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Abstract

The new computer control system is conducting the heavy ion accelerator GANIL from the beginning of 1993 and has reached a state of routine operation. It was carried out to supersede the obsolete initial system and to cope with the harsh experimental conditions required by the very high intensity beams envisioned for the next future. Hardware and software implementations, as well as human interface, are presented. Emphasis is placed on the three-layer distributed architecture adopted. An ETHERNET local area network (LAN) links the basic components : a VAX/VMS cluster, XWINDOWS interfaced operator consoles, VAXELN driven CAMAC crate controllers and programmable logic controllers for front end controls. Also data management with the INGRES relational database management system (RDBMS), as well as operating software written in ADA language, are described. First experience with the new control system is reported. Finally, trend considerations are addressed.

1. INTRODUCTION

The GANIL three-cyclotron accelerator provides fast heavy ion beams for fundamental research in experimental physics and for industrial applications. Any ion species from Helium to Uranium is able to be accelerated, with output energy ranging from 95 MeV/u for light ions to 25 MeV/u for the heaviest ions.

The 10-year old control system of GANIL had to be renewed to meet the increasing requirements of the accelerator operation [1]. These requirements cover the current operator activities (beam setting and tuning, supervision, diagnostics, etc..) and prospectively the control of very high intensity beams and radioactive beams.

Implementing the new control system in the existing environment had to face two types of constraints :

- *manpower overwork*. The team in charge of renewing the control system had also to support the old system which often overshadowed the new system construction.
- *operation continuity*. The need to guarantee continuous experimental program prescribed to migrate to the new system in a transparent fashion for the accelerator users.

Design and implementation guidelines are :

- Purchase, whenever possible, commercial hardware and software products which comply with acknowledged open standards, to minimise development time and to save investment.
- Adopt the distributed architecture urged by breakthroughs in the field of local area network technologies and communication protocols, to favour modular structures and easy extensions .
- Promote windowing , color graphic oriented operator interface, to achieve smart man-machine interaction.
- Introduce a relational database management system to master the increasing number of data and the large diversity of information necessitated by modern accelerator operation [2].

The renewal of the GANIL control system is a considerable undertaking. It actually means in hardware : replacing all the computers and other processors, replacing the operator consoles, restructuring the CAMAC network, and in software : replacing the operating software and all the user tasks which are not portable. The renewal project was launched by fall 1989 and conducted to completion at the end of 1992. Commissioning was carried out during the yearly machine shut down, from December'92 to February'93 . Accelerator control was handed over to the new system which runs thenceforth without disruption and in a fully encouraging way.

This paper will cover the present status of the new control system from the standpoint of computer controls. Also, operator controls will be addessed.

2. SYSTEM OVERVIEW

This section presents the new control system from the viewpoint of computer controls.

2.1. ARCHITECTURE

The architecture of the new control system is widely distributed, in contrast to the first generation system which featured a centralized topology ruled by an outdated 16bit minicomputer. At present, powerful processors provide local intelligence deployed along three functional levels as shown on Fig.1 .

