Common Tools for Large Experiment Controls—A Common Approach for Deployment, Maintenance, and Support

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Abstract—**The four major LHC experiments have agreed to a common supervisory controls approach under the auspices of the Joint Controls Project (JCOP). This approach is based on a commercial SCADA product called PVSS. Apart from that, several other sub-projects of JCOP address common aspects of the experiments' Detector Controls Systems (DCS).**

Within JCOP a number of packages are being developed for the experiments. One of these is the so-called JCOP Framework which is a package of tools and devices to facilitate the implementation of the various control systems for the sub-detectors and their electronics. This framework went through a redesign to take into account user feedback, and now effort is being put into deployment as well as the consultancy for the users—the experiments. This is important as the detectors are being prepared for testbeams and increasingly also for the final systems. All experiments have by now built prototype controls applications and tested them in beam tests as well as part of integration tests for larger detector parts.

The current state of the development and deployment of this framework and selected other JCOP sub-projects as well as the plans for the nearer and farther future, together with experience gathered during deployment, consultancy, and training are presented.

Index Terms—**CERN, controls, JCOP, LHC, SCADA.**

I. Introduction

THE Joint Controls Project (JCOP) is a collaborative effort by the four LHC experiments and several support groups[1] in the research sector of CERN. It was originally initiated by a recommendation from the Working Group on Common Projects in the Field of Software/Computing and Trigger/DAQ at the Large Hadron Collider (LHC). The mandate of this project was defined in a document in 2000 [1], but has been extended during the last years, partly due to an external review [2] in 2003. One of the major additions has been the inclusion of the support and maintenance plan [3].

The control systems for the LHC experiments will integrate all detector controls into one Detector Control System (DCS). This spans from the hardware devices on the bottom to the supervisory control level at the top.

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[1]CERN's research sector controls support group (IT/CO) and the physics department's electronics support group (PH/ESS).

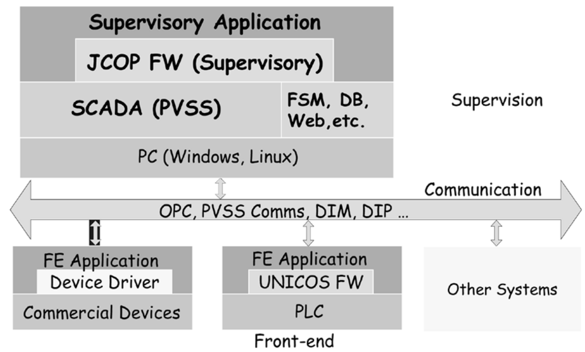

Fig. 1. General JCOP Framework Architecture.

CERN has chosen PVSS[2] as the standard SCADA[3] system and hence the JCOP Framework is based on this tool.

II. JCOP Sub-Projects

The Joint Controls Project has several sub-projects, the broadest being the supervisory software framework [4]. Three other projects with major impact on the design, implementation, and operation of all LHC experiments' DCSs are the Detector Safety System (DSS) [5], the Gas Control System (GCS) [6], and the common Rack Monitoring and Control System (RCS) [7].

A. The JCOP Framework

The JCOP Framework in its basic sense is a software component framework for the supervisory applications of sub-detectors and complete experiments, but also addresses the connection of these software components to the front-end devices, and other systems. The position of the JCOP Framework (JCOP FW) w.r.t. all components of the control systems is illustrated in Fig. 1.

All framework developments are driven by the JCOP Framework Working Group (FWWG), where the four experiments and the IT/CO group are represented. This working group has the task to decide on the long-term developments as well as the general implementation concept.

[2]*P* rozeß-*V*isualisierungs-und *S*teuerungs-*S*ystem made by ETM GmbH, Eisenstadt, Austria. See http://www.pvss.com for details.

[3]SCADA stands for *S*upervisory *C*ontrol *A*nd *D*ata *A*cquisition and these are commercial software systems used extensively in industry for the supervision and control of industrial processes.

