Requirements

Task of the Computing and Controls Group

The task of the Computing and Controls group at the SLS is, in conjunction with the equipment groups and representatives of the machine users, to specify, design, build, and maintain the computer systems which control the operation of the SLS sub-systems and to provide a general scientific computing facility for the experiments. The sub-systems to be controlled include the Injector, Booster, Storage Ring, Beam Lines and Experiments. The SLS control system will provide a set of hardware and software tools to monitor and control each individual SLS sub-system, and co-ordinate those sub-systems into a functioning whole. The system will be largely built using technology developed at other laboratories and in industry. The use of home built technology will be minimized. The Computing and Controls group will provide support to the experimental groups including equipment for the control of standard experiments, data archiving facilities, and standard scientific analysis tools.

Scope of the Control System

The scope of the control system is from the electrical interface of the I/O devices (ADC, DAC and Digital I/O), to the graphical displays that an operator uses, and all software and hardware in between. This scope includes the provision of I/O devices over field-bus interfaces. Standard signal conditioning is included in the scope of the control system, but unusual, or device specific conditioning will be the responsibility of the equipment groups. Standard signal levels will be expected at the controls interface, for instance 0/24V levels for digital I/O and -10V to +10 V differential for analogue signals. Controls will provide standard solutions for Opto-Isolation of signals. Not all elements of the control system will be built by the controls group, for instance equipment specialists will develop low-level software, accelerator physicists will develop application and modeling programs, and external collaborators and industry will provide technology. However all of these efforts will be carried out within a well defined design framework which is managed by the controls group. All equipment must protect itself in hardware, but the cause of a hardware protection event must be made available to the control system for analysis and display.

Users of the Control System

The users of the SLS control system fall into a number of categories, whose requirements and view of the control system is different but often overlapping. These groups include machine specialists, operators, experimenters and others whose work involves being in or around the SLS complex. Machine specialists require the ability to develop and operate programs to test and operate their equipment, sometimes locally in isolation from other systems, when some central services might not be available. Operators require a clear, up to date and complete representation of the machine state, the ability to modify machine operational parameters and rapid notification of the occurrence and reason for alarms. Experimenters need information both visually and in computer readable form of the critical machine parameters that affect them, they require the ability to have (limited) control of some accelerator equipment such as insertion devices. Others, not in these groups, still need some basic information on the operation of the machine complex, such as which components are operating, and beam lifetime.

Reliability

In order for the SLS to provide beam to experiments when they expect it and with a minimum of unscheduled interruptions, control system reliability should be high enough to not significantly reduce overall availability of the machines. In order to achieve this, as the control system consists of so many individual components each control system component should be designed to a high standard to provide a long mean time between failures, and a short mean time to repair. Due to high cost it will not be feasible to use redundancy at the level of all signal inputs to the control system, but the design needs to be tolerant of failure of components which affect the operation of all systems. For example a software service such as a device naming service, that is needed by the whole system should not be restricted to running on one particular machine that might fail, and might well be replicated. Failures of services or non critical systems, should as far as possible, not cause the beam to be lost when in stored beam mode. However such failures if they do occur are more likely to affect operation when filling the machine. Some software systems such as fast feedback for beam orbit correction are critical at all times.

Performance

The performance of the SLS control system needs to be sufficient for the most demanding application required of it. The control system should not be a collection of ad-hoc solutions to particular problems, but be an integrated system capable of meeting the demanding requirements of present and future needs. The most demanding application for the control system is fast beam orbit correction, which requires the ability to close global control loops involving a large number of sensors and controllers throughout the storage ring, including significant processing, at a rate of 100 Hz. However this requirement should not necessitate the use of expensive or unproven technology. This level of performance should be available to other applications, such as other feedback loops, when the need arises. Correlation of any measured or calculated signal must be available as a standard facility. To achieve this all data must be time-stamped at the point of measurement. General time-stamping should be to a resolution of 1ms and an accuracy of 100micro seconds. Some equipment will require a higher resolution and accuracy. It must be possible to relate these time-stamps to higher level periods, such as which Linac cycle the measurement was made. Network performance should be should be sufficient to handle traffic generated by any changes to data made at a rate of up to 10 Hz.

