USER'S ASSESSMENT OF THE COMPUTER CONTROLS SYSTEM OF THE CERN PS BOOSTER

G. Baribaud, G. Benincasa, A. Daneels, P. Heymans,
C. Metzger, F. Pedersen, M. Rabany, K. Schindl and J. Stark

MPS Division, CERN, Geneva, Switzerland

Summary and Introduction

The CERN PS Booster[1] (PSB) was designed to be completely computer-controlled and no manual back-up was foreseen. The physical construction of the four-ring PSB necessitates simultaneous operation of different parts of the accelerator and therefore requires a multientry software facility. A significant feature of this facility is the data base, which links the software to the hardware of the accelerator and also leads to an increase in the versatility of tests and operation. The evolution of the system from its conception, through the phases of commissioning and running-in, each with its different needs, to the present operational stage is described. Attention is drawn to the lessons that have been learnt during the first two years of exploitation. The initial phases were made more difficult because it was impossible to separate completely effects due to the commissioning of the controls system and the first tests of the accelerator. However, the investment in this first phase gave rise to substantial benefits as soon as basic settings for the PSB were found. The current phase of operation typifies some of the problems involved with simultaneous development of a machine and its computer-controls system. There is a certain conflict between those who have to operate the machine as it is and those who want to develop the control system further. Most aspects of the system have worked satisfactorily from the start, but some have been less reliable. However, it is hoped that the effort which is being given to the hardware will allow more sophisticated tasks, such as closed-loop control, to be carried out.

Computer-Controls System

The basic computer configuration[2,3] for the Linac, PSB, and CPS (Fig. 1) includes an IBM 1800 with 48K of core memory (16-bit words) operating under MPX (Multiprogramming System), and several peripheral devices (two PDS-1 minicomputers to drive alphanumerical and graphical displays and a Varian 620i satellite to generate analog functions). A 4K partition is dedicated to each accelerator where application programs are housed. Core resident programs go into higher level partitions called Special Areas, shared with other users. A larger partition of 6.5K, called Variable Core (VCORE) is used for background programming and for execution of long or special programs called on interrupt (Interrupt Core Loads) when requested by a partition. The more important application programs in use are listed in Table 1. The total length of programs is about 350K words; 20 man-years were required to define, write, debug, and optimize these programs. Most programs refer to the data base[4] (∿ 700 process variables) which was introduced to avoid conflicting control from the various operator consoles: three midi-consoles (Fig. 2) (for the injection line, RF, and transfer line), a central maxi-console (Fig. 3) concentrating control of all subsets, and a mobile console, used for hardware tests in the equipment rooms (Fig. 4). The control and data acquisition of the four PSB rings are largely independent of each other but are synchronized with the Linac and the CPS. The essential components of the control system are assessed in Table 2.

Problems During Running-In

At present the system works as specified. While certain parts were satisfactory from the start, others had teething troubles, though not more than would be expected for a system of such newness and complexity. Two types of problems are discussed, those which turned out to be more serious than anticipated and those which had not been fully foreseen.

When deciding that there would be no manual back-up from the Main Control Room (MCR), it was realized that if one of the major components of the control system failed, the accelerator could no longer be controlled. (In view of the expense of full manual back-up, the risk was nevertheless taken.) Thus the situation of sometimes not being able to change a parameter setting by computer was a major handicap until reliability improved sufficiently.

Trouble was caused by the front-end equipment (transmission system, converters, power supplies) in the early stages of running-in. This was mainly due to trying to start up the accelerator at the scheduled time although some of the construction staff had moved to another project before they had reached the testing stage of their equipment. It was only with the first beam in the machine that the control system could be fully tested out, and therefore it had to be accepted that the last part of the running-in of the software coincided with the running-in of the PSB.

As for the multi-user computer system itself, computer crashes caused by program development occasionally disturbed the PSB program under execution. Since less program development occurs now, this is less noticeable. Besides this, the data base on disk was sometimes erroneously overwritten. The situation has been improved by introducing protection in the form of a software indicator. A long-standing puzzle has been solved only recently. An injection line magnet changed its value when no-one was working with it. It shared, by error, its control address with an ejection dipole (controlled from a different midi-console). There is no protection against this, but a checking program has been written.

Three problems arose in connection with the function generator, which has been in heavy use since the beginning. Firstly, some operators found it clumsy to use (possibly because of insufficient contact during the design). As a remedy, for some functions (choice of Q-values during cycle) an automatic setting procedure has since been implemented. Secondly, up till now, there has been no digital acquisition of a complete function. This will be rectified. Finally, if the Varian computer breaks down, the PSB stops. A back-up Varian has recently arrived.

