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THE IMPROVEMENT PROJECT FOR THE CPS CONTROLS

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1. Summary

Computer assisted controls at the 28 GeV PS made their entry in 1967 and today around 80% of the processes are included in various styles. Beam intensity has since increased two orders of magnitude and interleaved cycles of different beam properties are now serving SPS, ISR and the 28 GeV experimental area. This came about by substantial additions to the accelerator equipment, the main one being the Booster and Linac. Plans up to the end of 1980 include: addition of the Antiproton Accumulation Ring, acceleration of antiprotons in the CPS, the concomitant beam transfer and switching, and multibatch filling of the SPS, requiring cycles times down to 0.65 sec. The improvement programme for controls aims to alleviate the operational and maintenance problems ensuing from this explosive expansion and to create a framework for further growth.

2. Introduction

The importance of efficient controls in the machine studies which led up to and accompanied the improvements and new projects, can hardly be overestimated. Machine studies and even routine operation indeed find themselves growingly impaired by shortcomings, diversity in presentation and underlying logic and by the disjointed nature of the controls that followed the expansion. The upkeep and improvement of hardware and software are scattered over a number of groups and are often only known to one single specialist, hence vulnerability and hard to asses total use of resources.

Recent trends make a life cycle of another 10 to 15 years highly probable and further growth cannot be ruled out. It was thus decided to build an integrated and user-oriented control system[1] that can cope with growth, taking the SPS philosophy[2] as a starting point.

3. Users aspects

(i) Operators[3] and machine experimenters wish to see a virtual machine, i.e. an apparent structure, following the actions on and the behaviour of the beam, hardware and control intricacies being hidden. As attributes they wish, efficiency, simultaneity, and flexibility for machine experiments, a trustworthy survey-and-alarm system for routine operation.

The process is thus divided up so that operationally relevant subsets may be selected through a tree structure from the touch-panels. There are separate trees for different contexts, e.g. starting-up, setting-up and machine study, normal operation, probably also a hardware tree and a controls specialist tree. Operations have further specified the applications programs, in particular interactions and displays and they have participated in the choice of console hardware and facilities. A structured naming scheme for process variables and interactions has been divisionally accepted.

(ii) Process equipment engineers expect assistance for maintenance and improvements of their hardware. The main consoles being essentially reserved for operation, there is a need for local access through terminals at several levels and facilities for engineers, to develop, load and run their own detailed diagnostic programs for process-hardware off-line or on-line tests. Operators must be able to call first aid diagnostic programs for coarse localisation of faults.

(iii) Controls engineers need adequate diagnostics at multiple levels, in particular at the interfaces with the other two user groups, and recovery strategies. For maintenance, improvements and additions they need modularisation and standardisation of hardware and software as well as a good documentation.

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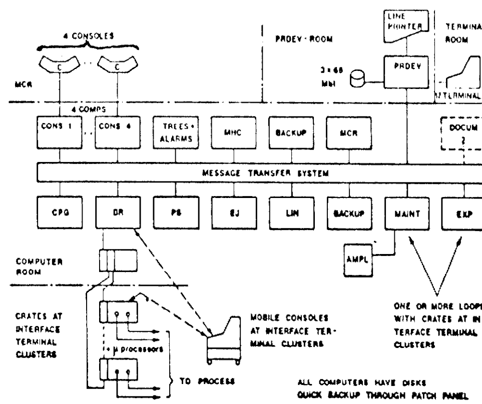
4. Layout and Topology[4]

Main operator consoles and other common facilities act on process hardware through a ND-10 minicomputer network and a serial CAMAC process interface containing TMS 9900 microcomputers. Communication between minicomputers is via SPS type package switching system, using a central store-and-forward message handling computer (MHC). There is thus a process oriented part and a common, i.e. operations and systems oriented, part.



The structure of the former follows that of the processes and there are no general purpose computers. This is possible by the use of serial CAMAC. Console computers predominantly communicate with only one process computer per application. Since the short cycle times exclude program file transfers over the links, these files are kept on the relevant process computer disks. There is no library computer. Further decentralisation of tables and processing into microprocessor-based auxiliary CAMAC crate controllers is foreseen from the start for the most time-critical transactions, mainly pulse-to-pulse refreshing of parameters and handling of data bursts from beam measurement equipment. The booster computer will thus manage 20 to 30 microcomputers, running as single-task slaves. Synchronisation is twofold: by computer-settable preset counters on pulse trains from clocks and stepping integrators, and by so-called programme lines, i.e. serial telegrams, containing information about the imminent cycle and the next one, distributed by the cycle program generator (CPG) to process interface and computers. The MAINTenance computer will handle off-line interface hardware testing and is linked to AMPL, the TMS 9900 microprocessor development system. The temporary experiment computer TEMPEX will support off-line and on-line development of new process hardware, and temporary use of ad hoc process hardware for machine experiments.

