View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by CERN Document Server

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN ¾ SL DIVISION

CERN-SL-2001-063 DI

Summary and Recommendations from the Review of LTI and CNGS Controls held at CERN on July 10th, 2001

M. Lamont, R. J. Lauckner, V. Mertens, M. Vanden Eynden

Abstract

The Review of LHC Transfer lines and Injection (LTI) and CERN Neutrinos to Gran Sasso (CNGS) Controls was the first overview of requirements and preparations for the control of these facilities. Participants were asked to outline work that was already underway or planned in order to build an account of activities and responsibilities. The control of CNGS facilities downstream of the primary target was not included.

Geneva, Switzerland
30th October, 2001

Contents

1 Introduction

Controls activities for the LHC Transfer Lines and Injection (LTI) and CERN Neutrinos to Gran Sasso (CNGS) projects are not being managed directly by the respective project teams but are rather relying on the line organisation of the groups concerned. Simultaneously, these groups are providing solutions for three major controls projects — LHC Controls Project (LHC-CP) [1], SPS Controls Re-Engineering project (SPS2001) [2] and the CERN Experimental Areas Software Renovation project (CESAR) [3]. Resources and priorities are already stretched between these activities, therefore it is not clear whether another controls project is appropriate to provide controls solutions for LTI and CNGS.

This situation has led to concern and therefore this review was organised with the following goals:

- identify the systems that will be needed to control LTI and CNGS equipment;
- examine the interfaces between these systems and the SPS and LHC accelerator controls;
- identify areas where new initiatives are required;
- clarify controls responsibilities at all levels.

The programme and the slides of the various presentations are accessible from [4]. In this report Sections 2 to 9 are a summary of the material presented during the review and some of the discussions. In Section 10 recommendations are made for achieving the above goals.

2 Projects Overview

2.1 LHC Transfer Lines and Injections

Two transfer lines, TI 2 and TI 8, are under construction to transport beams from the SPS to the LHC. TI 2 leads to an injection point (kicker centre) approximately 154 m left of IP2 where beam will be injected into LHC ring 1. TI 8 brings the beam to a point at the same distance right of IP8 (note that this IP is displaced by 11.22 m) where it will be injected into ring 2. An overview of TI 2, TI 8 and their injection systems has been given in [5]. Details of the injection systems are given in [6]. Comprehensive status information and further details are accessible from the home page of the LTI project [7].

To send beam down TI 2 the existing extraction in SPS LSS6 will be modified. Two new fast extraction kickers (MKE) will be installed to bypass the electrostatic septa and the diluter protecting the magnetic septa will be upgraded. For TI 8 a new fast extraction is being built in SPS LSS4.

2.2 CERN Neutrinos to Gran Sasso

The CNGS facility, presently under construction, will provide a beam of neutrinos to detectors at the Gran Sasso Laboratory, located some 120 km away from Rome, to measure neutrino oscillations. A comprehensive description is contained in [8]. More information is accessible from the home page of this project [9].

The primary proton beam line, TT41, branches off from TT40, downstream of the new SPS extraction in LSS4, and deflects the beam over some 600 m in the direction of Gran Sasso. At the end of TT41 the beam hits a production target, T40, consisting of a number of graphite rods cooled by a forced helium flow. Magnetic lenses downstream of the target, the horn and the reflector are used to largely parallelise the secondary particles. These decay, producing a large number of the desired ν_μ in the subsequent 1 km long evacuated decay tunnel. At its end a hadron stop removes non-interacting protons and all secondaries. The flux and spectrum of muons are measured in two downstream muon counting stations.

2.3 Beam Parameters

Beam will be transferred to the LHC at 450 GeV/c, with a nominal (ultimate) intensity of 1.1 (1.7) 10^{11} protons per bunch and a bunch spacing of 25 ns. The normalised transverse emittance is 3.5 μm rad. In the presently favoured injection scheme three or four trains of 72 bunches (each set of trains is called a batch) will be transferred per SPS cycle of 18 or 21.6 s, respectively, to fill each LHC ring with 2808 bunches. Note that the flat top duration of the LHC injection kickers can be varied up to 7.8 μs to accommodate alternative injection schemes. The nominal three-train batch intensity is therefore 2.4 10^{13} p, whereas for an ultimate four-train transfer the intensity comes to 4.9 10^{13} p.

Extraction towards the CNGS facility will be at 400 GeV/c to optimise the neutrino production, although the TT41 line is designed to transfer beams of up to 450 GeV/c. The beam for CNGS will have a 200 MHz structure and a nominal emittance of 12 μm rad. Beam will be sent in two fast extractions, each of about 10.5 μs duration, interspersed by 50 ms. The nominal (ultimate) intensity per 6 s cycle is 4.8 (7) 10^{13} p. Various SPS supercycles to combine CNGS running with other tasks of the SPS are imaginable. For example, one supercycle where a 450 GeV/c SPS cycle for the other fixed target users is followed by several 400 GeV/c cycles for CNGS, or another where each LHC transfer is interleaved with several CNGS cycles.