Finally, the human element played its role in determining the speed of running-in. To the operators, not only the accelerator but also the control system was completely new, and they were unaware of the full capabilities of computer-assisted control. For some of them, accustomed to controlling a machine by hand, confrontation with a control system, supposedly easier but in practice more difficult during the early stages of running-in, led to psychological problems.

Among the problems not fully foreseen were the following. Initially, the information on the status of the elements was not displayed continuously. When a power supply tripped, the operator would notice this through its effect on the beam but there was no immediate information from the control system on such an event. This has been overcome with the introduction of the Status Display and the Repetitive Varilog on the midi-consoles (see Fig. 2 and below).

The injection line quadrupoles which are controlled by stepping motors (incremental control) were lengthy to set by hand or by program. Recently a closed loop iteration procedure program has been used successfully to set up the injection line focusing.

While the bulk of the measurement, data treatment, and display programs (which were ready at start-up) fulfilled their requirements, some modifications and additions were, on occasion, needed rapidly. This presented no particular problems, notably thanks to the close collaboration between machine and software specialists.

Aspects of Special Interest to the Users

i) During optimization from the midi-console, the operator can compare the current machine set-up with a reference set-up without, however, losing the current values (stored in a buffer on the disk-based data base). Owing to the slowness of the computer disk accesses, these subset operations are used much less frequently than had been hoped. Such an operation takes about 40 seconds. As often only a few parameters vary between different settings, the operator does not take much longer to make a comparison by tuning only these parameters. However, a subset operation regularly used is the setting from the maxi-console, for which 40 seconds is very short compared with the time for a manual setting of some hundred parameters.

ii) The voltages of the four accelerating cavities are controlled by high-speed generators. The parameters of the given mathematical function are controlled by program through the RF midi-console. This allows one to obtain a mathematically described function from the digitally controlled voltage generator just like any ordinary process variable. At present the procedure to enter changes is slow owing to limitations of the present system. A program orientated more towards advanced machine experiments is being developed and will include a facility to reduce the voltage slowly during the cycle to obtain a constant bucket area.

iii) Watchdog programs fall into three categories. Firstly, whenever a status changes, the number of parameters that are OFF (power supply disconnected) and NOT READY (down) is displayed on the midi-console (Fig. 2). Secondly, there are programs called at regular intervals: a) Vacuum Survey displays an alarm message forewarning vacuum specialists of possible breakdowns; b) RF Voltage Generator Survey checks the memories of the Voltage Generator and displays and resets those that have varied; c) Repetitive Varilog warns the operators of parameters drifting away from reference values. A problem with the Varilog is that only one reference value exists on disk and different operators require different reference values -- a fixed theoretical value, a value gained from experience, or a value taken when the beam was running well. Finally a statistics program compiles beam histograms[1].

iv) The Booster electronic equipment is located in the Booster building (about 400 metres from the MCR), and it is there that various calibrations and adjustments have to be made. Originally the results could be observed only on the maxi-console in the MCR, which implied, in addition, communication between the MCR and the operator working on the electronics. It was decided to introduce a second, mobile, maxi-console in the Booster building. It can be connected, through a single cable, to the computer network from any one of seven different points. This allows the operator to move the console close to the equipment being tested. The mobile console offers the same facilities as the maxi-console in the MCR, so the 'computer-control-acquisition' loop can be thoroughly checked locally. The console is regarded as an extremely useful tool by those responsible for PSB systems.

v) The data base may be updated and modified via the interactive display by means of a special program. Users quickly learned how to check or modify characteristics such as conversion factors, status bit coordinates, maximum values, permissible variations, etc. They had the possibility of fitting the relevant data bank parameters to reality, masking a status bit, etc., within a few minutes. Whole runs might otherwise have been lost! Thus we found that the risk of having vital parameters changed by inexperienced operators is small compared to the advantages of a flexible data base for program development and accelerator operation.

Conclusions and Outlook

At this stage the correctness of the major options (use of existing IBM 1800, addition of a satellite for real-time work, choice of multi-access consoles, introduction of a data base, no manual back-up, addition of the mobile console) are confirmed by our good experience. The midi-consoles remain an easy to handle setting-up tool. The maxi-console is used for more complicated tasks. We are less sure whether we should not have already introduced an interpreter facility (not available when the control system was defined). We expect this to be particularly useful for machine experiments. While nearly all PSB parameters are computer controlled and/or acquired, there remain a few (important) exceptions. We expect to complete their computerization in the framework of the expansion of the PS computer system. At the same time we plan to expand the PSB system's monitoring and fault analysis facilities. Like any other system, the computer control system needed running-in. This progressed more quickly and easily where there was close co-operation between the control engineers, PSB system specialists, the programmers, and the operations team. Most of the authors were newcomers to the field; now that we are familiar with computer controls we are looking forward to using the extended capabilities of the expanded system under construction.

