need to be trained by the DCS experts puts a non-negligible load on the limited resources of the central team. For the future, a partly web based operator training might be envisaged, given the positive experience with such training courses at CERN.

Documentation and Instructions

Clear, extensive, and explicit documentation is fundamental to guide the majority of operators that have only limited experience. Classical (word processor produced) documentation is used for static documentation, and for more volatile instructions, Twiki is used.

As the central operator is responsible for the operation of all sub-detectors, the recovery of anomalies and errors is the primary task of the central operator. To facilitate this, sub-detectors have to provide a set of instructions for events that can be recovered by the central operator. One can easily understand that collecting these instructions from such a large number of sources is a managerial challenge.

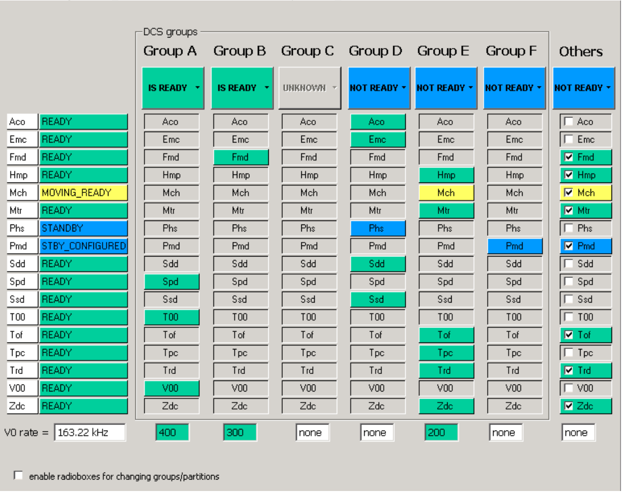
This large collection of instructions shall be made easily accessible for the operator. To achieve this, context sensitive access to instructions is integrated into the main tools and interfaces used by the operator.

Hiding Complexity

Obviously, the central DCS operator cannot have the detailed knowledge of all the operational details of all sub-detectors, therefore central operation is only possible when the complexity and specificity of each sub-detector is hidden for the operator.

Each sub-detector is represented by a limited set of states (e.g. ready for data-taking, standby, etc.) and a limited set of generic commands (e.g. go ready, switch off, etc.). The calculation of the state and the internal processing of the generic commands are programmed in Finite State Machine logic by the sub-detector experts.

Experience has shown that it is nowadays relatively uncommon to operate a single sub-detector; they are typically operated in 3-4 groups. Therefore, recently, a new tool (Fig. 2) has been introduced to allow the operator to operate groups of detectors; the configuration of the groups can be done by experts.



DCS groups

		Group A	Group B	Group C	Group D	Group E	Group F	Others
		IS READY	IS READY	UNKNOWN	NOT READY	NOT READY	NOT READY	NOT READY
Aco	READY	Aco	Aco	Aco	Aco	Aco	Aco	☐ Aco
Emc	READY	Emc	Emc	Emc	Emc	Emc	Emc	☐ Emc
Fmd	READY	Fmd	Fmd	Fmd	Fmd	Fmd	Fmd	☑ Fmd
Hmp	READY	Hmp	Hmp	Hmp	Hmp	Hmp	Hmp	☑ Hmp
Mch	MOVING_READY	Mch	Mch	Mch	Mch	Mch	Mch	☑ Mch
Mtr	READY	Mtr	Mtr	Mtr	Mtr	Mtr	Mtr	☑ Mtr
Phs	STANDBY	Phs	Phs	Phs	Phs	Phs	Phs	☐ Phs
Pmd	STBY_CONFIGURED	Pmd	Pmd	Pmd	Pmd	Pmd	Pmd	☑ Pmd
Sdd	READY	Sdd	Sdd	Sdd	Sdd	Sdd	Sdd	☐ Sdd
Spd	READY	Spd	Spd	Spd	Spd	Spd	Spd	☐ Spd
Ssd	READY	Ssd	Ssd	Ssd	Ssd	Ssd	Ssd	☐ Ssd
T00	READY	T00	T00	T00	T00	T00	T00	☐ T00
Tof	READY	Tof	Tof	Tof	Tof	Tof	Tof	☑ Tof
Tpc	READY	Tpc	Tpc	Tpc	Tpc	Tpc	Tpc	☐ Tpc
Trd	READY	Trd	Trd	Trd	Trd	Trd	Trd	☑ Trd
V00	READY	V00	V00	V00	V00	V00	V00	☐ V00
Zdc	READY	Zdc	Zdc	Zdc	Zdc	Zdc	Zdc	☑ Zdc
V0 rate =	163.22 kHz	400	300	none	none	200	none	none

☐ enable radioboxes for changing groups/partitions

Figure 2: Group operation.

Automation

The majority of tasks the operators must perform currently require active intervention. This implies the operator has to judge when and what action to perform (e.g. switching off certain sub-detectors when beam conditions change). In order to aim for a more coherent operation we try to automate as much as possible in any routine operation.

Currently a tool is being prototyped that allows an expert to define automatic actions triggered by external events (such as a beam mode change). The tool will be accompanied with an interface where the operator can follow the automatic actions that are performed.

THE COORDINATION CHALLENGE

Integration

Each sub-detector DCS is developed under the responsibility of that sub-detector, by their experts. In order to guarantee integration of all these separate developments into a single, homogeneous control system, a strong coordination of the developments and integration is needed. At a very early stage - with the start of the first developments - strong guidelines were issued and regular reviews performed to monitor the progress.

Also now, as development still continues, the strict coordination continues to ensure the correct integration of all sub-detector systems.

Maintenance and Development

All control applications are developed and maintained by the sub-detector teams. As with many of these projects in the HEP community, application development is often done by programmers with limited duration contracts, or that spend only a limited time in the project.

With the original author no longer available, long term maintenance or new developments are more and more delicate. In some projects, the applications are now maintained by the 3rd or 4th generation developer.

FUTURE

The sub-detector details are hidden from the central operator, and all standard operations are done with dedicated tools or interfaces. However, for error recovery procedures, the operator might be instructed to access more detailed sub-detector interfaces. In order to ease the navigation through such expert interfaces, and to limit the risk of operator errors, an effort shall be undertaken to encourage further uniformity of these interfaces (e.g. same look and feel).

Error recovery instructions are created by the relevant sub-detectors using templates, so that at least the form is homogeneous. However, there is currently only a limited check on the content of these instructions. A more systematic quality assurance of these instructions is currently under study.

CONCLUSION

The Detector Control System of the ALICE experiment was designed with flexibility in mind. It was with the start of a more centralized operation that the full power of the architecture of the DCS was unveiled and this architecture allows it to cope with the challenges it faces. Some of these challenges are typical for HEP experiments (as opposed to accelerator control), such as a relatively dynamic environment, and many inexperienced operators due to the high turnaround. The challenges are not only technical, but also managerial; a strong coordination closely following the activities in the sub-detectors is the key to preserving the homogeneity of the DCS.

REFERENCES

[1] ALICE Collaboration, Technical Design Report of the Trigger, Data Acquisition, High-Level Trigger and Control System, CERN/LHCC/2003-062.

[2] ETM website http://www.etm.at/index_e.asp (the product was recently rebranded as “Simatic WinCC Open Architecture”)

[3] Holme, O. et al., “The JCOP framework,” proceedings ICALEPCS 2005, Geneva, Switzerland, 2005