P005/LHC/A3

IMPLEMENTING ARRANGEMENT

to

THE ACCELERATOR PROTOCOL

between

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

and

THE DEPARTMENT OF ENERGY OF THE UNITED STATES OF AMERICA

concerning

SCIENTIFIC AND TECHNICAL CO-OPERATION ON LARGE HADRON COLLIDER ACTIVITIES

May 2002

The European Organization for Nuclear Research, hereinafter referred to as "CERN" represented by Lyndon Evans, Director, LHC Project Leader,

on the one hand,

and

Brookhaven National Laboratory (BNL), represented by Peter Paul, Interim Director,

Fermi National Accelerator Laboratory (FNAL or Fermilab), represented by Michael Witherell, Director,

Lawrence Berkeley National Laboratory (LBNL), represented by Charles Shank, Director,

on the other hand,

Have agreed as follows:

I. INTRODUCTION

I.A. Parties to the Implementing Arrangement

The parties to this Arrangement are on the one hand CERN, the European Organization for Nuclear Research, and on the other hand the U.S. Laboratory Collaboration, consisting of Brookhaven National Laboratory (BNL), Fermi National Accelerator Laboratory (FNAL or Fermilab), and Lawrence Berkeley National Laboratory (LBNL).

I.B. Purpose of the Implementing Arrangement

Article III, "Items provided by U.S. National Laboratories," of the Accelerator Protocol to the International Co-operation Agreement between the European Organization for Nuclear Research (CERN) and the Department of Energy of the United States of America and the National Science Foundation of the United States of America concerning Scientific and Technical Co-operation on Large Hadron Collider Activities calls for Implementing Arrangement(s) to "specify the equipment; detail the technical specifications, schedules and acceptance procedures; and specify other activities of U.S. laboratories in support of the construction of the LHC," and which "shall also define the procedures for modifications to the technical specifications." It has been agreed that there will be a single Implementing Arrangement to specify the work of the U.S. laboratories.

This Implementing Arrangement specifies the scope of work of the U.S. part of the LHC Accelerator Project (also referred to in this document as the U.S. Project), which is the sum of the efforts by the U.S. Laboratory Collaboration in support of the LHC Project. It specifies the means by which the collaboration between the U.S. laboratories and CERN is governed and by which the U.S. effort is controlled to ensure proper integration within the LHC Project. This includes definitions of authorities and responsibilities of the two parties with respect to each other, systems of formal and informal communication, baseline and change control procedures, systems of technical, safety and other reviews, and requirements for safety and quality assurance and quality control. It also specifies the principle schedule milestones for the U.S. part of the LHC Accelerator Project.

I.C. Related Documents

The management of the U.S. Project, and of the relationship between the U.S. Project and the U.S. Department of Energy are specified in the U.S. LHC Accelerator Project Management Plan (US-PMP). The Project Management Plan specifies those aspects of the project management that are internal to the U.S. Project, while this Implementing Arrangement specifies those aspects that concern the relationship between the U.S. Project and CERN. Appropriate references are made in each document to the other. While CERN approval is not required for the US-PMP, the LHC Project Leader or his designee will be consulted in the development of the US-PMP and when changes to it are considered. Copies of the US-PMP will be provided to the LHC Project Leader for consideration in the approval process of the Implementing Arrangement, and all changes to the US-PMP will be communicated promptly to him.

This Implementing Arrangement specifies the scope of the U.S. Project by giving summary descriptions of the sub-projects of which it is made. Full, detailed descriptions of the hardware systems and technical support provided by the U.S. Laboratory Collaboration, including detailed requirements and specifications, detailed descriptions of the designs of hardware systems and of the technical support work to be carried out, and of the supporting R&D programs are provided in the U.S. LHC Accelerator Project Technical Design Handbook (TDH).

I.D. Principles and Goals of the U.S.-CERN Collaboration

The U.S. contribution through its national laboratories to the LHC accelerator should aid in the timely construction of the LHC, based on the principles of optimizing technical performance and maximizing the impact of the U.S. contribution within budgetary limits.

The U.S. contribution through its national laboratories will also present a significant opportunity for U.S. laboratories to maintain or improve their technological capabilities.

II. SCOPE OF WORK

II.A. Method of Scope Specification

The scope of the U.S. Project is defined by its Work Breakdown Structure (WBS). The WBS is summarized in Table I, in which it is carried out to the level required to define clearly the scope of the project and the boundaries of responsibility between the U.S. laboratories and CERN and among the three U.S. laboratories. This is typically level 4, where level 1 is the U.S. Project as a whole. (Level 4 tasks are the responsibility of the lab listed for the parent level 3 task unless otherwise indicated.) The following sections give a summary description of each element in this WBS. Full descriptions of each of these elements, including detailed requirements and specifications, detailed descriptions of the designs of hardware systems and of technical support work to be carried out, and supporting R&D programs, are presented in the U.S. LHC Accelerator Project Technical Design Handbook.

Table I (part 1)
Work Breakdown Structure (WBS)
U.S. Part of the LHC Accelerator Project

WBS	Task	Responsible Laboratory
1	**U.S. PART OF THE LHC ACCELERATOR PROJECT**	
1.1	**INTERACTION REGIONS**	
1.1.1	INTERACTION REGION QUADRUPOLES	FNAL
1.1.1.1	Interaction Region Quadrupole Tooling	
1.1.1.2	Interaction Region Quadrupole Cold Mass	
1.1.1.3	Interaction Region Quadrupole Cryostat	
1.1.1.4	Interaction Region Quadrupole Testing	
1.1.1.5	Interaction Region Quadrupole Cable and Wedges	LBNL
1.1.1.6	Interaction Region Quadrupole Shipping	
1.1.1.7	Interaction Region Quadrupole EDIA	FNAL, LBNL
1.1.2	INTERACTION REGION DIPOLES	BNL
1.1.2.1	Interaction Region Dipole Tooling	
1.1.2.2	Interaction Region Dipole D1 Production	
1.1.2.3	Interaction Region Dipole D2 Production	
1.1.2.4	Interaction Region Dipole Testing	
1.1.2.5	Interaction Region Dipole EDIA	
1.1.3	INTERACTION REGION CRYOGENIC FEEDBOXES	LBNL
1.1.3.1	Interaction Region Feedbox Fabrication	
1.1.3.2	Interaction Region Feedbox Shipping	
1.1.3.3	Interaction Region Feedbox EDIA	
1.1.4	INTERACTION REGION ABSORBERS	LBNL
1.1.4.1	Interaction Region Absorber Fabrication	
1.1.4.2	Interaction Region Absorber Shipping	
1.1.4.3	Interaction Region Absorber EDIA	
1.1.4.4	Luminosity Instrumentation Development	
1.1.5	INTERACTION REGION LAYOUT AND INTEGRATION	FNAL
1.2	**RF REGION**	
1.2.1	RF REGION DIPOLES	BNL
1.2.1.1	RF Region Dipole Tooling	
1.2.1.2	RF Region Dipole Prototypes	
1.2.1.3	RF Region Dipole D3 Production	
1.2.1.4	RF Region Dipole D4 Production	
1.2.1.5	RF Region Dipole Testing	
1.2.1.6	RF Region Dipole EDIA	
1.3	**SUPERCONDUCTING STRAND AND CABLE**	
1.3.1	SUPERCONDUCTING STRAND AND CABLE TESTING	BNL
1.3.1.1	Superconducting Strand and Cable Testing Tooling and Equipment	
1.3.1.2	Superconducting Strand and Cable Tests	
1.3.1.3	Superconducting Strand and Cable Testing EDIA	

Table I (part 2)
Work Breakdown Structure (WBS)
U.S. Part of the LHC Accelerator Project

WBS	Task	Responsible Laboratory
1.3.2	SUPERCONDUCTING CABLE PRODUCTION SUPPORT	LBNL
1.3.2.1	Dipole Cable R&D	
1.3.2.2	Cable Measurement Support	
1.3.2.3	Cable Manufacturing Support	
1.3.2.4	Superconducting Cable Production Support EDIA	
1.4	**ACCELERATOR PHYSICS**	BNL, FNAL, LBNL

II.B. WBS Dictionary

1.1 Interaction Regions

The U.S. Laboratory Collaboration is responsible for providing CERN with integrated inner triplet magnet systems for the four interaction regions (IRs) at points 1, 2, 5 and 8. This includes the design, development and fabrication of half the high gradient quadrupoles required; design, development and assembly into cryostats of multi-element systems composed of U.S.-built quadrupoles and quadrupoles provided through CERN by KEK, the High Energy Accelerator Research Organization in Japan, together with correction coils and beam and cryogenic instrumentation provided by CERN; design, development and fabrication of special dipoles which move the beams from two separate channels into a common channel in order to bring them into collision; and design and fabrication of the cryogenic feedboxes which provide interface between the superconducting magnet system and the CERN cryogenics, DC power distribution and instrumentation systems. In addition, the U.S. laboratories will design and build the front absorbers and neutral beam absorbers, which are required at IR1 and IR5.