On the common side, the CONSole computers each autonomously drive one of the four main operator consoles, assisted by microcomputers for displays. There is no common display computer. The TREES computer manages and arbitrates the reservation and mutual exclusion of parameters from subsets relevant to applications chosen from different consoles through the touch panel tree-structure. It also handles alarm messages and drives the analog signal observation system (SOS) through CAMAC. The MCR computer will handle number crunching, logs and sundry tasks. The program development computer (PRDEV) with 17 terminals and various other peripher-

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als is also linked into the network for down-loading of programs. A documentation computer may be added at a later stage.

Concentrating all computers except PRDEV in one air-conditioned room, together with the CAMAC serial transmitters, yields the advantages of controlled environment, rapid computer backup through patch-panels and convenient network checkout and service.

5. Systems Software[5]

Here there are three main subjects: (i) programming language support, (ii) operating system(s) and (iii) communications system(s).

NODAL has been adopted, due to intrinsic advantages of interpreters for certain goals, due to its ready availability, and for compatibility with SPS. It will be used for interactive programs, for direct commands and for test programs concerning new control schemes or hardware. Micro-NODAL, a subset to run on the TMS 9900 for hardware checkout, will also be available.

For many applications an interpreter is 100 times too slow, in the future short (600 ms) PS cycle time, so that a compiled language must also be available. PASCAL has been chosen for its structuring features which should yield significant gains in maintenance and modification effort, and in reliability over the life-cycle of the new system. Micro-PASCAL is planned to cross-compile on the ND10 for the TMS 9900 as target machine, at a later stage.

A number of systems software packages are written in the manufacturer's intermediate level language NPL. Assembler coding is being avoided if possible. Only on the microcomputers is it used until delivery of micro-PASCAL.

The manufacturer's operating system SINTRAN III was the obvious choice for all ND-10 computers (except MHC). The microcomputers will run on a simple home-made monitor as long as they do single slave-tasks.

The SPS message transfer system has been chosen and adpated to Sintran III. Only the MHC runs under Syntron, but since its software is by now stable it may be treated as a black box.

A general purpose serial CAMAC driver has been developed.

6. Main Operator Consoles [6]

The exterior aspects, general philosophy and facilities follow very much the style of the SPS consoles. Each equipment or system can be operated from any of the four consoles. Interaction is via buttons, touch-panels, rotating knobs, keyboard and tracker ball. Each console with its computer is completely independent, yielding graceful degradation in case of faults. Besides one high resolution refreshed graphics device driven by a satellite microcomputer on each console, displays are exclusively on TV screens of various sizes, black-white or colour. Interfacing of all devices (except keyboard) to the CONSole computer is via parallel CAMAC. For service reasons the latter is not in the consoles but in the computer room.

Two novel features make operation and applications software writing substantially more efficient:

Besides the various device drivers, there are five interactive programs, the Main Interactive Program (MIP), Trees (TIP), Video (VIP), Signal (SIP) and Alarms (LIP), each dealing with interactions of the relevant sub-system. Interactive resources are allocated in a fixed way between them. For the operator this means that in the midst of one interactive program he can use any other one, e.g. changing analog signals on an oscilloscope, without disturbing the program he was working on and losing all the entered context.

There is a multiple independent and protected channel access to the display devices. For the application programmer this means that several independent display programs may be written to run simultaneously on the same screen, the only precaution necessary being not to physically overwrite on the screen. One special channel per output device is reserved for interaction.

Unlike for DECs, RSX 11-M, the ND-10 operating systems have no multiple significant events available for the users. Consequently, in order to provide for the facilities, an addition to the I/O system had to be made allowing to wait simultaneously for events from process, knobs, touch-panels and programs.

7. Process Interface[7]

The dominant problem here is the historical diversity of the process hardware and its present specific electronics. Unselective, ex cathedra definition of standards would result in excessive conversion effort and cost. Instead, an intensive survey of the existing situation - with all groups concerned - led to a compromise, conserving the more modern existing solutions. The resulting CAMAC interface, with a spectrum of about 50 different types of modules, should cater for present and future needs. One of these is the ACC[8], housing a 16 bit microprocessor, able to address 16 K of resident memory and all addresses on the dataway. Standard combinations of modules are recommended for a number of interfacing cases. In addition, standard control protocols have been agreed upon for power supplies (half the total address space) thus also permitting software standardisation[9]. Part of the modules are existing commercial types, part are modifications or new developments

For a particular process the distribution of systems and equipment over the loops is done considering the aspects geography, operation, graceful degradation, diagnostics and noise immunity. In the bit serial mode the hardware transmission time is about 50 μs per word.

The service, in particular diagnostic aspects, have obtained particular attention. The transmission system and the modules will have diagnostic software from the start. Module tests are possible from the interface laboratory and at interface clustering points through work stations consisting of a CAMAC crate and terminal connected to the MAINTenance computer. Later, software may localise faulty modules in on-line loops. Further diagnostic tools are loop collapse and crate bypass, a dataway display module in each crate, and output register and analog value readback capability from modules. In addition, local access through terminals is possible at different levels: in the process computer and through ACCs in the CAMAC crates. Finally, mobile terminals with autonomous, ACC equipped CAMAC crates will support process equipment checkout.

