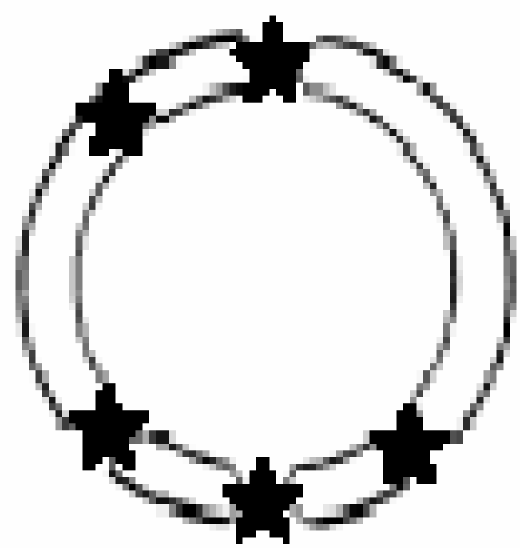
Appendix 2.A

U.S. LHC Accelerator Construction Project Management Plan



US LHC ACCELERATOR PROJECT

PROJECT MANAGEMENT PLAN

October, 1998

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1 INTRODUCTION

1.1 The US LHC Accelerator Project Description

The US contribution to the construction of the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) consists of the design and fabrication of specialized equipment and the providing of technical support by three US national laboratories, and of providing CERN with agreed-upon products manufactured in the US. The contribution through the national laboratories is the main subject of this document, and is referred to here as the US LHC Accelerator Project, the US Project, or simply the Project.

The US LHC Accelerator Project is a subproject of the overall LHC construction project at CERN. The LHC consists of an accelerator and storage ring with two counter-rotating proton beams, each with an energy of up to 7 TeV. These beams collide at four intersection points, where most of the work and deliverables from the US LHC Accelerator Project are focused. The LHC is fed by an existing chain of proton synchrotrons and will be constructed in the existing 27 km circumference tunnel, which currently houses the Large Electron-Positron (LEP) accelerator. The US contribution to the construction of the LHC accelerator will shorten the time required to bring the accelerator into operation. Furthermore, involvement in the US LHC Accelerator Project will provide an opportunity for the US national laboratories to take part in forefront hadron collider research and to build the global cooperation that will be necessary to construct future colliders beyond the LHC. American physicists are also important collaborators on the two LHC experiments that will explore physics up to the TeV mass scale.

General program oversight for the US LHC Accelerator Project is the responsibility of the US Department of Energy (DOE) and the Project is administered through the DOE Office of Energy Research, Division of High Energy Physics (DHEP), the DOE Chicago Operations Office, and the DOE Fermi Group Site Office. The project work will be undertaken by three US national laboratories: Brookhaven National Laboratory (BNL), Fermi National Accelerator Laboratory (Fermilab or FNAL), and Lawrence Berkeley National Laboratory (LBNL), directed by the Project Manager and Project Management Office. When taken together, these laboratories will be designated in this document as the

US Laboratory Collaboration. Fermilab has been designated as the lead laboratory with the major responsibility to ensure the successful completion of the US LHC Accelerator Project. The Project Manager is a Fermilab employee.

The major thrust of the US LHC Accelerator Project focuses on the interaction regions and the RF straight section of the LHC accelerator. This involves the design, fabrication, and integration of the specialized components required to provide adequate beam handling in these regions, especially the superconducting magnets. The US LHC Accelerator Project is responsible for delivering to CERN integrated inner triplet magnet systems for the four interaction regions at points 1, 2, 5 and 8. The Project will design and build the front absorbers and neutral beam absorbers that are required at points 1 and 5. In the RF straight section at point 4, the Project will provide specialized magnets and collaborate with CERN on the integration of these magnets into this region.

In addition to building these magnet systems, the US laboratories will help CERN in the design and construction of LHC by providing technical support in several areas. The US laboratories will participate in the R&D and perform production testing of the superconducting wire and cable in order to characterize it for use in the main LHC magnets. The US Laboratory Collaboration will also work with CERN on a number of special accelerator physics topics of mutual interest, which are focused primarily, but not exclusively, on issues related to the US-provided hardware.