CERN has responsibility for ensuring that the KEK-provided quadrupoles meet their specifications and for their timely delivery to the U.S. laboratories for assembly. The KEK-provided magnets and all correction coils will be delivered to the U.S. Collaboration after a full set of acceptance tests have been performed, and the responsibility of the U.S. laboratories will be limited to assembling them into their cryostats, performing sufficient electrical tests at room temperature to verify the integrity of the coils following assembly, and measuring the position of their magnetic axes with respect to external fiducials.

1.1.1 Interaction Region Quadrupoles

This task involves the design, development and fabrication of 18 high gradient superconducting quadrupole cold masses (16 plus 2 spares), which will be used as the Q2 element of the inner triplet at all four IRs; the design, development and fabrication of the cryostats for the low-beta quadrupole systems at all four

Mf

IRs; the assembly of U.S.-built and Japanese-built quadrupoles together with intermediate absorbers, CERN-supplied correction coils and instrumentation into the cryostats. Fermilab has overall responsibility for this task, and LBNL plays a supporting role.

1.1.1.1 *Interaction Region Quadrupole Tooling*

This task is the design, development and implementation of all tooling required for the R&D as well as production fabrication of the IR quadrupoles and cryostats. Fermilab is responsible for this task.

1.1.1.2 *Interaction Region Quadrupole Cold Mass*

This task is the design, development and fabrication of the IR quadrupole cold masses. Included in this task is the construction of a series of short (2 m) model magnets and associated R&D, construction of a full-scale prototype quadrupole, and the fabrication of the 16 quadrupoles plus 2 spares. Fermilab is responsible for this task.

1.1.1.3 *Interaction Region Quadrupole Cryostat*

This task is the design, development and fabrication of the cryostats for the IR quadrupole systems. It includes construction of a full-scale model heat exchanger, R&D on support structures, design and fabrication of the intermediate beam absorbers, construction of a cryostat for the full-scale prototype quadrupole, fabrication of cryostats, and assembly of U.S.- and Japanese-built quadrupoles together with intermediate beam absorbers, and CERN-supplied correction coils and instrumentation into the cryostats to produce complete units for all four IRs, plus one spare assembly of each type, ready for installation in the machine. Fermilab is responsible for this task.

1.1.1.4 *Interaction Region Quadrupole Testing*

This task includes the tests of the short model magnets, the full-scale prototype, and the qualification testing of the production quadrupoles. Cold tests of all the U.S.-built quadrupoles will be performed, including quench training, field quality measurements and determination of the quadrupole axis. Room temperature magnetic measurements performed during magnet fabrication are included in this task. For the Japanese-built quadrupoles, cold tests will be performed on the first two to verify the proper assembly into the cryostats and understanding of the warm-cold offset of the quadrupole axis position for these magnets. For the remaining Japanese-built quadrupoles, only room temperature field axis measurements will be performed. This task also includes the design, development, and fabrication of instrumentation and facilities required to measure and test the quadrupoles. Fermilab is responsible for this task.

1.1.1.5 *Interaction Region Quadrupole Cable and Wedges*

This task is the design, development and fabrication of the superconducting cable and the fabrication of the wedges for the IR quadrupoles. It is anticipated that all of the outer coil cable and some of the inner coil cable can be made from surplus SSC strand. This task includes the purchase of new strand as required. LBNL is responsible for this task.

1.1.1.6 *Interaction Region Quadrupole Shipping*

This task is the shipping of the completed quadrupole assemblies to CERN. It includes the design, development, and fabrication or procurement of shipping containers, internal and external systems of shipping restraints, and instrumentation required to verify the magnet conditions during shipment. Fermilab is responsible for this task.

1.1.1.7 *Interaction Region Quadrupole EDIA*

This task is the engineering, design, inspection and administration (EDIA) required for the design, development, fabrication, qualification, shipping, and, if resources allow, participation in installation and commissioning of the IR quadrupoles, including all of the tooling and R&D required. Fermilab has overall responsibility for this task, with LBNL playing a supporting role in areas of magnetic and quench protection system design and with respect to the cable and wedges.

1.1.2 *Interaction Region Dipoles*

This task is the design, development and fabrication of single- and twin-aperture beam separation superconducting dipoles for the interaction regions. Five single-aperture dipoles (4 plus 1 spare) will be provided for IRs 2 and 8. (Conventional magnets, supplied by CERN, will be used at IRs 1 and 5.) Nine twin-aperture, parallel field dipoles (8 plus 1 spare) will be provided for use in all four interaction regions. BNL is responsible for this task. CERN will provide some cryostat parts for the twin-aperture dipoles, which are of the same design used in the cryostats for the main magnets.

1.1.2.1 *Interaction Region Dipole Tooling*

This task is the design, development and implementation of tooling required for the fabrication of the interaction region beam separation dipoles and cryostats, beyond that required for the IR4 dipoles.

1.1.2.2 *Interaction Region Dipole D1 Production*

This task is the fabrication and shipping of the single aperture beam separation superconducting dipoles, including cryostats, to be used at IR2 and IR8. These are RHIC dipoles, except that the cold mass is fabricated without a sagitta and other modifications are made to adapt to the LHC requirements. Four magnets plus one spare will be fabricated.

1.1.2.3 Interaction Region Dipole D2 Production

This task is the fabrication and shipping of the twin-aperture, parallel field beam separation superconducting dipoles, including cryostats to be used at IRs 1, 2, 5, and 8. CERN will provide lower heat shield extrusions, support posts for the cryostats and other components whose design is common with the main dipoles. Eight magnets plus one spare will be fabricated.

1.1.2.4 Interaction Region Dipole Testing

This task is the qualification testing of the interaction region beam separation superconducting dipoles, including quench training and field quality measurements. Room temperature magnetic measurements performed during magnet fabrication are included in this task. This task also includes the design, development, and fabrication of instrumentation and facilities required to measure and test the dipoles beyond those required to test the IR4 beam separation dipoles.

1.1.2.5 Interaction Region Dipole EDIA

This task is the engineering, design, inspection and administration (EDIA) required for the design, fabrication, testing, shipping, and, if resources allow, participation in installation and commissioning of the interaction region beam separation superconducting dipoles.

1.1.3 Interaction Region Cryogenic Feedboxes

This task is the design, development and fabrication of the cryogenic feedboxes which provide the interface from the inner triplet superconducting magnet system (including the single-aperture beam separation dipole at IRs 2 and 8) to the LHC cryogenic, DC power and instrumentation systems. A total of 8 such feedboxes is required. This task is the responsibility of LBNL.

1.1.3.1 Interaction Region Cryogenic Feedbox Fabrication

This task is the fabrication of the eight inner triplet cryogenic feedboxes. The task also includes specification, procurement, and testing of HTS current leads capable of carrying 7.5 kA.

1.1.3.2 Interaction Region Cryogenic Feedbox Shipping

This task is the shipping of the completed cryogenic feedboxes to CERN. It includes the development, design and fabrication or procurement of shipping containers, internal and external systems of shipping restraints and instrumentation required to verify the conditions of the feedboxes during shipping.

