

CONVERSION OF THE CERN PS BOOSTER CONTROLS :
LOCAL HARDWARE TEST AND ACCELERATOR STUDY FACILITIES

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Summary

The CERN PS Booster (PSB) has been connected to the new computer control system (NORD-CAMAC) during the four months' shutdown in summer and autumn 1980. Subsequently the PSB had to furnish beams of high quality, particularly for the Antiproton Accumulator (AA). To make the change-over efficient and possible within the time and manpower limitations, local autonomous microcomputer-aided test facilities were used for more than a year. These were designed (i) for the development of process equipment including its electronics, (ii) for equipment commissioning, (iii) for fault diagnosis and (iv) for the improvement of the future machine performances. The specifications, the detailed implementation and the results are reported.

Introduction

Much of the equipment of the CPS accelerator complex was connected to a computer control system in the late sixties. This computer system was built from an IBM 1800 computer¹, a CERN-designed digital data transmission system (STAR) and three IMLAC PDS1 mini-computers used either as central control consoles in the Main Control Room (MCR) or as a slave local console in PS-Booster (PSB) equipment rooms². As the CPS developed a new control system based on a NORD 10 computer network^{3,4}, CAMAC (both parallel and serial) and general-purpose consoles, were designed and are being implemented. The PSB, already almost completely under computer control, was selected as the first slice to be converted during the four months' shutdown in the summer and autumn of 1980. Local computer-aided test facilities were necessary to prepare in advance the hardware interfaces, to commission equipment during the conversion period, to localize faults and to carry out local machine experiments after the conversion, in particular those involving new and as yet manually controlled PSB equipment or requiring local observation or manipulation.

Constraints

To gain meaningful experience and to facilitate operation afterwards, the entire PSB switch-over was to be made in a single operation (July 20th to November 19th, 1980). The PSB still had to be operated from the old IBM control system up to July 20th, while it had to furnish high intensity proton beams for the Antiproton Accumulator (AA) and in the new ten bunch mode of operation shortly after the conversion, with operation entirely from the new control room. During this short period of time one had i) to disconnect equipment from the old control system, ii) to connect equipment to its new specific interface and to CAMAC, iii) to test and calibrate the entire analog chain, iv) to connect to CAMAC systems or sub-systems not previously under computer control and test them with the new computer system and v) to rebuild and commission some essential systems such as the central timing system.

The switch-over operation concerned roughly 400 magnet power supplies of various types (about 70 of which were of entirely new design) four radio-frequency accelerating systems, the beam control system, the control timing system, some displacement mechanisms, the vacuum system, the usual beam transducers (beam current transformers, beam position detectors, beam profile monitors) and a few sophisticated instrumentation devices such as the Q-measurement system.

As new control protocols, specially for the power supplies or the R.F. accelerating system, were introduced and standardized, much of the PSB equipment had to be modified or adapted via a specific interface to comply fully with the new control rules.

As regards staff, due to time and manpower limitations, all persons involved in the conversion of the accelerator hardware had to be trained to write the software required to test their own equipment via the computer interface; so some staff had to become acquainted with the particularities of a computer system whose possibilities and limitations were not fully understood.

The conversion period being limited to four months (including the summer holidays) much preparation work was done in advance before the central computer services were fully available. Hence some local facilities were necessary to simulate the future computer system; manual test boxes were not sufficient for this.

Specifications of the local test facilities

Responsibility for the conversion was shared mostly between two technical groups. One group (CO) is responsible for the computer network, the CAMAC interface and the consoles, while the other group (BR) is responsible for the PSB hardware and its specific interface to CAMAC. This distribution of tasks favoured a solution where any fault could be localized quickly and without ambiguity as being in the CAMAC and computer system or in the PSB equipment and specific interface. A hardware specialist working party (HSA) defined the specifications of the means to gain access to equipment locally, before and during the conversion period on the one hand and the means for future local accelerator studies, on the other hand.

The local test facility was specified as follows:

- i) it had to be mobile, so as to be operated from as close as possible to the equipment under test, hence it should be a device of limited weight on a single trolley,
- ii) its use by non-software experts had to be relatively easy, the use of a high-level language was essential to start with, assembly language was also to be available for time-critical applications (should the need arise),

- iii) it had to have a means to store and print out programs and data files; for this, floppy disks and reliable printers were desirable,
- iv) it had to be able to generate CAMAC commands at the level of the CAMAC dataway so as to incorporate the CAMAC modules in the local equipment test (overlapping test through CAMAC modules to get rid of fault localization ambiguities),
- v) at least three identical units were to be provided,
- vi) compatibility with the NORD 10 computer system would be an asset for future software portability and a good communication means between experts from various areas.

