EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN — A&B DEPARTMENT

CERN-AB-2004-013

The AB-LHC Technical Review November 2003

M. Albert, G. Arduini, R. Bailey, O. Bruning, P. Collier, K. Hanke, M. Lamont, S. Myers, S. Page, J. Poole, F. Tecker

Abstract

The AB-LTC review was held over 3 days and five open sessions in November 2003. It was designed to cover all technical sub-projects of the LHC under the authority of the AB department. There had been no consistent review of this type for some time. The review therefore promised to bring up-to-date information for all AB-LHC technical activities and to provide a clear picture of the present state of each LHC system. Each project engineer was requested to give a status report for his system. Covering aspects of system development, manufacture, integration and installation, the review is complimentary to the LHC design report where information on the system parameters and design can be found.

Geneva, Switzerland
January, 2003

1. Introduction

The AB-LHC review was organised to generate a snapshot of the status of LHC activities under the responsibility of the AB division. It limited itself to technical LHC work-packages – i.e. those having the responsibility for the design, construction and installation of some part of the LHC machine. Activities undertaken by AB personnel, but under the responsibility of other departments were not covered as well as theoretical studies for the machine design and activities looking at the operation of the LHC. The LHC transfer lines as well as the preparation of the injectors for the LHC were likewise not covered. Each project engineer was requested to present the status of his system. In addition to the equipment itself, any issues regarding integration, installation and documentation were addressed. Hence the review is complimentary to the LHC design report where information on the system parameters and design may be found.

The review was organised jointly under the authority of the LTC and TCC committees. It consisted of a total of 38 presentations given during 5 half day open sessions. Each session was organised and animated by a chairman and scientific secretary. The sessions, chairmen and scientific secretaries are listed below.

	Session	Chairman	Scientific Secretary
1	Injection & Extraction	J. Poole	R. Billen
2	Powering	M. Lamont	S. Page
3	Beam Instrumentation	O. Bruning	K. Hanke
4	Controls	R. Bailey	M. Albert
5	Radio Frequency & Collimation	G. Arduini	F. Tecker
6	Executive Summary	S. Myers	P. Collier

The transparencies from each of the presentations are available on the review web-site. After the review the chairmen and scientific secretaries, together with the review organisers, held a closed half day session to discuss the major issues raised during the review. The outcome of this session is the present document. In addition to allowing the management to identify problems areas and conflicts, it is hoped that the information presented during the 3-day review can be used to fill some of the holes in the present LHC project baseline.

In section 2 the guidelines issued to the project engineers are outlined. Section 3 contains the summaries from each chairman/secretary for their session. In section 4, some more general comments are given followed by the overall conclusions.

2. Review Aims

In order to generate a consistent picture of the different activities the reviewers gave a list of points that had to be addressed during each presentation. These covered the different aspects of a typical project: design, prototyping, technical specification, manufacture, integration, installation and documentation.

The following summarizes the main points that were to be covered by the engineers for each system:

- What is the overall Status of the System?
  - Are the technical specifications and functional specifications known?
  - The design/prototyping for each major component?
  - Manufacturing contracts?
  - Are there any difficulties in meeting any of the design parameters or possible trade-offs between parameters?
- The delivery schedule
  - Are there any changes to the Cost-to-Completion or problems to meet the installation schedule?
  - Are there any difficulties for storage of delivered components?
  - Will the system be partially/completely tested at CERN before installation?
  - Are there any quality control/acceptance issues for the system or its components?
- The status of integration of the equipment into the machine environment
  - Has the integration been done?
  - Is there any interference with other installations?
  - Are all required services/cables etc. ordered?
- What is the planning for the Installation in the tunnel?
  - Are there any difficulties in terms of access or co-habitation with other installation teams?
  - Are the needs for transport & handling already defined?
- Documentation and the LHC Hardware Baseline
  - Is the system part of the baseline?

- Is the system fully documented in EDMS?
- Is the MTF being used for manufacturing follow-up?
- Where is the detailed data on the system stored?

Each engineer was requested to emphasise the subjects that were of most concern to him and to address managerial and resource problems as well as technical and planning issues. In the following sections the summary prepared by the chairman and secretary of each session is given

3. Session Summaries

3.1. Session 1: Injection and Extraction

This session covered the activities of AB-BT, together with the AB-ATB activities concerning protection elements and beam dump blocks. The following Presentations were made:

1.1	Injection Kickers, MKI	L. Ducimetiere
1.2	Injection Protection elements, TDI, TCDD	L. Bruno
1.3	Transfer Line & Auxiliary Collimation	H. Burkhardt
1.4	Beam Dump System Overview	B. Goddard
1.5	Kicker Generators for Extraction, Dilution & QA-Measurement	E. Vossenberg
1.6	Kicker Magnets for Extraction, Dilution & QA-Measurement	U. Jansson/F. Castronuovo
1.7	Injection & Extraction Kicker Controls	E. Carlier
1.8	Beam Dump Blocks	L. Bruno
1.9	Extraction Protection Elements, TCDQ, TCDS	W. Weterings

Injection Kickers

In general, work is progressing quite well for the injection kicker systems. The series production of the generators is almost complete and the magnet design has been proved and manufacture of components is progressing well, if somewhat delayed. The BT Group has been able to modify the assembly schedule for the magnets in order to adapt to the manufacturing problems.

The chosen technology for the injection kickers is delicate and flashovers continue to be a problem. The kickers are at the limits of technical feasibility, given the cost and space constraints. A rate of 1 per year during LHC operation was quoted. The worst case effect of such a breakdown has been checked. The ripple on the kickers is just within the tolerance of ±5%. A programme of study to allow further reductions in the ripple is underway. Other aspects of the kickers were not treated during the presentation (notably the ceramic chambers and any possible heating of the ferrites by the beam).

The new requirements coming from SC (Safety Commission) concerning the provision of fire protection around the PFN's are new and should be treated by the Safety working group – not by AB-BT alone.

Whilst there have been delays, delivery, installation and commissioning of all systems remains on schedule. Storage has been well planned and prepared for all of the components and integration studies are now advancing.