Security

The design of the SLS control system will be such that it is very easy to use the system from within the SLS complex. In order for this to be so there will by very few security meaures in place within the system. It will not be necessary to login to any SLS console. It will be possible for any parameter to be read or set from any SLS console in the control room or equipment hall. The requirement that anyone can carry out any action, requires very strict control of access to the systems form outside. To this end, it will not be possible to logon to any SLS controls computer from outside the SLS complex, including from PSI offices. It will be possible to read SLS parameters from outside, but this will be via, WWW or similar access mechanisms. There is a need for operators to be able to initiate modem access for equipment specialists at home. Each beam line will however be treated as a seperate domain, protected from each other and the machine control system.

Ease of use

Ease of use, for each of the user types defined above, is concerned with minimizing the effort and training necessary to make use of the control system, and reducing the likelihood of error. While interfacing with and operating a machine as complex as the SLS cannot be made ?idiot proof?, it should not demand skills outside of those normally expected within the peer group of an individual user type. Thus an equipment specialist should be expected to have a complete grasp of the terminology of and operational states of his equipment. An experimenter would not be expected however to interface with the control system in terms of low level parameters of the RF system. Parameters should always be presented in standard engineering or universally accepted units, Amps, Volts, but mm rather than meters for beam position, and GeV for beam energy is acceptable. It should also be possible to make adjustments at the finest possible level of precision, that is plus or minus one bit value of an digitized value. Units should always be indicated and scales marked on any displays. It should be possible to easily extend the control system software functionality during machine development, by providing tools that can quickly develop test applications. However normal machine running will only use tested released software.

Software development

The SLS control system must provide a software development framework. This must include a structure to manage the whole life cycle of the software needed for the operation of the complex. All software from the largest system to the smallest utility will be subject to the same constraints. The software development cycle will include a requirements document, interface definition, manual page, testing specification, and change request. Tools must be available for version control, including the ability to generate previous versions of all code and utilities.

Tools

Tools are the facilities provided to facilitate the efficient operation of the control system. By offering a set of standardized high level tools, the application programmers are spared much repetitive work, and the interface to and operations of the control system is made more consistent. Tools to be provided include:

- Display tool - a standardized way of building operator interfaces including buttons, menus, sliders, graphs, strip charts, synoptic displays and bitmaps.
- Super Knob - a graphical widget such as a slider, that can control more than one parameter. The relationship between the parameters must be settable 'on the fly'. For instance one might wish to control the current in a set of magnets by a fixed or variable ratio (from a table).
- Archive tool - the ability to save and restore individual or groups of device values and parameters. This should be possible at run time rather than having to be hard coded into software. It should be possible to treat archived data interchangeably with on-line data.
- Alarm tool - a tool to monitor, classify and display alarms in a consistent manner. The alarm tool should have to ability to both poll devices to check status and to accept asynchronous alarms. Alarm limits (Hi, Low) should be settable and conditional alarms should be possible of the type: if device X value is above value (a) then if device Y value is below value (y) then alarm state is true. Alarms should be hierarchical, and of multiple levels (green, yellow, red). Alarms should be filter-able according to machine state and time of occurrence, thus it should be possible to identify the first failure to occur, which may itself cause a cascade of other alarms.
- Failure analysis tool - A tool to configure and examine a history buffer associated with any hardware or derived signal. It must be possible to configure a history buffer for all channels, which can hold at least the last 5 seconds of data measured. This history buffer can be frozen on an specified alarm condition (such as beam dump), and examined at leisure.

- Database tool - The ability to interrogate and update a relational database in the same manner as other devices in the control system. The database should hold a complete record of the machine components, such as survey data as well as installation, test and maintenance histories. The database will also hold data such as calibration values used for conversion to engineering units.
- Configuration tool - for installing and configuring hardware and software. This will be primarily concerned with arranging and re-arranging which objects reside on which processors at what level of the machine control system. Also it will be used to simplify installing new hardware, providing information on jumper settings etc. It should be possible to migrate objects between nodes without affecting other control system operations.
- Sequencing tool including Start-up / Shutdown tool - for creating high level sequences of actions to carry out on accelerator objects. The tool should allow for a hierarchy of sequences that can be represented graphically.
- Program generator tool will allow a large amount of repetitive programming to be automated using pre-defined modules. Ideally this tool would have a graphical interface.
- Command and operation history tool - It must be possible to log all commands and operations carried out on the control system. This would record all actions as a function when, from where, and by whom any operation was carried out. For this reason group accounts for a common login will not be permitted for the operation of a the facility, as individuals must always be identified.
- Correlation tool - This would allow the relationship between any signal and any other to be displayed. All signals will be time-stamped at source to provide an accurate correlation of signals.

