CHAPTER 1

INTRODUCTION

The Large Hadron Collider Project was approved by CERN Council in December 1994. However, in order to allow the machine to be built within a constant budget with no financial contributions from non-Member States, it was decided that the accelerator was to be built as a 2-stage project, the first stage with an energy of 10 TeV in the centre-of-mass, to be operational by 2004, with an upgrade to its final energy of 14 TeV by 2008. It was also decided that a comprehensive review of the Project would be made before the end of 1997 and that if sufficient extra contributions could be secured from non-Member States then it would be possible to re-examine the 2-stage project and revert to the immediate construction of a 14 TeV accelerator.

During the years 1995-1996, intense negotiations with non-Member States secured a substantial commitment to participate financially in the construction of the Machine. Consequently, the review foreseen before the end of 1997 was brought forward. In December 1996, Council passed a Resolution approving the construction of the 14 TeV accelerator in a single stage. The LHC will be the first machine built at CERN with substantial material contribution from non-Member States. Machine hardware is being constructed in National Laboratories in Canada, India, Japan, Russia and the USA.

In parallel with the diplomatic activity, a substantial redesign of the machine was undertaken in order to reduce cost and improve performance. This work culminated in the LHC Conceptual Design Report (the “Yellow Book”) published in October 1995, which has served as the basis for the detailed design. The basic design of the machine and its performance projections have remained remarkably stable over the ensuing years, with a few exceptions mentioned below.

In the superconducting magnet system, the most significant change is in the design of the main dipoles. The Yellow Book design was based on the use of high-strength aluminium collars to contain the electromagnetic forces, with a gap in the yoke that closed when cold. After testing a number of models based on this concept it was decided to replace the aluminium collars with austenitic steel collars and to close the yoke gap at room temperature. The main reason for this was the much tighter tolerance requirements for the aluminium collars. It was considered that the cost of achieving these tolerance in an industrial environment would exceed the extra cost of the collar material. This choice has proved to be a very good one. Dipole production is proceeding smoothly, with consistent quality.

The design of the beam collimation systems has evolved considerably. Since the difficulties and performance goals are distributed in time, the collimation systems are designed so that they can be installed in three phases. In the first phase, robustness is favoured to ultimate performance. The primary collimator jaws are made from carbon, able to resist high beam loss. As experience with the system grows, further collimators will be installed to efficiently protect the machine and detectors at the highest intensity.

The RF and Beam Feedback systems have evolved somewhat since the “Yellow Book”. The longitudinal damping will no longer be performed with separate damping cavities. In addition a new 200 MHz system to reduce capture losses and to ease operation has been designed, although recent success in controlling the longitudinal emittance in the SPS have shown that this system will only be required at the highest intensity.

The design of the vacuum system has remained unchanged in the cold regions of the machine except in the insertion regions, where beam screens have been introduced in all superconducting magnets in order to avoid cold traps. In the room temperature regions it has been decided to coat the chambers with Ti-Zr-V Non Evaporable Getter (NEG) which can be activated at low temperature (200°C). Considerable experience has also been accumulated in the SPS on the electron cloud instability, which will limit the luminosity in early operation. A “scrubbing” period will be needed to clean the vacuum chamber through electron bombardment before it will be possible to operate at full intensity.

The detailed optical design of the machine has been modified in the dispersion suppressor and insertion regions in order to improve the flexibility and tuneability of the machine.

Finally, a new small experiment for small angle scattering (TOTEM) has been approved to be installed in the region of CMS (Point 5). This has required a number of layout changes in order to integrate the “Roman Pot” detectors.

The present report, published in three volumes, is intended to serve as an accurate record of the machine and its experimental areas as constructed. The first Volume concerns the LHC Machine itself. In chapters 2 to 5, the main parameters are described and the many issues in accelerator physics that have to be taken into account in the design in order to achieve the required performance are discussed. Following chapters deal with the detailed hardware design of the main components.

A very considerable amount of modification of the existing LEP infrastructure has been necessary. On the surface, additional buildings are needed to house the huge cryogenic plants and other equipment. Underground, the most demanding civil engineering work has been the excavation of the experimental caverns for the two large detectors ATLAS and CMS. Other conventional infrastructure, including cooling, ventilation, access and safety systems, electrical infrastructure has all needed considerable modification. This is documented in Volume 2 of the report.

The LHC will be supplied with protons and Pb ions from the existing injector chain comprising linac, booster, PS and SPS. These accelerators have undergone a major upgrade in the last five years in order to meet the demanding requirements of the LHC. The upgrade project involved an increase in Linac2 current, new RF systems in the PS Booster and PS, increasing the Booster energy from 1 GeV to 1.4 GeV and the modification of the LEAR ring to allow Pb ion cooling and accumulation. In addition, a number of modifications of the SPS have been necessary, including an impedance reduction programme and the installation of a new extraction channel. Volume 3 of the report documents the work done on the LHC injectors.