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NSLS Control System Upgrade *

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Abstract

The NSLS consists of two storage rings, a booster and a linac. A major upgrade of the control system (installed in 1978) was undertaken and has been completed. The computer architecture is being changed from a three level star-network to a two level distributed system. The microprocessor subsystem, host computer and workstations, communication link and the main software components are being upgraded or replaced. Since the NSLS rings operate twenty four hours a day a year with minimum maintenance time, the key requirement during the upgrade phase is a non-disruptive transition with minimum downtime. Concurrent with the upgrade, some immediate improvements were required. This paper describes the various components of the upgraded system and outlines the future plans.

1 Introduction

The National Synchrotron Light Source facility located at Brookhaven Lab, USA consists of two storage rings (one for UV and one for XRAY region), a Booster and a Linac. The NSLS Control system originally designed in 1978, was adequate during the commissioning and initial operation of the facility. When the storage rings became more complex, the control system could not cope with the increasing demands for data acquisition speed and complex diagnostics. By 1991 the control system was 13 years old and much of the hardware was obsolete, and maintenance was difficult. A control system upgrade plan was proposed in Oct. 1991 and completed by July 1993 [1-3].

2 Old System Description

The original system had a three level star-network consisting of two Data General 16-bit host computers that communicate with five Nova Computers over a high speed DG proprietary bus. Each Nova Computer was connected to sixteen micro systems using 19.2 kbaud serial lines. The Novas act as store and forward processors. The initial design used 8-bit 8085 microsystems with a NSLS designed realtime operating system. The micros provide hardware control and continuous monitoring of input signals (Figure 1).

Since 1987 new control micros are VME-based and a commercial realtime kernel (RTUX) is used. When huge modeling and orbit correction programs could not run due to memory limitations on the DG computer, a Vax computer was integrated into the control system using a UNIX VME Server subnet which allowed communications between the Vax and the existing micros. Workstations were added for graphical program development but their use was limited by the slow serial links. The resulting system was complicated, slow because of multiple links, and difficult to maintain.

Figure 1

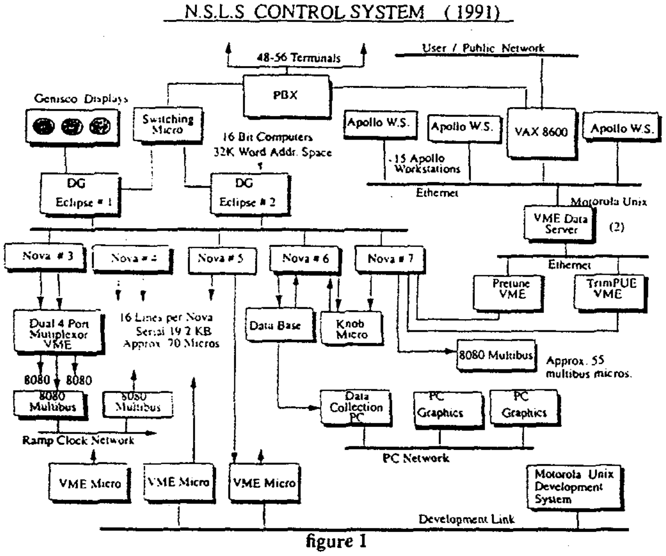

figure 1

3 Upgrade Plan

The upgrade planned in late 1991 involved changing the architecture to a two-level distributed system, consisting of high performance workstations and VME micros for hardware control and adding ethernet communication. It was required that the upgrade takes place in a short time frame with existing manpower and most important of all, there should be no impact on the storage ring operations. The changes had to take place smoothly in incremental stages with minimum down-time during machine weekly maintenance periods. Another goal was to preserve the large investment in existing VME and host computer software.

