

INTEGRATING CONTROLS FRAMEWORKS: CONTROL SYSTEMS FOR NA62 LAV DETECTOR TEST BEAMS

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Abstract

The detector control system for the NA62 experiment at CERN, to be ready for physics data-taking in 2014, is going to be built based on control technologies recommended by the CERN Engineering group. A rich portfolio of the technologies is planned to be showcased and deployed in the final application, and synergy between them is needed. In particular two approaches to building controls application need to play in harmony: the use of the high-level application framework called UNICOS, and a bottom-up approach of development based on the components of the JCOF Framework. The aim of combining the features provided by the two frameworks is to avoid duplication of functionality and minimize the maintenance and development effort for future controls applications. In the paper the result of the integration efforts obtained so far are presented; namely the control applications developed for beam-testing of NA62 detector prototypes. Even though the delivered applications are simple, significant conceptual and development work was required to bring about the smooth inter-play between the two frameworks, while assuring the possibility of unleashing their full power. A discussion of current open issues is presented, including the viability of the approach for larger-scale applications of high complexity, such as the complete detector control system for the NA62 detector.

INTRODUCTION

NA62 is a fixed-target experiment [1] being constructed at CERN that aims at studying ultra-rare decays of K particles (kaons) and thus follow the research performed by the NA48 detector. The detector is scheduled to start Physics Data-taking in 2014, yet many of its components will already take part in preliminary operations in autumn 2012 to measure their performance.

The NA62 apparatus is composed of 10 subdetectors positioned inside and at either end of a 115 meter long vacuum tank. It is expected to observe around 100 ultra-rare K particle decays in two years of operation with proton beams delivered by the SPS accelerator at CERN.

The detector hardware of the NA62 experiment is a mixture of legacy NA48 equipment, such as its unique high-resolution Liquid Krypton calorimeter and brand new equipment that exploit the newest technologies, such as the ultra-fast Gigatracker [2] and the Large-Angle Photon Veto (LAV) subdetector.

In terms of controls, the detector is bigger and more complex than other contemporary fixed-target experiments at CERN, yet smaller than the scale of the

LHC experiments. In the order of 5,000 high voltage channels and 10,000 analog and digital values and parameters need to be commanded and monitored.

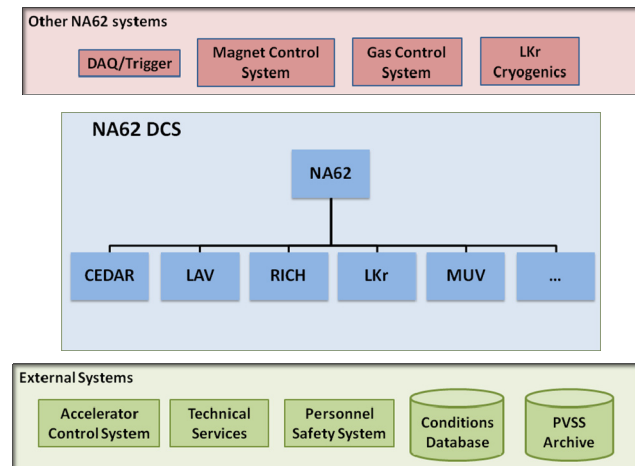


Figure 1: The NA62 DCS subdetectors and other essential systems from the CERN and NA62 infrastructure. [3]

To develop the Detector Control System (DCS) for NA62 (Fig. 1), a collaboration between NA62 and the CERN Industrial Controls & Electronics group (EN/ICE) was established in 2009. The aim is to develop and deliver the full-scale control systems for the final physics run, as well as other control systems that might be necessary for NA62 to test and commission their equipment. In this paper an example of the control systems used for beam-testing of the prototypes of the LAV subdetector is presented. These beam tests have been conducted in two-week periods of October 2009 and February and August 2010, and made use of the controls tools that are described in later sections. In April 2011 an application that monitors the environment of the storage area for the LAV equipment was developed using the same technology. This control system is still in operation.