The performance of the local accelerator study facility was specified as follows:

- i) to allow, after MCR agreements, unrestricted control of all PSB parameters, thus enabling machine experimenters and hardware specialists to create and deal with any operating mode of the accelerator,
- ii) to allow acquisition of all PSB parameters and relevant subsets of parameters of the downstream and upstream machines required for the more complex beam measurements,
- iii) to have the interactive means and procedures and the display facilities similar to those of the MCR general-purpose consoles,
- iv) to provide adequate mobility and range to reach the principal hardware concentrations with only one such facility,
- v) to allow occasional local debugging of application programs as well as access to data files, provide hard-copy facility and inter-communication to the MCR,
- vi) output from the analog signal observation system (SOS)⁵, logging and public information facilities were not required.

All these specifications were discussed with the computer experts and both commercial and CERN designed solutions were contemplated.

Various local test configurations

The various control modes of a given equipment are shown in Figs. 1a through 1d. Fig. 1a shows the connection of a process equipment to the central computer network through serial CAMAC, in such a configuration there are no local test facilities available other than manual ones. This version was used to test locally the various safety interlocks (alarm tree), communication with the MCR being made via head sets. The most popular configuration used during the conversion is shown in Fig. 1b. The equipment under test can be disconnected from the central CAMAC system and reconnected to a local stand-alone CAMAC microcomputer. These connections are easily made on the front panel connectors. Any test can then be carried out with this facility. Local test programs stored on floppy disks can be run to test equipment, to diagnose faults or to calibrate. The CAMAC modules are exactly the same as the ones shown in Fig. 1a. Once the equipment is ready for operation, connection to the central CAMAC system is straightforward. There exist two versions of this stand-alone CAMAC microcomputer (see below).

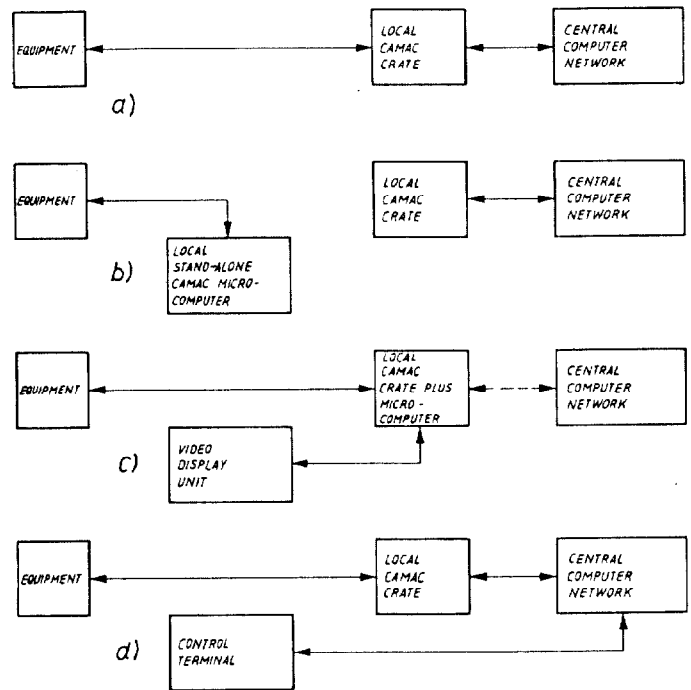


Fig. 1

- a) No local controller
- b) Local stand-alone CAMAC microcomputer, no central comp. action
- c) Local control via local microcomputer
- d) Local control via the central computer network.

Another configuration also used in the PSB is shown in Fig. 1d. A local terminal connected to the central computer is used as an interaction means after MCR agreement, test commands go through the usual data communication link between the process equipment and the central computer. There are no hardware connection modifications at the level of the equipment to be tested. This local terminal facility appeared very useful for debugging programs running in the TMS 9900 based microcomputer which is housed in the CAMAC crates (there are 24 decentralized CAMAC microcomputers⁶ in the PSB control system).

The intermediate solution shown on Fig. 1c, though implemented, was rarely used in practice.

Development and results obtained with the local test facilities

Fig. 2 shows the integration of the various local test facilities in the computer network of the PSB control system.

Various test programs were developed by hardware specialists. Three test programs are used to test the actuation bits, the status bits and the calibration of magnet and kicker power supplies. One program tests all the features of the four radio-frequency accelerating systems, another one is used to monitor the septum mechanism. All the specific interface modules of a set of power supplies were automatically tested in the laboratory, by means of one of these facilities. Beam position pick-up electrode electronics and timing system were also tested in a similar fashion.