A modular, computer settable analog multiplexing system (SOS), built like a telephone network, has been developed so that each console can at choice bring 4 different analog signals on 2 oscilloscopes. This system is also used for video signal switching and in certain cases for transmission of standard pulses.

8. Applications Software[10]

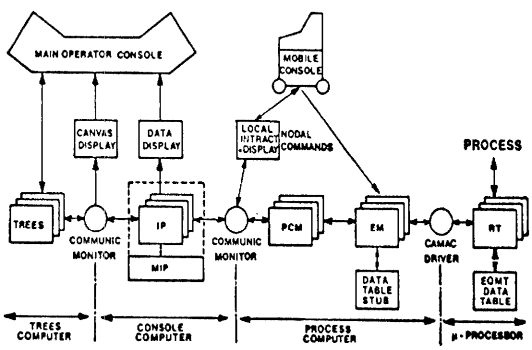
This is all software performing the actual control, acquisition, interaction and display tasks, as distinct from systems software which provides the environment in which applications may function efficiently.

The dominent reason for the adopted approach is the enormous programming effort involved. 70 manyears of applications have been estimated originally, but this may confidently be doubled for the life-cycle of the system, due to new projects and wishes. Hence the need for economy, and also some form of management in applications design, production and upkeep.

The key-approach to economy (in addition to the obvious one: a cricital look at the "needs"), is modularisation and standardisation. It reduces duplication, facilitates growth and modifaction and makes procurement and upkeep manageable. The price is a longish layout and overall design period, to produce a framework into which present and future modules may be linked with standardised calling sequences and adequate error reporting.

Once defined in their overall functions, modules are handed out to individual programmers for design, coding, testing, final installation and documentation. Progress is monitored by counting the completed phases. Documentation along standards is built up in parallel and becomes public property. Testing is planned from the start: to alleviate on-line testing, simulation and diagnostics is built-in throughout. The management scheme[11] is crucial, due to numerous participants from other groups, due to limited access to the running process and since a specified product must be delivered at a specified time.

The handler concept has in the SPS design been amplified to the Data Module (DM), which hides the hardware intricacies and allows calling system variables by acronyms. It contains its own data tables with hardware addresses, limit and demand values, conversion for factors, protection code, etc., one entry per equipment. In the PS context, this concept yielded the Equipment Module (EM). Since the pulse-to-pulse change of parameters multiply the size of the data tables by 8, they are not included in the module. The larger part of the tables is spread over microcomputers in the interface, where interrupt triggered real-time tasks (RT) send relevant values to the hardware each cycle. The EM also gives fast data manipulations for large sets of process variables, e.g. reservation, swapping set- and reference-values, etc. The EM has interpreter and high level compiled language interfaces.



Various TREES modules do the context selection, register and arbitrate reservation of process variables.

The main interactive program (MIP) manages the interactive procedures (IP) which actually dialogue with the operator. The latter call and instruct the related process control module (PCM) which executes the actual control algorithm.

There will be beam surveillance and equipment status surveillance as input for the alarms system.

9. Conversion Problems

Conversion of a long existing accelerator complex to integrated standardised controls, has aspects of its own. Most are painful but the positive ones may give a special dimension to the project.

(-) There is little access to the process for tests, so simulations, intensive short term scheduling during short and long stops, and solid overwork are necessary;
(-) Accelerators often grow by ad hoc additions so that introducing standard hardware and software require many adaptations;
(-) Discussing adaptations is often felt as critique of previous approaches and may meet resistance per se;
(-) Since controls relate to every process equipment hence close to every equipment engineer, communication is a substantial fraction of the job;
(-) This is amplified by existence of many little controls groups with competent specialists, but of heterogeneous opinions, defended with authority and ardour;
(-) In such an environment and since computer controls are still unfamiliar to many, people may have difficulties to decide whom to back in case of differences. The controls group must thus gain authority through results.
(+) The existence of a mature operations group with experience on these very accelerators, permits defining a control system with good operational relevance and limited risk of being far off the mark;
(+) The distributed expertise, if turned to constructive participation, can help produce a running- and maintenance-friendly control system.

10. Status

Civil engineering work for the new main control room, computer room, etc., is complete.

All computers and peripherals have been delivered and installed. So has the message transfer system hardware and software. The latter has, where relevant, been adapted to the Sintran III operating system and the network has been working as a whole. First versions of the systems software have been working and are expected to stabilise during this Summer.

Operations aspects definition has been completed. Specific aspects for process hardware users are still being settled.

All console hardware is on order and has been largely delivered. Four console bodies are in place and are being equipped. Specific console software is defined, implementation is halfway. The first console is due in autumn this year.

All interface hardware is on order and delivery has started. Newly developed modules, including the microprocessor ACCs, are scheduled from Summer till the end of the year. The layout has been made with the relevant process equipment groups; adaptations are defined, material is on order, and installations have begun.

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