Acknowledgements

We are greatly indebted to the former and present members of the CO/CCI Group, in particular E. Asseo, H. van der Beken and J. Bosser, who designed and built most of the PSB computer control system and are now working on its expansion. C. Bovet has defined the machine physics content of a large number of application programs and contributed to their implementation. Constructive criticism by the PSB operating team has led to numerous developments. K.H. Reich suggested substantial improvements to the manuscript.

References

1. The PSB Staff, this conference.

2. E. Asseo et al., Proc. Particle Accelerator Conference, Chicago, 1971 [IEEE Trans. Nuclear Sci. 18, No. 3, 354 (1971)].

3. G. Benincasa et al., Proc. IEE Conf. on Software for Control, Warwick, 1973 (IEE Conference Publ. No. 102), p. 57.

4. A. Daneels, Proc. National Computer Conference, Chicago, 1974, to be published.

5. K.H. Reich, Some thoughts on the data acquisition and control systems for the CPS Booster, CERN Internal Note SI/Note DL/69-5 (1969).

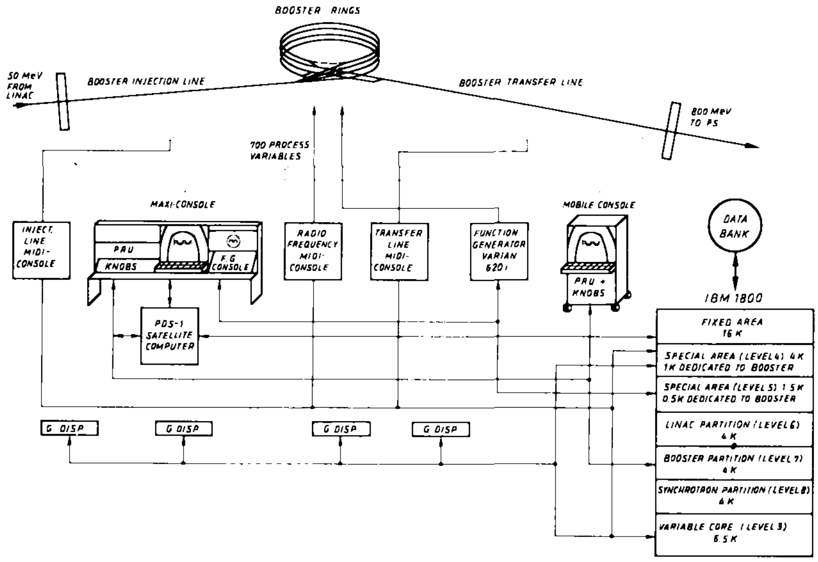

Fig. 1 On-line operation facilities at the PS Booster

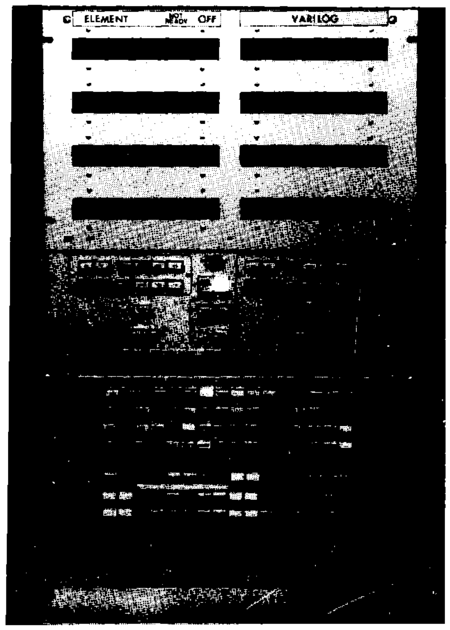

Fig. 2 A midi-console

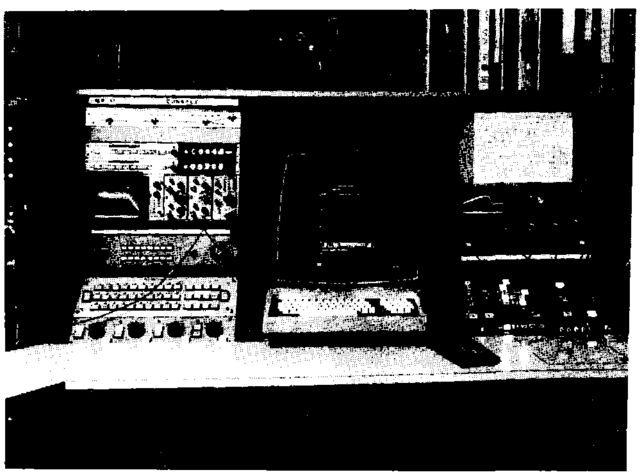

Fig. 3 The maxi-console

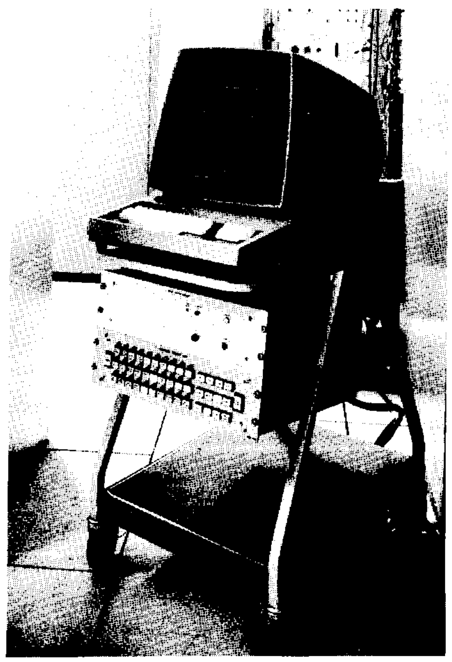

Fig. 4 The mobile console

TABLE 1 COMPUTER PROGRAMS

No.	Program name and description	Frequency of call/week	Length of time/ call (C= Continuous)	Further uses (see below)	Input media (see below)	Output media (see below)	Refers to data base	Length (K words on disk)
	GENERAL OPERATION PROGRAMS							
1	MIDI-CONSOLE (see Table 2)	300	5 sec	HT	M,D	M	YES	15
2	KNOBS	50	15 min	HT	P,KNOBS	P	YES	27
3	STATISTICS. PSB intensity	21	8 h		P	L,D	NO	10
4	LOG. parameter print-out	50	2 min	ME,HT,ST	P	L	YES	16