3.1 Micro Software Changes

All the VME application software is designed around the NSLS Micro Control Monitor which provides an easy environment to develop application-specific tasks. The monitor handles all the system related tasks and manages the communication and command decoding. Messages received were interpreted and only requests that deal with the hardware (such as on/off, setpoint commands) are sent to the application tasks. All the read requests from the host com-

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puters are handled by the monitor system tasks. For the upgrade, a new system module was added to the monitor that handles messages via ethernet from the new system. Messages can be received simultaneously over the serial and Ethernet links. The source of the message is transparent to the micro application tasks. Without any modification, by relinking with new system libraries and adding an Ethernet board, the existing twenty VME systems were able to communicate with both the new and old systems.

3.2 Work Station Software Changes

The host workstation application software is built around the Device Data Record(DDR) database and User Interface(Ucode) library.

All the hardware signals and soft logical devices in the micro are referenced by meaningful names such as UVlifetime, XrayEnergy, BdipoleSetpt *etc.* The host application needs only the device name to access a device. The DDR provides the address resolution for each device. The DDR library has utilities to build new database, add/delete data records, and a DDR Browser to inspect, sort, search, save and print the required information.

The UCODE library provides a standard interface to devices for high level application code. All programs use UCODE to access data in the Micros. The data from the micros are decoded and returned in simple understandable formats. For the upgrade a new Ethernet UCODE library and a new DDR library were built which provide an interface compatible with existing application programs. For workstation programs the new DDR provided the address resolution for the communication via ethernet. The procedures necessary for error detection, retransmission and error reporting are built into the library. Most of the existing programs were easily moved to the new system by relinking the application code with the new UCODE library.

3.3 Implementation Plan

After completing the necessary system library at the micro level, existing Multibus micros were converted to VME micros. The increased power of the VME system allowed more functions to be incorporated into one system. Multiple multibus micros could be combined into single VME micro. As an example, eight multibus micros used for main magnet supplies were replaced by one VME system for each ring. This eliminated the need for an external synchronization clock system. The original eighty micros were converted to about forty five VME micros. When a micro was moved to VME, programs accessing that micro were relinked with the new UCODE library and installed on the HP workstations. Because the controls group always emphasized software modularization, standard interface specifications and libraries the porting of programs from DG, Apollo and Vax computers was relatively easy.

During the conversion period many additional requirements were imposed. Some micro subsystems were upgraded, eight new micros were installed and many new workstation programs were added. The conversion has been completed faster than expected. The new features at both micro and host level are described below.

4 Upgraded System: Architecture

Figure 2 represents the present control system. The architecture of the new control system is simple compared to the old system. It consists of VME micros communicating via Ethernet with HP Workstations in the control room on a realtime network. A building ethernet is connected to the realtime ethernet via a bridge. This allows the staff to run control programs and access the micros but keeps the building traffic off the realtime network. All system parameters are stored on a file server. A copy of the data is periodically copied to a backup server. All programs check if the file server is running. If not, they request data from the backup server. Because the server, backup server and control room workstations are crucial to operations, they are connected to UPS systems.

Figure 2

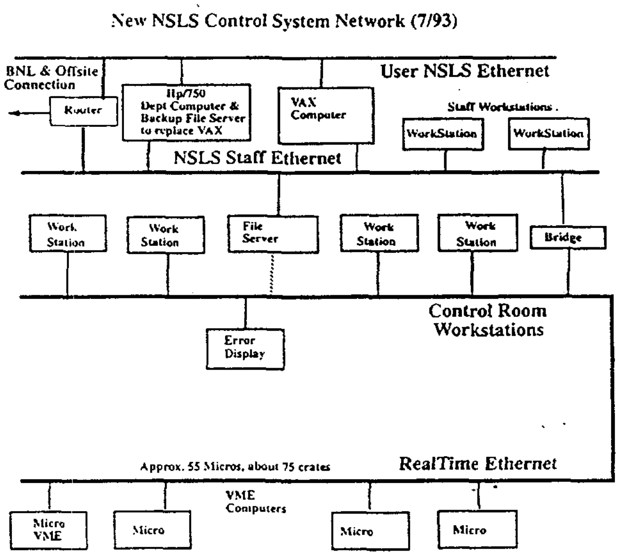
New NSLS Control System Network (7/93)

Figure 2

5 Upgraded System: Micro Systems

All the micros are VME-based systems and use 680xx family CPU's with an Ethernet Controller, 1 megabyte battery backed-up ram and a General Purpose Light Source (GPLS) board which has timers, serial ports, video display generator, diagnostic LED's and software selectable switches. Other hardware is dependent on the equipment to be controlled. The hardware I/O interfaces include ana-

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log and digital cards in the VME crates, GPIB, RS232/422 and Camac Interfaces. Wherever possible commercially available boards are used. Some micros use special hardware designed and fabricated in-house.

