THE CONCEPTUAL DESIGN OF THE ESRF CONTROL SYSTEM

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Introduction

The construction phase of the ESRF facility can be partitioned into different steps separated by the following milestones:

*Ground Breaking	Jan.1989
*Linac commissioning	Jun.1990
*Injector commissioning	Sep.1991
*Storage Ring commissioning	Sep.1992
*Routine Operation	Jun.1993

Apart from the Linac, which has been ordered with a small stand-alone control system and which will be smoothly integrated into the general control system, the first important milestone for the control system to be operational - at least in a phase 0 version - is the commissioning of the Injector. Counted from now this allows only a total of 3 years for the construction of the basic parts of the control system.

Basic Philosophy

In order to cope with the complexity of a control system design, we aim to use - as clean as possible - a fundamental strategy known as "Information Hiding". The basic idea is simply the definition of a hierarchy of different levels of abstraction, that allow to ignore in detail on any level what happens inside a lower level than the current one. A level tries to hide details of internal functionalities to the level that sits on top of it. Levels may be regarded as abstractions that communicate by messages via predefined interfaces so information is kept locally within a level and is not smeared out over the whole system.

The System's Concept

Logically the system is structured into four levels ***(Fig. 1)***. From top to bottom we call them:

*Presentation Level;
*Process Level;
*Group Level;
*Field Level.

On the lowest level, the "Field Level", all control-, set- and read-points will be interfaced. There will be no data exchange within this level between different equipments. Each equipment together with its interface, represents a single "Cell" within this layer. Data that are received from the upper level are in general simple commands addressed to an equipment to get its latest setting, to start, stop, reset or clear it or to read its current status. Within this Level no horizontal data flow between cells will take place.

Equipment of similar type will be grouped together and will be controlled by nodes in the next higher level, the "Group Level". The nodes of the Group Level will be responsible for the correct organization of input/output and addressing of equipment and to accomodate the hardware specific device drivers for Field Level interfaces. Group level nodes, representing the cells in this level, will be organized in different "Branches". To each branch several Field Level nodes will be attached at a time. A dedicated process acts as the cell master possibly managing data exchanges betwe Field Level nodes. Horizontal communication - cell to cell - with the Group Level will not be allowed.

In a certain sense our Group Level nodes are very similar to t Process-Control-Assemblies (PCA) of the LEP control system(but in order to avoid the well known difficulties with multimaste multiprocessor units during the initial design phase, we decided run these units in a classical single master-multislave mode. Cont tasks within this layer shall be kept as simple as possible.

On top of the Group Level sits the "Process Level". This le represents the most essential level of the control system. Within tl level the real process control will take place. Each cell within tl level controls - in a centralized manner - different functions of t machine. It has to provide real time and powerful multitasking ca bilities. Horizontal data flow will be minimized and should rem inside a cell.

If a human being could read binary information as easy as it c read and interpret graphical information, there would be no need introduce a fourth level, the so called "Presentation Level". T level represents the interface between the human being and machine control system. Within this level data entering from lower level are represented graphically or formatted to readal reports. Commands that are entered from interactive devi (keyboard, mouse, graphic tablet, rotary knob,.....) are decoded internal messages and sent to the lower level. Since the cells wit the Presentation Level are the operator consoles and since there v be several of them, a strong horizontal data flow between differ cells will be needed to synchronize concurrent activities on differ consoles.

As a general rule it can be said, that horizontal data flow is m difficult to organize than vertical data flow because vertical data fl is inherently sequential in time whereas horizontal data flow concurrent. Therefore the software problems within a given le will be more complicated if strong intercell communication allowed.

The Physical Picture

Figure 2 depicts the system's hierarchy and its networks.

The largest amount of in-house hardware development certainly to be made for Field Level components.

In order to simplify and to reduce the cost of cabling and minimize the number of hardware interface boards at the Gr Level, we plan to connect groups of similar devices on a sim multidrop data link. The distances to cover (in the order of 1 k together with our requirement for a high noise immunity make t choice not straightforward. We finally focus on a product, read available from industry, the LAC2 network from COMPEX, a sm company expert in such a business for years.

Nevertheless we fear that the baseband frequency - 250kbit/s - is wasted due to both the asynchronous mode of transmission and the time to execute the network software in the LAC2 interfaces. Also the latter has not yet been implemented on a VME module.

In parallel we consider an in-house solution to be able to cope with more demanding performances. So far we fully tested an enhanced physical layer based on a chip from AMD - type Am 7960 - and investigated the possibility to manage the datalink layer with a new microcontroller - type i80C152 - from INTEL.

