The UNK Control System

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Abstract.

The design considerations and current status of the distributed control system for the UNK Accelerator and Storage Ring Complex is presented. All process devices will have intelligent equipment controllers using 8 and 16 bit processors, connected by a field bus to VME based frontend computers using 32 bit processors. The latter interconnect with UNIX based workstations and servers at the main control room. The network may have a Token Ring or FDDI backbone with Ethernet LAN segments and use the TCP/IP protocol. A maximum of commercially available hardware and software will be used. The user friendliness for operation and servicing is emphasized by early definition of application software and by providing facilities for local access and stand alone operation.

I. Introduction.

The UNK complex will combine - in one tunnel of 20.7 km circumference and 5.2 m diameter cross section - a 400 GeV conventional magnet synchrotron ("stage I") and a 3000 GeV superconducting synchrotron/storage ring ("stage II"). At a later stage a second superconducting ring ("stage III") may be added with the aim of doing proton-proton collider physics at 6 TeV.

The 400 GeV synchrotron is injected at 70 GeV from the existing proton synchrotron "U-70". For one filling up to 12 pulses from U-70 may be stacked in longitudinal phase space, accelerated to 400 GeV and transferred to the superconducting ring which in turn accelerates them up to 3 TeV.

Three main modes of operation are presently foreseen.

(i) Fixed Target at 3 TeV: fast or slow extraction will send the 3 TeV beam to the fixed target experimental area. During the acceleration of the superconducting ring, U-70 may produce beams for its own 70 GeV experimental area.

(ii) Colliding Beams at 3 + 0.6 TeV: the beams from, respectively, the superconducting ring and the conventional one are made to collide. For this the conventional ring is operated first as booster and, after field reversal, as a storage ring run at 600 GeV.

(iii) Colliding Beams at 3 + 3 TeV: the conventional ring will first inject into one superconducting ring and, after field reversal, into the second one.

The accelerator controls equipment will be distributed over near to 20 on-surface buildings situated mainly along the accelerator ring. In one of the these is the Main Control Room (MCR), the other ones house the remote nodes of the control system. The latter are totally controlled from the MCR and are in general not manned. The typical distance between any two adjacent buildings is about 1.8 km and the maximum is about 3.5 km.

The more than 2500 superconducting magnets require a cryogenic plant and elaborate distribution, recovery and safety installations and their concomitant controls in the surface buildings around the ring tunnel.

The secondary beamlines and external experimental areas cover an area of roughly 12 km length. Controls for their equipment may follow closely the principles of the accelerator controls.

The upgrade of U-70, for meeting UNK injector specifications, requires intensive machine studies which in turn make a controls upgrade mandatory. since this must precede UNK, the principles and equipment may differ somewhat from UNK controls proper.

2. Hardware Architecture.

The size and complexity of UNK, together with real time and other requirements, dictate a multilevel multiprocessor controls architecture (see figure).

Various components of the accelerator equipment are driven by more than 4000 equipment controllers (EC) which perform low level control and data acquisition tasks in hard real time and provide a uniform equipment representation for the upper levels of the control system. The ECs are based on 8/16 bit microprocessors and vary in implementation from dedicated single board devices to modular crates with standard backplane buses, mainly Multibus I in Euromechanics.

A general timing system distributes reference events and clock trains to all ECs. A separate alarm and interlock network collects signals from all ECs monitoring vital accelerator subsystems. These signals may be used to trigger the beam abort system and inhibit beam injection.

The next higher level of control is represented by the front end computers (FEC) spread around the main UNK ring and beam transfer lines and interconnected with upper level computers by the

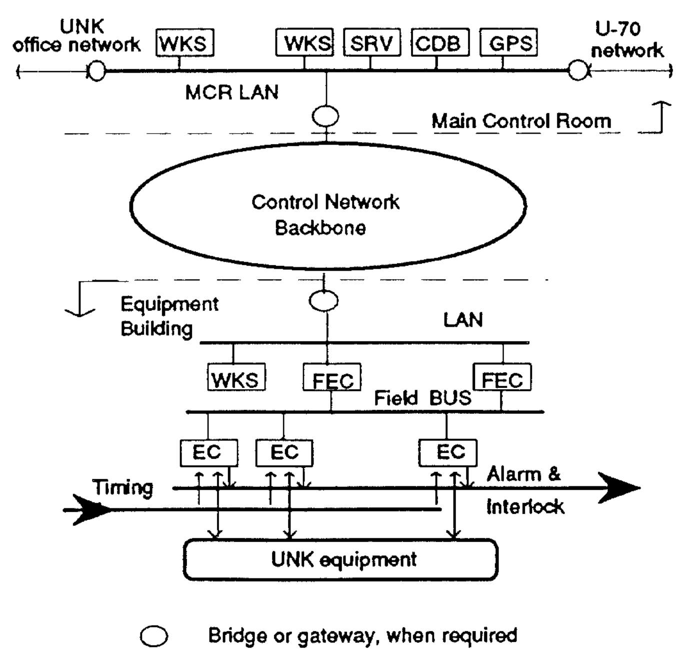

Figure 1. The UNK control system layout.