Injection Protections Systems

The injection protection systems are still at a relatively early stage in their procurement and production phases and they are not yet in production. The TDI has been proved to be technically sound and prototyping is advancing well. The TCDD is a smaller project which is only just getting started. An urgent open question concerns the integration of the TCDD together with the tertiary collimators. This is presently under discussion in the Injection Working Group.

Transfer Line and Auxilliary Collimation

The decision to install collimators in the transfer lines was only taken at the beginning of 2003 and therefore this project is still in the study phase. However, good progress has been achieved and the technical design is now starting and early integration studies have been positive. The $135^{o}/45^{o}$ transfer line collimators have never been discussed before. They are not presently part of the hardware baseline, but are being considered as a possible future upgrade, if needed.

Kicker Generators & Magnets for Extraction, Dilution and QA Measurements

The MKD generator prototypes have been successfully built and tested on the MKD kicker magnet prototypes. Component manufacture for MKBH/V and MKD has started and is on track. Storage for the final components has been arranged and space for testing allocated so space is not a problem in these areas.

The manufacture of the beam dump diluter kickers has been staged to match the requirements from a beam power point of view. In order to reduce costs, multiple contracts followed by assembly at CERN are being used. Following initial quality problems, the manufacture of the moulded C-cores is now progressing satisfactorily. Contracts for the high voltage cables are also advancing well, with the 40Ω cables ready for delivery and the 20Ω ready for acceptance tests. All of the components concerned by the kicker magnets for extraction dilution and QA measurement remain within the cost and time schedule.

For the kicker magnets, the planning looks very tight and the risk of serious delay is significant – particularly for the MKB. It was noted that no spare MKB magnets will be built initially. Spare MKB kickers will be built together with the staged kickers. As both kickers in one plane of one beam are in the same module any problem here would lead to a limitation on the intensity that can be injected into the LHC. Adding the construction of additional spare MKB kickers to the already very tight schedule is not feasible. However, the procurement of critical items should be made to allow construction to continue naturally once funds and resources are available. It was noted that the construction of the complete set of staged MKB kickers will take 2 years.

The most urgent open question concerns the functional specification of the MKQA. This will be needed early next year and is pending in the LTC. AB/BDI has promised an answer regarding the need for the aperture part of the kicker, by March 2004.

Kicker Controls

The technical specification for the injection system process and interlocks is well advanced and work is on-going for the interfaces to other systems. The design for the MKI controls has been proven during the tests of the new extraction system in the SPS during 2003. The whole of the controls aspect for injection systems remains on schedule and in budget.

The situation for the extraction kickers controls is very similar; the systems are well defined and are ready for full or pre-production phases. This work also remains on schedule and in budget and early in 2004 the last major contracts will be placed.

Beam Dumps

Theoretical studies to verify the design have been successfully completed. An innovative solution for the iron shielding using the ISR dipole magnet cores has been successfully implemented. Construction procedures based on the shrink-fitting of the core segments has been successfully tested and proven. The detailed design of the TDI is now close to completion and technical choices for sub-assemblies are frozen. Prototyping and optimisation are well advanced and the final touches are being put to the handling and positioning ancillaries. Finally it was noted that the damage to the beam dump blocks and TDI remains to be clarified as does the need for cooling of the dump block.

Extraction Protection Elements

Functional specifications are approved for the TCDS and completed for the TCDQ. Work is on schedule and within budget.

3.2. Session 2: Powering

The session was dedicated to the activities of the AB-PO group and covered the following topics:

2.1	Introduction	F. Bordry
2.2	High Current Switch Mode Converters (4-13kA) and Atlas	V. Montabonnet
2.3	Medium and low Current Converters (600, 120 & 60A)	Y. Thurel
2.4	Thyristor Converters (RF, CMS, Alice, LHCb etc.)	A. Beuret
2.5	Current Measurements, DCCT/ADC	G. Fernqvist
2.6	Power Converter Controls	Q. King
2.7	Quench Heater Power Supplies	F. Bordry
2.8	Integration, Tests & Commissioning	H. Thiesen

Introduction

In the introduction the challenges in terms of performance, installation and operation were outlined and the general approach of the Powering group was described:

- Minimise the number of converter types;
- Separate out the subsystems that can be produced by industry and then place development and production contracts where appropriate;
- Design and build prototypes of remaining subsystems in collaboration and then place production contracts;
- Assume converter integration responsibility;
- Converter integration and tests at CERN before installation in the tunnel.

High Current Switch Mode Converters

Sixteen 13 kA, twenty 8 kA, one hundred and seventy-two 6 kA and thirty-six 4 kA high current switch mode converters will be required in total. In addition one 20.5 kA converter is needed for the Atlas Toroid circuit.

Voltage sources

The production of voltage sources is on target with respect to the LHC Cost to Completion. However, only a single 13kA prototype from Transtechnik has been approved. Its performance in terms of bandwidth and ripple meets the specification. In spite of this, more work must be done to improve EMC, air losses and performance in the case of the loss of a sub-converter.

String 2 was used to test a Kempower 6 kA prototype and an older generation 13 kA, 16 V Transtechnik power converter. A second Kempower prototype for the 4, 6 and 8 kA converters is foreseen for January 2004 with which significant design modifications can be validated. The company is well organised for massive production. The voltage source project may incur some delays in order to meet CERN safety requirements and due to delays in obtaining Burndy connectors through the CERN stores (a large CERN-wide volume order). Delays for the pre-series can be absorbed into series production.

Current sources

Load tests performed in String 2 at levels similar to those in LHC revealed a few points to be improved (including EMC). A set of performance tests with the different pre-series sub-systems forms the next milestone in 2004. Installation in the tunnel will start at the beginning of September 2004.

Medium and low Current Converters (600, 120 & 60A)

Some fifteen hundred 600, 120 and 60 A converters will be required. These are four quadrant, low and high precision converters with four different external companies involved in their production.

60 & 120 A

The voltage source was tested in String 2 and was technically okay. An initial delay of two months with the contract will be absorbed later. Tests of the current source in String 2 were largely successful. However, there were some issues with the DCCTs. Further extensive tests will be performed for high precision performance, EMC and checking of thermal points. A new DCCT prototype will be tested in 2004. Problems during the tests, which have manpower demand, would lead to delays.

600A

The voltage source was tested in String 2. Some tests remain to be performed. Both the 10V and 40V contracts incurred two-month delays due to contract administration at CERN.