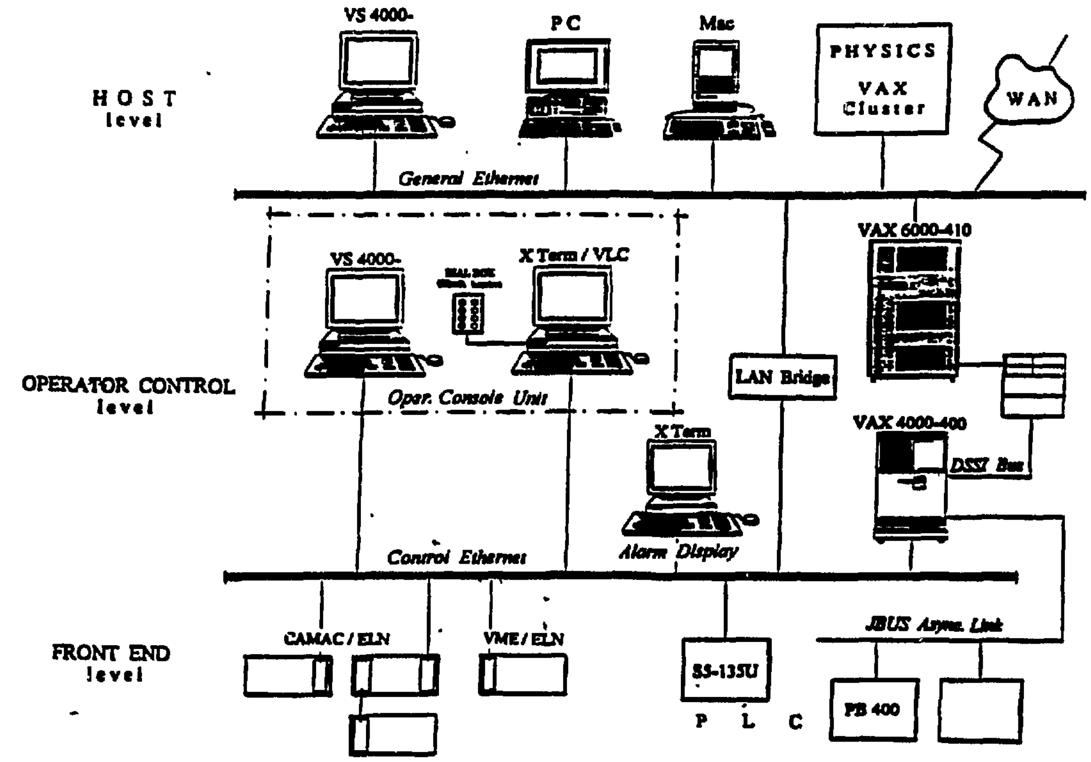

Fig.1 : Architecture of the New Control System

- 1/. ***The HOST level*** provides a fully equipped environment for off-line development : ADA programming, debugging, data management, accelerator parametrization, .. This level is supported by a supermini computer VAX 6000-410 from DIGITAL EQUIPMENT, workstations VS4000 with high definition color screens for graphics oriented development. The system operating on the VAXs is VMS. The HOST level also gives access to other facilities of the laboratory like PCs and Macs, to the Physics Acquisition VAX cluster, and to remote laboratories.

- 2/. ***The OPERATOR CONTROL level*** supplies all the appropriate man-machine tools for operators to conduct the accelerator. This level is ruled by a computer VAX 4000-400 running under VMS. Operator consoles are equipped with workstations VS4000, Xterminals for multi-windowing color graphics, and shaft knob boards for incremental controls. Operator interface will be emphasized in §3.1. The VAX 6000-410 and VAX 4000-400 are mounted in DSSI cluster for resource sharing.

- 3/. ***The FRONT END level*** deals with real time field controls. Processors currently used are : -a/ CAMAC front end controllers (FECs) KSI3968 from KINETIC SYSTEMS. FECs embed the RTVAX300 chip and execute real-time applications under the VAXELN operating system, within a host/target configuration. They replace the former L2-type serial controllers in the 25 crates of the CAMAC network. -b/ Programmable logic controllers (PLC) to control subsystems like vacuum, interlocks, ion source. In addition to the 20 old APS30-12, there are two PB400 from TELEMECANIQUE-APRIL and five S5-135U from SIEMENS.

2.2. NETWORKS

ETHERNET local area network is used to link the functional levels described above. The so-called General ETHERNET LAN links the HOST level to the OPERATOR CONTROL level, which is in turn connected to the FRONT END level via the Control ETHERNET LAN. A LAN Bridge is used to filter communication between the General ETHERNET LAN and the Control ETHERNET LAN. Today, the traffic load is still moderate , but future communication between FECs may change the figure. Moreover, distributed architecture permits to scatter intelligence for local processing and favours reduction of traffic. Communication protocols currently used are DECNET, TCP/IP and LAT. Links to remote laboratories are provided by wide area networks (WAN). S5-135U PLCs are directly connected to the Control ETHERNET LAN and communicate with VAX processors through OSI/ISO standard services provided by the software packages VOTS and VSH1. PB400 PLCs are hooked to the node VAX4000-400 via an asynchronous serial link which supports the JBUS master-slave communication protocol. Use of JBUS as field bus is envisioned for power converter control.

2.3. SOFTWARE

The new system software was carefully designed and implemented to achieve high performance controls, with provision for easy future evolution.

2.3.1. Choices

Basic choices presented two years ago to the ICALEPCS'91 Conference at Tsukuba are final [1].

Noteworthy choices are briefly recalled :

-Operating systems : VMS is used for VAX and workstations, while VAXELN is devoted to real time controls. VAXELN is fully compatible with VMS within the host-target model : applications are developed on the host VAX 6000-410 to target the CAMAC FEC's for real time control.

-Languages : the first choice language is ADA, selected for its capabilities in multitasking, software components, real time constructs and realibility. FORTRAN and C are runners up, but fairly far behind.