The US contribution to the construction of the LHC accelerator also includes the providing of funds for purchases by CERN from US vendors of materials and supplies needed for construction of the LHC, as specified in Article IV, "Procurement from Industry," of the Accelerator Protocol between the European Organization for Nuclear Research (CERN) and the Department of Energy of the United States of America. CERN is responsible for the management of these purchases, and payment is made by the DOE directly and not through the national laboratories. This part of the US contribution is tied to the US LHC Accelerator Project through a common funding profile and through the responsibilities of the US LHC Accelerator Project Manager (see Section 3.3.2) who serves as the official contact within the US for information from CERN regarding these purchases.

1.2 Scope of this Plan

This document is the Project Management Plan (PMP) that the US Laboratory Collaboration will follow to meet the technical, cost, and schedule objectives of the US LHC Accelerator Project. It is consistent with the general management approach used to manage major DOE projects. This PMP covers the construction of the US part of the LHC Accelerator, i.e., the design, fabrication, testing and delivery of components to CERN, and the providing of other technical support to the LHC Construction Project by the US Laboratory Collaboration. It does not cover the installation and commissioning of the delivered components at CERN, which are outside of the scope of the US LHC Accelerator Project.

Included in the PMP are the systems used to manage the common funding profile for the US LHC Accelerator Project and the reimbursement of CERN for procurements from US industry under Article IV of the Accelerator Protocol. The specific procedures to be used for payment for these purchases are given in a letter from John R. O'Fallon, Director of the DOE Division of High Energy Physics to Lyndon Evans, LHC Project Leader, and a letter of reply. Together these constitute the written understanding referred to in Section 4.6 of the Accelerator Protocol. Copies of these letters are included as Annex I of this PMP.

This PMP describes the management systems and procedures to be used to manage those aspects of the Project which are internal to the US, that is control of budget and work in the US laboratories, the management structure of the US Project, the relationship among the collaborating laboratories, and the relationship between the DOE and the US Laboratory Collaboration. Aspects of the project management which concern the relationship between the US Project and CERN, including a complete description of the scope of work (deliverables), communication and coordination between the US and CERN, CERN involvement in configuration control, technical reviews, etc., are specified in the Implementing Arrangement to the Accelerator Protocol between the European Organization for Nuclear Research (CERN) and the United States Department of Energy Concerning Scientific and Technical Co-Operation on the Large Hadron Collider, which is included as Annex II of this PMP.

The PMP together with the Implementing Arrangement establish the technical, cost and schedule baseline to which the US LHC Accelerator Project will be managed and to which the performance of the Project will be measured. The PMP defines the highest level Work Breakdown Structure (WBS) for the Project and presents a corresponding organizational structure with responsibilities assigned to the key management positions. The major schedule milestones are defined, along with the budget authorities of the project managers to support this schedule. This PMP also describes the project management control mechanisms, configuration and change management, reporting requirements, and contingency allocation procedures.

This PMP will be reviewed and revised, as required, to reflect new project developments or other agreements among the participants. Revisions will be approved by the US LHC Accelerator Project Manager, the Directors of the three laboratories, the US LHC Project Manager, the Manager of the Fermi Group of the DOE Chicago Operations Office, the US LHC Program Manager, and the Director of the DOE Division of High Energy Physics. To the extent that there are inconsistencies or conflicts between this plan and the terms and conditions of applicable laws, regulations, existing contracts, the International Co-Operation Agreement or its subsidiary Protocols, or the Project Execution Plan for the US Large Hadron Collider Projects, the provisions of those documents shall prevail over this plan.

1.3 Reference Documents

(US LHC Accelerator Project documents will be available on the Internet at www-td.fnal.gov/LHC/USLHC.html.)

1. "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 the Large Hadron Collider Activities," December 8, 1997.