2.4 Beam Instrumentation

Appropriate beam instrumentation along the transfer lines and particularly in the LHC injection and CNGS target regions is needed to achieve the required steering and delivery precision and to monitor the beam characteristics.

The beam instrumentation requirements, layout and performance for LTI have been given in detail in [10], only a very basic account is given here.

An appropriate and cost-effective basic scheme for the arrangement of the beam position monitors (BPMs) has already been described in [11]. A subsequent study [12] has resulted in further optimisation of this scheme. The intensity will be measured at the beginning and end of each line using a beam current transformer (BCT). Intensity measurements are also possible with BPMs if both planes are equipped with read-out. To measure beam losses, about 30 ionisation chambers are foreseen at strategic locations in both TI 2 and TI 8; another 18 are planned for TT41. In total 13 Optical Transition Radiation (OTR) type screens are foreseen for profile and emittance measurements along TI 2 and TI 8 — five in locations upstream and downstream of the injection septa and kickers, and upstream of the injection beam stopper. Another six are planned for TT41.

The BPMs are in fabrication. The instrumentation requirements are currently being finalised for the SL-BI Review to be held in November 2001.

2.5 Main Challenges and Resulting Demands

The beam parameters (energy, intensity, emittance), the dimensions of the lines, their relatively small physical apertures and the required delivery precision on the LHC orbit and the CNGS target present considerable challenges. Demands are high on the SPS orbit, extraction precision, beam observation, beam correction and on steering facilities for the new transfer lines. The proper functioning of interlocks is primordial especially at higher intensities.

Physics goals place strong demands on operational efficiency soon after commissioning. This in turn implies well-conceived, user-friendly and fully debugged tools for the operators at the time of the start-up. The control system as well as the beam instrumentation must be available, set up and debugged early enough to be able to concentrate on the understanding of the behaviour of the transfer line and the LHC machine. Applying operational procedures with rigour will be essential. Computerised checklists must support critical operations. The access and interlock systems must not compromise on safety. They should also be able to handle varying conditions, arising from the multicycling operation and the progression from installation to commissioning and testing, and later to operation of the facilities.

2.6 Planning

It is foreseen to test the extraction from LSS4 and TT40, common to LTI and CNGS, after the shutdown 2002–2003. According to the present planning [13] the first of these lines, TI 8, including its injection should be fully installed by April 2004, to provide beam to the LHC during the sector test. This also includes the part of the LHC between the injection point and the inner triplet at the other side of the IP8 insertion which will be substituted during the sector test by a warm line, which could be considered as a temporary prolongation of TI 8. The TI 8 installation and commissioning planning which has been elaborated by the time of this write-up shows the possibility to checkout and commission the bulk of TI 8, up to TED87765, during the 2003 operation period. Because the downstream part of the TI 2 tunnel will be used as a main transport path for LHC machine components, TI 2 will only be completed in early 2006, just before the planned LHC pilot run. The CNGS facility is presently scheduled to deliver beam as of May 2005.

3 Low-level Controls

The responsibility for providing equipment specific controls solutions is split between four SL groups (Beam Instrumentation, Beam Transfer, Power Converter, Resistive Magnets) and one LHC group (Vacuum). The SL Controls (SL-CO) and the LHC Industrial Automation (LHC-IAS) groups are providing infrastructure support for these systems. Another important support group, the Communication Services group in the IT division, is responsible for data, video and voice communications.

3.1 Vacuum Control

The vacuum systems in TI 2 and TI 8 extend from the TT60 and TT40 lines down to the injection regions at points 2 and 8; the pressure in these lines will be less than $3\,10^{-6}$ mbar. Design and manufacture of all vacuum components, dipoles, quadrupoles and pumping ports are the responsibility of the Budker Institute of Nuclear Physics in Novosibirsk. Each line will consist of four vacuum sectors of similar length. Each sector will be equipped with 12 ion pumps of the LEP type, one turbo-molecular pumping station, six roughing valves and one Pirani or Penning gauge. Valves and pumps will be recuperated from LEP.

The CNGS beam will share part of TT40 then will continue to the target at the end of the TT41 line. TT41 pressure will be less than $2\,10^{-7}$ mbar and the line will be divided into three vacuum sectors.

The control system for vacuum will follow the solutions adopted for the SPS ring. Principle building blocks will be:

- Oracle RDBMS for equipment management;
- PVSS[14] Supervisor;
- TCP/IP communication over Ethernet;
- Siemens S7/400 Programmable Logic Controllers (PLCs);
- Compact gauges or TPG300 gauges connected by a 3 km cable.