Thus we should be able to run at least at 500 kbit/s on the whole ESRF area and locally up to 2Mbit/s. The protocol is intended to be purely master-slave, based on HDLC frames.

The I/O connections to the equipments will be achieved either with open standardized systems commercially available - VME, G64,... - or through an Universal Filed Interface (UFI) that directly fits into the device hardware. Such an interface could rely on the above standards with embedded firmware in EPROM to benefit of low cost I/O boards available from the shelf. We believe that about 80% of all equipments that have to be interfaced during the project design phase can be covered by such a specific solution.

Where larger amounts of software and (or) I/O is needed we plan to use VME systems running under the OS9 real time kernel - keeping uniformity in software and hardware inside ESRF. Being enforced in our choice by the rapid growth of the VME market, we expect very competitive cost margins on VME products in a few years which nicely fits in the scale of our project.

The Group Level nodes or cells will be realised by VMEbus crates. Each crate will drive one or several multidrop branches and will be equipped with 680xx CPU boards and the necessary multidrop bus-master interfaces.

These systems will operate under the OS9 multitasking real time operating system which, due to its modularity, easily can be tailored to our various needs. It is intended to run these systems, once the software has stabilized and proved to be free of bugs, in a pure memory resident fashion. Hardware on this level, with the exception of the multidrop interface modules, is available from industry and has not to be developed inside the ESRF.

In terms of hardware the Process Level and the Presentation Level are the same. Both levels will consist of state-of-the-art mini- and supermini -computers and workstations that are interconnected by a high performance LAN based on CSMA/CD protocols as has been standardized by the IEEE 802 Committee. UNIX - System V from AT&T - has proved to be the only operating system that provides off the shelf functionalities to interconnect multivendor computers and to allow - if carefully used - source transportability of software between them. On the Process Level on the other hand, we need real-time functionality, which is not provided by standard UNIX implementations. At least for the nodes in this level we have to stick to a vendor who provides a validated UNIX-Implementation with real time enhancements.

On the Process Level we will separate the total workload into cells which are devoted to:

*Magnets;
*Vacuum;
*RF;
*Insertion Devices;
*Beam Diagnostic and Closed Orbit;
*Hot Spare, Watchdog & Technical Services.

The Presentation Level will consist of several high perfofmance workstations. They are chosen as the primary human interface to the control system because they offer the full power of a high-resolution graphic display system with excellent processing power. There are four key advantages, all of which are integrated into scientific workstations:

*High Resolution Graphics;
*Windows;
*Mice, Graphic Tablets and Rotary Knobs;
*Pop-Up Menus.

With the support provided by powerful high level network facilities like X-Windows, NFS (Network File System) and RPC (Remote Procedure Call), which already have become defacto standards on UNIX-based workstation environments, the ideal operator station can be tailored from commercially available products.

The Host Computer will play a special role in this scene. It will hold the main Data Base, function as a Name Server for the Presentation and Process Levels and it will be used for running time consuming modelling and analysis programs in background. Last not least the whole system will be initialised from this computer and a regular system-back-up will be performed on it.

The Software

The software required for a control system can be divided into:

*Operating Systems;
*Programming Tools and Languages;
*Protocol and Network Software;
*I/O Driver Software;
*Common Data Base;
*Application Specific Software.

In an environment dictated by UNIX and OS9 the evident choice is C as a basic programming language. Higher level applications will predominantly be written in MODULA 2 or FORTRAN. In addition UNIX provides per default sufficient programming and source code management tools.

Together with the operating systems, the choice of Protocol and Network Software is of paramount importance for the overall system design. Since TCP/IP is fully integrated into most of the UNIX systems, it seems to be a natural choice. Industry just recently has started to implement TCP sockets on VME-based operating systems, one of them being OS9. By that we have a unique software layer - TCP/IP socket library - that allows us to base our software design on a unified RPC (Remote Procedure Call) scheme throughout the whole system.

The I/O driver software will partly be situated in the Group Level cells and partly in form of table driven firmware in the field level. For dumb devices this software will be supplied by the control groups, for intelligent subsystems - like the Linac Control - the equipment groups should provide these programs themselves. Provision will be made for loading these programs through the network at start-up. The programs will be written as table-driven tasks to make them as flexible and uniform as possible.