1.1.3.3 *Interaction Region Cryogenic Feedbox EDIA*

This task is the engineering, design, inspection and administration (EDIA) required for the design, development, fabrication, shipping, and, if resources allow, participation in installation and commissioning of the cryogenic feedboxes. Included is engineering work done in collaboration with Fermilab and CERN to define the requirements for the IR cooling system and for the valve boxes which interface to the feedboxes. (The fabrication of the valve boxes is CERN's responsibility.)

1.1.4 Interaction Region Absorbers

This task is the design, development and fabrication of room temperature absorbers needed to protect the final focus system and twin-aperture beam separation dipoles from secondary particles from p-p collisions at the two high luminosity interaction regions (IRs 1 and 5). It includes 4 room temperature front quadrupole absorbers, which are situated between the collision point and the first inner triplet quadrupole on each side of IRs 1 and 5, and 4 room temperature neutral beam absorbers, which are situated adjacent to the twin-aperture beam separation dipole. Both absorber types have provisions that allow them to be instrumented for fast luminosity measurement. Included in this task is design and development of a fast ionization chamber which could be used as the fast luminosity instrumentation. LBNL is responsible for this task.

1.1.4.1 *Interaction Region Absorber Fabrication*

This task is the fabrication of the IR absorbers for IRs 1 and 5. Four neutral beam absorbers, including the support system required to align them precisely with respect to the beam, will be built. Each neutral absorber will have provisions that allow them to be instrumented for fast measurement of luminosity and beam-beam separation. Four quadrupole absorbers, including the support system required to position the absorbers precisely with respect to the beam within the shielding for the experiments at IRs 1 and 5, will be built. These also will have provisions that allow them to be instrumented for fast measurement of luminosity and beam-beam separation.

1.1.4.2 *Interaction Region Absorber Shipping*

This task is the shipping of the four quadrupole absorbers and neutral beam absorbers, together with their associated support and alignment structures, to CERN.

1.1.4.3 *Interaction Region Absorber EDIA*

This task is the engineering, design, inspection and administration (EDIA) required for the design, fabrication, shipping, and, if resources allow, participation in installation and commissioning of the four quadrupole absorbers and neutral beam absorbers, together with their associated support and alignment structures; and for the development of the fast ionization chamber.

1.1.4.4 *Luminosity Instrumentation Development*

This task is the design, development and beam test of a fast ionization chamber, which is a candidate for the luminosity instrumentation that could be installed into the IR absorbers. The deliverable to CERN is a documentation package defining the design, its specifications and its measured performance in the test beam.

1.1.5 Interaction Region Layout and Integration

This task is the engineering and design required to ensure that all of the equipment fabricated and assembled by the U.S. Laboratory Collaboration for IRs 1, 2, 5, and 8 are laid out according to the LHC system requirements and are integrated into complete and operational systems. It includes oversight and coordination of the development of general layout drawings and of interface drawings which define the interfaces between U.S.- and CERN-supplied equipment and systems and between equipment and systems provided by different U.S. laboratories. It includes oversight of the cryogenic, electrical and alignment systems designs. If resources allow, it will include participation in the installation and commissioning of the U.S.-provided interaction region systems. It does not include the development of the engineering solutions or of the detailed part drawings at the various interfaces, but rather includes the engineering oversight required to assure that all such parts and systems are correctly designed and that proper communication occurs among the participants in the design and fabrication of components for the final focus systems for with the U.S. Laboratory Collaboration is responsible. This task is the responsibility of Fermilab.

1.2 RF Region

This task is the design, development and fabrication of specialized magnets required in the RF straight section (IR4) where the beams are separated by a larger distance than elsewhere in the machine as required for implementation of the radio frequency acceleration system. It also includes engineering work done in collaboration with CERN required to integrate the U.S.-provided magnets with the other components and systems in this region. CERN will provide some cryostat parts for the twin-aperture dipoles, which are of the same design used in the cryostats for the main magnets. This task and all its subtasks are the responsibility of BNL.

1.2.1 RF Region Dipoles

This task is the design, development and fabrication of twin-aperture, parallel field beam separation superconducting dipole magnets for the RF straight section. A total of 6 dipoles will be provided -- 2 of each of 2 different aperture separations, plus 1 spare of each. The task also includes work done together with CERN to integrate these magnets with the other components and systems in this region.

1.2.1.1 RF Region Dipole Tooling

This task is the design, development and implementation of all tooling required for the R&D as well as production fabrication of the IR4 beam separation dipoles and cryostats.

1.2.1.2 RF Region Dipole Prototypes

This task is the fabrication of two 3-m long twin aperture prototype dipole cold masses of the D4 type.

1.2.1.3 RF Region Dipole Magnet D3 Production

This task is the fabrication and shipping of the D3 beam separation dipoles, including cryostats. These magnets consist of two single-aperture RHIC-type dipoles in a common cryostat. CERN will provide lower heat shield extrusions, support posts for the cryostats and other components whose design is common with the main dipoles. Two magnets (two cold masses each) plus one spare will be fabricated.

1.2.1.4 RF Region Dipole Magnet D4 Production

This task is the fabrication and shipping of the D4 beam separation dipoles, including cryostats. These are twin-aperture, parallel field dipoles. CERN will provide lower heat shield extrusions, support posts for the cryostats and other components whose design is common with the main dipoles. Two magnets plus one spare will be fabricated.

1.2.1.5 RF Region Dipole Testing

This task includes the tests of the prototypes and the qualification testing of the production magnets, including quench training and field quality measurements. Room temperature magnetic measurements performed during magnet fabrication are included in this task. This task also includes the design, development, and fabrication of instrumentation and facilities required to measure and test the dipoles.

1.2.1.6 RF Region Dipole EDIA

This task is the engineering, design, inspection and administration (EDIA) required for the design, development, fabrication, testing, shipping, and, if resources allow, participation in installation and commissioning the RF region dipoles, including all of the tooling and R&D required.

1.3 SC Strand and Cable

The U.S. Laboratory Collaboration supports CERN in the development of the superconducting cable for the main magnets and in the testing of the superconducting strand and cable for the main magnets.

1.3.1 Superconducting Strand and Cable Testing

This task is the testing of superconducting strand and cable for the LHC main magnets. Modification and enhancement of the test systems required to provide for testing in superfluid helium and to support the production testing rate are included in this task and consist of the construction of two additional cable test systems and modifications and upgrades to the cryogenic, DC power, control and data acquisition systems. This task is the responsibility of BNL.

1.3.1.1 Superconducting Strand and Cable Testing Tooling and Equipment

This task is the design, development and fabrication of modifications and upgrades to the BNL strand and cable testing facilities required to provide for testing in superfluid helium and to support the production testing rate. It includes the construction of two new test dewar systems with magnets to provide the magnetic field for cable testing, one of which has the capability to operate with superfluid helium; the construction of new sample holders; and modification and upgrades to the high current DC power system and its control system, to the helium refrigeration system, and to the data acquisition system.

1.3.1.2 Superconducting Strand and Cable Tests

This task is the testing of the strand and cable, including both R&D-type tests to aid CERN in the development of the strand and cable, and production testing of the cable during LHC construction. The total number of strand and cable samples to be tested under this agreement is specified in a memo between the CERN official contact person for superconducting strand and cable (see Appendix 1) and the BNL WBS level 3 manger for this task. This memo is included as Appendix 3 to the Implementing Arrangement. Changes to the number of tests will be subject to the change control procedures of both parties and will in addition require the approval of the U.S. Project Manager and of the LHC Project Leader or his designee. Such changes will be documented by a new memo replacing that in Appendix 3. Other signatories of this Implementing Arrangement must be notified of such changes, but their approval is not required. If additional tests are required beyond those specified in Appendix 3, these tests will be performed by CERN in their own facilities, or, if performed at BNL, will be paid for by CERN.

1.3.1.3 Superconducting Strand and Cable Testing EDIA

This task is the engineering, design, inspection and administration (EDIA) required for the testing of superconducting strand and cable for the LHC main magnets and for the modification and enhancement of the test facilities required to support the testing.