Two Siemens S7-400 PLCs will be required. These will control the valves from a DOx32 card. Power supplies and gauges will be connected via Siemens ET200M remote input/output modules through Profibus DP. The current X/Motif based high level application is to be replaced by a supervisory application built from PVSS for all SPS and transfer line vacuum systems.

The Vacuum group expects the SL-CO group to supply the following extensions to the infrastructure:

- Data network;
- Time of day support;
- Logging and alarm facilities;
- Three racks in BA7 and four in BA4;
- Infrastructure for mobile control.

No electronics will be installed in the tunnel.

3.2 Magnet Surveillance and Protection

A total of over 700 warm magnets will be required to transport the beams in TI 2 and TI 8 (including TT40) to the LHC of which 75 will be recuperated. The CNGS project will require an additional 145 warm magnets in TT41. Magnets will be equipped with Elmwood thermal switches that open at 65°C and close at 45°C. The system will also be instrumented with temperature probes, flow meters on the magnets and will monitor ambient conditions.

The basic control architecture is similar to that of the vacuum system. Siemens S7-300 PLCs will be equipped with remote I/O modules connected by Profibus DP. The remote I/O crates will be cabled to the thermal switches and the PLCs will in turn be cabled to the power converters. This implies that the equipment protection will depend on the reliability of this system. Analogue remote I/O will collect the temperature and flow information via the same infrastructure. It is proposed to install the ET200 remote I/O modules in the transfer line tunnels.

The consequences of the radiation environment and the operation of this equipment in a controlled access area have yet to be evaluated, particularly for the CNGS transfer line. No plans have been made for integrating this system above the PLC level. The CERN recommended SCADA System, PVSS, could meet the supervision needs of the equipment specialists. The further requirement to integrate this system into the central logging and alarm facilities has also to be addressed.

3.3 Power Converters

One hundred pulsed converters for dipole and quadrupole magnets and 130 DC converters for corrector magnets are required to power the magnets for these projects. Pulsing the major converters will reduce the energy bill. It should be noted that some correctors in TT40 are DC and settings are common for CNGS and LHC beams if they are in the same supercycle. Additionally, a thyristor switch will permit sharing of the same power converter for the main bending magnets of TI 8 and CNGS.

The CNGS line will be equipped with a hardware protection interlock acting on the SPS extraction to prevent the extraction of the intense neutrino production beam if the magnets in the line are not correctly powered. This Fast Extraction Interlock (FEI) will compare the measured and nominal currents about 20 ms before extraction. The extraction will only take place if the errors of the pulsed converters and the DC correctors are less than 0.1% and 1% respectively.

The controls for these power converters are considered as an extension to the SPS. This strategy has been chosen for economical reasons and many existing power converters are being re-used; these are often housed in existing SPS buildings and share the existing infrastructure. Thus the current ROCS/Mugef control crate will be the basic control crate.

ROCS/Mugef is a VME Power PC system running Lynx OS, each crate providing control for up to 40 power converters. It provides 15 bits of status information, an 8-bit command word, and generates pre-defined current reference waveforms for each converter. Several waveforms are pre-loaded from the network. The SPS slow timing selects and triggers the reference waveform. Two 16 bit analogue channels sampled at 1 kHz monitor each power converter.

This centralised control is well suited to the development of the FEI system that is currently underway. The FEI condition will be generated by an extension to the Mugef software and triggered from the accelerator timing. A complete prototype has already been successfully tested. A standard Mugef channel will also be used to control the TI 8/CNGS thyristor switch.

Construction and delivery of Mugef electronics are already very advanced and the installation will proceed in parallel with the power converters, commencing in the second half of 2002.

The following extensions to support and services are necessary:

- Racks for housing the Mugefs;
- Controls Ethernet extension to these racks;
- Control room software including programs for setting up the FEI and associated timing events;
- Surveillance software to monitor converters and reduce invocations of the FEI;
- Definition of the interface for the FEI output interlock signal.

3.4 Beam Instrumentation

The basic control of all the instruments for both projects (134 BPMs, 39 profile monitors, 5 fast BCTs, 90 beam loss monitors (BLMs), 2 beam absorbers: TBIU/TBIDs) will be based on the SL Beam Instruments (SL-BI) group’s Beam Instrumentation Software Common Template and Organisation (BISCoTO) infrastructure. This is implemented in VME Power PC systems running Lynx OS with the remote GUI written in Java. This does not cover the remote access needs of the Control Room operators. Services from the SL-CO group currently used are the PowerPC Lynx OS support, slow control hardware and software GUI Java classes and the SL-Equip distributed control library. The full list of basic services required is:

- Remote reboot and consoles for front ends;
- MTG timing messages and fast pre-pulses;
- Middleware and remote API;
- Development and operational front end platforms, RTOS, drivers and libraries;
- Development and operation back end platforms;
- Configuration and measurement databases;
- Alarm and interlock interfaces and strategy;
- LHC beam description.