2. "Accelerator Protocol between the European Organization for Nuclear Research (CERN) and the Department of Energy of the United States of America," December 19, 1997.

3. "Implementing Arrangement to the Accelerator Protocol between the European Organization for Nuclear Research (CERN) and the United States Department of Energy Concerning Scientific and Technical Co-Operation on the Large Hadron Collider," July 1998.

4. "Project Execution Plan for the US Large Hadron Collider Projects," February 1998 (Draft).

5. "Anticipated Economic Escalation Rates," DOE Construction Projects, Energy Research and Nuclear, January 1998.

6. "US LHC Accelerator Project Baseline, " April 1998; Letter from John O'Fallon to James Strait via James Yeck approving the Baseline, June 15, 1998; Reply letter from James Strait to John O'Fallon, July 14, 1998.

1.4 List of Abbreviations

Item	Definition
ACWP	Actual Cost for Work Performed
AP	Accelerator Physics
BC	Budgeted Cost
BCR	Baseline Change Request
BCWP	Budgeted Cost for Work Performed
BCWS	Budgeted Cost for Work Scheduled
BNL	Brookhaven National Laboratory
C&S	Cost and Schedule
CAM	Cost Account Manager
CCB	Change Control Board
CDR	Conceptual Design Review
CERN	The European Organization for Nuclear Research
CH	DOE Chicago Operations Office
CSM	Cost and Schedule Manager
DHEP	DOE Division of High Energy Physics
DOE	United States Department of Energy
DOE-PGM	DOE/NSF US LHC Program Manager
DOE-PM	DOE/NSF US LHC Project Manager
EAC	Estimate at Completion
EDR	Engineering Design Review
EM	US LHC Accelerator Project Engineering Manager
ES&H	Environment Safety and Health
Fermilab	Fermi National Accelerator Laboratory
FNAL	Fermi National Accelerator Laboratory
IR	Insertion Region
JOG	Joint Oversight Group
L3M	WBS Level 3 Manager
LBNL	Lawrence Berkeley National Laboratory
LHC	Large Hadron Collider
LPM	Laboratory Project Manager
OER	DOE Office of Energy Research
PAG	Project Advisory Group
PEP	US LHC Project Execution Plan
PM	US LHC Accelerator Project Manager
PMO	US LHC Accelerator Project Management Office
PMP	US LHC Acclerator Project Management Plan
PRR	Production Readiness Review
QA	Quality Assurance
R&D	Research and Development
RF	Radio Frequency
TDH	Technical Design Handbook
TEC	Total Estimated Cost
TPI	Total Amount Allocated for Direct Purchases from Industry
TPC	Total Project Cost
WA	Work Authorization
WBS	Work Breakdown Structure

2 GENERAL PROJECT OVERVIEW, WORK BREAKDOWN STRUCTURE (WBS), MILESTONES AND BUDGETS

2.1 Project Objectives

The primary objective of the US LHC Accelerator Project is to assist CERN, the European Laboratory for Particle Physics, in the construction of the Large Hadron Collider (LHC) by providing equipment and technical support, in order to shorten the time required for its completion and to ensure that physics research at the electroweak symmetry breaking scale is done. Two important secondary objectives have guided the choice of work to be done to implement this objective. First, the work should present a significant opportunity for the US national laboratories to maintain and improve their technological capabilities. Second, the US collaboration on LHC construction should advance international cooperation in the construction of large science projects.

The scope of the US LHC Accelerator Project is specified in the US LHC Accelerator Project Baseline and in the Implementing Arrangement, which is included as Annex II of this PMP. The scope of work described in this PMP encompasses those tasks that are the responsibility of the US national laboratories. It is consistent with the proposed $110 million budget for the US contribution to the LHC accelerator through these laboratories as defined in the Accelerator Protocol.

2.2 Work Breakdown Structure (WBS)

2.2.1 Management Needs Satisfied by the WBS

All work required for successful completion of the US LHC Accelerator Project is organized by a WBS. The WBS contains a complete definition of the scope of the Project and forms the basis for planning, execution, and control of the US LHC Accelerator Project.