1.3.2 *Superconducting Cable Production Support*

This task is the aiding of CERN in developing the cable for main LHC magnets and in developing and optimizing the production methods and quality control. This task and all its subtasks are the responsibility of LBNL.

1.3.2.1 *Dipole Cable R&D*

This is R&D on the design of cable for the LHC main magnets. It includes the manufacture of cable samples with varying compaction, cable samples with stainless steel cores, and other R&D cable samples as requested by CERN and mutually agreed by LBNL.

1.3.2.2 *Cable Measurement Support*

This task is the upgrading of four cable measuring machines (CMMs) and their associated software, which were developed and built for the SSC, so that they can operate with the parameters of the LHC cable, and the fabrication of six spare measuring heads. The CMMs will be loaned to CERN, with shipping expense paid as part of the U.S. Project, and they will be used as part of CERN's quality control program for the LHC cables. LBNL personnel will aid in their installation and initial operation. LBNL will also develop an eddy current flaw detection system for cables and provide one such system for the LHC project to be operated by CERN.

1.3.2.3 *Cable Manufacturing Support*

This task is the support given by LBNL to CERN to help achieve the required mechanical tolerances and quality of the LHC cable during mass production. One powered Turks Head with temperature controls (developed for the SSC program) will be provided to CERN and will be used to define manufacturing tolerances that can be achieved with this equipment.

1.3.2.4 *Superconducting Cable Production Support EDIA*

This task is the engineering, design, inspection and administration (EDIA) required for the support to CERN as specified above in developing the cable for main LHC magnets and in developing and optimizing the production methods and quality control.

1.4 Accelerator Physics

This task is a set of accelerator design and beam physics calculations and related activities done in support of the design of the LHC and performed in collaboration with CERN and with the builders of the U.S.-supplied hardware systems for LHC. These calculations are focused on, but not limited to, supporting the design and construction of the U.S.-supplied equipment and systems for LHC.

Studies supporting the design of the U.S.-supplied equipment and systems include the following.

a) Accelerator physicists work with the builders of the magnets for the low-beta insertions and the RF region beam separation dipoles to determine the optimum design for the highest performance magnets that may be practically built within the limits of available resources. Work includes studies to define the requirements for the final focus magnets, including the inner triplet quadrupoles, beam separation/recombination dipoles, and the corrector magnets included in the inner triplet; to define the requirements for the beam separation dipoles in the RF straight section; and to understand the impact on the machine performance of the as-built magnets.

b) Studies of the beam-induced energy deposition in the insertion magnets are carried out both to characterize the phenomenon and to aid in the design of the IR quadrupole absorber and the neutral beam absorber as well as internal absorbers placed inside the quadrupole cryostat.

c) Studies are carried out to determine the utility for accelerator diagnostics and control of instrumenting the IR absorbers with particle detectors which would make fast luminosity measurements.

Other beam physics and accelerator design calculations, which make use of specific expertise in the U.S. laboratories, which take advantage of the overlap of problems in the LHC with those in actual or proposed U.S. accelerators, or which are otherwise of mutual interest, include the following.

a) The electron cloud effect.

b) PACMAN closed orbit corrections at the IP.

c) Sources and effects of spurious dispersion in the IRs.

d) Ground motion and external noise.

e) Other studies or participation in commissioning as mutually agreed and as resources allow.

It is expected that the specific work done will evolve in time according to the needs of the Project as jointly determined by the U.S. Project and CERN. This work will be carried out at an effort level of about 26 person-years over the U.S. fiscal years 1998 – 2002, spread across the three U.S. laboratories. In apportioning the finite resources, priority will be given first to tasks in support of the design and construction of the U.S.-built hardware, then to tasks where there is special expertise in the U.S. laboratories, and finally to other tasks of interest if resources allow.

III. PROJECT MANAGMENT

III.A. U.S. Project Management

The U.S. Project is managed internally following standard practices of managing DOE-funded High Energy Physics projects, and the management methods and structures are described in the U.S. LHC Accelerator Project Management Plan (US-PMP). The U.S. Project is led by the Project Manager, an employee of Fermilab, the lead laboratory, who works under the oversight of the Fermilab Director and the Department of Energy, Division of High Energy Physics. The Fermilab Director is advised by a Project Advisory Group which includes representatives from the Directorates of all three U.S. laboratories, CERN and others that he appoints. The primary responsibility for the completion of each U.S. laboratory's part of the Project lies within a specific organizational element of that laboratory, and authority and responsibility for executing that laboratory's part of the Project is delegated to the Head of that organizational element. Day to day planning and organization of the work at each laboratory is in turn delegated to a local Laboratory Project Manager. Detailed technical management of each of the WBS level 3 tasks is then delegated to WBS Level 3 Managers. An Inter-Laboratory Steering Committee advises the Project Manager on the resolution of inter-laboratory issues and the management of resources among the three laboratories. It also serves, with additional members that may be appointed by the U.S. Project Manager, as the U.S. Project Change Control Board. The specific responsibilities and authorities of these and other members of the U.S. Project Management team, as well as the names of the specific individuals, are given in the US-PMP.

III.B. CERN Project Management related to the U.S. Project

CERN has the ultimate responsibility and authority for the completion of the LHC, and this responsibility and authority is vested in the LHC Project Leader. The official point of contact for the U.S. Project and the official source of information concerning requirements and specification for the U.S.-provided equipment and technical support, and of approval for the technical designs and technical support work plans is the LHC Project Leader. The LHC Project Leader specifies official points of contact for technical matters related to the U.S. Project as a whole and to tasks within the U.S. Project. Appendix 1 lists the names of these contacts. The names listed in Appendix 1 can be modified by mutual agreement of the LHC Project Leader and the U.S. Project Manager. Other signatories of the Implementing Arrangement must be notified of such changes, but their approval is not required.

III.C. Communication and Co-ordination of Activities

III.C.1 Principals of Communication and Co-ordination of Activities

It is crucial for the success of the U.S.-CERN collaboration that information be shared freely among the collaboration members. It is the responsibility of each laboratory and of the personnel involved in the work of this collaboration to provide to their colleagues at other laboratories all information that is necessary to carry out the work described in the Implementing Arrangement.

The close co-ordination of activities among the U.S. laboratories and between the U.S. and CERN is essential. Each laboratory is responsible to ensure that its activities are adequately coordinated with the needs of the project. It is the responsibility of the U.S. Project Manager to maintain adequate coordination of the activities of the U.S. laboratories. The U.S. Project Manager and the LHC Project Leader (or his designee) are jointly responsible to maintain adequate coordination between the U.S. Laboratory Collaboration and CERN.

III.C.2 Informal Communication

The U.S. part of the LHC Accelerator Project is conducted as a team effort involving the three U.S. laboratories and CERN. For the Project to progress rapidly, all parties must be fully informed of progress, plans, issues, problems, solutions, and achievements in real time. Communication among participants is free and informal to the maximum extent feasible. Technical notes, phone calls, electronic mail with attached documents, World Wide Web postings, video teleconferences, informal discussions, and personal visits and meetings among members of the staffs of the U.S. laboratories and CERN should be exchanged frequently to facilitate information flow, raise issues for mutual resolution, and explore the viability of plans and solutions. Distribution of copies of informal correspondence to all participants is desirable to keep them fully apprised of these communications.

To ensure that the U.S. participants are adequately and promptly informed of developments in the rest of the LHC project which may affect their work, copies of the minutes of relevant CERN committees and working groups, together with attached copies of transparencies and other documentation presented at their meetings, will be posted on the World Wide Web or sent to the U.S. Project Manager who will then distribute them to the three U.S. laboratories. Included among the relevant committees are the Technical Board (TB), the LHC Commissioning Committee (LCC), and the Technical Coordinating Committee (TCC). It is the responsibility of the official contact people listed in Appendix 1 to ensure that other committee and working group meetings relevant to the U.S. Project are identified for each U.S. subtask, and that the U.S. Project Manager is included in the distribution of minutes of meetings of these committees and working groups.