In general there are very tight deadlines with further pre-series tests still to be performed. If everything works, there should not be a problem; however, if there are problems then delays and extra costs will have to be faced. There has been some slippage already (≈2 months) with a worst case of 4 months foreseen. A precise status of the situation should be possible in May 2004.

Thyristor Converters (RF, CMS, Alice, LHCb etc.)

Thyristor power converters are required for CMS, Alice, LHCb, TI2 & 8, the high voltage-high power RF, main dipoles and warm magnets.

The CMS 20kA, 26V converters were delivered and installed in May and will be commissioned on a short-circuit load at the end of 2003. This fits in with the CMS schedule. Tests are being performed to assess the effects of stray magnetic fields. The Alice solenoid converter recuperated from L3 was refurbished and re-commissioned on-load in September. The Alice dipole converter and LHCb converters were installed at the end of 2003 and will be commissioned on-load in 2004. The transfer line converters are an extension of the SPS standard and the majority are fully refurbished and tested already. On-load commissioning of TI8 will take place in summer 2004.

Five 100kV, 40A converters are to be re-used from LEP for the RF system. There is some concern regarding the state of the transformer windings. Investigations will be performed during the first half of 2004 at an estimated cost of 50,000 CHF. If corrective action is necessary it could cost up to 1 MCHF.

For the main dipole converters the orders to the main subcontractors are placed and manufacturers' assembly started in November 2003 with pre-series delivery planned for March 2004. Green light for series production should be given mid-2004. A similar schedule is in place for the delivery of the 18 kV transformers.

In general, no major problems are foreseen. The RF transformers situation has to be monitored.

Current Measurement

A demanding area with DCCTs required for 4-13 kA, 600 A, 120 A converters and those supplying beam transfer and warm magnets. Also required are 22 bit and 16 bit ADCs and calibration systems.

4-13kA DCCT prototypes have not yet been approved. Their sensitivity to external magnetic fields and their EMC are outside of specifications. Improvements are foreseen which will probably result in sufficient performance. Performance pushes the industrial state-of-the-art.

The pre-series 600A DCCTs have been tested completely and minor problems corrected. Any delays should not affect converter planning.

120A DCCT prototypes from a new company have failed tests and there are still technical problems. The situation is behind schedule. Pre-series is now planned for January 2004 with first production in June 2004. Studies have been started for a backup solution. Converter production will be affected.

The first delivery of DCCTs for BT and warm magnet were outside specification. The DCCTs were sent back to the factory for modifications and have been returned for further testing. No problems are expected. All DCCTs should be available for installation by January 2004.

A new prototype of the 22-bit Sigma-Delta ADC is in the design phase and should be ready in 2004. Series production is planned for 2004. Converter integration tests of the 16-bit Sigma-Delta ADC are upcoming and the results will be important. Following prototyping, series production of the main components of the calibration system will start in 2004.

Performance of all DCCTs, except the 120 A ones, is close to target. All DCCT contracts are late, but only the 120 A will impact converter planning. Converter integration tests should get a high priority.

Power Converter Controls

The version 1 Function Generator Controller (FGC) has been installed and running in SM18 since 2001 and will run until the end of MTB operations in 2006. Version 2 of the FGC will be used for LHC. There is some concern about production quality of 2 out of 5 of the FGC cards after faults with 30% of the prototypes. The contract has been re-negotiated with the production company.

The potential risks for the FGC are: production quality, bankruptcy, design faults and radiation. Contingencies have been foreseen to respond to any problems in these areas and were detailed in the presentation. Electronics pre-series can be manufactured locally and an alternative used for main series. (Note: use of now out-dated components: spares sufficient for 500 units are to be kept in-house.)

Quench Heater Power Supplies

Some 6200 units will be required; these will be placed underneath the LHC magnets with associated demands on radiation tolerances and lifetime. Successful tests have been performed for radiation and temperature tolerance. Industrialisation techniques have very successfully optimised the design and cost of the units. Experience with pre-series units has been positive, however there were some quality problems with the units manufactured in India (100 units: split 40 Europe - 60 India). The production strategy is for 1000 units to be produced in Europe and 5500 units in India with the Indian price aligned with the European one. Production in India will take place between June 2004 and December 2005. The administration process with the Indian company is slow and difficult with some concerns about quality assurance with some problems noted with the prototypes.

There is some concern about the MTBF of the capacitor banks and requirements for accessing the tunnel for replacement.

Integration, Tests & Commissioning

The aims here are to define: the converter location; the necessary transport; and the interfaces to water, cabling, controls etc. There are issues to be resolved but situation is not too serious. Converters are to be transported and installed complete without dismantling after they have been tested. Storage of the converters is an issue. (AB/PO is waiting on a flexible hose Engineering Specification from TS/CV.) The commissioning procedure will be defined in HWC.

General Issues

Overall the effort in the powering group appears to be well coordinated. The deliverables and deadlines are understood. The inevitable problems and delays are being tracked and contingencies are planned where required. There is a high degree of technical knowledge and thorough testing before acceptance of industrial components; this is reassuring.

- EMC problems remain a concern and more effort will have to be devoted to the subject during the converter integration phase of electronics and DCCTs inside power parts. Follow-up clearly required.
- Delays in getting contracts through SPL are an annoyance.
- Manpower is critical in several areas.
- There is exposure to a limited number of specialised manufacturers working under difficult market conditions with possible problems: production quality; bankruptcy; design faults etc. Problems in prototype/pre-series production can rapidly lead to delay.
- Delays (3-4 months) are accumulating; 2004 will be critical.

3.3. Session 3: Beam Instrumentation

The third session of the AB-LTC work package review was devoted to the work packages related to the LHC beam instrumentation and was covered by the following presentations:

3.1	The Beam Position System	R. Jones
3.2	Beam Loss Monitors	E. B. Holzer
3.3	Profile Measurements and Matching	C. Fisher
3.4	Transverse Diagnostics	A. Burns
3.4bis	BCT's	D. Belohrad
3.5	Longitudinal Profile, Gap Population and Luminosity	E. Bravin
3.6	Controls and Software for Instrumentation	J-J. Gras

The Beam Position System

The AB/BDI and the AT/VAC group share the responsibility for the Beam Position Monitor hardware. The AB/BDI group follows the contracts for the button and coupler and the warm feed throughs, the cryogenic cables and the strip-line detectors. The AT/VAC group follows production of the standard arc BPM bodies, the cold non-standard BPM bodies and the warm BPM bodies.