2.2.2 Organization of the WBS

The successive levels of the WBS reflect the logical breakdown of the work required for the successful completion of the Project, with lower levels providing progressively more detailed work descriptions. For the day-to-day functioning of the US LHC Accelerator Project, the lowest level in the WBS has been established by extending the description down to a point where individual components, or deliverables, can be identified. At the higher WBS levels, these components can be assembled into well-defined pieces of equipment or systems.

For the purposes of this PMP, the Project Summary WBS is presented which, consistent with DOE definitions, is the consolidation of the top three levels of the US LHC Accelerator Project WBS. The Level 1, or highest Level, corresponds to the Project as a whole. The Level 2 tasks specify the major systems or group related technical support activities. The Level 3 subtasks represent major equipment items or technical support activities. The work at this level has been divided so that, to the maximum extent possible, the responsibility for each subtask can be assigned to a specific laboratory. The Project Summary WBS to Level 3 is given in Appendix 1. A WBS dictionary giving detailed description of each WBS task to level 4 is presented in the Implementing Arrangement.

2.3 Project Technical Baseline Requirements

The US LHC Accelerator Project Technical Design Handbook (TDH) is the highest level specification of the technical baseline of the US Project. It provides detailed descriptions of the hardware systems and technical support provided by the US laboratories, 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. The technical performance of the engineering designs developed and of final fabricated parts will be measured against the Technical Baseline defined in the TDH.

The TDH is a controlled document of the US Project requiring approval of its initial contents and of any changes by the Project Manager (see Section 3.3.2) following recommendation by the Change Control Board (see Section 5.3). The TDH is organized by chapters corresponding to the WBS level 3 tasks shown in Appendix 1, and each chapter is a separately controlled document. The initial contents of, and any changes to, the TDH must also be approved by CERN, as specified in the Implementing Arrangement.

2.4 Project Baseline Schedule

2.4.1 Overview of the Project Schedule

The US LHC Accelerator Project is a small but essential part of the entire LHC construction project, and it must proceed in a manner consistent with the overall project schedule. The current versions of the LHC Project Working Summary Schedule and the LHC Installation Schedule are found at the web site wwwlhc01.cern.ch/planning.htm. These show the dates of installation of the major systems and components of the LHC accelerator, including those built by the US laboratories. Coordination of the US Project schedule with the master LHC schedule maintained by CERN is accomplished by setting milestones, typically corresponding to the delivery of equipment to CERN by the US Project or to the US laboratories by CERN for incorporation into US-provided systems. These milestones are under joint US-CERN change control as specified in the Implementing Arrangement and in Chapter 5. The Level 1 and Level 2 milestones are listed in Appendix 5.

Detailed schedules are developed for each WBS level 3 task or group of closely related tasks at one laboratory, which must be consistent with the milestones defining the linkage to the master LHC schedule. These schedules are controlled documents of the Project. Coordination of schedules between WBS level 3 tasks at different US laboratories and control of the overall schedule by the US Project Office are accomplished through milestones, typically corresponding to delivery of equipment or services by one laboratory to another, major design reviews, and the initiation or completion of major phases of a WBS level 3 task. These milestones are under Project change control, as specified in Chapter 5.

2.4.2 Baseline Schedules

Detailed schedules are developed for each WBS level 3 task or group of closely related tasks at one laboratory, using commercially available scheduling software. These schedules are organized according to the WBS to a sufficient level of detail to allow clear tracking of the progress of each task and the identification of the required resources as a function of time. These schedules are used to develop, and must be consistent with, the controlled milestones. The baseline schedule for each WBS level 3 task is a controlled document of the Project.

Since many of the tasks are largely independent of each other, and because the tasks have been divided among the laboratories to enhance their independence one from another, the different sub-project schedules are linked only through the controlled milestones.

The Baseline Schedules may be supplemented by working schedules, which more accurately reflect the current work activity than the baseline schedule. However, the baseline schedule will be retained as the basis for program tracking and evaluation.