CONTROL SYSTEM FRAMEWORKS

The supervisory control software called WinCC Open Architecture (WinCC OA is the new name for the product previously known as PVSS) [4] was selected as the basis of the NA62 DCS, in line with the selection made by the JCOF (Joint Controls Project) collaboration for the LHC experiments. The EN/ICE group at CERN develops and supports two controls frameworks based on WinCC OA. These are the UNICOS (UNified Industrial CONTROL System) and JCOF frameworks. These frameworks have been successfully deployed in large scale control systems

in the LHC accelerator and experiments, enabling considerable practical experience to be gained, permitting continual improvements and extensions of the features of both frameworks.

In addition to the WinCC OA frameworks, a suite of CERN communication systems are available for the exchange of information between systems and between the supervisory level and front-end. These systems include CMW (Controls MiddleWare) [5], DIM (Distributed Information Management) [6] and DIP (Data Interchange Protocol) [7].

UNICOS Framework

UNICOS [8] is a CERN framework developed to produce control applications for three-layer control systems (Fig. 2). UNICOS provides developers with the means to rapidly configure and generate full control or monitoring applications and provides operators with ways to interact with all the items of the process from the most simple (e.g. I/O channels) to high level compound devices with little effort.

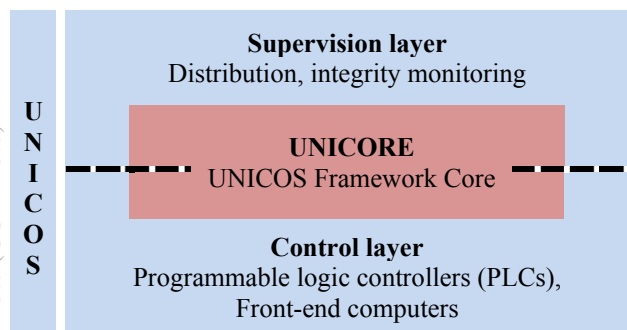


Figure 2: The three-layer control system architecture of the UNICOS Framework.

UNICOS offers tools to diagnose problems in the process being controlled and the control system itself as well as tools to access and operate the devices without specific development. The framework proposes a reusable environment composed of a set of components for the UNICOS-WinCC OA and UNICOS-Front End parts. At the supervision level in both Linux and Windows operating system, functionality such as application distribution across many SCADA data servers, monitoring the integrity of the application (e.g. status of the front-end) and configurable device trending are available. In addition it offers operators and application developers a configurable and homogenous user interface that is entirely customizable and which does not imply prior knowledge of the WinCC OA scripting language and the use of basic WinCC OA device access interfaces.

JCOP Framework

The JCOP Framework [9] focuses on providing a set of guidelines and software tools that can be used by control system developers to facilitate the building of controls applications. The framework provides a simple and standardised high-level programming interface to

common functions that are required at configuration and runtime in a controls application. In addition, developers are able to directly access the underlying WinCC OA features, enabling developers to go beyond the scope of the JCOP framework in order to take advantage of all the functionality offered by WinCC OA itself.

The software tools provided allow simple creation, configuration and hierarchical organisation of instances of device classes. The device centric nature of the JCOP framework defines the architecture of the final application. The JCOP framework provides a substantial library of functionality targeted to applications based on this architecture. A pre-defined set of hardware devices is provided as standard, covering devices that are commonly used in the LHC experiments at CERN.

Functionality of the JCOP framework includes:

- Saving and restoring hardware configurations and settings, with data being stored in a database.
- Organising devices into multiple hierarchical tree views, based on off-detector and on-detector layouts.
- Control of all devices via a hierarchy with integrated Finite State Machine logic.

Comparison of Frameworks

Historically, features of both the JCOP and UNICOS frameworks were developed by coordinated effort between the relevant development teams, meaning that at a low level, several fundamental principles of the framework internals are similar. However, due to their very different aims, there are considerable differences in some conceptual models and design assumptions upon which the frameworks are based. For instance, both frameworks are based around a method of modelling classes of devices. Yet the modelling concept of each framework is different, so any integration of the two must first address the issue of how to enable interoperability of tools previously designed to work with only one of these specific model types.

UNICOS offers a methodology to create a ready-to-use controls application by following a series of configuration and generation steps. It provides a framework that encompasses the hardware interfaces up to the final operator's view of the system. This high-level, comprehensive approach allows a developer to create a complete system without needing to understand many of the internal workings of the framework or WinCC OA.

The JCOP philosophy offers a set of tools and a defined architecture which the developers of control systems can use as a basis for building the complete application. The advantage of this is that an application developer has a greater degree of flexibility in the design of the final application, particularly at the level of the operator user interfaces. However, the JCOP approach requires a good understanding of the functionality of the framework itself and more knowledge of the WinCC OA scripting language as the developer must build their application from a library of pre-defined components.

The concept of combining both frameworks in the DCS of NA62 was inspired by the different and

complementary features of the two frameworks. By combining the functionality associated with many pre-existing JCOP device classes, with the simple and holistic application generation approach of UNICOS, the maximum benefit could be derived from these frameworks. NA62 is the first target of such a unification effort, acting as a driver for the innovative work that is required for this task. It is important that the functionality should be merged seamlessly for the final application builders and operators. There is a considerable amount of design, prototyping and testing effort needed to achieve the goal of a smooth harmonisation of these frameworks.

INTEGRATION APPROACH

As mentioned previously, the device modelling concepts of UNICOS and JCOP are different and the unification of frameworks at this level is the key to interoperability of tools from each framework. Previously, the high-level UNICOS application tools could only work with UNICOS-specific devices and front-end devices. The JCOP devices cannot make use of these tools by default.

One solution to this would have been the creation of duplicate models and instances of devices for both frameworks. This approach would have increase complexity and maintenance effort and, as such, is clearly not desirable. In order to avoid such duplication, a novel proxy interface was designed (Fig. 3). This proxy enabled JCOP device instances to be visible within the UNICOS domain with little effort for the application builder.

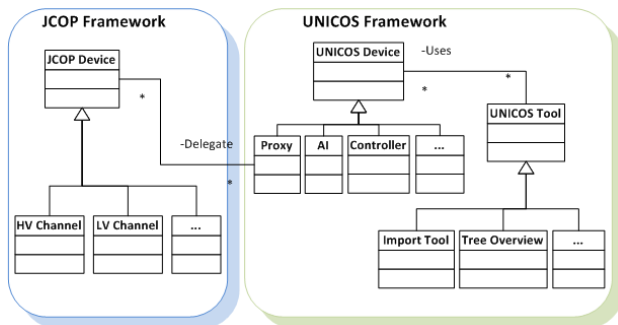


Figure 3: The proxy concept for enabling interoperability between UNICOS and JCOP domains.

In order to use this proxy mechanism, it is necessary to create a device or front-end in the UNICOS domain that contains no data. This object will act as the proxy to the JCOP device. Whenever a UNICOS utility is used with a UNICOS device, the proxy checks if the JCOP object is available and, if so, provides a transparent access to the data in the JCOP domain.

The proxy interface allows flexibility in the way devices are mapped between the JCOP and UNICOS frameworks. For instance, a UNICOS powering device could act as a proxy for a single JCOP powering channel, or a group of devices such as a multi-channel power supply.

FIRST PRODUCTION SYSTEM

As part of the collaboration between EN/ICE and the NA62 experiment, two prototypes were developed with the dual purpose of testing the framework integration concepts and providing the necessary control applications for the LAV subdetector.

The LAV subdetector is composed of 12 independent stations situated at points between 120 and 240 meters along the experiment. Each station is composed of 160 to 256 lead glass crystals with photomultipliers attached. These are assembled into rings, with 4 or 5 rings in each station (Fig. 4).

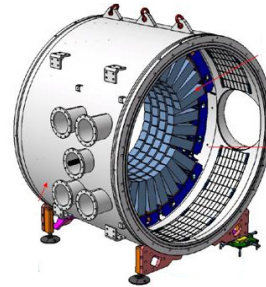


Figure 4: A representation of a LAV station. [1]

In the first LAV station alone, there are 30 PT1000 sensors to measure temperature as the LAV is sensitive to rises in temperature in the order of tenths of a degree. It is expected that 2496 high voltage channels will be needed, distributed between the 12 LAV stations.