5	VARILOG, Display of parameters outside tolerance	10	3 min	ME,HT,ST	P	P	YES	10
6	STATUS DISPLAY on PDS-1	40	30 sec	ME,HT	P	P	NO	6
7	GENERAL DISPLAY (see Table 2)	100	C	ME	Push-buttons	Nixies	NO	3
8	REPETITIVE VARILOG. Watchdog	10 min	30 sec	ME	P	M,D,P	NO	6
9	TRANSFER LINE PICK-UPS CALIB.	2	3 min	HT,ME	P	P,T,D	NO	5
10	SETTING, of 12 PSB sub-sets	10	30 sec	HT	P	P	YES	57
11	PARAMeter behaviour display	20	5 min	ME,HT	P	P,T	(YES)	9
12	VACUUM, Past and present state of pressure in pumps	30	10 sec	HT	P,Vacuum panel	P,L	NO	15
13	RF VOLTAGE GENERATOR	5	10 min	ME	M	P,M	YES	16
14	FUNCTION GENERATOR (see Table 2)	20	10 min	ME	F.G. Console	Oscillo-scope	NO	1
	BEAM OBSERVATION PROGRAMS							
15	LINAC SPECTROMETER	30	30 sec		P	Televi-sion	(YES)	7
16	LINAC EMITTANCE	20	30 sec		P	Televi-sion	NO	4
17	Q-MEASUREMENT in both planes	30	10 min	ME	P,Q-meas panel	P,T,L	NO	5
18	ORBIT DISPLAY (with dipoles control and Q-calculation)	50	10 min	ME	P,RU-panel	P,D,L, Cards	YES	38
19	IONIZATION BEAM SCANNER (IBS) Evaluation of beam profile	15	5 min	ME,HT	P,IBS-panel	P,L,D	NO	33
20	800 MeV LINE MEASUREMENTS Spectrometry and emittance	10	10 min	ME	P,800 MeV-panel	P,T, Cards	YES	16
	CONTROL SYSTEM DIAGNOSTICS (HARDWARE AND SOFTWARE)							
21	UPDATE DATA BANK	15	2 min	OP	P,D	P,D	YES	7
22	READ DISK	20	30 sec		P,D	P	NO	2
23	REPETITIVE RF VOLTAGE SURVEY	2 hours	2 min		P	P,T	YES	3
24	RING PICK-UPS HARDWARE TEST	1	10 min	OP	P,RU-panel	P,RU-panel	NO	3
25	MIDI-CONSOLE HARDWARE TEST	1	5 min		P,M	M	NO	2
26	KNOBS HARDWARE TEST	1	5 min		P,KNOBS	P	NO	1
	MISCELLANEOUS FAULT RECOVERY							
27	RESTART PARTITION	1	30 sec		P,IBM switches	IBM 1800	NO	1
28	RESTART PDS-1	4	30 sec		PRU button	P	NO	1
29	ENABLE FUNCTION GENERATOR	2	10 sec		PRU button	F.G.	NO	1
30	COLD START MIDI-CONSOLE	2	30 sec		PRU button	M,P	NO	1

OP = Operation, ME = Machine experiments, HT = Hardware Test, ST = Software Test

T = Typewriter, L = Lineprinter, M = Midi-console, P = PDS-1, D = Disk

Table 2 Survey of the PSB control system

Item	Purpose and reasons for choice	Performance expected	Assessment in March 1974
IBM 1800 (in MCR)	Process control computer (already used by CPS). Use by PSB implied i) no delay in making choice and ordering a new computer; ii) profit from CPS knowledge and experience.	i) Almost all elements effectively controllable and acquirable from MCR. ii) Watchdog and statistics programs. iii) Hardware tests[5] and calibration facilities.	All performance aims attained. However, sharing the existing computer led to some constraints, particularly program length.
Alphanumerical and graphical display (in MCR and at PSB)	Centralized interactive console driven by IMLAC PDS-1 mini-computer.	i) To allow fast on-line interaction with programs. ii) To display results of programs in an easily understandable form.	Good for alphanumerics but should be improved for graphical displays. Hard copy facility very much appreciated.
Varian 620i (at PSB) with special console (in MCR)	Flexible generation of up to 48 analog functions in real time.	Interactive creation and modification of functions from the console.	i) Performs as expected. ii) Sampling of function incomplete.
Three midi-consoles (in MCR)	To allow simultaneous control of three PSB sub-sets without syntax handling; simultaneous control of two selected parameters of a sub-set (increase, decrease, inversion of polarity, ON/OFF).	i) Possibility of linear coupling of variables. ii) Common operation on all parameters of the entire sub-set. iii) Display of information on parameters under display and watchdog programs.	i) Very useful in setting-up periods. ii) Watchdog programs are a useful diagnostic tool. iii) Slow in operation, owing to repetition rate (twice per acceleration cycle) and disk access time on IBM. iv) Too many buttons (120) for operator comfort.
KNOBS (in MCR and at PSB)	Four incremental encoders with which one can control most of the PSB parameters from a central point.	i) Ability to form special couplings. ii) Ability to work alongside other programs, e.g. beam quality measurement programs.	Very useful during steady operation and for machine experiments.
General display (in MCR)	Twenty Nixie displays distributed over the control room. Already used by CPS.	Cycle-to-cycle display of manually selected parameters such as Q-values, efficiencies, mean radial position.	Gives an over-all view of the machine. Name of displayed parameter difficult to read.
Program Request Unit (in MCR and at PSB)	Push-button matrices from which i) programs can be called into core; ii) options can be exercised in running programs. Already used by CPS.	i) Queueing of programs. ii) Easy to handle by operators. iii) Flashing light to show which program is running.	Performance expectations attained. With increasing number of programs, limited number of buttons led to: i) regrouping of several programs in one button; ii) too rigid nomenclature for the option buttons.
BCER console (at PSB)	Alphanumerical and graphical display and Program Request Unit. A facility for local hardware testing in the Booster building.	To give most of the facilities of the central console.	Turned out to be indispensable for maintenance and calibration. Shares computer access with central console.
Data base	Up-to-date image of the current accelerator state covering most PSB variables ($\sim$ 700) with their characteristics.	Easy to use for setting and other application programs. Automatic updating of current control values. Easy modification of parameter specifications.	Its flexibility has been greatly appreciated, especially during the running-in period, but misuse possible.
STAR	16-bit parallel data transmission system for acquisition and control. Already used by the CPS. Designed for use over long distances.	i) Reliable transmission in range of 20 to 100 K words per sec. ii) Random addressing of up to 1024 process variables per call.	i) In general, meeting requirements. ii) Connection to specific electronic systems is very simple. iii) Diagnostic equipment to speed up fault localization is being improved.