2.4.3 Revised Baseline Schedules

The approved Baseline Schedules and associated controlled milestones are the reference for evaluating the progress of the Project. If fundamental changes occur in the basis on which one or more of the Baseline Schedules were created, for example a change in work scope or a substantial change in funding profile, it may be necessary to create a Revised Baseline Schedule. The new schedule will reflect the new basis facts, and will form the basis for program planning and tracking under the new, revised conditions. Even if the changes in the basis facts directly affect only one WBS level 3 task, it may be necessary to revise some or all of the other WBS level 3 Baseline Schedules, since some are linked through milestones and all are linked through a common funding profile. The Revised Baseline Schedule must be approved according to the change control procedures specified in Chapter 5.

2.5 Project Baseline Budgets

The Total Project Cost (TPC) for the US LHC Accelerator Project has been capped by US Congressional action at $110 million in then-year dollars. Taking into account inflation and contingency, the US LHC Accelerator Project has been scoped such that the total cost of the components at the time of delivery matches this budget cap to the highest degree possible under the present understanding of the work to be accomplished.

The Baseline Budget is a controlled document, which can be changed only through the change control procedure given in Chapter 5.

2.5.1 Cost Estimate

The cost estimate is presented in Appendix 6 with details given to WBS level 3. The cost estimates for each WBS level 3 task, including the contingency estimates, have been developed "from the bottom up" by estimating costs at the finest level of detail feasible with respect both to materials and services purchases and to labor. To the sum of material and labor costs is added the indirect costs charged by each laboratory to yield the estimate at completion (EAC) or base cost for each task. A contingency allowance is made for each item at the lowest level based on a standard scale, which reflects the degree of understanding or engineering backup concerning the item estimated. The contingencies so estimated are rolled up to WBS level 3, and compared with a top-down analysis, which evaluates the overall risk of the program. Adjustments may be made as necessary. The sum of these WBS level 3 EAC and contingency estimates is the Total Estimated Cost (TEC). All estimates have been made in FY1997 dollars. An allowance is made for escalation over the life of the Project, giving the TEC in then-year dollars. The difference between the TEC and the $110M TPC is added to the contingency. The contingency is held as a single fund for the Project as a whole. It can be allocated only according to the provisions given in Chapter 5.

Appendix 6 also shows the total amount of US funds allocated for purchases by CERN from US industry (TPI) as specified in Article 4 of the Accelerator Protocol. The TPC, TPI and their sum are specified in the Accelerator Protocol.

It is planned that as the Project progresses, knowledge of the costs and risks will improve, and the cost estimate will be modified accordingly, following the change control procedure specified in Chapter 5, to reflect this improved understanding. Copies of all previous versions of the cost estimate will be retained as official documents of the Project, together with the documentation generated as part of the change control procedure, to show a clear and traceable record of how the cost estimate evolves.

2.5.2 Obligation and Funding Profile Plans

An integrated network schedule has been developed for each WBS level 3 task, with resources linked to the lowest level WBS tasks identified in the schedules. Thus, the resources are time-phased in accordance with the integrated network schedules which, in turn, generates obligation and funding profiles. Appendix 7 displays the obligation plans for each of the three laboratories' programs in FY 1997 dollars, without contingency, and in then year dollars, using the escalation factors shown in Appendix 8. These escalation rates are based on "Anticipated Economic Escalation Rates," DOE Construction Projects, Energy Research and Nuclear, January 1998. The difference of the EAC in then-year dollars from that in FY 1997 dollars yields the escalation allowance shown in Appendix 6.

3 MANAGEMENT ORGANIZATION AND RESPONSIBILITIES

3.1 Project Oversight Organization Structure

3.1.1 Introduction

The US LHC Accelerator Project is part of the LHC Accelerator Project located at and directed by CERN. The CERN management has ultimate responsibility for LHC, and the US Project must operate within this context. The organizational relationships between the US funding agencies and CERN are defined in 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 the Large Hadron Collider Activities.