Concerning the last point the SL-BI systems need an advance warning of which beam is about to arrive. The first four services must be delivered 6 months before the first beams. The other standards and interfaces are requested with prototypes or simulators 12 months before the beam. In addition, support is necessary for a 31.25 kHz WorldFIP fieldbus. All acquisitions will be based on the revolution frequency and 40 MHz RF trains.

BISCoTO infrastructure is incompatible with the SPS2001 infrastructure and the Beam Instrumentation team considers that it is the responsibility of the latter project to bridge this gap.

3.5 Extraction, Injection and Beam Obstacles

The SL Beam Transfer group (SL-BT) will contribute the following new equipment for the LTI and CNGS projects:

- Kicker systems for SPS extraction and LHC injection;
- Electromagnetic septa for SPS extraction;
- Beam dumps, safety stoppers and possibly collimators in the transfer lines;
- LHC injection stoppers and shielding;
- The neutrino target.

There will be no electronics in radiation areas and no need for any particular real time infrastructure. Solutions used for the recent upgrades to the SPS proton injection kicker, the North Extraction septa and the beam obstacles will be re-used. The variety of controls tasks will be tackled in the following ways:

Slow controls techniques will be used for controlling parameters that are independent of the accelerator beam cycles and slow timing. Examples are cooling circuits and equipment state control: on, off, standby. The architecture is based on industrial components: Siemens S7 series PLCs, Profibus DP and SCADA for local supervision. Integration into the SPS controls infrastructure is done using the Siemens Softnet S7 protocol to connect to the SPS2001 compliant device server.

Fast Control is required for variables that depend on the beam cycles and slow timing. Solutions are based on the VME Power PC systems running Lynx OS. Timing control employs VME TG8 timing receiver cards or remote timing receivers in G64 connected via the MIL1553 bus.

The requirement for waveform acquisition systems is currently an open issue.

The integration of the SPS injection kickers into the SPS2001 control room software has been completed for the 2001 start-up. The stoppers and dumps for the north and west extractions will be added by the end of 2001. Other systems will be added progressively, ending with the LHC injection in early 2004.

4 Technical Services

The CERN ST division is in charge of the study, implementation and control of the following systems for CNGS and LTI:

- Electricity distribution — high voltage power and low voltage transformers;
- Ventilation and air conditioning for the underground areas;
- Water cooling, chilled water plant and supply of demineralised water;
- Fire detection for the muon stations;
- Access system;
- Safety alarm transmission.

These systems will be monitored from the Technical Control Room (TCR) under the responsibility of the ST Monitoring (ST-MO) group.

The Electrical Network Supervisor (ENS) system developed under the responsibility of the ST Electrical (ST-EL) group will connect various electrical equipment in BA4 via local links and the CERN network to a proprietary SCADA running on dedicated central servers near the TCR.

The cooling and ventilation control system, under the responsibility of the ST Cooling and Ventillation (ST-CV) group, will be composed of PLCs connected through direct TCP/IP connections to a SCADA system, Wizcon, running on Windows NT. The monitoring of the system in the TCR will be done through the Technical Data Server (TDS) [15]. Some Web-based diagnostic tools will enable remote diagnostics and interventions.

The SPS is now becoming an "Installation Nucléaire de Base" (INB) and will have to comply with special safety standards. For the access control system new CNGS and LTI important safety elements, "Eléments Important pour la Sécurité" (EIS), will be controlled with new PLCs which will be connected to the existing SPS controlled access system.

For the monitoring of Level 3 alarms the CERN Safety Alarm Monitoring project, CSAM, is preparing a dedicated controls architecture based on PLCs communicating with PVSS, through a dedicated TCP-IP network to avoid common failure modes with any other system. SCADA synoptics will be presented to the fire brigade in the Safety Control Room (SCR). A gateway will export safety alarm information to other control systems at CERN.

The TCR is a central monitoring centre for a large variety of technical systems. For TCR to be as efficient as possible, a detailed functional and dysfunctional analysis of each system monitored from the TCR is being carried out, as well as a clear description of the interfaces and dependencies between systems.

5 Networking and Communications

Recently the direct responsibility for implementing and maintaining the networking and communications systems for all control systems at CERN has been conferred upon the Communications Services group in the IT division. This group will implement facilities to comply with the connectivity requirements of users. At the time of the Review no requests had been received for the CNGS project and no requests for networking installations for LTI.