-Industry softwares : Additional software packages used are the INGRES Relational Data Base Management System from the ASK Group, the IMAGIN packages from SFERCA for supervision of programmable logic controllers, XWINDOWS MOTIF for operator console display within a standard windowing environment.

2.3.2. Controls

To achieve controls of the GANIL facility, a key software layer was built upon the industry softwares . This so-called GANICIEL layer, which rules over the whole control system, is not a translated version of the former one which is by no means portable. The new GANICIEL is thoroughly redesigned and coded in ADA language, with nearly one half million code lines. It obviously makes use of the client-server model to fully benefit from the distributed architecture. The following updates the distribution of main GANICIEL functions described in [1] :

- *At operator control level,* the VAX 4000-400 operates as a global server. It executes functional processes to handle the requests sent by console workstations or by CAMAC FECs : initiation of functions on boot or on resumption, supervision of networking operation and FECs execution, alarm handling , database management (more in §2.3.3). Workstations are chosen for operator interface. Principal functions accomplished are : Xterminal management for operator choice (tasks and pieces of equipment names), algorithm to translate hook names into hardware addresses, local presentation of alarms, beam control applications with MOTIF widgets [3],[4],[5].

- *At frontend level,* field controls are achieved by CAMAC FEC's running VAXELN. The GANICIEL on FEC's (alias GANICIEL/ELN) is presented in detail in [6]. Its main functions are : communication serving and incoming message processing, hook command processing, alarm handling and pertinent alarm message dispatching to the main alarm server installed on the VAX4000-400, and last but not least, control of about 1800 pieces of equipment of the accelerator. The GANICIEL/ELN design stipulates, for coherence purposes, that each piece of equipment is under the control of solely one CAMAC FEC. Some CAMAC modules have to be re-structured to comply with the above rule. Moreover, the 1800 pieces of equipment are sorted into 11 classes of equipment. Each class is controlled by a specific piece of GANICIEL/ELN named "handler", with a relevant driver for each model of CAMAC module.

2.3.3. Data management

Data management is taking a significant part in the new control system, considering the different natures of information (e.g. machine configuration, acceleration conditions, beam parameters, real-time controls, operation logs,..) and the number of data to handle. This topic is discussed thoroughly in [7]. Only the basics is presented below. Following the decision made at the outset of the renewal project to use a database management system and benefit from technology progress in this field, the INGRES RDBMS was chosen for the main following reasons: this mature commercial product is widely used in different laboratories and industrial plants, it fits our environment : hardware independence which permits integration in our VAX/VMS system, ADA/SQL interfacing, it may be managed and administrated by a small team of two persons, it provides tools which feature high integrity, homogeneity and nice ergonomic capability, it supports the WINDOWS/4GL language which allows to build graphic database user interface, it is famed as a reliable product with good support.

The INGRES configuration is based on a client/server architecture : An INGRES server is running on the VAX6000-410 to perform software development and off-line database access. WINDOWS-4GL applications are developed on workstations. The real time layer has its own INGRES server installed on the VAX 4000-400 to serve operator consoles applications. A complete data management environment, with a set of databases, was constructed :

- *Database for front-end equipment controls* . Each CAMAC crate has its specific live database which is a subset of the INGRES database fragmented into 4 files and downloaded into the CAMAC FEC's. FECs run thence in autonomous mode to achieve real time performance, the INGRES RDBMS only operates at the background level.

- *Database for alarm system* at management level as well as at real time level. Alarm messages are archived for retrieval and off-line inspection .

- *Database for beam parameters* following an object-oriented parametrization of the machine. This database contains all the parameters related to each ion beam accelerated. Data stored are either produced by off-line calculation or captured from actual tunings of the machine. A W4GL application can be activated from any console and permits operator to consult easily the archived parameters with many retrieval criteria.

- *Ancillary databases* . These databases provide additional services to improve the comfort of the operation :

. Viewing and statistics : a dedicated W4GL application help operators to store the chronology of actual operation conditions: experimental rooms served, failures, etc .. Data stored are extracted afterwards from a MacIntosh station to feed an EXCEL application for statistical reports.

. Management of the operator menus.

3. ACCELERATOR CONTROL

This section overviews the new control system as seen by the operator.

3.1. OPERATOR INTERFACE

Operator interface at GANIL mainly consists of console units. Some dedicated graphic terminals provide local access to the SIEMENS programmable controllers.