III.C.3 Formal Communication

Formal communication of Project business will flow through appropriate project management channels within the U.S. Project and within CERN. Formal communication will typically involve the overall parameters of the U.S. Project, the transmittal and approval of system requirements and specifications and of the system and equipment designs and of the technical support work plans that are developed to meet the specifications. These will include development, approval and subsequent changes as necessary to the Implementing Arrangement, Functional and Interface Specifications; official drawings, schedules, and milestones; results of reviews, both programmatic and technical; and quality assurance and acceptance plans. Such formal communication will proceed either through the U.S. Project Office and the Office of the LHC Project Leader or (for example in the case of official drawings) by direct transmission with the approval of the two Project Offices. Official copies of all communications will be maintained by the two Project Offices and copies will be distributed promptly to all affected participants.

It is anticipated that most such formal communication will involve documents under change control by both the U.S. Project and CERN. Formal communication of such documents will not be considered final until all of the relevant change control approvals of both parties have been obtained.

It is anticipated that all formal communication will have been preceded by extensive informal communication which will have developed the necessary agreements and understandings on the subject at hand. This will minimize the burden on the official communication channels, maximize the efficiency and effectiveness of the official communication, and minimize the possibility of surprises.

III.D Baseline and Change Control

III.D.1 Functional Specifications

Functional Specifications are utilized by CERN to ensure that all personnel involved in the design process use the same verified input information to carry out the design. Each specification is reviewed by the appropriate personnel, approved and released for general access through the CERN Engineering Data Management System (EDMS). As early as possible, the U.S. Project will develop functional specifications for each of the hardware systems it provides. Each functional specification will outline the requirements of the hardware to be designed, establish that the design requirements are appropriate, and address intended use of the equipment. The functional specification shall address at least the following points:

a) Performance objectives, operating conditions, and the requirements for reliability, availability and maintainability.

b) Mechanical, electrical, cryogenic, radiation resistance and other technological constraints on the design.

c) Safety and regulatory requirements.

d) Manufacturing and installation requirements.

e) Basic technical interface requirements.

III.D.2 Interface Specifications and Drawings

Interface Specifications are used by CERN to ensure that all groups and individuals involved with specific hardware and its operational environment are aware of the hardware interfaces and are given the opportunity to review and approve these interfaces. Each specification is reviewed by the appropriate personnel, approved and released for general access through the CERN EDMS. As early as possible, the U.S. Project will develop interface specifications for each of hardware systems it provides. Each interface specification should describe and document, in particular with the help of drawings, the physical and functional boundaries with other systems, sub-systems and equipment. It should also describe and document the responsibility boundaries of all groups or individuals involved in the design.

III.D.3 Fabrication Drawings and Engineering Documentation

Following the engineering development phase, a set of drawings and engineering specifications will be made which will completely specify all of the construction and performance parameters of the U.S.-provided equipment and systems. They will be approved for release subject to the change control procedures of the originating U.S. laboratory.

The U.S. Project will submit an engineering file containing full documentation on the as-built items it provides to the LHC, including all information required for proper assembly and installation into the LHC and for operation and maintenance. The standard contents of the engineering file will be: design notes and calculations, material certifications and tests, operating and installation procedures, as-built equipment drawings, inspection and test results and fabrication travelers. The U.S. Project will not be required to provide (although at its discretion and by mutual agreement with relevant CERN personnel it may provide) detailed documentation on the tooling and procedures used to assemble the equipment nor other documentation not directly related to the delivered items.

III.D.4. Change of Work Scope

During the course of the development of the LHC Project and of the U.S. part thereof, technical, cost or schedule changes may arise which may require that the scope of the U.S. Project be re-evaluated. Such changes may be required, for example, due to a substantial change in the requirements and specifications of U.S.-provided equipment or services which substantially affect the cost, either up or down, of the deliverable; to a significant change in the schedule of some Project element; or to a substantial change, either up or down, in the estimated cost of completing the agreed upon scope within the original specifications. Such changes may require a reduction in the U.S. Project scope to ensure successful completion of the part remaining following the reduction, or make possible an addition to the scope allowed by the availability of funds freed by cost savings within the original scope.

Proposed changes in scope must first proceed through the normal change control procedure of the U.S. Project. The U.S. Department of Energy may, at its discretion, require that it review the proposed scope changes to ensure that the modified scope can be accomplished within the remaining anticipated funding for the U.S. Project. Coincident with the approval of the new work scope, this Implementing Arrangement and the US-PMP must be amended to reflect the new scope of the U.S. Project.

In this context, a change of work scope refers to fundamental changes in the nature of one of the WBS level 3 task definitions, the deletion of an existing WBS level 3 task, or the addition of a new task not currently contained in the scope of work specified in Section II. It does not refer to changes which do not affect the fundamental nature of any of the existing tasks as defined in Section II and which do not affect the fundamental basis on which the cost estimates and program plans were made.

III.E. Technical Reviews

III.E.1 Technical Reviews Called by the U.S. Project

The US-PMP specifies a series of formal reviews which will be carried out for each major system or equipment item provided by the U.S. Project. These reviews are designed to ensure that proper and complete specifications have been developed which meet LHC requirements, that the engineering system design is adequate to satisfy these specifications, and that adequate fabrication procedures and quality assurance programs have been developed prior to the start of fabrication. Each of the reviews will be conducted by a committee of experts assigned by the U.S. Project Manager, in consultation with the LHC Project Leader or his designee, and will include one or more members of the CERN staff who are knowledgeable in and responsible for the larger LHC systems into which the U.S.-provided equipment will be installed. Normally these will be the relevant contact person shown in Appendix 1 or his designee, as mutually agreed between the U.S. Project Manager and the LHC Project Leader or his designee. It is anticipated that to the extent possible, the membership of a review committee for a given subsystem will remain the same through the series of reviews of that system.

A formal report will be written summarizing the findings of the review, including a recommendation to the U.S. Project Manager as to whether or not the subsystem is ready to move to the next stage of development or to begin fabrication, and a set of recommendations for future action which may be required before approval can be given to move to the next stage. The report must be available for comment by the CERN representative(s) on the review committee before it is sent to the U.S. Project Manager. The approved report, its disposition by the U.S. Project Manager, and documentation concerning follow-up action taken by the subsystem manager in response to the committee recommendations, will be maintained as official Project records by the U.S. Project Office and will be forwarded to the official contact person as specified in Appendix 1

III.E.2 Technical Reviews Called by CERN

CERN may, by request and in consultation with the U.S. Project Manager and the responsible personnel at each laboratory, carry out additional technical reviews of any component of this program to ensure compliance with the performance and schedule requirements of the LHC Project. These reviews will follow procedures similar to those of the reviews called by the U.S. Project, including the generation of a formal report recommending appropriate action, the requirement of documentation of follow-up action, the entering of such documentation into the official record of the U.S. Project and submission of the documentation to the LHC Project Leader's Office. It is anticipated that the committees for such reviews will normally include the same members as for the corresponding U.S. Project called reviews, with changes in membership being made by mutual consent of the U.S. Project Manager and the LHC Project Leader or his designee.

III.F. Safety Requirements and Reviews

Equipment provided by the U.S. laboratories for installation and operation in LHC must conform to CERN safety standards. Each US Laboratory has procedures that require the independent review of devices, culminating in formal certifications authorizing the operation of the device in that laboratory. A Memorandum of Understanding (Appendix 4) has been concluded between CERN and the US Project setting out the procedures for the definition of the safety procedures and certifications applicable to mechanical equipment manufactured or purchased by the U.S. Laboratories and delivered to CERN for installation in the LHC. The U.S. Project ensures compliance with CERN radiation safety requirements by including a member of the TIS Radiation Safety Group on all relevant design reviews and on the review groups of functional and interface specifications submitted to the CERN Engineering Data Management System (EDMS).

III.G. Quality Assurance and Quality Control

Each of the U.S. laboratories has its own Quality Assurance (QA) systems and procedures, that call for the development of specific implementation plans for all projects within the laboratory, which includes the U.S. part of the LHC Project. Specific QA programs and procedures for each part of the U.S. Project will be developed within the framework of the host laboratory's QA program and its requirements, and in consultation with relevant parties at CERN, normally the official contact person specified in Appendix 1. The subproject-specific QA implementation plans and associated set of Quality Control (QC) procedures will be developed and approved by each laboratory following its own procedures, and will be submitted for approval by the U.S. Project Manager and for concurrence to the LHC Project Leader or his designee. It is the responsibility of the U.S. Project Manager and the relevant Laboratory Project Manager and Level 3 Manager to ensure that an adequate QA program is developed and implemented for each component of the U.S. Project.