It is foreseen to equip the LTI related tunnels with wireless communications, as in the LHC tunnel. The choice of the wireless technology is based on the results of a study carried out by collaboration between the CERN IT-CS group and an external audit (Teleplan). The GSM GPRS standard has been selected for wireless data transmission at 155 KBits/s while GSM 900 will be used for underground voice communications and GSM 900/1800 for surface voice communications. The fire brigade will also use a dedicated VHF system.

A leaky-feeder cable with boosters will be installed in LTI underground zones and dedicated GSM surface stations and VHF repeaters will be installed at the LHC surface points. The implementation of this proposal requires additional infrastructure and further negotiation with the telecom provider.

6 Interlocks

Interlocks at the SPS accelerator encompass the concept of hardwired and software interlocks. Hardwired interlocks are chosen where the signal transmission has to be particularly fast and reliable. They act as last protection barrier before destruction in case of an emergency situation or an operational error. Software interlocks that provide more flexibility and diagnostics complement them. Their main goal is to improve operational efficiency, this is achieved through better fault diagnostics and avoiding unnecessary beam dumps. Whilst the current concepts can continue to ensure equipment safety they are an important limit to future efficient running. Simple extension of the current system will inevitably lead to faults on CNGS equipment inhibiting LHC beams and vice-versa.

Beyond the immediate SPS consideration the interface to the future LHC interlock system remains to be addressed. An LHC injection interlock will be required. This should not prevent independent operation of the TI 2 and TI 8 lines unless equipment safety is compromised. The LHC may also require more sophisticated beam parameter interlocks to ensure that the SPS complies with the LHC requests; an application would be to avoid injecting nominal batches instead of pilots!

A new software interlock mechanism is currently under study in the scope of the SPS2001 project and is required for 2003–2004. For hardwired interlocks, the possibility to share common designs with the LHC interlock system is desirable but has to be considered in the light of the LHC and CNGS-LTI time scales which are rather different.

7 INB Issues

The CNGS and LTI zones are fully included within the INB perimeter, and are subjected to the same framework as the SPS and LHC. The main impacts of INB operation for the Control System are requirements for monitoring and logging. However the access control system and components which are important for personnel safety will feature in INB documentation and the regular inspections. INB quality assurance will have an impact on all of the systems mentioned.

A permanent record covering the life cycle of LTI and CNGS components is essential for adequate waste management. Consequently another impact of INB for control is on the full monitoring and logging of:

- Beam currents and energy;
- Beam losses and their distribution;
- Optics configuration including steering;
- Radiation monitoring.

Other INB aspects, which do not have direct impact on controls, such as traceability, will also apply to CNGS and LTI zones.

8 Central Controls

Central controls requirements are the responsibility of the SL-CO group who assume that the LTI controls infrastructure will be closely linked with that of the SPS. However, there are some domains, such as equipment in the LHC injection channel, where a closer link with the LHC controls infrastructure, as yet undefined, will be more appropriate. Until now the SL-CO group has not addressed requirements for the control of the CNGS facilities. Accelerator application software is discussed in subsequent chapters.

8.1 Alarms

The alarm system will be an evolution of the existing system which has to be adapted to the increasing scale dictated by the LHC and the need to interface new types of systems (industrial controls in particular). To meet these challenges the internal architecture of the alarm system is being adapted and new platforms are being explored.

8.2 Middleware

Support for the current SL middleware components, SL-EQUIP and RPC, is limited to preventive maintenance; developments are frozen. A replacement to provide get/set, publish and subscribe functionality is required. It should be based on commercial products and support the device/property model. The SL-CO group considers that it should incorporate slow timing semantics and be available for the various operating systems and programming languages in use. The Control Middleware (CMW) [16] project team has been working for some time to provide a product capable of meeting these requirements and aims to provide:

- Support for the device/property model;
- Support for publish/subscribe (device/property and topics);
- Support for inter-object communication by installing CORBA and JMS infrastructure;
- Support for integration of industrial devices (via OPC);
- Support for access to existing SL and PS devices.

The first version is available and will be used in the operation of the SPS experimental areas, currently being upgraded. It will replace SL-EQUIP as the middleware used by the Excel based rapid application development tool in the Prévessin Control Room (PCR). Consolidation before start-up 2002 will provide: access control, administrative tools, logging, a generic browser as well as a C client API.

8.3 Timing

This is a central component of the SL controls architecture. A large volume of hardware and software has been developed based on this architecture and therefore timing must continue to offer a high level of stability. The transfer line timing will be based on that of the SPS offering a centralised, fibre based distribution system with optimised signal latencies. This will include MTG slow events, pre-pulse signals and the revolution frequencies. GPS will also be available. The current hardware interfaces will continue to be supported. There are requests for new flavours including G64 based accelerator and time of day receivers.

A synchronisation system between the extraction of protons at CERN and the arrival of neutrinos at Gran Sasso has been proposed. This consists of fast time stamping, based on the UTC standard (provided by GPS equipment located at CERN and Gran Sasso), and information transfer in both directions, using existing international networks.

8.4 Workstations

PCs are starting to take over from X-terminals at SL and there is now an architectural split between GUIs and the so-called business layer. A separate server layer is developing to host the business layer. Strong support is evolving for GUIs and business software written in Java.

8.5 Front Ends

Long lifetimes and stability are required for solutions at this level. Nevertheless there are strong trends which are impacting on the requirements:

- Accelerator cycle independent slow controls applications are moving quickly to solutions based on PLCs and SCADA;
- Users are expecting VME, although the Controls group is also considering support for CPCI; this is based on considerations of cost, OS support, and available interfaces;
- Remote reboot and remote terminals continue to be a firm priority requiring specific developments;
- MIL1553 support must continue for many years;
- WorldFIP is increasingly being chosen and support is required including the provision of a bus arbiter gateway;
- A real-time infrastructure will be required for the LHC but will probably not be essential for the lines.

8.6 Network

Responsibility for the installation and maintenance of the communication network is the responsibility of the IT division as explained in section 5. However, the services and the level of support offered for the control system have not yet been defined; neither have the interfaces between the controls teams involved in the CNGS and LTI work and the support groups.

8.7 Timescales

The SL-CO group aims to provide the required LTI/CNGS central controls infrastructure, following mainly that of the SPS. It is planned to provide stable APIs one year before beam commissioning starts and to complete the infrastructure 6 months later. Where the LHC is to act as template the requisite control items have to be delivered with the same promptness.

9 Application Software

In this section the major systems taking beams from the SPS to the CNGS target and the LHC are re-called and candidate approaches to provide the necessary application software are described.

9.1 SPS Extraction

Focusing on the 2003 first tests of the new extraction system in LSS4 the relevant systems are magnets, kickers, septa, TEDs, beam instrumentation and interlocks. The magnets and septa will be controlled through ROCS/Mugef; the extraction kickers by the same infrastructure as the proton inflector, the beam instrumentation by the BISCoTO and interlocks will be derived from the monitors.

A short wish list for the 2003 tests included:

- MKP verification of pre-pulse using the general PS/SPS signal digitalisation system, the New Analogue Observation System (NAOS);
- All measurements to be read out at each extraction, a CNGS requirement;
- Kicker and septa settings integrated into a settings management and trajectory control system that is coherent with the downstream transfer line;
- Trajectory correction for the extraction channel and TT40.

9.2 Transfer Lines

TT40 and TI 8 commissioning will start from early 2003 as described in Section 2.6. The main challenges for operation have been described in Section 2.5. All equipment in these lines except for the Beam Position Monitors will be controlled through the same low-level systems as the other SPS beam lines. The functionality required to operate the lines, at least during their commissioning is also similar to existing SPS lines.

9.3 LHC Injection

Concentrating on the last part of the transfer lines and the LHC injection channel a variety of approaches are foreseen by the equipment providers. Downstream of the final TED the last magnets before the injection channel will be controlled by ROCS/Mugef while the closed orbit in the LHC will be steered through the LHC Magnet Current Control System (MCCS). Instrumentation in the transfer line, injection channel and LHC ring will be equipped with BISCoTO controllers. Control room applications will have to span the SPS and LHC solutions in order to meet the operational requirements; briefly these include:

- The need to hold the energy of the SPS and LHC constant during the injection process;
- Trajectory stability at the injection point plus orthogonal steering;
- Batch to batch stability;
- Matching to ensure emittance preservation;

- Alignment of the TDI and orbit control at the TDI, septa and kickers.

The operational sequence for setting up injection will involve the use of pilot bunches to correct transverse and longitudinal injection errors. To achieve nominal performance of the machine it will be necessary to implement rigorous procedures for the whole transfer and injections process and feedback control of critical parameters such as the trajectory at the injection point. A very comprehensive machine protection system will be implemented to prevent damage to the LHC machine. Comprehensive and reliable, control and good diagnostics of the injection process will be essential to operate the machine at nominal performance.

The sector test will provide less stringent requirements but should be used to test the future LHC control as far as possible.

9.4 Candidate Software

Two possible approaches have been identified to provide the necessary application software:

- An enhanced version of the existing SPS transfer line software, called the Transfer Zone (TZ) software,
- A new suite of software based on the framework being developed for the SPS general software upgrade, SPS2001.

9.4.1 The TZ Option

The TZ package already handles the north and west extractions from the SPS; an extension to include the new east extraction (LSS4) could be integrated into the other work for LTI and CNGS. The requirements for signal acquisition and improved interlocks would not be covered as these are separate systems today.