While the production of components for the cold arc button BPMs is on track there are still some outstanding issues for the insertion BPMs with rotated beam screens, the special BPMs for transverse diagnostics, the warm BPMs and the strip-line monitors behind the D1 magnet in IR2 and IR8. The design work for the BPMs with rotated beam screens and the special BPMs for transverse diagnostics has not yet started. Avoiding potential delays for the production of these special BPMs requires more resources. An additional designer was requested already during 2002 but became only available in mid 2003 implying a delay for the cryostat integration. The warm BPMs in the cleaning insertions (IR3 and IR7) have an integration problem around the warm quadrupole magnets where is not enough space available in the current insertion layout. However, the IR3 and IR7 insertions are currently being re-designed and the integration problems should be resolved once the new layout is finalised. The warm strip-line monitors behind the D1 magnet have an aperture limit for the ALICE ZDC detector in IR2. Two solutions are currently under study and the problem should be soon solved. The design for the warm BPMs in the dump lines was released in November 2003 and a special design for the oval vacuum chambers in front of the TCDS is still missing.

Problems with the integration of the WorldFIP control card and the production of the Wide Band Normaliser have generated time delays for the BPM acquisition system. Furthermore, the prototypes of the negative regulators of the power supply cards were out of specification. New prototypes are foreseen for the end of 2003 but the delivery of the series production is not yet known. The problem can, in principle, be solved by relying entirely on the positive regulators but this solution would imply a redesign of the power supply cards and the loss of the ON/OFF control. A final decision must be taken soon in order to be ready for the TI8 installation. The TI8 test in 2004 is very demanding for the BPM system installation and the production of the digital acquisition board is currently the most critical item for BPM system in TI8.

The timing of the BPM system is based on the TTC system which is developed for the experiments. There is, however, currently no manpower and no clear responsibility assigned to the TTC timing system.

The Beam Loss Monitors

The BLM system consists of five different monitor types: BLMA for the arc installation (ca. 3000 monitors), BLMS for critical aperture locations (ca. 400 monitors), BLMS* at positions with injection losses featuring an extended dynamic range (ca. 100 monitors), BLMC for the collimation sections (ca. 110 monitors) and BLMB for the primary collimator jaws (ca. 10 monitors). The last are not presently in the LHC baseline. The specification of the BLMA and BLMS is mostly done. A contract for manufacturing is in preparation (to be produced in Protvino). Two different versions are foreseen for the BLMS* and BLMC monitors: one type based on ionisation chambers and one type based on SEM detectors.

The design of the ionisation chambers is challenging because of activation and the resulting background rates in the chambers. The main challenges for the second type include vacuum aspects. Main problems in the BLM development include delays in the electronics due to the lack of manpower.

The analog electronics is late by ca. 1 year and the digital electronics late by about 3 months. The delays translate into a tight schedule which, however, is still compatible with the overall LHC schedule for completion. However, the delays might have implications on the installation for the sector test (SEM detectors) and the overall cost of the system (200 to 300 new channels are not yet financed).

The discussion at the end of the presentation addressed in addition problems with the integration in the tunnel and the future operation for the LHC. The BLMA encroach into the tunnel transport zone and therefore potentially interfere with the installation of magnets in the tunnel. One option to deal with this difficulty is to install the BLM in the arc only after the magnet installation in the tunnel has been completed and to remove them whenever magnets need to be transported.

The review further encouraged the BDI group to look into the aging aspects of the monitors due to radiation and the options for a calibration of the BLM signals (what is the required MD time for such a beam based calibration?). Furthermore the review asked the BDI group to specify in more detail what exactly delayed the studies on the ionisation chambers and to justify the introduction of 200 to 300 additional channels. The question was raised, how one can identify a faulty dipole magnet which is responsible for beam loss. As the BLM are sitting next to the quadrupoles, there is no way to do so. During the discussions it was proposed to solve this problem by using movable BLM which can be put in place in case of problems.

For the primary collimators it was confirmed that there will be dedicated detectors with a different electronics than the standard ones.

Profile Measurements and Matching

The presentation covered beam screens for the measurements on the injected as well as monitors for the circulating beam. The design of the TV screens in the transfer lines is completed and CERN prototypes have been tested in 2002. The design of the TV screens near the injection elements was interrupted in August

2003 but should, in principle, be resumed in January 2004. However, there are still potential delays due to problems with the drawings office. The designer, who was working on the TV monitors, was sent to work on the collimators. Since then, nobody is working on this any more. The design of the monitors next to the TDI and the beam extraction lines has not yet started and each of them requires a specific design. There is not yet a well defined interlock system for the LHC beam screens to prevent a movement of the screens into a circulating beam. It is not clear, whether such an interlock system will be provided by BDI.

The monitors for the circulating beam include a synchrotron radiation telescope (BSRT), gas monitors (BGIH/V) and wire scanners BWSH/V. Two LEP telescopes could be recuperated for the BSRT. However, this solution implies that the telescope volume interferes with the space reserved for survey and the cryogenics line. Furthermore, the BSRT implies interferences with the BGIH/V and implies that the telescopes are rotated by 180 degrees for better accessibility. The discussion evolved in particular around the space conflicts of the BSRT with other equipment and concern was expressed that the implied negotiations with AIR LIQUIDE might imply a cost increase for the overall installation of the LHC cryogenics line. The review asked what resources could be gained if the transverse profile measurement in the transfer lines is abandoned. The information could, in principle, be gained by the profile monitors in the LHC. The question was raised, how well gas and SR monitors work with ions and it was stated that the gas monitors give a better signal for ions than for protons and the SR monitors should perform as for the protons.