Software architecture

Careful attention must be paid to the choice of software architecture. Which will affect the operation of the SLS complex throughout its lifetime, not just during construction. Some of the primary criteria that must be considered are:

- PERFORMANCE - should be judged on real-time response as well as throughput considerations.
- FLEXIBILITY - the ease with which it possible to modify software, add new functionality, and how well it can adapt to changing requirements.
- SCALABILITY - the ability for the system to grow in terms of number of control points, as well as absence of limits of the number of nodes in the system.
- ROBUSTNESS - Tolerance to errors, by users, programmers, and due to system hardware and software failures.
- OPENNESS - the adherence to standards. Also the ability to interface easily and without performance degradation to other software packages and systems including shrink-wrapped software such as Labview. It is also very desirable that the software runs on a variety of operating system and hardware platforms.

Control Room

The accelerators of the SLS complex will all be controlled from a single central control room. This control room will house the operator stations from which it will be possible to control all aspects of machine operation. Three consoles will be provided, in order to be able to carry out machine development in parallel with normal machine operation. Consoles will not be dedicated to one task or accelerator, all consoles will have the same facilities no specialized hardware or software will be installed on just one console. Consoles will each have three display monitors (multi-headed), sharing a mouse and keyboard to avoid operators too often having one program window hidden under another. One display monitor might only have fixed tiled display windows to make sure critical application displays are not hidden by other tasks such as editor sessions.

Generally program development will be discouraged in the control room, with the exception of rapid application development during machine development sessions. The control room will be equipped with a number of large fixed displays showing critical machine status and parameters, these will be mounted high on the front wall so that they can be viewed from any console. The principal machine status page including information on Beam current history, lifetime of the beam, fill mode, status of experiments, and status messages. This information must be distributed to displays in locations such as the canteen and other public places, and should be made available via the world wide web.

Supervisory level

This level will include operator interface consoles, file, print and database servers. The operator interface shall consist of medium to high performance computers providing high quality graphics and multi-head configuration. This level as well as offering the environment for operating the machine will also provide the environment for systems development. Appropriate network technology at this level is needed to ensure no degradation of system performance to network throughput restrictions under load. System consoles will also be provided at equipment locations in the machine, these could be single head configuration, perhaps with 17? displays, but with the full functionality of the control room consoles. Supervisory level services will include support for file servers, database servers and print servers, and perhaps specialized compute engines. Interface to and support for access to industry standard database (OODBMS and RDBMS) products is desired.

Processing level

The processing level will consist of computing equipment designed to provide real- time (deterministic) processing of signals and operation of control algorithms. Specialized processors such as DSP cards should be supported at this level to carry out computationally intensive calculations. It should be possible at this level to carry out standard operations on all signals such as conversion to engineering units, and monitoring for alarm condition. It is an advantage at this level to support action on exception (asynchronous) as well as a polled method of data transfer.

Device interface level

Front end equipment will be interfaced to the processing level by a field bus, such as Lonworks or CAN. It is desired that the system supports more than one industry standard field-bus. It is hoped that equipment suppliers, such as power supply vendors, will be able to provide equipment with the supported field bus standard, eliminating the need for front end crates. PLC devices will be supported at the device interface level where required. PLC devices should only be used where a solution in the system core software model is not possible, in classes of problems such as interlocks. A standard PLC type should be selected and used for all PLC implementations at SLS.

Application programming

Application level software will consist of the application programs, standard tools, and commercial packages that are used to control the running of the accelerator complex. The applications will be written in-house mainly by equipment specialists and accelerator physicists, using tools supported by the controls group. Some applications might be ported from other laboratories, therefore standard tools such as Fortran and C compilers should be available.

Naming convention

A naming convention and naming service shall be provided that:

- Allows a hierarchy of names, such as FACILITY, DOMAIN, FAMILY, MEMBER., etc.
- Is not geographically constrained (no use of node or crate names in device names)
- Name length should only limited by the system limits on the platform being used.
- A redundant naming service must be available (no single point of failure).
- Allows aliasing - the provision of more than one name for the same object.
- Allows 'short' names when the context is defined - such as MOD_VOLTAGE instead of RING/RF/MOD_VOLTAGE

Interface definition

An interface control document will be provided for each equipment being controlled. This will specify:

- The physical interface to the device
- The electrical interface to the device
- The Protocol used to talk to the device
- The behavior of the device (when signal A goes high the device turns off)

This document will also specify the test procedures to be followed for acceptance, and under what machine states the interface will or will not be available. All modifications to this interface will be subject to standard change control review procedures.