3.1.1. Operator Consoles

Operator consoles in the new control system are constructed upon off-the-shelf industry products, to free from the burden of home-developed equipment. Workstations are adopted for their standard windowing environment. An operator console is a twin-screen unit built around a VAX/VMS workstation VS4000-60 and a Xterminal/VLC-workstation for processing power and high definition color graphics, under the MOTIF XWindows system. Each console unit is equipped with shaft knobs to perform controls in incremental mode. These knobs, grouped by eight units into the so-called "dial-box", are supplied by DEC for CAD purposes (Fig.2).

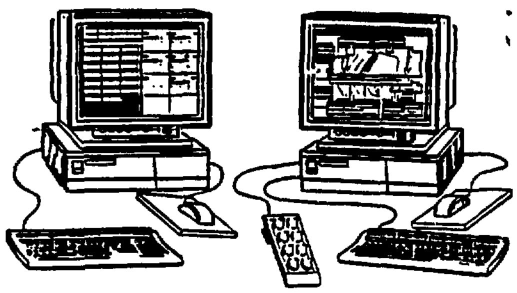

Fig.2 : An Operator Console Unit

Accelerator controls are exercised within two interleavable modes :

- a/ **Individual mode** to provide standardized incremental control of any piece of equipment, by turning assigned shaft knob and observing the read-back results on screen windows,
- b/ **Global mode** to achieve fully customized control of many types of components by running ADA applications.

The current operator consoles lay out is : four units in the Main Control Room (Fig.3) for centralized control , one unit in the electronic backbone gallery for field control and servicing, one unit for provisional local control of SISSI (a Superconducting Intense Source for Secondary Ions), and three units in the Physics experimental areas.

Fig.3 : View of the Main Control Room

In the Main Control Room, thermal wax-transfer printers provide fast color screen hard copies. Also pertinent alarm messages are displayed on a specific Xterminal screen with color/severity level coding to speed up interpretation.

3.1.2. Supervision

Supervision at GANIL is built on top of the commercial software package IMAGIN, with satellite components such as a graphic editor, a real-time database, an acquisition module. Applications are written in ADA or FORTRAN. In use since fall 1989, supervision stands for our first approach of the new control system. Available applications are : - Beam Stoppers controlled by a PB400 PLC.,- ECR 14 GHz Ion Source installed on a 100kV platform, under the control of a S5-135U PLC,- Internal temperature of the seven RF cavities, sensored by PT100 probes to load a S5-135U PLC, - Septum of Medium Energy Output controlled by a PB400 PLC,- Vacuum System controlled by a S5-135U PLC,- Superconducting Intense Source for Secondary Ions (SISSI) controlled by a S5-135U PLC,- Dynamic fan-out of power converters in the switchyard controlled by a CAMAC FEC. A supervision interface is shown on Fig.4.

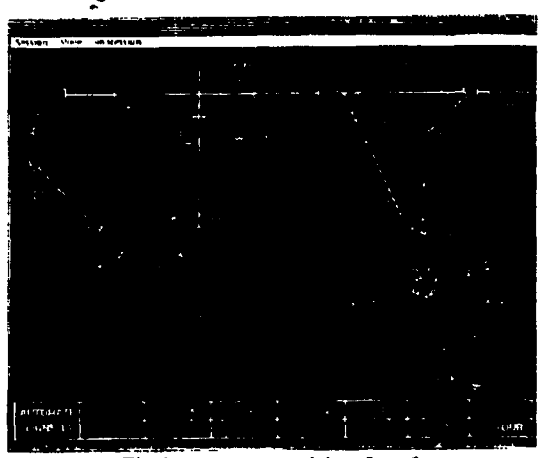

Fig.4 : A Supervision Interface

3.2. OPERATOR APPLICATIONS

3.2.1. Accelerator Control

A first set of operator applications was developed in ADA to provide the basics for accelerator control [8]. Operator may activate these applications by means of soft buttons displayed on console screen. Current operator interfaces feature MOTIF windowing (e.g. Fig.5 shows a visualization of beam loss at injection and ejection of the cyclotrons). DECTERM is still used in some applications.

3.2.2. Database Access

Operator may browse through the INGRES databases via graphic interface supplied by W4GL applications, as shown on Fig.6. Also, alarm messages can be retrieved for analysis, according to a multi-criteria selection (e.g. data, name, ETHERNET node,..).