Transverse Diagnostics

The presentation covered the systems for tune, coupling and chromaticity measurements. The functional specification for the complete system is one year late and is expected for the beginning of 2004. Furthermore, the system development lacks a clear specification of the different operational scenarios. Consequently no mechanical design for the detectors has started yet. However, a "day 1" system has been developed based on conventional coupler pickups that do not require a special hardware development. The phase lock loop (PLL) technology required for the final tune and the innovative coupling and chromaticity measurement systems is developed in the framework of US LARP and with collaboration with BNL. The present task sheet is based on first PLL tests in the SPS in 2004. However, with the current manpower assignment it is not clear yet if the system will be ready for tests in 2004. Since the SPS is shut down during 2005 this might imply first MD test for the PLL only in 2006. The hardware required for the beam excitation is under the responsibility of the AB-BT group. Provided the functional specifications become available at the beginning of 2004, the delay of the specifications should not be critical for the timely delivery of the system for the LHC startup. The major problems for a timely delivery of the system come from the manpower limitations in the TS design office. It was furthermore asked, whether there will be a way to measure the tune of a single bunch in order to control a feedback. This has not been addressed so far, but does not appear impossible.

BCT's

The presentation covered the FBCT and DCCT transformers beam current and power converter current measurements. The integration in IR4 is well under way (the cables are already ordered) while the system in IR6 still requires more detailed studies. The development of the DCCT is well under way. Open issues of the FBCT and DCCT systems include compatibilities with the LHC vacuum system (need of bake-out equipment), difficulties to meet the specifications, the lack of a spare systems within the current budget (spares have been taken out of the CtoC) and the lack of documentation. Furthermore a clearer specification for what equipment is required for the sector test is needed.

Longitudinal Profile, Gap Population and Luminosity monitors

All three monitors are developed at LBNL in the framework of LARP. CERN has little more than observer status and the monitor developments depend entirely on DOE funding. Currently, LBNL does not have sufficient resources for the development of the monitors but the situation will hopefully improve once LARP resources have been assigned. The functional specifications of the three systems have been written at CERN and the specification and cost estimate for the superconducting undulator are underway under CERN responsibility. The installation of the luminosity monitors requires a detector mounting on the TAN absorber. Since IR2 and IR8 do not feature TAN absorbers the integration of the luminosity monitors in IR2 and IR8 still requires additional design studies. Overall the luminosity monitor project is still on track and the main open issues evolve around the radiation hardness of the detector choices. The options studied for the luminosity monitors do not offer the possibility for bunch-to-bunch measurements. The longitudinal profile and abort gap monitors are behind schedule and run the risk of being late for the LHC startup.

Controls and Software for Beam Instrumentation

The software developments of the AB-BDI group include all the required software necessary for developing, testing and diagnosing the different instruments. This does not include the development of GUI software which lies under the responsibility of the AB-CO group. The functional specifications are done within the framework of the "Beam Instrumentation Functional Specification Board". All specifications are well advanced and should be approved and released during the 2003/2004 shutdown. Main concerns for the controls and BI software development include the large number of projects which include approximately 30 different front end software developments and the large amount of background activities that still needs to be performed in parallel (maintenance of approximately 120 different front end software). From now on 2 to 3 FTEs of the BDI software section will be devoted to the software development of the LHC. This will work as long as the BDI staff planning for the coming years is followed. Otherwise some "background" activities have to be reduced.

It was pointed out that the BDI software team will require help from the end users on the specification of the functionalities required in the control room. In the case of the orbit system this is already running well. The beam loss system requires a similar effort as there are major outstanding issues on the acquisition, treatment and presentation of the huge amount of data the system will generate.

3.4. Session 4: Controls

The Controls for LHC was covered by the following presentations:

4.1	Infrastructure	P. Charrue
4.2	Timing	J. Lewis
4.3	Front Ends	F. Di Maio
4.4	Databases	R. Billen
4.5	Applications Software	E. Hatziangeli
4.6	Industrial Controls	C-H. Sicard
4.7	The Machine Interlock System	R. Schmidt
4.8	The Post Mortem System	R. Lauckner

Introduction

The controls group have adopted a number of milestones providing key dates for deliverables;

- April 2004 New AB Central Timing System
- April 2004 QRL commissioning starts
- September 2004 TI8 beam test
- May 2005 LEIR commissioning starts
- June 2005 LHC Hardware commissioning starts (sector 7-8)
- April 2006 Operation from CCC starts
- May 2006 LHC injection test (sector 8-7)
- May 2006 CNGS operation starts
- April 2007 LHC beam commissioning starts

Infrastructure

The overall infrastructure for LHC controls is foreseen to be the standard 3-tier model, comprising the resource tier, the middle tier and the presentation tier. The resource tier utilises VME computers dealing with high performance acquisitions and real time processing, PLCs driving various industrial control systems, field buses for local connections and PC-based gateways interfacing these field buses. The middle tier contains application servers, which host the software needed to operate the LHC and run supervisory control and data acquisition systems, data servers containing all data necessary for LHC configuration and control, and a central timing system which provides the cycling information for the whole CERN accelerator complex. The presentation tier provides the control room with consoles running interfaces allowing the operators to interact with the accelerator systems, and drives fixed displays of real-time summary data.

Yearly targets have been established;

- 2003: medium sized fileserver will be available, 10 application servers will be available for tests, Windows and LINUX consoles will be available, network infrastructure will be deployed on the PS and SPS
- 2004: deployment of central timing system, deployment of first version of LHC monitoring tool, decision on the type of console for the CCC, prototyping of application servers in farms
- 2005: upgrade the fileserver, deploy application servers, deploy infrastructure for LEIR, deploy infrastructure for the field control rooms
- 2006: deploy complete infrastructure in the CCC (40 consoles and 24 file and application servers, communications infrastructure)
- 2007: massive deployment of operational applications for LHC, infrastructure ready for LHC start-up with enough file space, CPU power, and bandwidth.

With the last point in mind, it is difficult today to assess the overall needs of the control system, and so a flexible approach is needed. Furthermore, with the rapid developments in Information Technology, the strategy will be to purchase as late as possible so that equipment is not obsolete before it is needed in operation.

Timing

The aim is to have a unified approach to timing across all CERN accelerators, known as the Central Beam and Cycle Manager (CBCM), making use of the same hardware and software everywhere. Tests have already been made on the PS and SPS (without beam), and consolidation of this is foreseen for the 2004 start-up. The first full new deployment is foreseen for LEIR in 2005, with the LHC following in 2006.