Timing

The timing systems used at SLS will be used to synchronize the operation of the machines. Most timing signals are local to equipment, however there will be a need for some limited distribution of hardware timing signals. The three principal timing signals are the Linac Clock- 3 Hz cycle clock indicating the start of a Injector cycle, Booster clock - the revolution clock of the booster (referenced to a specific bunch passing a reference point in the Booster), and the main ring clock the revolution clock of the storage ring. These signals will be distributed to each control location by the RF group. The interface to the control crates shall be via a 50 ohm coax cable, with Lemo connector. The clock signals will have an accuracy (jitter) of less than 1 micro second. These signals will be used by counter cards that are part of the control system, used to generate hardware signals used to trigger hardware actions and measurements, as well as software interrupts to trigger less time critical software events. The control system will be able to program these counters. The control system will also count the cycle clock in order to be able to time-stamp measurements for archiving. As the RF clock will not be distributed, it will not be possible to make measurements referenced to a specific bunch in the machine.

Modeling

Each hardware device interfaced to the control system, will have a equivalent simulated device used for testing. Some of these simulated devices will be fed data from standard modeling programs such as MAD. The interface to these simulated devices should allow the user to choose between a variety of models that might be available.

Database

A database system should be available to hold both persistent and archival data tables. The archive tool will use the database allowing the use of standard database reporting tools as well as access through the control system. Persistent data held in the database will include parameters such as conversion constants and tables, as well as installation, test and maintenance history of devices such as survey data. The database parameters for devices include default and start-up values for devices, and can hold values for test devices used when the real devices are not available.

Access and revision control facilities must be available to limit access to some parameters, and be able to restore old settings. Some data may rarely or needed change, while some may be updated often.

Software development Methodology

It is desired that support be available for the Object Oriented Analysis and Design of SLS application and system software. Ideally this should use the Object Modeling Technique (OMT) developed by Rumbaugh. Using this methodology three models are built, the **object** (static) model, the **dynamic** (state diagram) model and the **functional** (Data Flow Diagram) model. These three models are used throughout the system software life-cycle. By providing a clear graphical representation of the system, a more precise definition of the system operation can be obtained for the initial specification, without resorting to a long and complicated written document. This initial specification model can then be developed in an interactive manner, giving more and more detail until final coding of the low level objects.

Computer Aided Software Engineering

It is hoped that the use of case tools, as well as providing verification of the models, will be able to automate the generation of at least some of the code necessary. One critical aspect of this is the facility, is to back-annotate a diagram when a change has been made to the low-level code. Software Through Pictures (STP) and Rational Rose is being used at CERN, including ATLAS.

Application Design

Most high level application will not be concerned with the details of the devices, most will only acquire, display and modify the attributes associated with the devices in the system and to combine these in a high level fashion. To aid this process standard modules should be provided to carry out repetitive or specialized tasks, such as calculating values such as minimum, maximum or average of functions, or providing PID or Ladder Logic processing.

Diagnostics

Diagnostic systems will require relatively high data rates and fast response times from the control system. Beam position monitors and beam current transformers will be the most common diagnostic tool. The signals from these devices will require digitizing at 16 bits (true 15 bits) at a rate up to 1 MHz. This corresponds to a measurement of the position of the beam on each turn of the booster or main ring. It must be possible from the control system to select the data to be read. This includes: The time of starting the measurement, typically ms after the start of the 3Hz cycle; the number of turns to acquire; the delay until the next measurement; how often to repeat this measurement. For example a request might be starting 5ms after start of cycle, read 256 turns every 2mS, and repeat 20 times. The data should be returned to the requesting program for further processing (example FFT), correlation with other signals, and display to an operator. Similar functionality is required from fast current monitors, although the slow current monitors have less demanding requirements.

