

The LHC Controls and Operations Forum, 1-2 December 1999

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Abstract

The LHC Controls-Operations Forum in December attempted to identify the challenges of running the LHC and the implications for controls and equipment. It is hoped that this information will act as input into current and future development. An outline of the forum, its objectives, perceived success, and some conclusions and recommendations are presented.

1 INTRODUCTION

In the September of 1999, it was suggested that it would be useful and timely to review the operation of LHC as known to date, see how this impacts on equipment and then start to refine the requirements and interfaces for the LHC controls. Thus it was decided to hold a Forum with three 1/2-day sessions, the sessions devoted to operations, equipment and controls respectively. There was also a summing-up session that included a presentation on operational aspects at HERA.

2 MOTIVATION FOR THE FORUM

The LHC is a large and complex superconducting collider. It will store two high energy proton beams (350 MJ per beam) in small apertures within superconducting magnets where a loss of about 10^{-7} of one beam could cause any one of the 1232 main dipole cryomagnets to quench. The superconducting magnets have large dynamic effects, many of which are difficult to predict and affect key beam parameters. They will need precise correction and control via the 1750 magnet circuits and RF systems used in the LHC. The operation of LHC will be challenging and will require careful preparation. Since no public debate had taken place on operations of LHC since the Dynamics Effects Workshop of February 1997, it was felt opportune to review the situation.

Optics version 6.1 has now been frozen and the engineering baseline design for LHC is being established. Hence hardware is being designed or even produced meaning that the definition for control interfaces and strategies need to be established. Certain decisions on controls need to be taken already during 2000. LHC will require some controls from an early stage and full availability for beam commissioning.

Important milestones are:

- Test String 2 starting in Q4 of 2000,
- Sector Test with anti-clockwise beam from March to June 2004,
- Commissioning with beam beginning in Q3 of 2005.

3 SCOPE AND OBJECTIVES

The Forum was intended as a first overview of the operation and control of LHC. The scope of the Forum was limited to:

- Examining the requirements on equipment and controls as the machine follows its duty cycle with beam,
- Taking into account the requirements and services which impact on machine availability, preparation and recovery from fault,
- Forming the first part of the inception phase of a more formal controls specification.

The objectives of the Forum were to provide a broader understanding of the nature and challenges of LHC operations and to identify the consequences of these challenges for the equipment groups and the control system. It was also expected to synthesise the work in progress, correct any misunderstandings or errors and identify any issues not yet addressed or needing clarification.

4 GENERAL REMARKS

The Forum was a first gathering of operations, equipment and controls specialists. A lot of material was presented in a short time and the speakers managed to stay focused on the objectives. Attendance was open to anyone interested and the Forum attracted a large interest; about 140 registered attendees. The Forum was mainly intended as an internal meeting although we were pleased to welcome five visitors from DESY (HERA).

Proceedings will not be produced. However, the programme, abstracts and a full set of the slides presented at the Forum can be found on the Forum Web page, (<http://nicewww.cern.ch/LHCP/TCC/PLANNING/TCC/Forum99/Forum.htm>). For the moment, this page can be accessed from "CERN Events" on the CERN homepage or from "News and Publications" on the LHC Project homepage. An overall summary will be published in the near future and this will also be available from the Forum Web page along with any other relevant publications.

5 SESSION OVERVIEWS

More detailed information on the outcome from the various sessions of the Forum can be found in the write-ups of talks that followed this presentation [1 to 7]. Therefore the summaries given below do not cover all the presentations.

Session 1 - Operations

This session, while giving background information and descriptions of possible operating scenarios, concentrated on the requirements imposed on equipment and controls. After a short introduction to the LHC machine, the session started with a brief description of the expected behaviour of the LHC main magnets. Aspects of operation with and without beam followed this and the session finished with a discussion on operational availability and interlocks.

From the presentations it became evident that LHC operation will be complex and require a rigorous approach. Careful preparation without beam and efficient recovery procedures from expected interruptions will be needed in order to obtain good availability for physics.