LAV Prototype

The DCS for the LAV prototype (Fig. 5) was needed for operations of the LAV in test beams. It controlled and monitored two ELMBs (Embedded Local Monitor Boards) [10]; one to readout temperature sensors and the other to supervise vacuum pressure. The high voltage is provided by a single channel ISEG power supply and distributed via a Hamamatsu distributor, providing 160 negative high voltage channels. Both ISEG and ELMB devices were already supported by the JCOP framework.

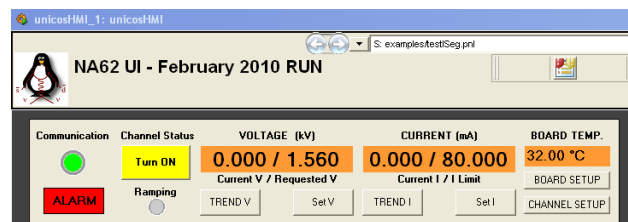


Figure 5: Extract from the LAV prototype DCS user interface.

The monitoring and control of the ELMBs and ISEG power supply was performed with WinCC OA and the combined framework approach mentioned in earlier sections. The high voltage distributor was controlled directly from a front-end program using a CAMAC controller and a CAMAC analog-digital converter.

In addition to the device level controls, a series of application level features were configured in the LAV

prototype DCS. These included an alarm screen, SMS notification of problems and checks on the DCS integrity.

LAV Environment Monitor

An additional application was required to provide long-term temperature monitoring of the area in which LAV stations are stored prior to installation. This application uses one ELMB with 32 PT100 sensors. The DCS application built upon the previous UNICOS-JCOP integration work for the LAV prototype DCS. Further work on this integration provided additional cohesion enabling the use of features such as the UNICOS trending tool. Other application features include access control and Oracle archiving to CERN central servers.

This application has been running in production for 6 months so far and was able to successfully detect of failure of the climate control system in the storage area.

CURRENT STATE AND FUTURE PLANS

In September 2011 the DCS for NA62 reached its first milestone: the completion of the “LKr (Liquid Krypton Calorimeter) Vertical Slice” application. This application provides integrated hierarchical control for custom high and low voltage systems of the LKr.

In this application, the synergy between the UNICOS and JCOP frameworks was raised to a higher level. The hardware that has typically been used in UNICOS, namely PLCs, has been brought under the supervision of the finite state machine based hierarchical control tool of the JCOP Framework and combined with analog value readout provided by JCOP ELMB devices. In addition, the hierarchical control tree has been embedded in the standard UNICOS user interface to act as the main navigation mechanism [11], providing the standardized look and feel compatible with other EN/ICE applications. The details of these integration efforts will be presented in a future paper.

The roadmap for future development of the NA62 DCS assumes that further synergy between the frameworks is achieved, so that a coherent and standardized engineering process could be established for future applications of a similar type. Based on the current experience and achievements of the “LKr Vertical Slice” milestone, a gradual evolution of the control application will proceed by including subsequent sub-detectors. An integration run in spring 2012 is planned to demonstrate the complete application in one quarter of its complete scale.

The work performed so far has demonstrated a significant interoperability between the frameworks. However, in order to reach the goal of closer integration, some topics will require further work:

- Further integration of the two device models.
- Widening of system integrity checks across the UNICOS and JCOP domains.
- Unified application generation including JCOP device instantiation.

CONCLUSIONS

The NA62 LAV and LKr applications have validated the approach to gain the benefits of both the UNICOS and JCOP frameworks. The device proxy concept enables the high level UNICOS tools to access JCOP data required at operations time. This provides a seamless interface to the control application operator.

Additional synergy can be obtained by integrating the frameworks together more closely. There are tools that are still limited to functioning in one of the two framework domains. As these issues are tackled, the full benefits of this combined framework approach will become available.

The further work required on the NA62 DCS will provide a suitable test bed and showcase for future integration work. There are still significant conceptual and design efforts ahead, but experience to date shows that the results of such work should be reusable in many future applications, providing a sustained improvement in efficiency of application building and maintenance.

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