Fast Orbit correction

Fast orbit correction will require the ability to acquire the orbit of the main ring from 72 beam position monitors around the ring in both horizontal and vertical planes. The new orbit needs to be calculated and the values distributed to the magnet power supply controllers. To achieve this an acquisition system consisting of a crate at each of the 12 sectors will acquire the reading from 6 Beam Position Monitors. These values may be selectively averaged over a number of turns of the machine. The values will be packed into a 36 Byte message, 16bits per reading x three readings per BPM (Horizontal + Vertical + status) x 6 BPMs per sector. This message will be transported at 100 Hz rate upon receipt of a hardware interrupt. This message will be sent to a central crate equipped with a fast (DSP) processor to carry out the necessary calculation. The changes are then propagated back to the corrector magnets. The round trip time should be less than 250uS. It is important that it is possible to allow different correction algorithms to be used, and to rapidly change between them.

Local Control of Insertion devices

Beamlines must have real-time access to the control of insertion device and also to have fast (up to 100 Hz) monitoring of the undulator gap. This will allow the movement of the monochromator to be synchronized with the movement of the insertion device. This will be facilitated by having beam-line and experiment control being well integrated with machine control system. Movement of the insertion device and corresponding magnetic compensation must be carried out to produce a zero integrated field. This will ensure that beam perturbations are minimized and quality of beam is not adversely affected. The 100 Hz fast beam orbit feedback system will correct the global orbit, in response to the relatively slow changes that might be introduced by moving the insertion devices.

Physics/Operations

Typical, traditional applications which are required to commission the accelerator are listed below.

- measurement of orbit/trajectory response matrices
- measurement/calculation of beam parameters/characteristics: dispersion, chromaticity, tune (transverse and synchrotron), beam lifetime, bunch length; as a function of a variety of parameters: beam current, lattice corrector settings, bunch pattern, etc.
- Comparison of machine behavior with theoretical models.
- Use of the beam for the measurement, calibration and optimization of RF parameters such RF voltage, bunch length, phase.
- Measurement of effects due to machine construction and assembly errors: power supply ripple, mechanical vibrations, defective and offset BPMs, higher order mode (HOM) excitation in cavities, magnet and beam position apparatus alignment errors.

To assist in carrying out these activities, a user-friendly system permitting the user to save the (partial) state of the machine, to be restored at a later time is required. A large number of these applications are run only on demand by the physicist in order to verify a theory or to identify an immediate problem or error. As such, these applications tend to temporarily stress the combined control system bandwidth in terms of data acquisition, real-time synchronization, on-line modeling of machine components, and the on-line processing and storage of data. The nature of these physics experiments require a flexible programming environment, such as provided by a scripting language, able to respond rapidly to changing scenarios and boundary conditions which are normal in commissioning accelerator systems. Many of these physics experiments will be re-written as permanent operational applications, requiring semi-continuous running:

Magnet Power Supplies

The magnet power supplies to be controlled include DC, Solenoid, Pulsed and Ramped supplies. Magnet subsystem consist of dipoles, and quadrupoles. Quantities required to be measured, set and stored by the control system include:

- Magnet excitations/calibrations.
- Field maps (simplified), including higher multi-pole content.
- Magnet ramps including optimization, slow ?feed-forward?, conditioning.
- operational properties e.g. temperatures, field values.

Some of this data may never change in the lifetime of the magnet.

Function Generators

Function generators will be required for ramping devices including **RF** and **ramping magnet power supplies**. These function generators will work in one-cycle mode only. A start pulse will enable the output and the pre-programmed values will be clocked out on receipt of a train of clock signals, or from an internal clock. The worst case error between the desired and actual output of a function generator at any time shall be one part in ten thousand, or 1 mV for a 10V output range. This error must include the quantization error of the DACs (number of bits) and the skew between outputting different channels. This requirement will limit the skew between any synchronized devices such as magnets being ramped.

The function generators shall be capable of clocking out the waveforms at a rate of 10KHz, with a jitter of < 10 uS. The output resolution shall be 16bits, and the function generator shall be capable of holding 5,000 values per waveform buffer. The function generator shall be able to hold up to two waveform buffers, and switch between them within 1 ms. Normally the changing between buffers is carried out between cycles. It shall be possible to download new waveforms to a function generator within 200 ms. The function generators must respond to a hold command received from the control system within a maximum of 1 ms of the command being transmitted from a console or front end equipment.