The US LHC Accelerator Project is the sole responsibility of one US funding agency, the DOE. The organizational relationships among CERN, the DOE, and the US Laboratory Collaboration are defined in: the Accelerator Protocol, the Implementing Arrangement, and the US LHC Project Execution Plan.

3.1.2 DOE Management Structure

The DOE has ultimate oversight responsibility for the US LHC Accelerator Project. The DOE organizational relationships relevant to the US LHC Accelerator Project are shown in Appendix 2. As described in the US LHC Project Execution Plan the primary point of contact within the DOE for the US LHC Accelerator Project is the DOE-LHC Project Office headed by the DOE-LHC Project Manager, who resides in the Fermi Group Site Office. The responsibilities and authorities of the DOE-LHC Project Manager and the other DOE (and NSF) participants shown in Appendix 2 are specified in the Project Execution Plan for the US Large Hadron Collider Projects and are summarized briefly here. If any contradictions exist between these descriptions and those in the Project Execution Plan, the latter take precedence.

3.1.2.1 Joint Oversight Group

The Joint Oversight Group (JOG) is responsible for ensuring effective management and execution of the US LHC program in a manner consistent with the Interagency Memorandum of Understanding between DOE and NSF on the management of the US LHC activities. The Joint Oversight Group is co-chaired by the Director of the DOE Division of High Energy Physics (DHEP) and the Director of the NSF Physics Division. Additional membership in the JOG is by the mutual agreement of the co-chairs. The JOG will coordinate DOE and NSF policies and procedures and establish programmatic guidance and direction.

3.1.2.2 LHC Program Office

The LHC Program Office, led by the LHC Program Manager (DOE-PGM), will provide day-to-day program management and support for the US participation in the LHC. The LHC Program Office receives direction from and reports directly to the JOG. The LHC Program Manager will be a DOE employee appointed by the Director of DHEP and subject to the concurrence of the JOG. The LHC Program Office coordinates the needs of the US LHC projects (US LHC Accelerator Project, US ATLAS Project and US CMS Project) within DOE Headquarters and NSF and serves as the principal interface for the US LHC within Headquarters.

3.1.2.3 Chicago Operations Office

The DOE Chicago Operations Office (CH) has the contract management responsibility for Fermilab. The CH Fermi Group is the responsible DOE office on site at Fermilab that provides the day-to-day DOE oversight of that laboratory. The CH Fermi Group will be the administrative home of the US LHC Project Manager. The Fermi Group Manager will delegate to the LHC Project Manager the authority for day-to-day implementation and direction of the Project.

3.1.2.4 LHC Project Office

The LHC Project Office, led by the LHC Project Manager (DOE-PM), will provide day-to-day Project management and support for the US LHC projects. The LHC Project Office receives guidance and direction from the LHC Program Manager and serves as the day-to-day contact for the DOE and NSF on issues specific to each of the US LHC Projects. The LHC Project Manager will be appointed by the Fermi Group Manager, subject to the concurrence of the LHC Program Manager and the approval of the JOG.

3.2 Laboratories Organization Structure

3.2.1 Lead Laboratory—Fermilab

The DOE has selected Fermilab as the Lead Laboratory for the Project and has given it overall management oversight responsibility for the US LHC Accelerator Project. The Director of Fermilab has the responsibility to ensure that the accelerator effort is being soundly managed, that technical progress is proceeding in a timely manner, that any technical or financial problems are being identified and properly addressed, and that an adequate management organization is in place and functioning. This oversight responsibility will be exercised in consultation with the Directors of the other laboratories so as to assure that the goals of the Project as a whole are achieved at all three laboratories.

The primary responsibilities of the Fermilab Director include:

• Appoint the US LHC Accelerator Project Manager (PM), subject to the approval of the Director of DOE DHEP and the concurrence of the other laboratory Directors.

• Establish an advisory structure external to the US LHC Accelerator Project for the purpose of monitoring both management and technical progress.

• Ensure that the PM has adequate staff and support, and that the management systems established at Fermilab for this Project are matched to the needs of the Project.