The JCOP Framework is not a complete "component-off-the-shelf" control system, but rather provides a coherent set of devices and tools to build one. Among the main aims is the reduction of the individual development and maintenance effort for the experiments. This is achieved by reusing software components, facilitating the integration of both common and specific devices, and helping in the learning process. Furthermore the users of the framework benefit from the higher level of abstraction that is shown to them, which reduces the need for in-depth knowledge of the underlying tools. Many industrial components exist that are used for detectors and the framework customizes and/or extends their functionality. The architecture as well as the then existing devices have been presented at RealTime 2003. The following gives an update addressing the most important changes w.r.t. [8]. In addition, the framework has been redesigned to reflect user feedback, but this did not change the basic approach.

Supported Devices: Already in the earlier version of the framework package, components for voltage devices from CAEN and WIENER were supported, as well as the ATLAS development "ELMB" [9]. The range of supported CAEN devices has widened, and will be extended by the new CAEN EASY system in a short while. Several other devices are pending and that number will increase, as soon as the hardware final choices are made by the experiments. Apart from these "simple" devices, for example complete racks are being supported (monitoring and control).

Available Tools: The main tool for controls system developers continues to be the JCOP Framework Device Editor and Navigator. From there most of the tools are reachable. These tools include the Finite State Machine (FSM)[10], a Trending Tool to ease the visualization of data, an access control tool, a Configuration Database tool, and a mass configuration tool, among several other tools.

Supported Protocols: In order to connect a control system to hardware devices, but also external systems, a basic set of protocols is needed. The framework provides support for the most important ones in relation with CERN installations: OPC as the standard protocol for connection to commercial hardware, DIM[4], which is mainly used for custom components, MODBUS, which is mainly used to connect to Schneider PLCs, and DIP[5], which is a DIM-based protocol for communication between external systems.

In order to manage these mix and match devices and tools, another tool has been developed to enable users and developers to install, re-install, and de-install components when needed. The current understanding is that also complete sub-detector DCS applications could be packaged as components and moved from one machine to the other, or split over several machines, if performance problems exist, in which case this installation tool will also be used.

The user feedback on the redesigned framework package is overall positive. This comes from mainly three advantages:

- users—in this sense developers of end-user applications—like very much the simple way, that real-world devices are included into the supervisory controls by very few configuration steps,
- the speed of including full devices, i.e., adding complete high voltage crates, cloning them, reconfiguring them and their peripheral connections in a few seconds, and
- easy integration of own devices using templates for device support

[4]Distributed Information Management, see [11]

[5]Data Interchange Protocol, see [12]

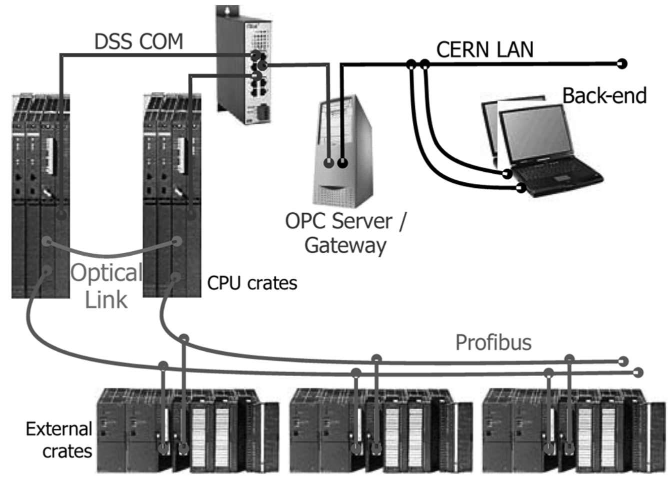

Fig. 2. General DSS Hardware Layout.

B. *Detector Safety System (DSS)*

One of the really common complete systems in all LHC experiments is the detector safety system. The DSS has the task of protecting the experiment's equipment, increase the data-taking efficiency by preventing situations leading to more serious alarms and decreasing downtimes due to system failures, and—in times of low budgets—should not cost too much.