CERN may specify, at its discretion, certain quality assurance procedures or quality control measurements which it requires to ensure that the U.S.-provided equipment and technical support activities meet LHC requirements or to provide data required for the optimal use of the U.S.-provided equipment in the LHC. Formal request for such additional procedures must be submitted to the U.S. Project Manager for approval and transmission to the affected laboratory. These procedures and measurements will be, to the extent feasible, incorporated as requested into the laboratory approved QA program for the relevant subsystem. However, should such CERN-specified procedures require substantial effort or expenditure of resources beyond that planned in the Project baseline, the U.S. Project may request simplification of the procedures, request that CERN provide some of the additional resources required, or negotiate a reduction of scope elsewhere in the U.S. Project before accepting the CERN specifications.

III.H. Acceptance Tests

The U.S. Project will develop, jointly with the relevant CERN contact people and others as appropriate, a plan for each WBS level 3 deliverable specifying the acceptance tests to be carried out before that system or equipment is released to CERN for installation in the LHC. The acceptance tests can include tests done in and by the responsible U.S. laboratory or in and by its subcontractors during fabrication, final tests and measurements performed on the completed device before shipping to CERN, and additional tests and measurements which may be performed at CERN after shipping. These subsystem acceptance test plans together form the Project Acceptance Plan called for in the US-PMP. Each WBS level 3 acceptance plan must be submitted to the U.S. Project Manager for approval. The U.S. Project Manager will then submit the acceptance plan for approval by the LHC Project Leader or his designee and the relevant CERN contact person shown in Appendix 1. Normally the existence of a fully approved acceptance plan will be a condition for approval in a Production Readiness Review.

CERN may, at its discretion, specify particular tests which must be included in the acceptance plan and points during the execution of the acceptance plan at which it must be notified in advance of tests to be performed or at which it must grant approval for fabrication to continue based on its evaluation of test results. The LHC Project Leader or his designee may request that CERN personnel be present to witness any acceptance test. However, should such CERN-specified procedures require substantial effort or expenditure of resources beyond that planned in the Project baseline, the U.S. Project may request simplification of the procedures, request that CERN provide some of the additional resources required, or negotiate a reduction of scope elsewhere in the U.S. Project before accepting the CERN-imposed requirements

IV. SCHEDULES

Schedule control and coordination between the U.S. Project and the LHC Project as a whole will be accomplished through a set of milestones, which are related principally to the delivery of hardware by the U.S. laboratories to CERN or by CERN to the U.S. laboratories for inclusion in U.S.-provided equipment, or to the approval of technical and interface specifications. One exception to this is the testing of superconducting strand and cable samples at BNL, which is specified by a rate of tests per year, rather than by discrete milestones.

The principal milestones are for the delivery of completed systems or devices for installation in the LHC, the dates of which are governed by the LHC installation schedule. These are specified in Appendix 2 of this document, and are set to be 3 months before the start of installation according to the current version of the LHC installation schedule. Changes to these milestones will be subject to the change control procedures of both parties and will in addition require the approval of the U.S. Project Manager and of the LHC Project Leader or his designee. Other signatories of this Implementing Arrangement must be notified of such changes, but their approval is not required.

Additional lower level milestones, which control and coordinate the U.S. Project schedule with the overall LHC Project, will be established during the course of program planning. Changes to the milestones will be controlled by both CERN and U.S. Project change control procedures and must also be approved by the U.S Project Manager and by the CERN official contact person responsible for the relevant part of the U.S. Project as shown in Appendix 1.

The baseline testing rate for superconducting strand and cable is specified in Appendix 3. This schedule and changes to it above agreed upon thresholds must be approved by the CERN official contact person for this task, as specified in Appendix 1.

V. REPORTING

The U.S. Project Manager will provide periodic progress reports, results of acceptance tests, and other documents to the LHC Project Leader or others as mutually agreed.

VI. AMENDMENTS

This Implementing Arrangement may be amended by mutual written agreement of the Parties to it, with the restriction that amendments which reflect a change in work scope must follow the procedures given in Section III.D.4. However, modification of the contents of the Appendices requires the approval only of the LHC Project Leader and the U.S. Project Manager, with notification of the change being given to the other signatories.

VII. FINAL PROVISIONS

This Implementing Arrangement cancels and replaces the Implementing Arrangement of July 1998 and shall be within the framework of the Accelerator Protocol to the International Co-operation Agreement. If ambiguities or conflicts exist between the provisions in this document and the Accelerator Protocol, the Accelerator Protocol will take precedence.

Done in two copies in the English language and agreed to by:

Lyndon Evans, Director, LHC Project Leader, CERN	17th May 2002 Date
Peter Paul, Interim Director, Brookhaven National Laboratory	June 4, 2002 Date
Michael Witherell, Director, Fermi National Accelerator Laboratory	4 June 2002 Date
Charles Shank, Director, Lawrence Berkeley National Laboratory	September 25, 2002 Date
James Strait, Project Manager, U.S. part of the LHC Accelerator Project	30 May 02 Date

Implementing Arrangement to the Accelerator Protocol
Between CERN and the U.S. DOE
Concerning Scientific and Technical Cooperation on the LHC

Appendix 1
CERN Official Points of Contact for Technical Information

WBS	Task	Point of Contact
1	**U.S. PART OF THE LHC ACCELERATOR PROJECT**	Thomas Taylor
1.1	**INTERACTION REGIONS**	Ranko Ostojic
1.2	**RF STRAIGHT SECTION**	Ranko Ostojic
1.3	**SUPERCONDUCTING STRAND AND CABLE**	Daniel Leroy
1.4	**ACCELERATOR PHYSICS**	Francesco Ruggiero

M. Sp

Implementing Arrangement to the Accelerator Protocol
Between CERN and the U.S. DOE
Concerning Scientific and Technical Cooperation on the LHC

Appendix 2
Principal Milestones
(Revised October 2002)

Action	Date
Decision as to whether or not the U.S. Project includes RF region quadrupoles	1 Jul 2001
Delivery of inner triplet magnets for IR8 left (MQX, D1, D2)	19 Dec 2003
Delivery of inner triplet magnets for IR2 right (MQX, D1, D2)	30 Apr 2004
Delivery of inner triplet magnets and absorbers for IR1 left (MQX, D2, TAS, TAN)	6 Aug 2004
Delivery DFBX for IR8 left	13 Aug 2004
Delivery of DFBX for IR2 right	1 Oct 2004
Delivery of inner triplet magnets for IR8 right (MQX, D1, D2)	8 Oct 2004
Delivery of inner triplet magnets and absorbers for IR1 right (MQX, D2, TAS, TAN)	21 Jan 2005
Delivery of inner triplet magnets for IR2 left (MQX, D1, D2)	4 Feb 2005
Delivery of DFBX for IR1 left	25 Feb 2005
Delivery DFBX for IR8 right	25 Feb 2005
Delivery of inner triplet magnets and absorbers for IR5 right (MQX, D2, TAS, TAN)	29 Apr 2005
Delivery of D3, D4 for IR4 right	24 Jun 2005
Delivery of DFBX for IR1 right	12 Aug 2005
Delivery of DFBX for IR2 left	12 Aug 2005
Delivery of D3, D4 for IR4 left	31 Aug 2005
Delivery of inner triplet magnets and absorbers for IR5 left (MQX, D2, TAS, TAN)	31 Aug 2005
Delivery of DFBX for IR5 left	31 Aug 2005
Delivery of DFBX for IR5 right	31 Aug 2005

Appendix 3
Memo Specifying the Number of Cable Tests to be Performed by BNL

Building 902a
P.O. Box 5000
Upton, NY 11973-5000
Phone 631 344-3974
Fax 631 344-2190
aghosh@bnl.gov

BROOKHAVEN
NATIONAL LABORATORY

managed by Brookhaven Science Associates
for the U.S. Department of Energy

Memo

Date: *March 23, 2001*

To: *Daniel Leroy*

From: *Arup Ghosh*

Subject: *Superconductor Testing at BNL under US-LHC Accelerator Project*

CC: *J. Strait (FNAL), E.Willen, M. Harrison*

The initial agreement with CERN, based on a memo dated October 27, 1997, outlined the rate of cable production and the estimated number of samples that would be tested at BNL. Table I from that memo is reproduced below for reference.