UNK controls network. The FECS will drive EC clusters through the 1 Mbit/s MIL-STD-1553 serial multidrop bus, which provides a cheap solution on a standard chip, noise immunity and galvanic insulation .

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Physically, the FEC is a modular board assembly in a standard VMEbus crate. The basic FEC configuration will consist of a 32-bit processor board, a network interface and a number of MIL-1553 bus controllers. It may also include I/O modules for direct interfacing to equipment needing full network functionality or/and bandwidth to handle high data rates.

The FEC's main purpose is providing access for the upper level control software via network to the ECs. It may thus be considered as a gateway linking the MIL-1553 field bus to the UNK controls network and as a specific kind of network server, providing a set of equipment access services for application tasks running in the networked computers.

In addition to this general task, a number of FECs may be dedicated to certain functions, either through their own I/O modules (e.g. for sophisticated beam diagnostic equipment), or for functional segregating For example, one presently considers dedicating certain FECs to a more intense task in the real time control of various cryogenic processes. Finally, the FECs may run some application tasks, in particular for local equipment access, test and diagnostics. It will perform also ECs downloading and surveillance via the MIL-1553 field bus.

The network will be layered: a so-called backbone will interconnect the buildings and a number of LANs will interconnect equipment at the MCR and inside other buildings. The development infrastructure forms a sub-network which will be attached to the backbone. LANs will mostly be Ethernet. The backbone will be fiber optics FDDI or 16Mb fiber optics Token Ring. The LANs and backbone will be connected by bridges/routers (Internet standard). The high level network protocols will be TCP/IP suit. Most networking hardware and software will be standard commercial products.

UNK operator's consoles, 3-5 in total, will each be equipped with 3-5 graphics workstations and one server. The latter will provide common services (file, print, plot, etc.) and can also be used to execute certain run-time application software.

Each console configuration will include auxiliary equipment for supporting dedicated displays, analog signal observation and TV video links. The analog signal observation will be based on TDM channels, linking remote digitizers with digital to analog signal converters and scopes in the MCR. Signals are selected via the controls network, while the main data flow will be carried by dedicated, possibly very high bandwidth channels.

There will be a dedicated UNK control system's data base management server CDB and a general purpose server GPS for number crunching, modelling. The latter also caters for general user program development, thus supporting numerous workstations and terminals spread around the buildings.

3.Software architecture.

The run-time software is divided on two categories: Specific Applications to operate with the accelerator controls, and Application Environment, providing the applications with routine and unified services for communications, common data structures access and user interaction.

The diversity and multiplicity of process devices, requires some uniformisation, i.e. hiding the device specifics from the operational applications. For doing so, the device specifics are encapsulated in software envelopes having a standardized access protocol. The applications' vision is thus strictly limited to a small number of a well defined logical device types. The logical device abstraction has two closely related aspects: the device frame (a collection of data and procedural components to actually drive the device) and the device control protocol.

Off-line data preparation, including descriptions of machine and control system objects and relations, will be done using Oracle DBMS and relevant tools. One presently considers organizing all data inside of the control system in a specialized home-made real time DBMS. It should to contain both static read-only data derived from Oracle and dynamic data of the current machine state, some pre-defined number of UNK states for pulse-to-pulse modulation (PPM) and accelerator development, etc. This real time DBMS will support access to read/write data for fixed and off-line prepared data structures. It will serve a number of distributed data bases. Each DB is a standard file, containing data in the form of three-dimensional tables, some of which may be duplicated in the memory of specified computers. Physically the DB organization is optimized for real time usage.

The human interface is based on graphical workstations and windowing techniques (X-Windows, OSF/Motif, XUI). Much recent work in this field is concerned with specific extension of a commercial products (which are mostly some kinds of interactive graphics packages) to unify human interaction procedures as widely as possible.

Unix will be used in the operator workstations and servers while a Unix-like real-time system will be chosen for the time-critical fields (front end computers, equipment controllers). The TCP/IP protocol package, now a standard feature of most Unix and real-time systems, will be used in the general network and is also a basic communication mechanism in most X-Windows implementations.

4. Application software.

Experience in development of individual applications packages world wide shows that certain functionalities appear in the same or similar way in the majority of them. The trend, which we shall follow, is therefore to extract these parts from the specific applications and to supply them as more or less standardized common functionalities which may then be used by each specific application. This reduces multiple code and improves quality and maintainability. The software implementation of those common functionalities may be called the Applications Skeleton. But while systems software is computer or network oriented, the skeleton is controls oriented. It is supposed to provide a relatively stable environment and only evolve slowly.