Furthermore, the DSS should be easily integrateable into the control systems of the experiments, be able to connect all subsystem and sub-detector safety systems, provide capabilities to easily adapt to the evolving LHC experiments, and be maintainable over the lifetime of the detectors from the first sub-system to be tested on-site until the dismantling (a time-span of approximately 20 years).

This system is composed of a highly reliable PLC front-end and a back-end supervisor based also on PVSS (cf. Fig. 2). The customization for the different experiments is completely data-driven, using common software and a configuration database with consistency checking for all four experiments. A complete description of the system can be found in [5].

C. *Gas Control System*

Four LHC experiments will use different gases to run their detectors. In total, 21 different gas supply systems have to be run. In order to save resources in development, implementation, support, operation, and maintenance, a common system project has been launched. This includes also a common controls system for these gas installations based on a model driven approach, where modules are common, and selected as required for the specific application. This sub-project currently goes into the deployment phase, after having produced and reviewed prototype installations.

D. Rack Monitoring and Control

Probably the most common item between all LHC experiments is a rack. As simple as it seems, a rack has a large variety of building blocks and with that a large number of items to control and monitor. The rack project hard and software development has been finished by now, and the project also goes into the deployment phase.

III. Deployment, Maintenance, and Support

After developing a component or an application, step one is done, after that the step of customization and deployment has to follow. This step is usually substantially underestimated, if at all reflected in the planning. Another step of great importance is maintenance, a phase which will be gradually entered in the near future.

During all phases, from development to maintenance and operation, it is crucial to have a working support concept, for the underlying software packages as well as all developed applications and components.

The overall plan for support and maintenance has been developed with the experiments and is laid down in a document [3].

A. Support Concept

Apart from the basic systems support (operating systems and computer support), a homogeneous support line has been put into operation.

Each experiment and sector at CERN has a central controls team providing support for their collaborators. This is the place where expertise about the SCADA software as well as the customization for the respective applications is concentrated.

On top of this, there is the so-called "first line" support, provided by the IT/CO group. Split internally into two lines—back-end and front-end support—the user has a single point of contact, which eases access to support resources and does not put the user into a position to choose which question go where. IT/CO maintains a very good contact to the producer of the chosen SCADA system, which in turn represents the next line of support for pure system-related problems. Apart from that, contacts to the providers and developers of all other used tools exist and IT/CO handles the dispatching of requests to those, in order to facilitate communication and avoid duplicate requests. This also includes contacts to PH/ESS, the group supporting the racks, and PH/TA1, the group providing the gas systems to the experiments.

In addition to all the standard support tasks, the first line of support also handles the issue of licensing of the used software packages.

B. Deployment Concept

Together with the experiments, a deployment concept has been set up. The central DCS teams of the experiments provide expertise on available tools and develop a concept for the overall architecture of their DCS. These small teams of typically 1-3 persons provide consultancy to the developers in the experiment. In addition, IT/CO has defined a contact person, who helps the central teams and follows the implementations and concepts inside the experiment.

A special role of the contact person is to help with the prototype projects of the experiments. Some of them have designated certain sub-detectors to be the first to implement a "final" controls system, and then to act as examples for the others. These projects need very close and in-depth support which cannot be provided by a support line, but rather by the controls contacts.

C. Maintenance Concept

The support and maintenance plan defines both the responsibilities but also what is covered by maintenance and support:

- the JCOP Framework components, no matter if they where developed by IT/CO or other JCOP members,
- all JCOP Framework documentation,
- the GCS framework and the 21 GCS applications, including all documentation,
- the DSS basic components and the 4 DSS applications, including all necessary documentation, and
- the rack monitoring, control, and safety system including all necessary documentation.