Table I

Dates	Quantities of Cables		Measurements		
	Cable 01 km	Cable 02/03 km	Cable 01 # samples	Cable 02/03 # samples	Total # samples
FY 1999	45	75	100	100	200
FY 2000	184	380	100	129	229
FY 2001	404	822	220	278	498
FY 2002	585	1223	318	418	736
FY 2003	585	1223	318	418	736
FY 2004	585	992	318	318	636
Total	2343	4640	1374	1661	3035
100% tested at 4.2K				3035	Unit Test
10% cables tested at 1.9K				304	Unit Test

Based on recent discussions with CERN, the US collaboration, and BNL in particular, propose to account the total number of production cable tests in terms of "equivalent 4.2K tests" (EFT). One EFT is one standard 4.2K cable test at one field polarity, yielding one standard test report. This typically involves several ramps of the cable current at each of several different field levels of the background dipole magnet. To compute the total number of EFT's for the whole program, one 1.9K test is equal to 2 EFT's. The total number of EFT's for the original program is 3035 + 2*304 = 3643.

Furthermore, CERN has proposed that BNL test cable samples from the production of 268 km of cable for the LHC MQM and MQY quadrupoles. These are designated as cable type 04,05 and 06, and the tests are done within the total EFT budget.

The 1.9K testing at BNL of the cable for the main magnets is essentially canceled, since such tests at BNL are not routinely successful. However the 1.9K capability at BNL will be kept operational and tests of the MQM or MQY cables are still contemplated.

Specific accounting rules include the following:

- To monitor the EFT counts, the date of the measurement will be used, rather than the date when the test report is sent to CERN.
- The first round of tests of the reference cable (01E00113A) will be counted against the EFT budget as 12 tests -- 4 field directions in 3 test stations. Subsequent test of the reference cable will not be counted.
- Samples are counted only if CERN has asked for the test. Samples measured twice or more (for example because BNL has some doubt on the correctness of the measurement or because the sample was used to be paired with a new sample) are not counted, unless CERN has explicitly asked for a second measurement.
- The EFT count is based on the actual number of 1.9K tests performed to date.

In Table II, shown below, is outlined the proposed testing budget in the agreed upon EFT units. This is based on the most recent production schedule from CERN.

Table II

	Pre-Production and Production Samples				EFTs				Other Tests	
	Actual	Projected			Actual	Projected			Ref Cable	Total
Cable Type	01,02,03	01,02,03	04,05,06	Total		Samples	Margin	Total	Tests	Tests
FY 1999	50			50	65			65		65
FY 2000	80			80	127			127		127
FY 2001 1Oct-31Jan	64			404	100			508	6	520
FY 2001 1Feb-30Sep		286	54			340	68		6	
FY 2002		750	64	814		814	-26	788	12	800
FY 2003		750	64	814		814	-26	788	12	800
FY 2004		750	64	814		814	-26	788	12	800
FY 2005		305		305		305	61	366		366
Sum	194	2841	246	3281	292	3087	51	3430	48	3478
	3035									
EFT Contingency								213		
EFT Grand Total								3643		

The first block of columns shows the schedule of pre-production and production samples for the different cable types. The next shows the EFT count derived from the sample delivery schedule from 1 Feb 01 forward, and the actual number of EFT's before that. The margin is set at 20% of the expected samples for FY 2001 and FY 2005. For the peak testing years of FY 2002 – 2004, when the sample delivery rate exceeds the agreed upon maximum capacity of the BNL test system of 800 tests per year, [report from the Cable Test Facility Production Readiness Review, September 2000], the margin is set to a negative number to indicate the number of samples that cannot be accommodated. The third block shows the reference sample tests. The right-most column shows the total number of tests for each year. The current best estimate is that a total number of 3430 EFT's can be accomplished, and this will form the new baseline budget for cable testing. The difference between this and the original budget of 3643 EFTs will be held in the US Project contingency. The cable testing schedule and plan will be reviewed periodically to evaluate whether or not we need to continue to hold this contingency.

Appendix 4

CERN/LHC – US/LHC
MOU ON ACCELERATOR MECHANICAL SAFETY

		CERN/LHC – US/LHC MOU ON ACCELERATOR MECHANICAL SAFETY	
US LHC Accelerator Project Document No. (if required) **N/A**	*CERN LHC Document No. (if required)* **TIS-TE-MB-98-74**	*Created* **14-DEC-98**	*Page* **1 of 6**
		Modified	*Rev. No.* **1.0**

MEMORANDUM OF UNDERSTANDING

I. Purpose

This Memorandum of Understanding (MOU) defines the mutual interactions between the CERN Technical Inspection and Safety Commission (TIS) and the US LHC Accelerator Project with respect to the structural safety of mechanical equipment manufactured or purchased by the US Laboratories and delivered to CERN for installation in the LHC. This MOU is compliant with the Implementing Arrangement between CERN and the US Laboratory Collaboration and the US LHC Accelerator Project Management Plan. This MOU does not address non-safety related QA tests, inspections, certifications, etc. that will be required such as leak checks or acceptance tests upon arrival at CERN. These requirements will be defined in other documents.

II. Transfer of Responsibilities from CERN/TIS to the US Laboratories

Each US Laboratory has procedures that require the independent review of devices, culminating in formal certifications authorizing the operation of the device in that laboratory. The US Project and CERN/TIS-TE (Technical Services and Environment Group) personnel will review the safety program of each of the US laboratories to verify that the individual safety structures are equivalent to those of TIS.

Upon satisfactory completion of the review, TIS will transfer the following responsibilities to the US Project:

- Assessment of design details and fabrication checks/tests by the relevant US Lab. This corresponds to the work usually done at CERN by TIS-TE between steps a and b in the Table 1 below.
- Verification by the relevant US Lab that all fabrication checks/tests are successfully completed with acceptable results. This corresponds to the work done at CERN by TIS-TE between steps b and c in Table 1 below.

M. A.

Table 1 – Equivalence Between CERN and US Laboratory Approvals	
CERN	US Labs
a) Issue of general remarks, based on preliminary information provided to TIS-TE in support of the initial safety discussion.	Approval to proceed with engineering design based on the results of the Conceptual Design Review (CDR).
	Approval to proceed with detailed design, parts and tooling based on the results of the Engineering Design Review (EDR).
b) Issue of the TIS Safety Study Report, completion of the design assessment based on the Engineering File, authorization within CERN to issue tender or begin fabrication.	Approval to begin fabrication based on the results of the Production Readiness Review (PRR).
c) Issue of the Safety Inspection Report and CERN authorization to install based on positive results of all fabrication checks and of final testing.	Issue of US Laboratory certification authorizing use of the device for its intended purpose.

These responsibilities will be executed by the safety structure of the relevant US Laboratory for each of the items provided by the CERN-US Laboratory Collaboration. The standard safety procedures of the US Laboratory will apply except where different agreements are reached between the US Project and TIS.