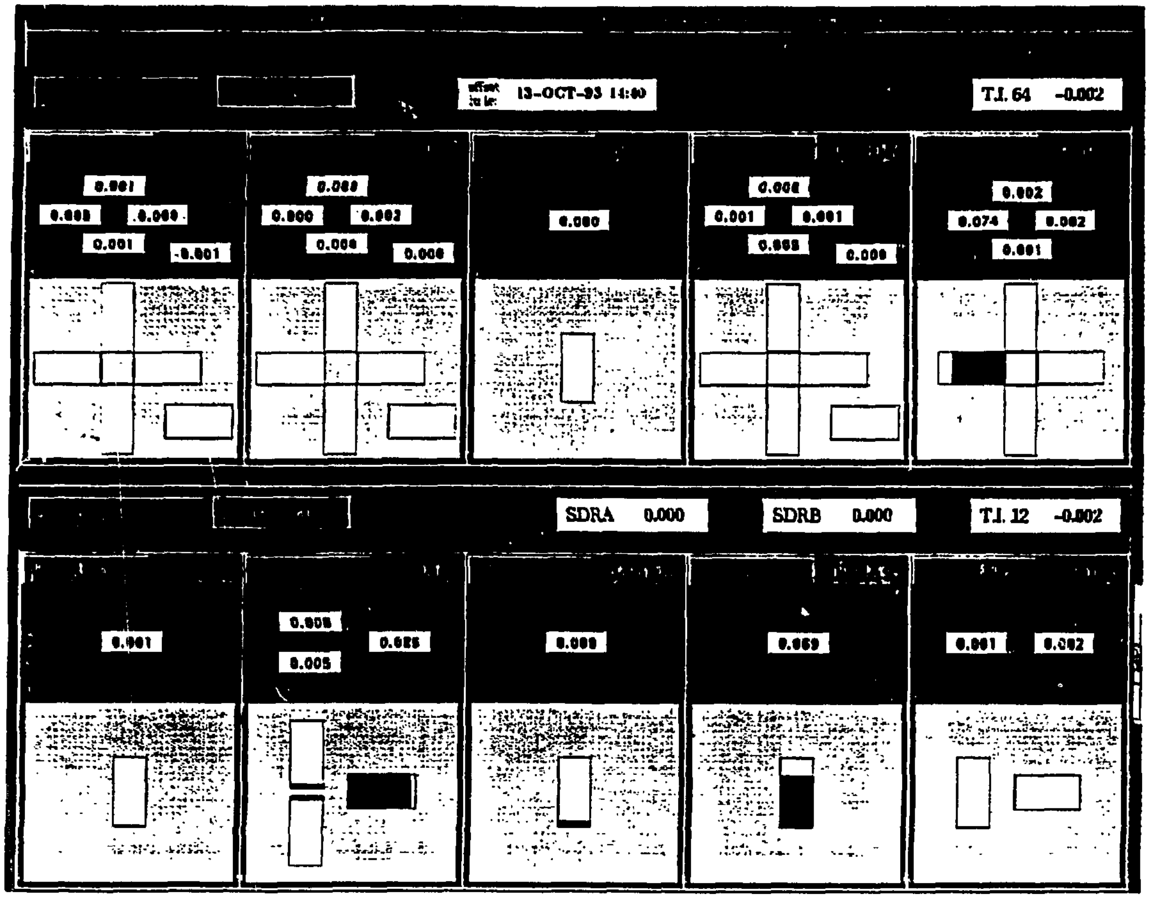

Fig. 5 : A MOTIF based Operator Application Interface

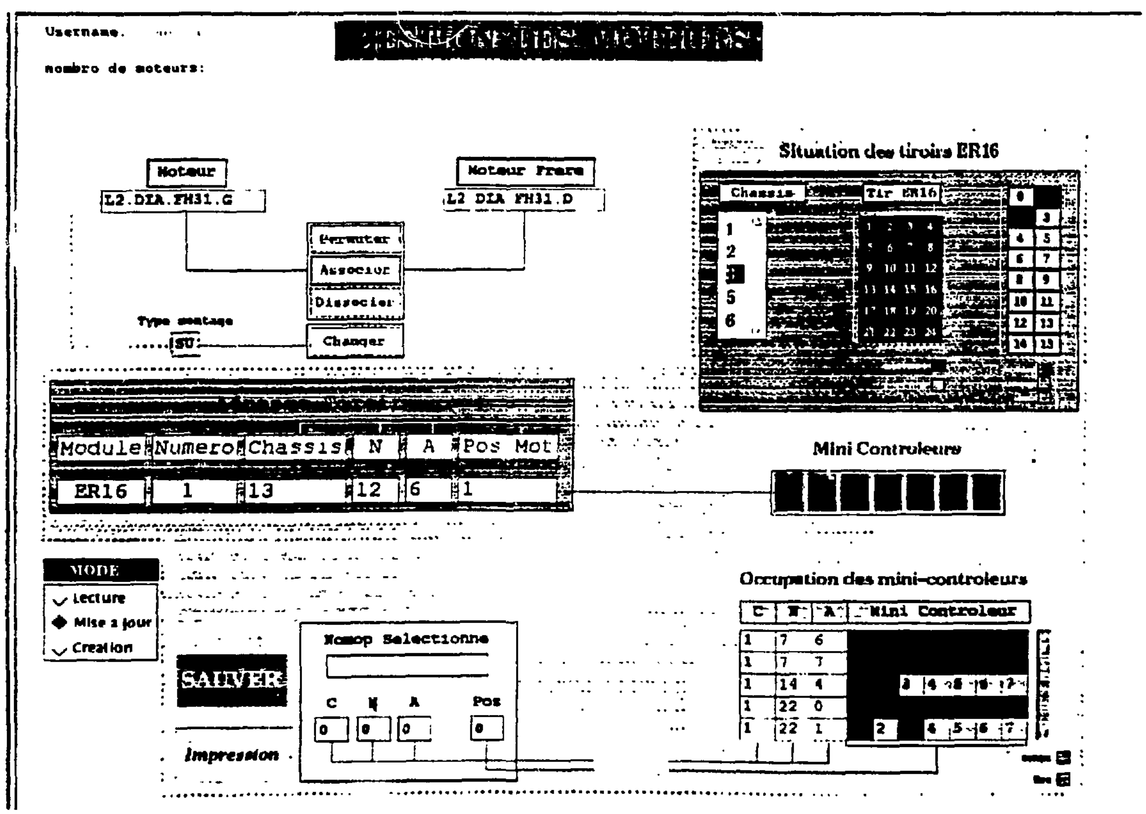

Fig.6 : A Databse W4GL Interface

4. FIRST RESULTS AND TRENDS

4.1. FIRST RESULTS

The new control system was commissioned during the accelerator shut-down, from December'92 to February'93. It was rapidly adopted by the operators and experimenters, thanks to the familiar twin mode of man-machine interaction, and the color graphic oriented interface which provided self-guided control screens. The operator application set has to be completed and expanded to fulfil the operation needs. The results achieved in the course of the three first quarters are quite promising.

4.2. TRENDS

Current activities are channelled along two main axis :-a/ Hardening the control system, to ensure reliable and efficient accelerator controls, -b/ Increasing the functional capabilities of control applications (e.g. on-line parameter calculation, beam profile displays,..), as well as extending the scope of RDBMS applications.

In the near future, the new control system will have to supply appropriate software tools to meet the severe operation conditions necessitated by the acceleration of very high intensity beams and radioactive beams.

5. CONCLUSIONS

An essential step was accomplished to provide the GANIL accelerator with a high performance and flexible computer control environment.

Renewal project.

. The project reached its challenging goal *on schedule*.

. About 40 man-years, in three years, was the manpower necessitated.

. The control system renewal is conducted to completion and commissioned in the smoothest possible fashion for the experimental program : no disruption of round-the-clock beam acceleration, no beam production schedule specially tailored to back up the migration to the new system.

Status.

. The accelerator is operating under the control of the new system since the beginning of this year.

. No unscheduled shut-down of the accelerator is caused by a malfunction of the new control system.

. The new control system is definitely qualified to conduct the accelerator. The old control system can be discarded soon, without harm for the GANIL operation.

Salient features.

. Commercial standard products (hardware and software) are used, whenever possible, to avoid specific in house-development.

. A three-layer distributed architecture is adopted, with VAX/VMS processors and workstations on the upper layers and CAMAC/VAXELN and PLC on the lower front end layer. Layers are linked by ETHERNET.

. High processing power with great expansion capabilities are provided.

. ADA, chosen as major language, is experienced as productive, efficient and reliable.

. XWINDOWS MOTIF operator interfaces feature widely accepted graphic oriented controls.

. The INGRES RDBMS with W4GL interfacing permits flexible and powerful information management.

Future.

Two domains are mainly aimed :

- ***controls techniques*** to fulfil performance and dependable services.
- ***accelerator operation*** to significantly improve the operation timing figures, to provide a high degree of beam availability and to achieve productivity, within comfortable operator controls conditions.

ACKNOWLEDGEMENTS

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