Front Ends

Hundreds of front-end computers are needed for the LHC; 330 general-purpose VME based systems, 120 gateways and 30 analogue signal observation units are foreseen. These need to be procured, installed and managed, on top of the ones already there, which amount to almost 300 more. Front-end software is divided into four components; communication, hardware interface, general services and equipment software. Two of these, communications and the hardware interface, are well covered. For general services, some aspects (timing and monitoring) should be solved in 2004, while others (alarms and post mortem) are less clear but the critical elements should be OK for 2004. For equipment software, there is a heavy workload ahead due in part to the diversity of systems involved. This diversity has to be reduced in order to cope with the workload. The strategy is therefore to stabilize the systems on the injector machines, using standard communications and services, and then to deploy a homogeneous architecture for future installations.

Databases

Data needed for an accelerator can be divided into 4 domains, describing physical equipment, machine layout, controls configuration and operational data. While in an ideal world these domains would fit seamlessly together, in practice they are separate, with different data sources in the different domains, and different tools and interfaces to access the data. They need to be linked together to give the overall picture, and herein lays the key to providing an efficient system. The LHC will be no exception to this.

Applications software

In large software developments, it is necessary to provide an efficient environment for applications development, including development tools, a configuration management system and a software architecture. This environment is now well established and will be used to develop applications for the PS complex, the SPS, transfer lines, LEIR and the LHC, according to the defined milestones. High-level controls components are being prepared for the LHC, based on experience with operating large machines; the SPS, transfer lines and LEP and the commonalities between them. The LHC applications software will be developed based on standard components that are under development today, which will be validated on earlier SPS needs, such as the TT40 and TI8 tests.

Industrial controls

This covers many projects of different scope, all based on industrial components. These are not only for AB division, but also for clients outside, typically AT division, and also numerous industries around Europe, and a few beyond, concerned with testing of LHC components. Major clients in AT include the magnet test facility in SM18 and the cryogenic systems for the machine and the experiments. The frequent changes in planning for the machine cryogenics generate more work in this field.

The machine interlock system

The machine interlock system is dominated by the Powering Interlock System and the Beam Interlock System, and will be of critical importance for LHC operation.

The Powering Interlock System allows powering when a number of conditions are met, and ensures the safe dissipation of the energy stored in the magnets in case of a quench or other failure. The system will be implemented with 28 powering sub sectors managed by a total of 36 Power Interlock Controllers (PIC). These ideas have been tested at String2, and prototypes are under development, leading to production of the 36 chassis. Installation will start late 2004, and commissioning will follow the general LHC schedule between 2005 and 2007.

The Beam Interlock System allows beam injection only when it is safe to do so, and requests a beam dump if any unsafe situation is detected. The system will be implemented as two Beam Permit Loops, one for each ring, which will fire the beam dump when broken. The loops are dependant on Beam Interlock Controllers (BIC), located to the left or right of each interaction point. The 16 BIC collect individual status from many clients. A prototype was successfully tested during the TT40 tests in 2003, and a second generation will be ready for the TI8 tests in 2004, after which production will be launched. After testing in the laboratory, 3 BIC will be installed and tested during the LHC injection test in 2006.

The post mortem system

The purpose of the Post Mortem system is to provide comprehensive monitoring of the functioning of the machine protection systems, and to improve the operational efficiency of the LHC through rapid diagnostics after beam and power aborts and other malfunctions. To achieve these aims the data must be complete and coherent. This means that every LHC equipment and diagnostics system must have a circular buffer, which can be frozen for use by the post mortem system. Data must be time-stamped, and a precise naming convention needs to be defined and supported. Data must be self-describing so that the system can combine it into a post mortem event, which is expected to contain several Gigabytes of data and must be stored. Analysis of this event will be complex, and supporting software will be needed in order to understand what happened before beam or power can be re-established.

Summary

While the above gave the picture that the controls group are aware of the workload and the milestones to be met, a number of points remained unclear.

For procurement of hardware, while accepting that the nature of the technology means that the choice should be left as late as possible, it should still be possible to identify when choices have to be made, taking into account ordering, manufacturing, delivery, installation and testing.

For production of software, while the staged approach looks sound, it was not clear if the necessary and correct resources are available to meet the deadlines. With this in mind, it cannot be stressed enough that the applications software for the LHC program must be given absolute priority. This includes the machine, which will need sophisticated software, and the production of the LHC beam, which requires a significant upgrade to the SPS controls. Providing a uniform look and feel across all machines would indeed make operation' life easier, but this has a lower priority and this should be borne in mind when planning migration to the CCC.

A practical approach is needed for the provision of a common naming scheme for signals. This should not attempt to go beyond the boundaries of the LHC itself. It should integrate the already existing LHC conventions and try and avoid having several names for the same object, as was the case in LEP. A good naming scheme is vital if the post mortem system is to be of use for analysis. Concerning the post mortem system, it was indicated that all equipment is expected to provide the relevant signals and data. However, it is not clear if the equipment groups are all aware of this. Indeed, AB-CO themselves should provide standard functionality for post mortem in the front-ends they provide.

3.5. Session 5: Radio Frequency & Collimation

The Session consisted of six presentations:

5.1	400MHz System: Cavities	R. Losito
5.2	400MHz System: Power	O. Brunner

5.3	Beam Control System	Ph. Baudrenghien
5.4	Transverse Feedback	W. Hofle
5.5	Ring Collimation System Overview	R. Assmann
5.6	Ring Collimation System	O. Aberle

400 MHz System: Cavities

The LHC RF accelerating system consists of eight niobium-sputtered copper cavities per beam providing up to 2 MV each. The cavities are equipped with mobile power couplers operating at very high RF power (300 kW CW) and are grouped in cryo-modules, each containing four cavities.

The design of the cavities is completed and all five modules (including one spare) have already been built and tested at low RF Power. The ceramic insulators and the vacuum windows (in particular those of the power couplers) are the most critical components of the system for their number (13 per cavity) and fragility. Modifications have been introduced to the manufacturing methods of such elements to minimize the risk of damage during bake-out and four prototype couplers have been built and are presently under test at high power on the first module in SM18. If the new manufacturing methods will prove to be successful no delay is expected in the delivery of the power couplers, nevertheless the fabrication of these components remains delicate and relies on the full support of several services (in particular the main workshop, transport and vacuum) and therefore remains critical.

Adequate testing time (about two years) must be foreseen and space and installations in SM18 will be required until 2006.

In the LHC tunnel, the magnets and the RF cavities share the same cryogenics distribution line. For that reason there is considerable interference between the magnets and the RF system:

- Commissioning in the tunnel can only start after magnet commissioning (supposed to be completed by the October 2006). Six months only are allocated for the commissioning of the full RF system (including power and low level) and therefore the testing time will have to be carefully optimised. Any delay in the commissioning of the magnets in octant 4 will result in a delay in the RF commissioning in the tunnel and should be therefore avoided.
- Breaking of a ceramic window would imply removal from the tunnel and dismantling of the full module. This would require purging the whole LHC sector. The procedures for such and event should be studied and the corresponding downtime for the machine, including re-installation, cool-down, testing and conditioning should be evaluated.
- The maximum acceptable He pressure in the RF modules is higher than that in the magnets cryostats and might result in a significant release of Helium into the tunnel. In a worst case scenario to the discharge of the whole of a LHC sector through the RF module release valve might occur. Both events should be carefully studied.

During operation, Helium processing might be needed to recover the cavity performances in case of degradation. This will require access of the vacuum personnel in UX45 with cavities filled with liquid Helium. The definition of the appropriate access procedures must be addressed.

400 MHz System: Power

The Power part of the RF system is reusing a significant fraction of LEP equipment: 100 kV- 40 A power converters, high voltage cables, RF oil tanks, ionic pumps, focus power supplies, RF drivers. This is old equipment and a gradual replacement programme will have to be implemented. The power converters will be inspected next year and might require the repair of the transformers with an additional cost of 1 MCHF. This should not translate in a delay in the delivery of the power system.

The construction of junction boxes in US45 using LEP RF oil tanks will limit the length of the HV cables to be pulled (from US45 to UX45). The integration of the junction boxes has been done but the HV cables have still to be integrated and the approval of SC is still pending concerning the safety measures to be implemented because of the presence of oil in the underground areas. This matter should be dealt by the Safety Working Group and cover all similar systems (as the kickers Pulse Forming Networks - PFNs).

The four HV bunkers have been fully specified and will be built by the end of 2004. All the prototypes power components have been built, tested and validated and the series production is under way at CERN or in external companies. A minor delay has been recorded in the delivery of circulators and loads after a modification of the load design to better protect the waveguides against shockwaves in the cooling system.

All the RF Power equipment, including controls, will be tested in Building 112 and SM18 before installation in the underground areas.

The responsibility of the integration of all the RF equipment has been taken by the AB/RF group and efforts have been devoted to the integration of the klystron, circulator and load in a “plug & play” chassis in the RF power zone to ease replacement in case of problems. More problematic is the integration of the waveguides in the tunnel, particularly those above the “external” modules. The replacement of a waveguide near one of these modules might require its removal! Integration solutions should be investigated to avoid such scenario.

The safety procedures during RF conditioning will have to be defined. This is particularly important given the short time available for commissioning in the tunnel.

Beam Control System

The beam control system is composed of four subsystems:

- Cavity Controller: to control the phase and amplitude of the cavity voltage and compensate for beam loading while keeping the demanded klystron power within specs.
- RF Synchronization: to guarantee the correct bunch-to-bucket transfer from SPS to LHC, to generate beam synchronous signals, to provide fine re-phasing of the two rings before physics.
- Beam Control: to generate the beam centred RF reference for each ring while minimizing phase noise for optimum lifetime in physics.
- Longitudinal Damper acting on the 400 MHz cavities: to damp phase and energy errors at injection and damp dipolar bunch oscillations.

Functional specifications, proposed implementation, choice of the platform, integration, cable list and routing have been established for all the systems. Detailed design of the hardware modules has started only for the cavity controller for which a prototype must be ready by April 2004 for testing in SM18. The accumulated delay (4 months) on the design of the cavity controller cards is partly due to the lack of manpower and in particular to the need of learning the Digital Signal Processing (DSP) technology and its tools. For that reason the delay might be absorbed later.

The present design foresees the use of Field Programmable Gate Arrays (FPGAs) in underground areas and might be sensitive to radiation. The number of expected single event upsets resulting from the hadron flux generated by beam-gas interaction has been estimated for an unrealistically low (by at least two order of magnitudes) value of the vacuum pressure during operation. This must be carefully studied and if confirmed it would imply a single event upset per day. This would be unacceptable taking into account that a RF module trip will imply dumping the beam. Similar investigations should be performed for the beam instrumentation electronics relying on DSP technology. The compatibility of the local pressure bump required at the Ionisation Profile Monitors located downstream of the RF cavities with the reliable operation of the RF controls should be also addressed.

Concerns have been raised about the support provided by the TS/DEM Service in charge of the development of the electronic modules, as this could be a potential bottleneck in the development of the project.

The needs for the Sector Test should be also clearly identified to guarantee the delivery of all the required hardware in time for the test.

It has been noted that the longitudinal monitors developed by the AB/RF group might not be sensitive enough to serve as abort gap monitor. The latter is under the responsibility of the AB/BDI group but does not appear in the LHC hardware baseline.

Transverse Feedback System

The transverse feedback will damp the transverse injection oscillation, will fight transverse coupled bunch instability and will be also used to excite transverse oscillation for beam measurements and abort gap cleaning. It consists of eight electrostatic kickers per beam (four per plane) and four spares (two per plane). Two wide-band (20 MHz) amplifiers power each kicker.

The design and the prototypes are completed. The kicker and the power amplifiers are built at JINR with some parts supplied by CERN (vacuum feedthroughs, water cooled resistors and other components for the power amplifiers). The pre-series are suffering from delays. The kicker vacuum tanks delivered by JINR had to be rejected because of the poor quality of the welding. Some delay has been accumulated at CERN in the procurement of components for the power amplifiers because of lack of manpower in the procurement follow-up. The pre-production units should be completed and tested by the first and third quarter of 2004 (electrostatic kicker and power amplifier, respectively) and are now on the critical path. Concerns have been raised about the limited control that can be exercised on the collaborating institutes in particular in the definition of the priorities with respect to concurrent projects. More effort of coordination and control of the contributions of the collaborating institutes to the LHC on a CERN-wide basis might be required.