Maintenance and support will cover:

- bug fixes,
- implementation and testing of agreed modifications,
- upgrading to new versions of the underlying technologies and operating systems, and the associated testing,
- liaison with the teams supporting these technologies at CERN resp. at collaborating institutes,
- provision of tutorials and training material, as well as
- hardware repairs for common parts in GCS and DSS.

D. Training

In order to facilitate the understanding of the technologies used by the developers of components and applications, it is necessary to provide training for those. Initially, ETM gave courses on PVSS at CERN. These courses took a full week and used examples from their mainstream customers. However, it was felt that courses need to be tailored to the needs and expectations of users within the high energy physics community.

Therefore, since January 2004, a combined PVSS and JCOP Framework Course exists [13], that also takes a week, but targets all aspects of controls systems for large experiments. The first day of the course brings all participants up to speed with the front-end technologies and communication protocols used, like ELMBs, power supplies, PLCs, and OPC. In the following two days, pure PVSS is addressed, followed by two days on the JCOP Framework. The whole course is hands-on and gives the participants time to try and get used to the chosen approach for their experiments. The course was held 14 times at CERN and also at outside institutes, and received generally positive feedback from participants.

Additionally, since the beginning of 2005 another specialized course on the usage of finite state machines in LHC experiments exists [14]. In the up to now 4 instances of the course, 35 participants have learnt how to design, implement, and operate controls systems in a hierarchical way, and how to integrate sub-systems developed by others.

Aside from the courses themselves, the material (course manuscripts, worksheets, hand-outs) is publicly available and can also be used for self-study.

As more and more sub-detectors build applications for controls, an increasing demand for special courses exists. New courses and tutorials are currently being developed to suit the common needs of the user community, such as tutorials on special functions of the framework, security of distributed systems, and custom device integration.

Of course, this concept is targeted at the developers of the applications. In the near future, courses for end-users need to be set up. These will be mainly done by the experiments (for shifters, etc.), but also centrally (for common applications, like GCS and DSS).

IV. Gathered Experience During Deployment, Training, and Support

The redesigned JCOP Framework has been deployed in all experiments and was used for testbeam setups as well as so-called "final" sub-detector DCSs. Following the implementation of these systems, a lot of experience about the real usage in the experiments, as well as suggestions to ease programming has been gained.

One of the experiments designated a complete beam test as a test-bed for the final DCS. In this DCS, a handful of developers worked closely together and were followed and supported by the controls contact person for their experiment. This approach showed substantial savings versus traditional development. It was a very valuable experience for all interested parties, the sub-detector team, the central controls team of the experiment, the controls contact, the framework developers, and the whole JCOP community through many improvements which originate from that.

The approach of having a group of software specialists developing software for experiments vitally needs the feedback from real usage in a real application.

This could already be seen by the large amount of feedback coming from using the framework components in the training courses, where a large number of participants (~ 12) is exposed to the software and its usage.

The courses have especially shown to be useful to improve the user interfaces. One should never underestimate the number of possibilities, a group of users can find, how to get through a very small number of steps.

The feedback gathered through these activities lead to better tools and with that was benefiting all others.

V. Conclusion

The approach followed by JCOP to find the commonalities between the LHC experiments and to provide solutions to these problems has proven to be helpful in the development and testing of controls systems.

Positive feedback has been received for the approaches taken for support and maintenance, which blends in with the standard support lines at CERN.

The feedback on the idea of controls contacts to the experiments received up to now encourages the continuation of that service. It also helps the support groups to gain knowledge in the application of their technologies which is very often forgotten otherwise.

Courses have been given at CERN and outside and have proven to give the necessary knowledge to their participants to go away and develop their own applications.

JCOP will continue to follow this approach and the experiments will make use of the provided technologies in order to have operable controls systems at the time of startup of their experiments and beyond.

Acknowledgment

The contributions to the JCOP Framework software by members of the four LHC experiments are crucial for the complete package.

Mentioned trademarks are recognized as such, and all online documents are available, unless specified otherwise, from http://cern.ch/itco, or http://cdsweb.cern.ch, the CERN document server.

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