RF

The component objects for the modulator subsystem are grouped into domains. Many of the building blocks in the user and equipment interface domains are re-used in the other systems in the accelerator. Each of the RF objects requires a finite state machine to track the behavior of the object, notify application programs of changes in state and alarm situations, perform power-up sequences, and to provide logging and archiving data streams. The control software should be able to notify the operator or alarm handler application within 100 msec of the occurrence of an interlock event. The control system must provide a time-stamped record of

RF trips for later off-line analysis of equipment malfunction. Power-up sequences must be provided to bring the RF station to a state of readiness (STANDBY, RFON, etc.), and bring the modulator back to operational state from a faulted state.

Vacuum

The vacuum system can be divided into 2 overall modes: pumping down, and beam- ready. In the beam ready state, the vacuum pressure readings at all points around the ring could be available to high level applications at a rate of at least 10 Hz. This would allow tuning and correlation measurements between beam loss and corrector settings, for example. Pump down curves must be made available for archiving and the identification of possible leaks and out-gassing.

Beam transfer

This includes injection and extraction kickers, and magnet power supplies, and may include the interfaces to beamline front ends for the extracted photon beams. Kicker timing must be programmable, to allow the analysis and optimization of beam properties during all parts of the injection cycle. Top-up mode of operation must be supported. On line transfer efficiency calculations must be generated, perhaps using readings from Beam Current Transformers.

Beam Line Control

Beam-line control will require many of the same facilities and features as the machine control system. It should therefore use the same system hardware and software, but with access to many of the features only available locally. Beam lines will require consoles that are tightly integrated with the scientific computing facility, as well as being part of the controls system. The consoles also require good access to external institutes. As beam line configurations are likely to change, it is in this area even more necessary to allow easy configuration and reconfiguration of devices. One of the most common hardware devices in a beam line are stepper motors and perhaps also DC motors. These are used for the primary and secondary slits as well as monochromators, and the movement of the experiment. It should be possible to synchronize the movement of these motors, and operate them in a continuous as well as incremental manner, that is for instance move a device at a constant velocity of X rad/sec until the device has reached Ymm of travel from its reference position.

Experimental data acquisition

Support from the control system for experimental data acquisition should include support of standard hardware and software components. This should include a wide variety of standard hardware devices such as counters, multi channel analyzers etc. The software provided to configure and operate an experiment should be simple to use but provide the ability to set up complex sequences of actions. The software provided should provide a high level interface and so incorporate knowledge of the optics of the controlled devices. Many devices used for an experiment will be provided as part of the experiment, and not by the control system. These specialized devices, such as piezo actuators would be integrated using standard interfaces such as GPIB, although in the future Field-bus or Ethernet may become more common. It must be possible to have an on-line processing of the data as it is acquired from the experiment. The facilities and analysis tools available as part of the scientific computing facility should be available at the experimental stations. The systems provided must be open to provide interfaces to third party products such as Labview.

This support will be offered as a standardized set of equipment and tools. Where an experiment wants to use other non SLS standard systems internally, they may do so, but support from COMPUTING AND CONTROLS group will be very limited. This means that we will provide all the systems necessary to control the beam-line and acquire data for permanently installed detectors, but specialized detectors, installed for a short time, may need their own data acquisition.

Scientific Computing Software

A scientific computing facility will be provided for use by the experiments and SLS machine development team. This facility should provide a standardized set of development tools and physics applications. development tools will include Fortran, C and C++ compilers and libraries. Applications will include the CERN library, PAW++, IDL, PV-Wave, Matlab, and data analysis programs from other synchrotron light source.

Scientific Computing Hardware Platforms

Due to the negative economies of scale of present generation computer technology (small computers are more cost effective than large ones), it is proposed to provide a distributed computing facility (cluster) rather than a single monolithic machine for experimental support. This would consist of a group of machines connected by a high speed network, with appropriate software to make it function as an integrated facility. If implemented today such a facility might provide a combined CPU power of 200 SPECmark/fp_95base (equivalent to 200 Sun Sparc Station 10 40Mhz., 100 M Bytes/sec aggregate network throughput, 5 G Byte of RAM and 1 TB of Disk, and tape robots for off- line storage. Based on todays technology this specification could be implemented using 10 Unix Workstations or 25 high end personal computers, connected via 100 M bit/sec switched Ethernet or ATM, and using RAID disk arrays. Critical to the effectiveness of such a facility is the software to integrate the machines and the tools to support parallel applications. An example of such an existing facility is the ESRF NICE facility, providing a cluster of HP-RISC machines. The computing equipment required for this facility could be located mainly either within the SLS complex, or in the PSI computing facility, but in either case the beam line work-stations must be logically within the facility at an equal level to the other nodes.