The procurement of the driver amplifiers and of the high voltage power converters is well on schedule. The market survey for the high voltage power converter damper was grouped with that of the LEIR auxiliary power supplies (the latter under the responsibility of AB/PO) and allowed to share the efforts in the procurement procedures.

Once at CERN the different building blocks (including low level and industrial controls, as well as interlocks) will have to be assembled and fully tested in a dedicated test area in building 867 before their final installation. The preparation of the test area has not yet started and it is now one year late. Although this is not yet on the critical path this sub-project involves the installation of services by TS. Their planning and resource limitations should be taken into account.

The low level-electronics will be built with DSP technology and its design is also delayed. Although the system will be based on the experience gained with the SPS damper and it is not yet on the critical path, its delivery might interfere with that of the longitudinal beam controls, relying on the same technology and manpower and sharing similar schedule and delays.

AB/RF is responsible for the integration in the tunnel, in the service galleries and in the surface building in point 4. That is well under way in the tunnel and in UX45, though some aspects concerning the routing of cables and cooling pipes still need to be clarified. The integration of the transverse feedback components in the surface building SR4 has not yet been tackled.

Ring Collimation System Overview

Re-launched in October 2002, the collimator design is still at an early stage. A phased approach has been chosen given the tight time schedule. The first phase should be ready by 2007 and should be compatible with acceleration and ramping up to ultimate intensities and with the requirements of commissioning and early physics runs at 7 TeV. The layout and optics are in the process of being finalized in IR7 and have still to be optimised in IR3 with the aim of minimizing the impedance while keeping a good cleaning efficiency.

In this moving context the collimator component design has just started and the estimate of the cost to completion of the first phase is still subject to large uncertainties. The shielding of the collimators, required to comply with the compulsory limits on the radiological impact of the LHC operation on the environment, has not been studied yet. The design of the shielding will have significant implications for the services (cabling, cooling, ventilation, vacuum) and necessarily on the cost, as well as on the schedule of ordering, assembly and installation. The goal for the definition of the shielding is mid-2004 and looks rather optimistic in spite of the doubling of the manpower in 2004. A large fraction of the project members are working part-time on the collimator design and their contribution is inevitably deemed to be variable in time and conditioned by the priorities set for them in the other activities they are involved. Stronger support by SC/RP (indeed reducing from 1 to 0.7 FTE in 2004) might be necessary to finalize the shielding layout.

The prototyping effort for the secondary collimators, finalized to the tests in the SPS in fall 2004, is noted and will certainly serve to give confidence in the solidity of the design and to verify the impedance models. No much time will be left, before the start of the series production (beginning of 2005), for possible modifications to the design deriving from the results of the tests. It was also noted that no time reserve is allocated in the present schedule.

Ring Collimation System Design

As previously mentioned the collimator design is necessarily preliminary and it is mainly focussed on the material choice and on the design of the motorization with particular emphasis on the prototype to be used for the tests in the SPS.

Surface flatness (better than 25 μm) might be difficult to obtain for the secondary collimators jaws. As that is a key parameter for the achievement of the required cleaning efficiency, clear quality control procedures will have to be defined to qualify the jaws for installation.

Reliability and precision of the movement and evolution of the material properties in a highly radioactive environment should be carefully studied to guarantee long-lifetime. Any intervention might be more difficult and/or requiring longer downtime in the presence of the radiation shielding.

4. General Comments & Conclusions

A few general issues came up during the review. These reflect common problems for the different groups and sections of the department. The four most significant are given below, together with some very brief notes from the reviewers:

Storage

Temporary storage space is a problem for several groups. The management of the available space (supposedly done on a sector basis) is inadequate. Some attempt must be made to control space more efficiently and to allocate holding areas for genuinely temporary storage. The groups must also be encouraged not to hold onto space un-necessarily. The safest place for storage of equipment is underground, in its final location. Where compatible with other activities, attempts should be made to advance the installation of components. With the new organisation of CERN into departments (no sectors) it is clear that a new structure for co-ordination of storage throughout CERN is needed.

Documentation / Hardware Baseline

There is still a lack of available documentation for many systems. The usual excuse is that there is no time to build the equipment AND to write the documentation. However, the EDMS/MTF systems should not be used just as an archive for the final documentation. They can and should be used to store working documents and data. Many groups do – in private EDMS structures. Links to more general EDMS structures should be envisaged – including the LHC hardware baseline. The relatively poor search facilities and the confusion between group and project structures were cited as reasons why EDMS is not as widely used as it should be. More training for staff is needed and requests to improve the search system and structure should be made to TS. Despite having the ability to keep documents private, some worries were expressed about putting documents into EDMS in a preliminary state. It is clear that project engineers and groups should be at liberty to decide at what stage to make documents available in the system.

Manpower Resources

In many presentations the problem of missing manpower was raised. The problem often arises because there has been a reduction in the manpower without a corresponding reduction in activities. The departmental staff plan is currently being revised and the needs expressed by the groups to satisfy the requests will be addressed. Where necessary, the priority of certain activities will be reviewed. There are even parts of the LHC that could be given a lower priority, if necessary. Not everything will be needed on day 1!

Design Office Support

In many cases the lack of designers was cited as being the cause of delays. This has been a problem for several years. The division must take this up again with the management of TS as the design effort needed for the LHC magnets should be less. However, the prioritisation of activities within the division must also be used to delay certain work in preference to other activities and hence to ease the severe shortage of designers available to AB.

The review covered a wide variety of systems illustrating the major contribution of the AB division to the LHC machine. The sessions were open to all. Members of the AB department were invited, together with a selection of people from other departments and the project management. The review was generally very positive. The quality of the presentations was very high and together the five sessions give a very good picture of the present status of the LHC related activities in the AB department. In most cases the LHC activities are proceeding well and within the agreed budget and planning envelopes. Some worries exist with systems where the planning is very tight, but no "show-stoppers" have been found.

The preliminary findings of the review panel were presented to the AB Management Board in December 2003. As a result of the discussions certain actions have been taken which are mentioned in section 4 of this report.