The central data base in the host computer will be of relational type. Auxiliary programs will at start-up construct virtual images in a suitable format out of this data base for use in the on-line control system data base. Part of this control system data base will be distributed around the process and the group nodes. There its dymamic parts will be automatically updated, so that it can be accessed by the host as desired.

The host will also hold the 'network description' and 'service location files' to give him the possibility to function as the central 'location broker' for the RPC system.

The Application Software will cover the whole range of software that will be written mainly by the machine physicists in the course of the facility's life. Some standard applications will be provided by the controls group and steadily developed. For the commissioning of the facility a couple of standard console programs will be provided. Specifications for these must still be laid down. The use of SASD methods for the formal design of these applications has been envisaged.

Other Services

Other services, which are not directly related to the computer system of the control system include:

- *The Timing System;
- *The Broadband Cross-Bar System;
- *The Access-Control Television System
- *The Beam View Television System
- *The Intercom System
- *The Remote Access from Offices and Laboratories

At present for these parts of the control system nothing more can be said than already has been done in the ESRF Foundation Phase Report (2).

List of Figures.:

Figure 1 The Basic Four Level Model
Figure 2 Control System Block Diagram

List of References:

[1] J. Altaber, P.G. Innocenti and R. Rausch "Proceedings of the Sixth IFAC Workshop" Distributed Computer Control Systems, (1985), pp. 55

[2] ESRF Foundation Phase Report, Februar (1987

Note:

This report is available in a more detailed version at the ES (Reference: ESRF-COMP-88-04).

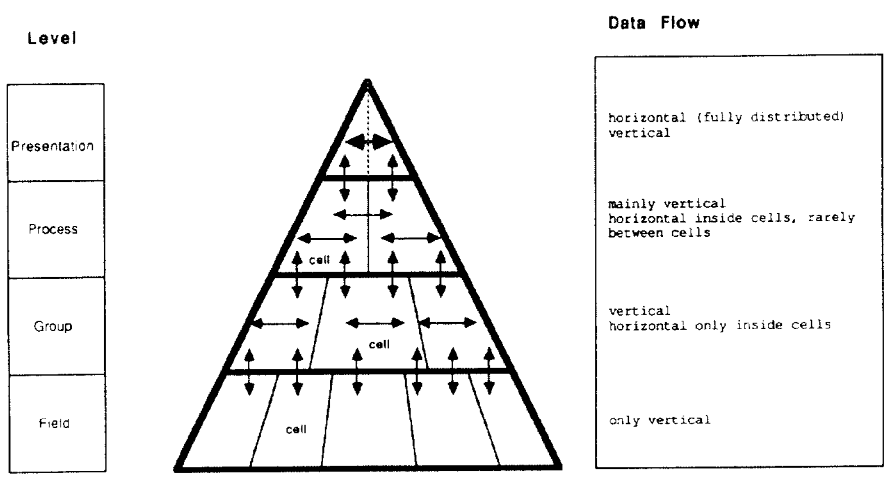

Figure 1 Basic four level model

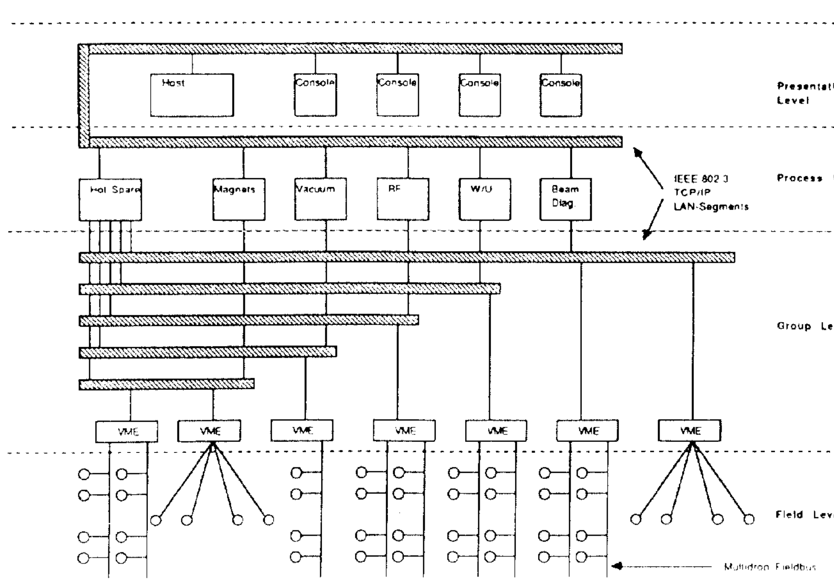

Figure 2 Control system block diagram