The accelerator physics tolerances are tight and are most difficult to meet at injection energy considering the operating range of 16:1. The main beam parameters are very sensitive to certain of the field errors of the main magnets and special precautions will be needed to deal with the persistent current decays and in particular the "snap-back" at the start of the ramp. A better, if incomplete understanding of how to model superconducting magnets has led to a higher level of predictability of these effects although not to the required precision.

In order to obtain acceptable efficiency for physics, quenches will need to be minimised or avoided wherever possible. This is a considerable challenge considering that a very small fraction of the beam can cause a quench. Careful collimation and beam-loss monitoring will be needed in order to achieve this goal. In this respect, the machine will need a well thought out protection and interlocking strategy in order to give adequate margins and confidence for tuning. While the machine interlock system must adequately protect equipment and, in particular, personnel, it must not be so complex as to degrade operational availability.

It was generally agreed that the LHC machine will place a high demand on Beam Instrumentation and Controls and that both systems will need to be fully available from the beginning of LHC operation and to a certain extent for the sector tests.

Session 2 - Implications for Equipment and Controls

This session aimed at interpreting the implications of the operational scenarios and tolerances on the equipment

and on the controls interfaces and requirements. Brief descriptions of some equipment were also given.

There was good consistency between equipment performance specifications and the accelerator physics tolerances. There is now a better understanding of the real-time requirements. These are based on certain assumptions, notably the level of predictability of magnet behaviour. Reasonable and acceptable levels of bandwidth and data rates were presented which impact mostly on the Beam Instrumentation, Power Converters and communications.

Before beam is injected and even after that, reliance on magnetic references will be necessary. These will consist of databases, models of LHC superconducting magnets and reference magnets. For instance, the integrated dipole field must be kept within 10^{-4} at injection for RF capture. This is equivalent to 7×10^{-6} of maximum field. Prediction of multipoles due to persistent current effects is now in the order of 80%, implying an error of 20% to be corrected by other means, notably real-time feedback. There is expected to be a learning curve that will improve this situation although this will probably be used for increased machine performance.

Falling into the category of items not yet addressed, is how to deal with the external trigger to the beam abort system. For the moment there is no clearly defined strategy of what elements should trigger the beam abort and the means by which this will be done. Further the policies of power and beam abort need treating together in a coherent manner.

The chairman of this session concluded by saying that there was a large spread in the controls requirements across equipment types and that the definition of the control requirements were not yet homogeneous. More work is needed to refine and complete the picture in order to freeze design choices.

Session 3 - Controls

The first part of this session proposed strategies for defining an LHC control system architecture in the light of SPS/LEP experience and the new LHC requirements. The second part reviewed the activities already started in specific control system areas.

The "Use Case" approach, which looks at a particular operating sequence, seems a promising tool. It brings together specialists from hardware, operations and controls to discuss requirements and helps to clarify thinking in everyone's mind. It is a formal approach to what has probably always been done but does result in a documented agreement among those concerned.

The interaction between the TCR and PCR was not within the scope of the Forum but in various talks it became clear that this needs further clarification. The problems associated with networking being under the responsibility of several groups were also raised.

Good progress has been made on low-level timing requirements and work will continue with the objective of producing a final definition of the timing system before the end of 2000.

The low-level Power Converter control is well advanced and certain hardware is being produced for the magnet test benches and the String 2. This can support synchronous ramps and trim as before but now has the capability of continuous real-time correction. Any combination of the three can be used.

Work on supporting distributed real-time controls is progressing well with tests underway on WorldFIP, ATM and gateways. Some of these will be used on String 2.

Throughout the Forum there were many requests for comprehensive post-mortem analysis. This will require the archiving of large amounts of data that will require efficient mining techniques for clear and rapid presentation of relevant data.

The chairman of this session concluded by saying that it is easier to produce efficient controls for machines after they had started but that this approach would not be possible with LHC.

6 RECOMMENDATIONS

Two specific recommendations were made at the Forum:

1. *An Interdivisional Project should be set-up for the controls of LHC* - This was proposed by the SL Division Leader, S. Myers and supported by the LHC Project leader, L. Evans.
2. *An LHC Interlock Manager should be appointed* - This is a person (but later a system) responsible for the integration of interlocks across the LHC machine to provide adequate protection of the machine compatible with efficient operations and personnel security.

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