III. General Approach

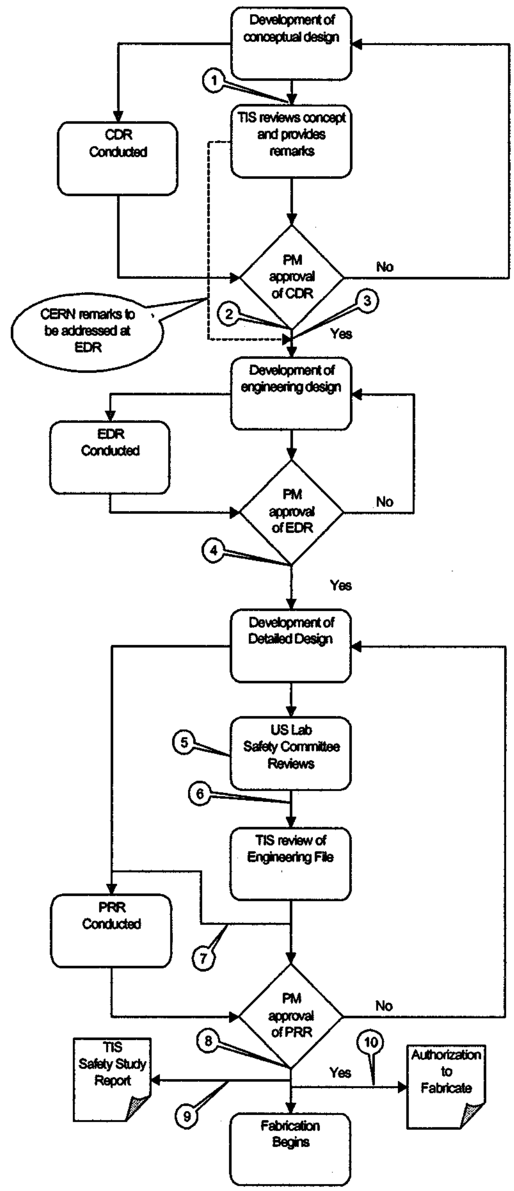
TIS will ensure that the equipment provided by the US Project conform to CERN safety standards as specified in Paragraph III.F of the Implementing Arrangement by issuing formal documents as indicated in the general approach outlined below. This general approach is consistent with the CERN Safety Policy, in particular with CERN Safety Code D2 Rev 2 and is valid for any systems or devices produced or procured by the US Laboratories.

1. At the time of the CDR for each design type, the US Project will provide TIS-TE with preliminary technical information describing the equipment. This is intended to provide TIS-TE with sufficient information with which to confirm the nature of the design type, e.g. pressure vessel.
2. The US Project will provide TIS-TE with a copy of the official report documenting the CDR.
3. TIS-TE will issue a formal document (step a) to the US Project Manager stating that either there are no remarks or there are comments or recommendations that must be

Ar, [illegible]

addressed in the EDR. TIS-TE may also make arrangements through the EDR Committee Chairman to attend the EDR.

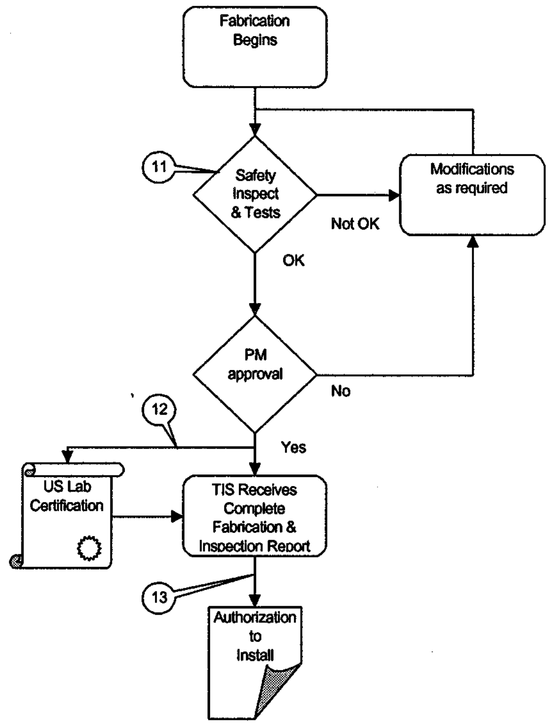
4. The US Project will provide TIS-TE with a copy of the official report documenting the EDR.
5. The safety structure of the relevant US Lab will monitor and assess the detailed design and the fabrication, inspection, and quality assurance plans to be followed.
6. Prior to the PRR the US Project will provide TIS-TE with a copy of the design contents of the Engineering Safety File described in Section *IV*. Fabrication related contents of the file that are specific to each individual unit (e.g. material certifications) will be provided with the device.
7. Before the PRR, TIS-TE will notify the US Project Manager stating that either there are no remarks or there are comments that must be addressed at the PRR. TIS may make arrangements through the PRR Committee Chairman to attend the PRR if desired.
8. The US Project will officially communicate the results of the PRR to TIS-TE immediately after the PRR. The US Project will provide TIS-TE with a copy of the PRR report.
9. TIS-TE will issue a Safety Study Report immediately after the PRR, addressed to the US Project Manager, confirming that there are no open issues regarding safety of the design or the readiness for production.



10. The US Project Manager will authorize production to begin (step b). This authorization is based on a positive recommendation by the PRR Committee and the confirmation from both the PRR Committee and TIS-TE that there are no open issue regarding safety of the design.
11. The safety structure of the relevant US Lab will verify that all of the planned inspections, checks, and tests are successfully carried out.

12. The relevant US Lab will produce official laboratory certification indicating that the device was fabricated, inspected, and tested according to the agreed criteria and is considered safe for its intended purpose in the LHC at CERN. Relevant inspection, check, and test documentation will accompany the certification. Material certifications and tests are expected to be available at this time.

13. TIS-TE will issue a formal document, addressed to the CERN LHC Project Leader or his designee, with a copy to the US Project Manager, granting the authorization to install the device at CERN (step c). This is based on receipt of the official US Lab certification.



IV. Delivery of Specified Documents

The Engineering Safety File for each device will be supplied to TIS-TE. The standard contents of the Engineering Safety File will be:

- Design Specifications and Calculations
- Material Certifications and Tests
- Operating and Installation Procedures
- Equipment Drawings
- Planned Inspections and Tests
- Descriptions of Planned Safety Devices
- Results of US Laboratory safety reviews

Additional documents will be included as appropriate.

V. Use of the ASME Pressure Vessel Code

The ASME Code will be used for the design, construction, and testing of mechanical equipment, or parts of mechanical equipment, that are designated as pressure vessels. In addition, the requirements of CERN Safety Code D2 Rev 2 will be applied when they are more stringent than those of the ASME Code.

- In the case of pressure equipment *purchased from industry* the equipment will bear the ASME Code stamp.

- In the case of pressure equipment *manufactured within the participating laboratories* of the US LHC Accelerator Project the intent of the ASME Code will be followed, however, the US Laboratories do not have the ability to apply the ASME Code stamp. Instead, the equipment will bear the certification of the responsible laboratory.

VI. ***Evaluation of Equipment not Designated as Pure Pressure Vessels***

Some equipment may be designated as not being pure pressure vessels. Their design, fabrication, and testing may require provisions other than or beyond that specified by the ASME Pressure Vessel Code. Such equipment will be subjected to additional engineering evaluation as agreed upon between the US Project and TIS-TE, consistent with good engineering practice and the requirements of the responsible laboratory.

VII. ***Evaluation of Equipment Provided by CERN***

Some equipment may be supplied by CERN for assembly into systems provided by the US Project and tested at one of the US Laboratories. For the equipment, CERN will provide sufficient documentation to enable the laboratory to meet its internal safety requirements. It is anticipated that an Engineering Safety File as described above will be available for each equipment item and will contain the information needed. Additional information will be requested as necessary.

Done in two copies in the English language and agreed to by:

14.1.99		15/1/99.		25 Jan 99	
Helmut Schönbacher Head, Technical Inspection and Safety Commission, CERN	Date	Lyndon Evans Director LHC Project Leader, CERN	Date	Michael Harrison RHIC Associate Project Director (Collider), BNL	Date
14 Jan 99		14.1.99		25 Jan 99	
Maurizio Bona Head, TIS-TE Group CERN	Date	Thomas Taylor LHC Deputy Division Leader CERN	Date	Peter Limon Technical Division Head, Fermilab	Date
		14.01.99		2 Feb 99	
		Gunther Rau LHC Project Safety Officer, CERN	Date	William Barletta Accelerator and Fusion Research Division Head, LBNL	Date
				14 Jan 99	
				James Strait US LHC Accelerator Project Manager, Fermilab	Date