TZ is a stable, well supported and fully debugged suite of software which provides all the functionality for the operation and development of the existing SPS transfer lines. It is based on the HPUX, X/Motif environment which will have to be phased out in the coming years. The major functional extension that is required to meet the requirements of commissioning and early operation of LTI and CNGS is an enhancement for fast supercycle changes; proposals to achieve this have been prepared. Additional developments would also be required to integrate new types of equipment — mainly beam monitors.

9.4.2 The SPS2001 Option

The SPS2001 project mandate embraces the SPS ring, extraction systems and transfer lines. The architecture of the new software anticipates control of all these systems and the associated software interlocks. An outline proposal for the gradual introduction of new SPS-2001 products is available [17]. Project phases are being structured to progressively replace existing software including TZ.

Since the beginning of 2000, SL has invested about two full-time equivalents (FTEs) for the development of this homogeneous application suite to control the SPS ring and its transfer lines in multicycling mode. A first prototype has been used in operation for accelerator timing control and slow control of the new SPS proton inflector. Resource estimates are being prepared.

Major difficulties are expected in finding the necessary resources to meet LTI and CNGS requirements on time.

9.5 Operational Issues

In this section the issues as presented by the SL Operations (SL-OP) group are summarised. A number of factors should therefore be kept in mind during the development of accelerator application software. Ergonomics is of key importance.

- Appropriate colours, font sizes and types should be chosen;

- The right balance of the amount of information presented per application must be found;
- Navigation within and across applications should be logical and thus user-friendly;
- Typing should be reduced where possible and unnecessary mouse clicking should be avoided - confirmations only for critical applications;
- Applications should be complete and self-consistent, actions such as changing gains or resets/reboots should be possible from within the application;
- Graphical or synoptic presentations are preferred to large amounts of alphanumerical output;
- Fast response to actions is important — the result of an action must be visible in the subsequent cycle.

All transfer lines must be controlled from the same suite of applications. Experience has shown that setting up and polishing a new application takes between two and four years. Any new system must be introduced in time to be adequately debugged before being put into operation. All useful ingredients being prepared for the LHC should also be made available to the SPS operation.

Future multi-cycling requires capability of rapid changes from one configuration to the next. Particular care must be taken to ensure that the beam instrumentation and related applications will be able to follow cycle changes without the need for manual intervention, for example adjustments to delay and gain settings. Equipment should come up in the correct state, ready for measurements, as beam instrumentation is often used to trigger equipment protection interlocks. Specific applications should be provided for the most common type of measurements, yet tools should always be available for rapid prototyping.

Protection against erroneous manipulations, cycle-dependent interlocks and good diagnostics in case of active interlocks are also deemed essential. Interfaces towards third party products such as MAD [18], spreadsheets and Mathematica [19] are required.

10 General Issues and Recommendations

Although not formally, the systems involved in, and the controls requirements of, the transfer lines to the LHC and CNGS have been identified, including SPS extraction, LHC injection and the high level controls functionality. The essential architecture appears to be taking shape, as do most of the supporting systems: alarms, timing, networks and workstations. The problems of interfacing the diverse equipment, industrial and otherwise, to the front ends are starting to be addressed. Our recommendations are based on the situation in summer 2001. They should be reviewed as circumstances evolve.

10.1 Interlocks

The concepts of the current SPS interlock system could provide equipment safety for the new facilities but would lead to inefficient operation: CNGS interlocks would inhibit LHC filling and vice versa. To extend the current system, hardware would have to be re-fabricated as few spares exist.

To operate efficiently both hardware and software interlocks must be conditioned by the accelerator cycling information. In hardware this would mean implicating the slow timing system in equipment safety matters.

Recommendation: SL-CO should be given the responsibility, subject to the availability of resources, for design and implementation of a new system (profiting from simultaneous developments for LHC) to be commissioned for the start of the new LSS4 extraction. Upgrading and fitting existing hardware and software interlocks to this system would be second priority.

10.2 Application Software

The minimum PCR software requirements for operation are an extension of the current facilities (TZ software package) to include the LTI and CNGS equipment. Resulting major limitations would be poor efficiency in changing supercycle and no specific developments for increasing performance after the commissioning.

Recommendation: TZ will be used as the extraction region, transfer and injection software for LTI and LHC commissioning. TZ must be extended to handle transfer to CNGS and to the LHC injection point as a first priority. Another top priority is the extension of the SPS statistics software to provide data for INB purposes.

A second priority will be to implement rapid supercycle changes using the TZ package for the extraction regions and transfer lines. SPS2001 should implement and document any necessary software extensions to the timing facilities. These changes shall be agreed with the TZ team and documented by February 2002.

