CONTROL SYSTEM (WBS 1.9)

The RHIC control system will be a unified system for operational control of the collider and the injection beam line. It must translate operational selections of beam energies, intensities, and other collider parameters into instructions which govern thousands of individual elements within the accelerator complex. The control system must provide high reliability, while maintaining flexibility in accommodating changes which can be expected in equipment configuration and usage, both during and after project construction.

The system will be implemented as a distributed system, in which the control processes and the accelerator data objects are both distributed over a large number of loosely-connected processors, geographically separated by as much as two kilometers. Most modern control systems for accelerators now use distributed designs. While similarities exist between the proposed control system for RHIC and the AGS distributed control system now in use for control of the AGS and Booster rings and beam lines, changes will be made in order to incorporate new technologies and software methods.

i. System Requirements

The RHIC Control System must provide control, timing, and data acquisition services for equipment in the collider rings and injection lines. The equipment requiring these services will be located in approximately 38 locations, as shown in Table 9-1.

Control system equipment will not be located in the beam line tunnel or in the collider tunnels. Limited control system cabling will be routed to the equipment alcoves in ring tunnel cable trays or conduits.

Timing and Synchronization

The control system must deliver to all equipment locations a reliable standard clock signal and time markers for significant events in the sequence of accelerator operation. In addition, the control system must make available a universal standard for calendar day and time. A standard clock frequency of 10 MHz, as presently used at the AGS, provides adequate resolution for timing events in the RHIC acceleration and collision processes. A means shall be provided for the simultaneous delivery of event signals to different locations

Table 9-1. Control System Equipment Locations

Location	Number
Equipment Alcoves (3 per sextant)	18
Service Buildings (1 per sextant)	6
Control Room (3rd floor Bldg. 1005S)	1
Injection Buildings (1005E and 1007E)	2
Transfer Line Buildings (NW,A, 1000P)	3
Experimental Areas	4
Other Areas (AGS, Cryo, Instrum.,Test Stands)	4 or 5

(except for fixed delays due to signal transit time differences). It should be possible to initiate events by external signal, by computer software command or delayed from a previous event.

For each collider ring, beam instrumentation and injection timing circuitry will require a clock that is synchronized with the beam bunch frequency. Certain event signals must be synchronized to such a beam clock, most particularly a revolution fiducial signal.

Permits and Special Reference Data

The control system shall provide a permit signal which indicates that beam may be allowed in the accelerator. The beam-permit mechanism shall be designed to fail safely to the "not permitted" state. A record shall be kept of the inputs leading to or triggering an abort and the times at which they occurred.

Many magnet excitation currents will be functionally derived from the main dipole current and its time derivative. In order to avoid laborious adjustment of hundreds of excitation functions to track the main magnet, the control system shall provide for the distribution of data on the main magnet excitation current and other parameters in a form that can be directly used by equipment control hardware.

Signal Acquisition

Accelerator equipment is the source of many signals which must be acquired at the equipment as an analog voltage and transmitted for display at an operator's console or for use in various control programs. These signals range from dc voltages to time-varying signals with characteristic

frequencies up to nearly 1 GHz. The control system shall provide modules for computer-controllable digitization of signals with multiplexed selection of channels. Maximum flexibility should be provided for modes of acquisition ranging from all channels of a module at modest sampling rates to one channel at the maximum rate. The system shall permit the selection of a continuous mode or digitization for a specific number of samples (or duration) and shall be triggerable by general timing event signals. The maximum sampling rate shall be 78 kHz. Data shall be digitized with at least 12 bit accuracy.

The control system should also support communication with commercial signal processing hardware, which may be installed near the sources of very high frequency signals. Such equipment is widely available with GPIB and/or VXI bus interfaces.

Data Flow and Rates

The control system shall transport data between the equipment and the operator consoles. The control system shall provide for several functionally different types of data transactions:

- Query/Reply
- Event-Synchronized Measurement
- Display Channel (continuous)
- Command
- Event-Synchronized Command
- Log (fixed frequency)
- Message(unsolicited, including alarms)

The bandwidth requirements for the control system are expected to be dominated by *Event-Synchronized Measurement* and *Display Channel* transactions. The infrequent nature or small size of the other transactions are expected to contribute a small amount to total bandwidth requirements.

Display Channel transactions are characterized by a continuous demand on network resources while the Display Channel is in use. They are expected to be used for visual display, therefore latency for Display Channel transactions should be unnoticeable to the operator. The most demanding scenarios for Display Channel transactions involve instrumentation subsystems and waveform digitizers. The maximum rate of acquisition of closed-orbit data for a beam position monitor (BPM) is 64 kbits/sec (8 bytes of data @ 1 kHz). The control system should provide sufficient network throughput for up to 8 concurrent Display Channel transactions (500 kbits/sec) from a single location.

Event-Synchronized Measurement transactions are characterized by bursts of data which put a large instantaneous demand on network resources, separated by relatively large intervals of no activity. The most demanding scenarios for Event-Synchronized Measurement transactions involve instrumentation subsystems and any postmortem analysis. Single bunch turn-by-turn BPM measurements will consist of up to 256 kbytes per BPM. In this case, several seconds of latency is not unreasonable. Event-Synchronized waveform digitizers are expected to have similar requirements. The latency requirements for equipment setup and postmortem analysis is less stringent. The control system should provide 500 kbits/sec of network throughput for Event-Synchronized Measurement transactions from a single location.

Network Connections

The network shall provide data paths between computers in Buildings 911 and 1005, 6 Electrical and 18 Alcove Buildings around the RHIC ring, injection buildings and miscellaneous other locations. There will be about 50 workstation class computers on the controls network. Inbound traffic to device control nodes could be 0.5 Mbyte/sec, outbound 1.0 Mbyte/sec. A limited access path to the BNL network will also be provided. Modern fiber optic technology shall be utilized for long haul runs to provide high noise immunity and ground loop suppression.

Network problems must be readily diagnosed and fixed - or the offending node prevented from accessing the net by network management. The design must be such that higher-performance networking technologies being developed now will be usable in the future with the same cable plant.

Performance Monitoring

The control system shall provide a means of monitoring equipment status and data from beam instrumentation and other accelerator equipment. In addition, elements of the control system shall be monitored to ensure continuous availability of network, timing and other link services. Particular attention must be paid to ensuring that software servers which constitute a common resource, such as a database server, alarm server, etc., are robustly implemented with redundant units or automatic restart mechanisms where appropriate.

The control system shall be able to generate messages and alarms to the operators when problems with the equipment or with accelerator performance are detected. Software-controlled alarms shall not be used to ensure personnel safety or equipment protection, but may be used to notify operators of protective measures that have already been taken in hardware.

Access and Local Control

Equipment check-out and commissioning activities will necessitate access to the control system at or near the equipment. Console computers (or terminals) for local control shall be located at the major equipment areas (approximately 8 to 10 locations). There should also be portable (or at least movable) terminals for use in the other equipment locations.

The control system shall provide protection against unauthorized or inadvertent access to its computer systems and data files. Control system operations and file access which affect machine operation shall be restricted to authorized personnel.