THE CONTROL SYSTEM OF THE OPAL DETECTOR AT LEP

A.K. Amundsen, C. Beard^(a), H.J. Burckhart, R. Hammarström,
S. Jaffer and E. Meynet

CERN, European Organization for Nuclear Research,
1211 Geneva 23, Switzerland

ABSTRACT

The OPAL detector at the LEP accelerator in CERN is an ensemble of 14 subdetectors provided by 24 institutions. A control system has been designed and implemented to ensure the safe operation of the detector and to present the operator with a coherent picture of the actual status of the whole experiment. All operational parameters are continuously monitored and automatic actions can be taken by the system.

The hardware consists of about 30 VME stations, based on Motorola MC68020 microprocessors, running under the operating system OS-9. The software, written in FORTRAN and C, is organized in 3 layers : Human Interface, a suite of Skeleton programs, and applications.

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(a) Now at British Aerospace, London, UK

1. INTRODUCTION

The experiments at the $e^+ e^-$ collider LEP at CERN are of a complexity and size which require a dedicated, computerized control system. In particular safety aspects – the OPAL experiment is situated 90 m underground – require continuous monitoring of all operational parameters with the possibility of taking automatic corrective actions. The OPAL detector [1] consists of 14 subdetectors, built by 24 institutions in different countries, resulting in a wide range of hardware types. A coherent control system is necessary to enable one operator to run the whole detector without the assistance of an expert for each detector element.

2. REQUIREMENTS, DESIGN PRINCIPALS AND ARCHITECTURE

As outlined above, the control system must provide a continuous supervision of all subdetectors as well as of the general infrastructure of the experiment. When problems arise it must notify the operator and, if required, take automatic actions. It must therefore be operational at all times regardless of the state of the experiment and of the LEP accelerator. In fact the control system has to be available for the commissioning and installation of the subdetector elements, well ahead of the operation of the complete detector. When the whole experiment is assembled, it should provide a coherent and easily understandable presentation of the actual status of the entire detector in the control room. Remote access to status information should also be possible.

Because of these requirements, the system has to be as independent as possible from all other services such as power distribution, computer network etc.. The control system has therefore been divided into several distributed and independent stations, each powered by an uninterruptable power supply. For all safety related functions, the sensors and activators are always connected to the same station. Thanks to this independency, hardwired logic for security functions is not needed in the present case.

The control system follows the natural partitioning of OPAL into 14 subdetectors plus one additional "Common Controls" partition, which comprises the general infrastructure such as power distribution, cooling and gas distribution. This partition also interfaces to the LEP security systems GSS [2] and SDN [3], the LEP-wide hazard detection system which alerts the fire brigade in case of severe problems such as gas leaks or fire. Care has been taken to use as much hardware and software in common as possible for all partitions.

In order to have a homogeneous connection to the experimental Data Acquisition System (DAQ) and to minimize system development and maintenance effort, a processor of the same family and network hard- and software as used in the DAQ has been chosen for the control system. The Common Controls partition is included in the DAQ readout stream in order to include information of general interest such as temperatures, pressures,

voltages etc. in the physics event record. However for slowly changing variables, the control system has its own database for storing, retrieving and viewing of data.

3. **HARDWARE**

Each of the 14 subdetectors is controlled by its Local System Crate (LSC), a MC68020 based VME crate, which performs the event readout for this detector element. The partition Common Controls has 7 stations, 6 distributed over underground electronics huts, and one in the surface building, where the detector gases are stored and mixed. Such a station is schematically shown in fig. 1. It consists of the Common Controls System Crate (CCSC), an auxiliary crate (CCAC), interface boxes, an Apple Macintosh SE personal computer, and a lineprinter. All LSC and CCSC are connected to an Ethernet network.

The CCSC is a VME crate with a processor module (MC68020, Floating Point Coprocessor, 4 Mb dynamic RAM), an Ethernet interface module, a multiplexed ADC (1024 channels, 12 bit), and 2 general purpose input/output modules (24 bits bidirectional). The first of these sets relays for control actions and also connects directly to special interface modules, which allow the control system as well as the LEP GSS to enable/disable experimental equipment such as high tension or the gas supply for individual detectors. The second general purpose input/output module connects to the Crate Controller (CC) of the CCAC.

The CCAC, mechanically identical to a VME crate but having two P2-busses, houses Input Registers (IR) to sense the status of different equipment (gas valves, power circuit breakers etc.), Output Registers (OR) to control equipment (electronic crates, ventilators etc.) and monitor modules (FANMON). The latter are connected to sensors of the cooling system and read temperature and flow values. The response of all sensors is either an analog voltage (0–10 volts) or the activation of an electrical opto-isolated switch (open/closed). A control station has typically 500 analog and 300 digital channels to read.