A new set of software for all SPS transfer lines will be required to fully meet LHC operational requirements. Commissioning of this software should start in 2006.

10.3 Networking and Communications

Equipment groups are accustomed to their networking needs being anticipated and satisfied by the SL-CO group. SL-CO has passed networking responsibility and staff to the IT-CS group that is not integrated into SL projects.

Recommendation: SL-CO must define the services and levels of service to be provided by IT-CS. SL-CO should also approve the technical guidelines for networking. These two groups should clarify the working framework for the end users such as how connections are to be requested. It is important to avoid a piecemeal approach to work for these projects.

The CNGS project team should announce their general communication requirements to IT-CS.

10.4 Equipment Interfaces

There are a conflicting variety of practices concerning software for accessing equipment. Equipment groups insist on a single software interface for their systems. A variety of interfaces and associated software exist or are being developed and prototyped. There is direct conflict between projects and between the equipment groups who favour different solutions.

Recommendation: all systems should employ the same generic communications software that must be robust, support a wide variety of users and be specified and strongly supported by the SL-CO group. This layer must be application free, carrying no semantics connected to accelerators and will support connectivity for all SPS and LHC equipment. Application specific enhancements to the interface or contracts shall be agreed between the application project teams and the equipment groups concerned.

Support for communication to the BISCoTO systems is needed for March 2002.

The technical requirements for equipment interfaces are evolving. Prototyping for LHC feedback control is underway and proposals for communication with industrial control are being developed. This must be completed by end 2001.

10.5 Support for Industrial Control Systems

Equipment groups are increasingly adopting standard industrial control systems – vacuum, magnet systems and slow controls for beam transfer. SL division has no operational support structure for these components.

Recommendation: the LHC-CP and the groups concerned should define the support and services required. SL Division should request that the IAS group of the LHC Division commit resources and expertise.

10.6 Signal Digitisers

The new kicker systems require signal digitisers.

Recommendation: The LHC-CP project should produce a functional description of a new generation of equipment by December 2001. Implementation should be scheduled taking account of LTI and CNGS time scales.

10.7 Responsibilities

While SL groups generally understand and are meeting their usual responsibilities for controls the overall management for controls activities is not being addressed.

Recommendation: the controls preparations for these lines should be handled within the existing management structures. Extensions to the present infrastructure remain the responsibility of the equipment and controls groups who will also ensure the maintenance. The SL-CO and SL-OP groups should manage high-level application software with an overall coordination assured by the LHC-CP project leader.

References

[1] http://cern.ch/lhc-cp.

[2] http://proj-sps2001.web.cern.ch/proj-sps2001/.

[3] http://proj-cesar.web.cern.ch/proj-cesar/.

[4] http://cern.ch/lhc-cp/lti_cngs/Agenda.html.

[5] A. Hilaire, V. Mertens, E. Weisse, "Beam Transfer to and Injection into LHC", Proc. EPAC'98, Stockholm, June 1998, and LHC Project Report 208 (1998).

[6] V. Mertens, "Injection Systems", Proc. LHC Days 2001, Villars-sur-Ollon (2001), LHC Project Report 471.

[7] http://proj-lti.web.cern.ch/proj-lti/.

[8] K. Elsener (ed.), "The CERN Neutrino Beam to Gran Sasso (NGS), Conceptual Technical Design", CERN 98-02 and INFN/AE-98/05 (1998).

[9] http://proj-cngs.web.cern.ch/proj-cngs/.

[10] M. Meddahi, "Instrumentation Needs for LTI", Proc. LHC Workshop Chamonix XI, Chamonix (2001).

[11] A. Hilaire, V. Mertens, E. Weisse, "Trajectory Correction of the LHC Injection Transfer Lines TI 2 and TI 8", LHC Project Report 122 (1997).

[12] Y.-C. Chao, V. Mertens, "Analysis and Optimisation of Orbit Correction Configurations Using Generalised Response Matrices and Its Application to the LHC Injection Transfer Lines TI 2 and TI 8", LHC Project Report 470 (2001).

[13] LHC Project Working Summary Schedule. LHC Project Document No. LHC-PM-MS-0001 rev 3.0.

[14] Prozessvisualisierungs- und Steuerungs-system, PVSS, ETM Aktiengesellschaft, A-7000 Eisenstadt, Kasernenstraße 29.

[15] P. Ninin et al., "Technical data Server: A Large Scale Supervision System", Proc. ICALEPCS'97, Beijing, November 1997.

[16] http://proj-cmw.web.cern.ch/proj-cmw/.

[17] Private communication, M. Jonker.

[18] http://cern.ch/mad.

[19] S. Wolfram, Mathematica: A System for Doing Mathematics by Computer, Second Edition, Addison-Wesley, 1991.