A first systems analysis of the applications functionality was made using the SASD methodology. Thus the main procedures, data flows and data stores were identified. As a result, a first applications catalog was composed, containing the foreseen application procedures and data structures. This analysis, design and data structure development will be pursued using a modern integrated CASE tool package. The latter should also provide project management and documentation support, which are important when numerous programmers of different level must cooperate..

Standardization trends result in the appearance of commercial packages for industrial control which can be configured to realize a range of functionalities also in accelerators. Examples are DV-Draw /DV-Tool from Data Views for the user interface and ORACLE for off-line database management. Even certain parts of non-specific applications may be covered by commercial systems like V-System from VISTA or G2 from Gensym Corp. Some candidates will be evaluated and, where appropriate, be used while the market will be further monitored.

5. Cryogenics Aspects

The cryogenics and related equipment is a substantial part of the UNK project and falls into three broad groupings: (i) the helium liquifier plant with satellite refrigerators, distribution and recovery, consisting in turn of 4 subsystems: (a) compression, purification and storage; (b) the liquifiers proper, (c) satellite refrigetrators and distribution, and (d) nitrogen store and supply; (ii) the quench protection system and (iii) the superconducting magnet main power supplies with their ramping and dc programs.

By their nature these systems have a close internal binding and require only a weak coupling with the main UNK control system. A fair degree of autonomy and stand alone capability is therefore foreseen, which is helpful in commissioning and later servicing.

Cryogenics controls will, like the main UNK control system but with some special flavours, be based on Multibus-I with 16 bit processors for the ECs, connecting by MIL-STD-1553 to FECs. A specialized programmed logic controller module has been developed and will be used for controlling all valves and local feedback loops in the cryogenic system.

In collaboration with CEA, Saclay, a first version of a FNAL-like quench protection system will be tested on an experimental sector of 8 protection units, each consisting of 12 dipoles and 2 quadrupoles. The surveyance electronics and emergency heating power supplies are located in shielded cavities in the ring tunnel.

The main power supply controls will form a closed subsystem, losely coupled to the main controls and interlocked with the quench protection system.

6. External Beam Lines

The external beam zones will comprise a 12 km long neutrino channel, leading up to the neutrino experimental area, and three 6 km long hadron beamlines leading to their own experimental area each. An important part in the whole setup form the different target areas.

The technology of the equipment used in these beam lines and experimental areas is similar to the one of the accelerators proper, including the use of superconductivity hence cryogenics. A strongly different aspect, however, form the target areas with their radiation problems and remote handling requirements. Some advanced devices such as polarimeters and crystal bending and focusing may be used. One presently thinks of a controls architecture which is very close to the one described for the accelerators. There will be workstations with the modern windows and graphics oriented software, these will be interconnected with a TCP/IP based network, which in turn connects to the accelerator network, and at the frontend to VME based 32 bit microprocessors driving ECs over the MIL-STD-1553 fieldbus. In contrast with the accelerator system, the ECs of the external beam zones controls may still be largely CAMAC based.

Systems software will essentially be the same as for the accelerators. Applications will be strongly data based and model oriented and an expert system is being contemplated for operator support.

The operational patterns of the beamline zones are, by their nature, different from the accelerators. The essential aspect is the more frequent and rapid changes, following the experiment's requirements. Although routine operation may be done from a central MCR (combined with the accelerators), a strong local access and stand alone component remains essential.

7. U-70 Controls Upgrade

Contrary to the situation for the accelerator and beam zones controls, for which options were open, the U-70 injector group has a strong historical bias since both booster and U-70 proper are largely computer controlled. Moreover, the upgrade must be done virtually without interruption of the U-70 experimental programme. Finally, the urgency of this upgrade practically dictates using products now readily available in the USSR and using a stepwise implementation, converting small slices during the short planned shutdowns.

The FECs for the U-70 upgrade will be SM1810.30 computer crates with an Intel-like single board computer with the 16 bit 8086/8087 processor combination, using a suitable real time kernel. They will have appropriate RAM capacities, a LAN interface and a parallel branch highway CAMAC driver. Each of the about 12 FECs, spread over 4 buildings maximum 4 km apart, drives up to 3 CAMAC crates catering for I/O. Servers for files and data base, 4 to 6 in total, will be enhanced configurations of the FECs, featuring larger memory, hard disk and a more complete generation of the operating system. Interaction will be using PC-AT computers under DOS. A commercial LAN product is still being sought in the USSR.

8. Present Status

The Multibus-I based ECs have been largely defined, prototypes of most modules exist, preseries are expected in 6 months, industrial contracts are being negotiated. The MIL-STD-1553 fieldbus connection and remote terminal is under development. A conceptual design study of the upper part of the control system has been made and is accepted. Prototype partial integrations of the main control system and front end assemblies, as well as a quench protection test facility, are being prepared and should be available early 1992. An applications development environment with servers and workstations is being prepared. The external beam zones controls are in the conceptual design phase. The U-70 controls upgrade has been largely defined an frozen and implementation has started.

9. References

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