4. **SOFTWARE**

The software is organized in 3 layers (fig. 2). The top layer is the Human Interface, and the bottom layer is formed by the application programs, which act on the hardware. The connections between these are dynamically provided by the Skeleton programs, which accept commands, validate them, hand them over to the application programs and take care that possible answers get back to the sender of the command. The three layers can run in the same station or be distributed over different stations, interconnected by Ethernet.

4.1 Human Interface

There is a variety of possible interactions with the control system, such as sending a command and retrieving an answer message. A comprehensive and powerful Human Interface to handle the whole of the OPAL detector has been implemented on an Apple Macintosh IIX personal computer, using the HyperCard tool [4]. It uses graphics to interact with the operator. SC_MENU is an alpha-numeric menu driven interface, which runs on a terminal. Run Control is a dedicated data acquisition program, while SC_ALARM displays warnings and alarms for the whole system. Commands are text strings which include the station name, the program name, the command itself, parameters for it and the receiver address for an answer message. Any computer on the network can be used as a sending or receiving node; however a clear separation is made between "harmless" commands (e.g. to get a status) and actions on the detector. The latter are normally not enabled from remote sources.

4.2 Skeleton

At boot time, SC_PROC starts all programs in layer 2 and supervises them. They are all written in the C-language.

Commands are sent to the program SC_FILTER, which checks their validity, writes them in a logfile if required, and passes them to the appropriate application in layer 3. This program executes the command, and may then send an answer message back to SC_ROUTER which has already been notified where the answer should be sent to, and which passes it on. Unsolicited output of the application programs, such as errors, is accepted by SC_ERROR, which logs it in a file and, if required, passes it on. Automatic corrective actions are handled in the same way and sent to SC_FILTER.

4.3 Applications

An important consequence of this clean separation into 3 layers is that the same application programs can run in both stand-alone mode, (e.g. for debugging, where the I/O is performed by a local terminal), and in integrated mode with the entire control system. They can be written in any language. The application programs are also supervised by SC_PROC, which starts and stops them on request.

A typical example is the program which reads the ADC of Common Controls, running in all CCSCs. This program is driven by a table which gives the characteristics of the individual channels such as their description, warning and alarm limits, actions to take etc.. It compares all parameters with their nominal values every 5 seconds, which uses about 10% of the computing power of a station. Asynchronously, it also accepts commands to show the status, change default values, disable actions etc..

5. OPERATION

The whole detector can be operated from a VME station in the control room via the network. This station is based on the same microprocessor as the others and has an Ethernet interface, a hard disk (60 Mb), a Macintosh IIx PC and a terminal. The station interrogates the distributed stations in regular intervals to make sure that they work and to get their status. It also retrieves the remotely acquired data and writes them onto disk.

The Macintosh normally displays the overall status of all subdetectors. The operator can request detailed information by clicking with the mouse on the appropriate field of the graphical status page. All data of the Common Controls partition of the last 6 months can be shown graphically on the screen. All displayed information can also be sent to a laser printer. The terminal shows permanently all warnings and alarms of all parameters monitored by the control system.

In case of failure of the interconnecting network, subdetectors can still be operated locally and safety related monitoring is of course still guaranteed and operational.

6. CONCLUSIONS

The OPAL control system design has used a layered architecture to achieve modularity. This makes it possible to run the same software in many places and enables very easy implementation of user written application programs. The system is easily extendable.

The architecture chosen has made possible the control in a coherent way of all the subdetectors, despite their diverse nature, of the common infrastructure and last but not least of the safety parameters.

The system was ready on time and has proven to be both user friendly and very reliable.

REFERENCES

- [1] OPAL Technical Proposal (1983).
- [2] GSS (General Safety and Surveillance), Technical Note No.3,
CERN/EF-LI/0031N/ES/lp (1985).
- [3] SDN (Station de Détection et de Neutralisation), Summary Technical Specification,
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FIGURE CAPTIONS

- Fig. 1 Hardware setup of a control station to monitor safety equipment and the general infrastructure of the experiment.
- Fig. 2 Software architecture of the control system. The bold arrows indicate the path for commands, the broken arrows refer to answer messages, and the faint arrows are for unsolicited output such as errors and commands for automatic actions. The connection across layer boundaries is dynamic.

Fig. 1

**Layer 1 :
Human Interface**

Fig. 2

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