• Consult regularly with the PM to assure timely resolution of management issues.

• Sign the Implementing Arrangement specifying deliverables to be provided by the US Laboratory Collaboration with DOE funds.

• Review and sign the Project Management Plan for the US LHC Accelerator Project.

• Review and approve baseline changes as prescribed in the US LHC Project Execution Plan and the US LHC Accelerator Project Management Plan.

• Ensure that accurate and complete Project reporting to the DOE is provided in a timely manner.

3.2.2 Project Advisory Group

The Fermilab Director shall establish a Project Advisory Group (PAG) to advise him on the management and technical progress of the Project. This Group will meet as needed, at least once per year, to review the status and progress of the Project. It can call for additional reviews of all or part of the Project as required to ensure that technical progress is proceeding in a timely manner and that technical and managerial problems are being properly addressed. The PAG is chaired by the Fermilab Director and consists of representatives of the Directorates of the three US laboratories and at least one representative from CERN not involved in LHC. The representatives from the other laboratories are appointed in consultations with the Directors of those laboratories. Other members, who have experience and expertise in the management of accelerator construction projects, may be appointed by the Fermilab Director.

3.2.3 Responsibilities of all Laboratory Participants—BNL, Fermilab, and LBNL

The BNL Director, the LBNL Director and the Fermilab Director will work to ensure that sufficient resources are provided for the successful completion of the Project tasks taking place at their respective laboratories. All three Directors are signatories of the Implementing Arrangement with CERN that specifies the work for which each of the US laboratories are responsible. They are also signatories of this PMP which describes the methodology by which the Project will be managed. At BNL, the laboratory oversight role has been delegated to the Associate Laboratory Director for High Energy and Nuclear Physics, and at LBNL to the Deputy Laboratory Director for Research.

The primary responsibility for completion of each collaborating laboratory's part of the Project lies within a specific internal organization element of that laboratory. Therefore, each laboratory Director has chosen to delegate some of his authority and responsibility for execution of that laboratory's part of the Project to the respective manager who serves as head of the relevant internal organizational element. For Fermilab, this is the Technical Division Head; for BNL, this is the Relativistic Heavy Ion Collider Project Associate Head for Accelerators who, for this work, reports to the BNL Associate Laboratory Director for High Energy and Nuclear Physics; and for LBNL, this is the Accelerator and Fusion Research Division Head.

The Project Manager will consult with each of these managers concerning the allocation of resources within their organizations, and to resolve any management issues that may arise during the execution of the US LHC Accelerator Project.

For the purposes of this Project, the relationships between Fermilab, BNL and LBNL laboratory management and the US LHC Accelerator Project management is shown in Appendix 3.

3.2.4 Inter-Laboratory Steering Committee

The Inter-Laboratory Steering Committee is charged with resolving inter-laboratory issues and optimizing the resource management among the laboratories involved in this Project. The Committee is chaired by the US LHC Accelerator Project Manager. The membership includes the three managers of the responsible internal organizational element discussed above, the Laboratory Project Managers (see Section 3.3.5), the Engineering Manager (see Section 3.3.3), and the Project Cost and Schedule Manager (see Section 3.3.4). The DOE-PM or his designee will be invited to participate as an observer. Other members may include key technical people appointed by the US LHC Accelerator Project Manager. The Committee meets at least quarterly or as required.

3.2.5 Inter-Laboratory Engineering Committee

The Inter-Laboratory Engineering Committee is charged with resolving inter-laboratory issues concerning engineering standards and designs. The Committee is chaired by the US LHC Accelerator Project Engineering Manager. The Committee includes one representative appointed by the Project Manager from each of the three laboratories. The DOE-PM or his designee will be invited to participate as an observer. The Committee may also include other key technical people appointed by the Engineering Manager with the approval of the PM. The Committee meets as required.