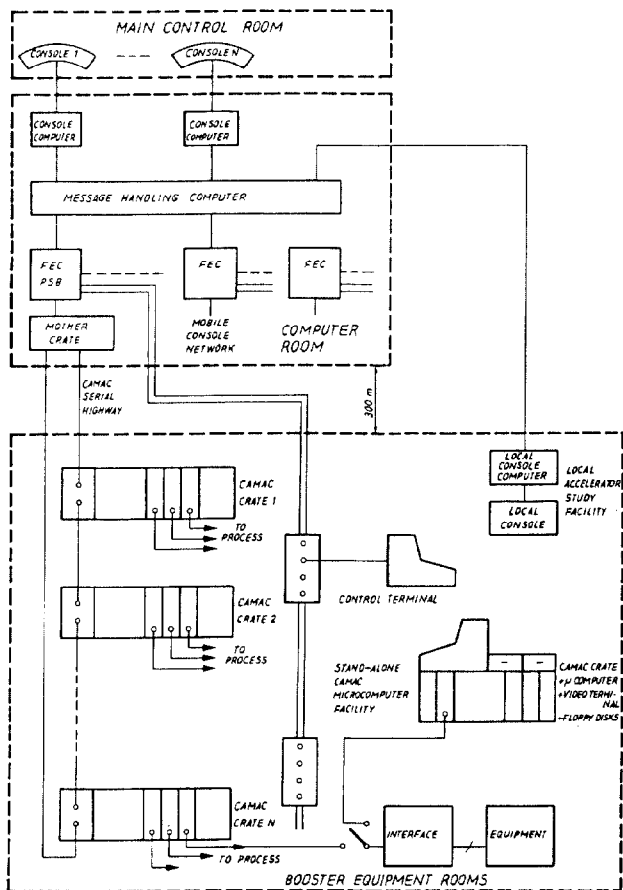


Fig. 2 - Integration of local test facilities in the PS Booster Control system.

During the PSB conversion a fully commercial solution was taken for the local hardware test facility shown in Fig. 1b; it consists of an Intel 8080 based CAMAC microcomputer manufactured by KINETICS Inc. This unit referred to as the 8010 has a keyboard, a video display unit, a set of two mini-floppy disks, the CAMAC microcomputer and the CAMAC crate to house the CAMAC modules to be used for the tests; provision is made for the connection of a serial printer. The programming languages are BASIC and the 8080 assembly language; the user memory space is 20 k bytes. An improved CERN-designed version of BASIC is much faster than the original version and allows easier references to CAMAC⁷. To insure future compatibility with the other machines the standard version of the local test facility is a CERN-designed CAMAC microcomputer using a 16-bit TMS 9900 microprocessor with the standard interpretive language NODAL⁸ and a NORD-10 compatible floppy disk driver. Central hardware tests could be modified to be run locally.

After training of the PSB hardware specialists, tests of the interfaces started in mid 1979. The use of an interpretive language with an 8-bit microprocessor did not show any speed limitations for our local test programs. Should the need arise, hardware specialists are now ready to use assembly language (either Intel 8080 or Texas TMS 9900) for time-critical applications or to improve application program.

Another test facility was implemented and mostly used by control experts (cf. Fig. 1d). A four-channel distribution system allows one to connect up to four independent control terminals to the process computer from a set of patching points distributed all over the PS Booster equipment rooms. A control terminal consists of a video display unit and a keyboard for the time

being, adding other facilities is considered. The control terminal is near the equipment and allows a complete check of the control link including the process computer, the CAMAC, the interface and the equipment. The equipment is then accessed by the interpretive language NODAL either through elementary serial CAMAC commands or directly through the relevant equipment oriented software driver. This terminal was first exclusively used by control experts for debugging auxiliary crate controllers; it is now gaining wider acceptance by PSB hardware specialists who can thus perform tests without disconnecting cables.

For the local accelerator study facility, a large subset of the main control room consoles is being implemented. This facility includes all the features of the central consoles with the exception of the analog and video signal multiplexing system, unmodified central hardware tests⁹ are then available locally.

Conclusion

Our cumulative maintenance and machine experiments procedures based on a local means of interaction showed that it was necessary to implement more specialized mobile computer facilities near to the equipment to be controlled or serviced. The new local test facilities proved to be indispensable both during the preparation and the carrying out of the controls conversion. They made the transition possible within the time and manpower limitations without too much stress on the hardware specialists, and thus also introducing the PSB hardware specialists to the use of computers (both micro and mini) in control applications. These local test facilities are now accepted and used daily. Future accelerator studies will benefit from the local support having the same interaction facility and the same display programs as the central control room.

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