Some micro systems are very large and consist of several VME crates connected with bus repeaters. For example the Xray trim micro has over 1000 adc signals and over 120 dac signals. For this system there are about 100 VME boards which require seven VME crates. Some systems use multiple CPU's, the slave CPU's being responsible for periodic monitoring of I/O signals and background calculations.

New software was added to the monitor to handle multiple requests in one ethernet message as opposed to a single command in a serial message. This improved the micro response time considerably at the host level. Every micro has a multipage TV compatible display which goes to the CATV system. Some are continuously displayed, others go to a multiplexors and are switched to the TV by operator command. Since the displays are generated by micros very little of the network bandwidth is used. These memory mapped displays provide a great diagnostic aid for realtime programmers. All the micros have power-fail interrupt module. The monitor traps the AC fail interrupt and invokes a user routine which has the option to save some critical parameters before the system dies. The battery backed-up ram is used to optionally restore the latest parameters when a micro is reset or powered up. This feature has been very useful because the last commands sent can always be restored. The monitor provides client services for generating/receiving messages from any micro to any other node on the realtime network. This micro to micro communication facility is used for knob control and a database micro which collects machine parameters for a TV display.

The monitor provides services for reporting alarm and out of tolerance conditions to the operators. The device error messages are sent asynchronously to a Realtime Error processor micro, which generates a scrolling display in the control room. In addition, all the messages are stored on disk for post-mortem analysis. One micro continuously checks the status of all other micros (up/down) and generates a TV Display indicating the failed micros in red for operator's attention.

6 Upgraded System: Workstation Programs

All the programs access devices through the UCODE library, which, in turn, calls the DDR library functions to get the device addresses and parameters. The UCODE allows reading/writing any number of devices in a single call. It takes all responsibilities for grouping the requested commands to a given micro and returning the data and completion status for each device in the same order as requested by the host program.

Most of the work station programs use Motif and X window graphics through the UIF (User InterFace) library built-in-house. The DDR browser, pretune, save-restore, ramping control, vacuum display, history data display, error and micro status display, orbit measurement, comparison, and display, *etc*, all use X-window graphics.

The self-contained standard file system makes the general history and display possible. One may read and understand standard files without prior knowledge. A sophisticated library lets users read, write and update them. One may read, add or change any row or column in a file.

Many applications become possible because of the fast ethernet communications. For example, the real time orbit display gives instantaneous orbit changes during the orbit correction. The plotter program plots the device response in real time. The fast orbit histories read the orbits of both rings at the rate of 5 to 20 Hz and store them in a ring buffer of about 12 hours data. One may dump a part of or the whole buffer whenever needed and display them graphically.

The interpreter has all the commonly-used data types, arrays, operators, scientific functions, any number of layers of if, then, else, while loops, formatted and disk I/O, a complete set of macro utility, *etc.* Macro may be nested to 16 layers deep. One may read/write any number of devices in one call. More than 200 macros have been written by engineers, technicians and operators, which play an important role in daily operations.

7 Future Plans

All the control programs are running on the HP workstations and all the micros communicate via ethernet. Since the main focus was to get the new architecture in place during the transition period, some desired improvements were postponed. Software to synchronize timing among micros and automatic device configuration module from a binary file image (representing the device parameters and hardware) will be added in the micro software. A commercial database package is being installed on the HP computers. This will be used to simplify the maintenance and updating of control system and configuration data. Other commercial software packages (GUI builders, graphic drawing libraries) are being purchased to aid in the development of workstation software.

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