3.3 US LHC Accelerator Project Organizational Structure

3.3.1 General Project Management Structure

Appendix 4 shows the organizational structure of the US LHC Accelerator Project. The US LHC Accelerator Project Manager has overall responsibility to provide programmatic coordination and management for the work performed at the participating laboratories to meet the objectives of the US LHC Accelerator Project. Responsibility for the design, fabrication and system integration of the components and systems as specified in the WBS is spread among the laboratories. The work has been divided to make the tasks at each laboratory as independent as possible. The responsibility for completion of the assigned tasks at each laboratory is vested in the respective laboratory Director, but can be delegated to the manager of the organizational element in the laboratory in which the work is being performed, as discussed in Section 3.2.3.

The day-to-day control of the Project will be performed by the Project Management Office (PMO). This office consists of the Project Manager, Engineering Manager, Project Cost and Schedule Manager and administrative support. The PMO is headed by the Project Manager and resides at the Lead Laboratory, Fermilab. The PMO will maintain all official documentation for the Project and ensure that the Project participants are fully informed of communications and action items that have been assigned to them for resolution. The Laboratory Project Managers and the WBS Level 3 Managers report Project status to the PMO.

3.3.2 Project Manager

The US LHC Accelerator Project Manager (PM) is appointed by the laboratory Director of the Lead Laboratory, Fermilab, subject to the approval of the Joint Oversight Group and the concurrence of the Directors of the other participating laboratories. The PM provides technical and programmatic coordination and management for the Project and is responsible for ensuring that the Project goals are met on schedule and within budget. He is the interface for the US LHC Accelerator Project in interactions with CERN and DOE. He chairs the

Inter-Laboratory Steering Committee. He is signatory to the Implementing Arrangement with CERN, which is called for in the Accelerator Protocol, that specifies the details of the US contribution to the LHC Accelerator by the US Laboratory Collaboration.

In consultation with the Inter-Laboratory Steering Committee, the PM makes recommendations to the DOE on the annual funding allocation for each of the three laboratories and the allocation for reimbursing CERN for the purchase of US industrial goods as specified in Article IV of the Accelerator Protocol. He is the point of contact within the US for information from CERN regarding these industrial purchases.

The PM is responsible to maintain a national view and to work to achieve the goals of the Project without bias among the laboratories. He is directly responsible to the Director of DHEP on programatic matters and to the Director of Fermilab in matters of project oversight.

Other responsibilities of the PM include:

• Provide general administration, planning, organization and control on a day-to-day basis to complete the US LHC Accelerator Project technical objectives on schedule and within the authorized budget.

• Establish design criteria for all Project hardware and establish the standards used to satisfy the Project Baseline Technical Requirements.

• Review and approve designs and specifications to satisfy Project functional requirements.

• Ensure that an adequate project management control and reporting system is in place and functioning.

• Develop the Project scope and integrated cost and schedule plans that are consistent with funding plans.

• Establish the US LHC Accelerator Change Control Board (CCB).

• Approve baseline changes at change control level 3, based on recommendations by the Control Board, as specified in Section 5.

• Recommend contingency actions to the DOE-PM, based on CCB recommendation.

• Establish the Project Acceptance Plan in conjunction with the Engineering Manager (see Section 4.2.9).

• Prepare annual Work Authorizations for each WBS Level 3 task (see Section 6.3).

• Approve procurement plans and make-buy decisions (see Section 4.2.5).

• Chair a weekly Project Management teleconference, involving the members of the PMO, the three LPMs, and the Accelerator Physics Coordinator, that deals with technical, cost, and scheduling issues.

• In consultation with the Director of DHEP (or his designee), the LHC Project Leader (or his designee), and the Inter-Laboratory Steering Committee, develop plans for the profile of the split between funding for the US LHC Accelerator Project and for purchases from US industry under Article IV of the Accelerator Protocol.

• Advise the Director of DHEP (or his designee) on matters related to the payment by DOE for purchases by CERN from US vendors of materials and supplies needed for construction of the LHC, as specified in Article IV of the Accelerator Protocol.

3.3.3 Engineering Manager

The Engineering Manager (EM) reports to the PM and represents the PM in all Project functions when the PM is not available. The EM has the following responsibilities:

• