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ADVANTAGES AND CONSTRAINTS OF MODERN ACCELERATOR CONTROL SYSTEMS

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Abstract.- An accelerator control system is the interface between the human operator and the machine and has to fulfil various requirements. Though increasing the complexity of a system automatic control and computing power are of great help for machine operation.

1. Introduction.- An accelerator control system acts as the interface between a human operator and machines in varying operational states generally called the process. Control systems are nowadays computer based and cover a large range of applications such as surveillance, man-machine interaction and closed loop control

Given today's state of the art the hardware can be designed to be modular and highly standardized. As a result these systems are reliable, easily maintainable, flexible with regard to their application and still extendable. The addition of microprocessors allows one to implement local intelligence.

The use of computing power has opened a new field of applications which facilitate machine operation and which cannot be made available in hardwired controls. These applications are, however, dependent on the computer operating systems and the facilities which they offer.

Accelerators are often one-off machines with specific requirements, often also entering a new technological field. Therefore, we find that control philosophies may be transportable to a new accelerator, but a specific implementation normally is not.

2. Control Requirements and Strategies.- An accelerator is designed to produce a particle beam with certain beam properties. A control system may be regarded as the communicator between the human operator and the various accelerator elements to make the machine produce that beam with given properties, i.e. it fills the 'grey area' of fig. 1.

On the one extreme end you can fill up this grey area with wires which establish a one to one correspondence between a knob, a meter, or a light and the corresponding machine parameter or status. The control of a parameter is direct and the reaction is easy to follow up. As a consequence control panels grow in size as the number of machine parameters increases. The operator finally has to walk around when operating the machine. In addition, if a certain beam property is to be changed the operator must know which algorithm correlates which parameters to which beam properties.

On the other extreme end you can imagine, nowadays, a sophisticated computer assisted control system within the 'grey area' which allows the operator to sit down with only the parameters of interest in view and varying a certain beam property as 'direct parameter'. He is handling beam optic parameters instead of power supplies. The computer system holds and executes the necessary algorithms. It will set all the corresponding machine parameters and will display the beam-dynamical reaction.

It goes without saying that this area can be reduced to some sort of black box with only a few buttons available for machines in 'fixed beam applications' such as isotope production, etc. In the scientific research area, however, a fully computerized control system must fulfil various kinds of operational requirements such as running in, start-up and normal operating, testing, trouble-shooting and maintenance, as well as machine development, thus fulfilling needs of engineers and machine physicists as well as those of operators 'merely trained for normal operation'. The system must provide single parameter access from the general purpose con-

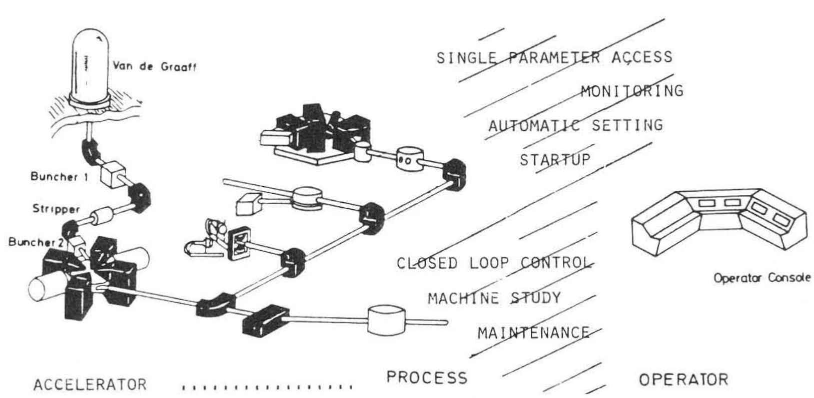


Fig. 1: Symbolic view of various requirements to be fulfilled by control systems

trol station as well as locally on the one extreme and should also provide the possibility for closed loop control on the other.

Within this scheme different approaches to computerized control have been taken in existing accelerator installations, depending very much on whether computer control was implemented right from the beginning or added at a later stage.

The methods may however be summarized as follows[1]:

- simple setting, logging and monitoring.

  The computer system will set the various parameters according to precalculated or previously logged values. This yields beams with prescribed properties if all systems involved are stable and reproducible to a very high degree.

- continuous non destructive measurement of beam properties or semi-continuous measurement with interception.

  On the basis of a beam with certain properties having been produced the computer system may monitor these properties, compare them to required values, calculate the corrections and may automatically perform the adjustments. In this case a highly developed beam diagnostic system and a thorough knowledge of the relations between machine parameters and beam properties are required.

  This approach may be combined with automatic setting, logging and monitoring. The strategies are either static, such as control to a prescribed value, or dynamic with iterative processes.

3. Control System Hardware and Software.- The arguments cited so far have dealt with the man-machine communication as it appears to the operator. Let us now have a closer look at the details of this 'grey area', i.e. the computerized control system itself, which is commonly broken down to the following items:

Hardware:	- computer (network) - interface system
Software:	- computer operating system - control software
Man-Machine-Interface:	- general purpose or dedicated consoles including the directly correlated software

During the last ten years some fundamental rules have been established for these items. However some of these rules can still not be fulfilled.

The computer (network) as well as its operating (and message transfer) system should be commercially available. The operating system must provide an event oriented and multi-user real time environment including all the tools to implement the control system hard- and software.

The interface system and control software should preferably be computer independent. They should be designed modular and strictly standardized in a way that the control system can be tailored to specific requirements with a small number of different modules, to facilitate use, maintenance, trouble shooting, extendability and flexibility. The system is extendable if accelerator hardware can be added without exhausting the resources of the control system. The system is flexible if new features which were not originally designed into the system can be added without requiring a considerable redesign effort. In the area of applications, the control system should take over all standard and well defined procedures allowing the operator to concentrate on problems he is interested in.

The man-machine interface must be easy to use and self explaining to a high degree, presenting the operator with all the tools necessary to concentrate on the process.

In the following I should like to illustrate some points made on hardware by looking at a few examples.

As control systems presently profit much from those of big accelerators. I'll start with a futuristic example which I'll then lead down to the needs of 'normal cyclotron controls'.

Fig. 2 is a schematic view of the principles proposed for the controls of future accelerators by the CERN-SPS controls group[2]. It is a result of the impact which microprocessors will most probably have on control systems. It is proposed to use "an assembly of microprocessors with sufficient memory, each of which performs one, single-stream type of task" including those of scheduling and communication. The idea is to break down the computer and control interface networks into similar units with communication, computing and control capabilities.

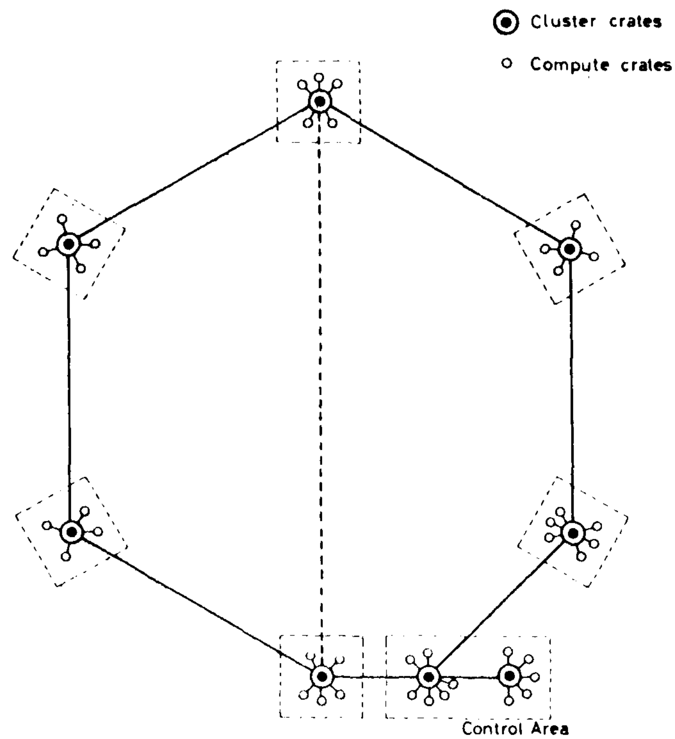


Fig. 2: 'Ring' layout of a multiprocessor solution as proposed in ref. 2. Identical crates with microprocessors plus adequate extensions control the message flow, provide message switching and computing or interface the individual types of equipment.

The example given in fig. 3 is a schematic view of the CPS control system[3] which is presently being implemented for the LINAC, BOOSTER and PS accelerators at CERN. Its topology is derived from the SPS controls[6]. Similar topologies are used in most large accelerator controls which use a decentralised scheme. A minicomputer is dedicated to each of the above mentioned accelerators or to a significantly important task. The

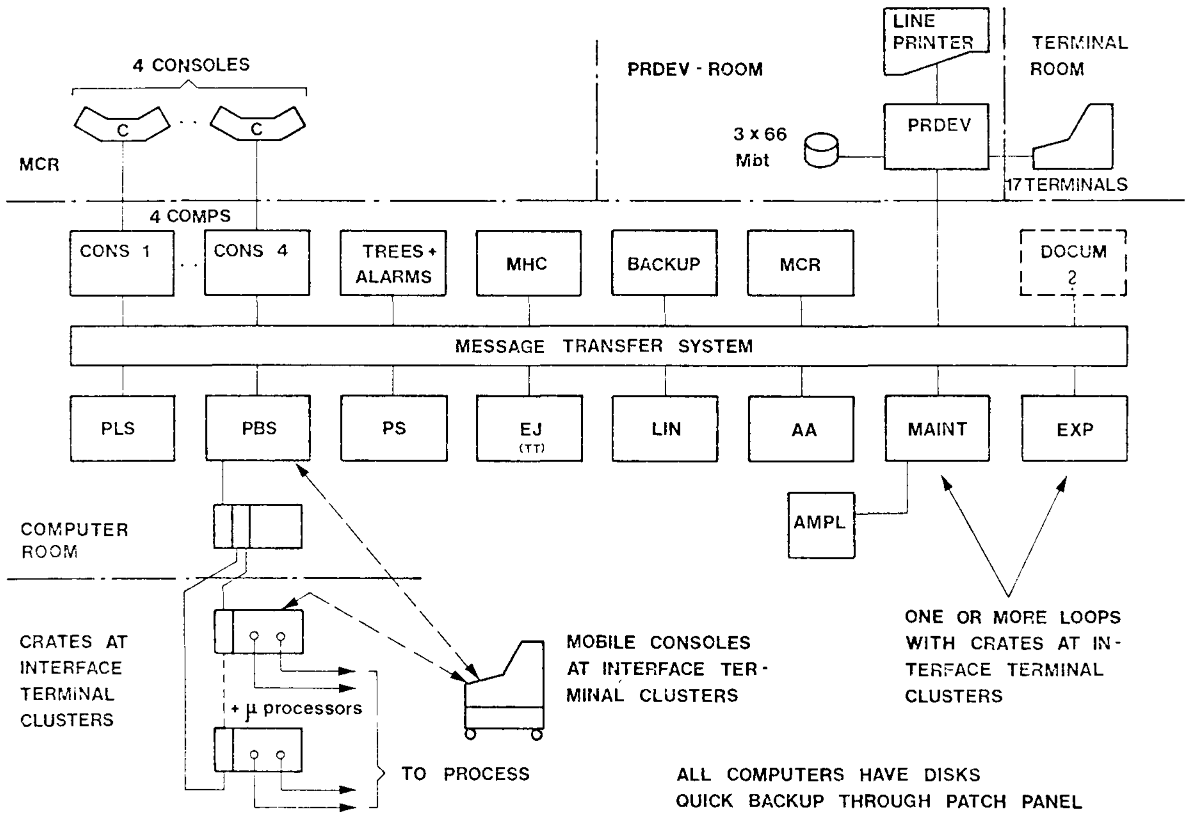


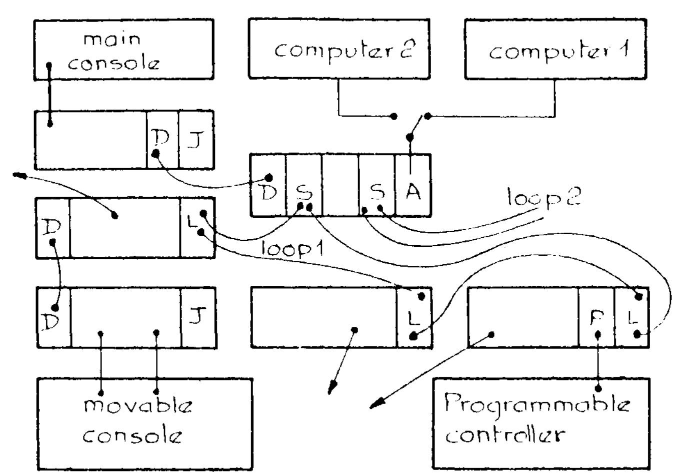
Fig. 3: Hardware Topology of the New CERN-CPS Control System.
The upper part is operations and systems oriented, the lower part is process oriented with a minicomputer and one or more serial CAMAC loops per process (accelerator subsystem).

CAMAC data handling system (parallel and serial) is used as control interface standard. You'll find it, nowadays, in almost all institutes with automatic control projects in various degrees of implementation. Microprocessors have been added at the crate level for autonomous control of certain subprocesses, such as pulse-to-pulse modulation of beam bunches in this case.

When we come down to the plane of medium size machines like most cyclotrons with or without injector you'll find that in general the control system hardware resembles just one control branch of the CERN-SPS example, including one minicomputer for control and another as back up. The example I'd like to show here (fig. 4) is the topology of GANICIEL which is presently being implemented for the GANIL cyclotron[4].

In fact, this philosophy is still similar to that used by some of the pioneers of computer assisted controls of cyclotrons. Their contributions to this conference will give you a more detailed view of them.

Although hardware has been standardized to a great extent and although minicomputer operating systems are fairly similar nowadays, this does not necessarily apply to the support that is available for the implementation of the control system software. And this is mainly due to fact that the minicomputers or microprocessors used differ from one system to the other because of historical or political reasons. The lack of a generally implemented high level language which allows the description of process hardware and operating structures forces the various control groups to write their own pieces of software. Although the



A : type A crate controller
L : type L crate controller
J : autonomous controller
S : serial driver
D : data link between Camac systems
arrows : links to the accelerator
P : data link with programmable controller

Fig. 4: Hardware Topology of the GANIL Accelerator Control.

control philosophy or strategy may be transported from one project to another the software mostly cannot unless exactly the same hardware is used. The cost, in manpower, of implementing the desired design may be considerable.

4. Constraints versus Advantages.- It goes without saying that a computer assisted control system adds to the complexity of an accelerator system, i.e. additional support is needed in running and maintaining the system. Nevertheless, experience shows that the downtime of accelerators due to the control system is extremely small. On the contrary the control system helps to increase the availability of the accelerator.

The more severe manpower problem, however, may arise from the implementation of a computer control system. We have seen that most hardware is commercially available (or can be commercialized). It can therefore be installed within reasonable time. The effort to be put in software may, however, be considerable and time consuming. CERN claimed to have overcome the "software barrier" by implementing an interpretive language which was easy to learn and use so that people envolved could write their own operating software. This approach may be useful in a certain way, but may on the other hand get easily out of control with a overwhelming number of files which often represent duplication of effort or become even unusable as people who created them leave the group.

Although the effort of implementation may be considerable the advantages outweigh the disadvantages. Automatic control is essential where beams of an injector must be matched into a cyclotron, or where a large number of correction coils is needed for beam centering or isochronisation. Beam properties can be measured more quickly and more often with accuracy and reproducibility. The correction of incorrect settings and disturbancies may be considerably faster. Furthermore, if you let the computer do the standard jobs such as monitoring, logging and setting it leaves the operator more time to concentrate on problems of interest.

5. Conclusion.- Many successful examples of computerized accelerator control systems can be found today and while many of these employ similar design philosophies, the software manpower investment has generally been relatively high. This situation reflects the lack of portability of presently available programming languages which satisfy the needs of control system designers. However, in principle a control system can always be designed and implemented in a way that if fulfils all control requirements. If appropriate diagnostic devices and control elements are made available closed loop control can also be achieved.

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" DISCUSSION "

D.A. DOHAN : How would the advent of very fast (but affordable) computers (such as VAK) with good operating systems, affect the design of control systems (such as SPS) which employ the layered message transfer system ? Would you replace the "building block" with these higher powered computers or restructure at the higher levels ?

W. BUSSE : I would replace the "building block" mini and restructure recombining the control computer with the computing power which is (now) mostly taken over by a separate computer. If the message transfer chips' were available at the same time, I would restructure the system in the way it is proposed by Altaber et al. These chips are presently developed and they take over the complete transfer protocol including error checking.

M.L. RENTON : Would the author like to comment on the computer languages ?

W. BUSSE : At the present time FORTRAN, PASCAL or ASSEMBLER can be used but none are ideal. It is hoped that the situation will improve when ADA becomes available.