Archiving of Experiment data

Tools will be provided to archive experimental data to appropriate magnetic or optical media. Equipment must be provided to allow archiving of data at each experimental location as well as at a central facility. Fast data links will be provided directly between each beam line and the rest of the computing facility, to ensure that data can be located on central raid disk arrays to provide global access to data. Networking technology will evolve significantly before the facility will become operational, it is therefore unwise to make a final decision at this time, however technology that looks attractive today includes ATM and Fiber Channel. Close contact should be made with other experimental facilities to follow developments in this field.

Milestones

The principle milestones for control system delivery include:

- Aug 1997, Approval of Requirements & and Implementation specification
- Sep 1997, Start detailed design and development of SLS Controls
- Sep 1998, Deliver complete working control systems for laboratory application development.
- Jul 1999, Start equipment installation.
- Jan 2000, Start Linac commissioning

- May 2000, Start Booster commissioning
- Oct 2000, Install main control room
- Jan 2001, Start main ring commissioning
- Spring 2001, first beam line commissioning
- Autumn 2001, Data from first experiment

Control application programs

Applications programs cover a number of domains including machine commissioning, operation and testing. major application that need to be written include:

- Beam Orbit Correction
- Ramp Control
- Power Supply control
- Transfer Line Steering
- Emittance measurement
- Longitudinal Bunch Profile Monitor
- Tune (H & V) + coupling
- Current Monitor (fast and slow)
- Vacuum
- Injection / Extraction control
- RF Control
- Scraper Control
- Beam Cleaning
- Beam Loss Monitoring
- Timing Control
- Insertion device Control
- Magnet Levelling Control
- Alarms

Other external systems that should be monitored but cannot be controlled:

- Machine (equipment) protection
- Water (status information only)
- Power (status information only)
- Air Conditioning (status information only)

Accelerator Hardware components to be controlled

*Family	*Equipment	*Linac	*X-fer	*Booster	*X-fer	*Ring	*Exp
*Power Supply	Dipole Power Supply 16bit	0	2	1	3	1	-
*	Quad power supply 16bit	5	11	3	10	174	-
*	Sextupole Power supply 16bit	0	0	2	0	9	-
*	Vertical corrector power supply	6	6	54	6	72	-
*	Horizontal corrector power supply	6	6	54	6	72	-
*	Skew Quad power supply	-	-	-	-	4	-
*	Kicker Power Supply	-	-	2	-	1	-
*	Scraper	-	1	-	-	1	-
* Diagnostic	BPM	-	-	54	-	72	-
*	Slow current monitor	3	-	-	-	2	-
*	Fast current monitor	-	-	1	-	1	-
*	Tune Monitor	-	-	1	-	1	-
*	Fluorescent Screen (CCD)	12	-	1	-	1	-
*	Profile Monitor	2	-	-	-	1	-
*	Visible Light Monitor (CCD)	2	-	-	-	-	-
*Vacuum	Ion Pump Power supply	5	-	20	-	156	?
*	Penning	0	-	0	-	48	?
*	Sector Valves	0	-	3	-	24	?
*	Front End Valves	0	-	0	-	24	?
*	Front end valve absorber	0	-	0	-	24	?
*	Beam Shutter	0	-	0	-	24	?
*	Beam Shutter Absorber	0	-	0	-	24	?
*RF	RF Modulator/Transmitters	2	-	1	-	4	-

*	Cavities	3	-	2	-	4	-
*	500 MHz Pre-buncher	1	-	-	-	-	-
*	3 GHz buncher	1	-	-	-	-	-
*	Accelerating structure	2	-	-	-	-	-
* Alignment	HLS Monitors	0	-	0	-	144	-
*	Magnet Movers	0	-	0	-	144	-
*	Wire Monitor	0	-	0	-	>192	-
*Beamline	Undulator Carriage	-	-	-	-	-	5
*	Monochromator	-	-	-	-	-	5
*	Streak Camera	-	-	-	-	-	5
*	CCD detector	-	-	-	-	-	5
TOTAL DEVICES	-	73	13	198	12	1029	>>20

A.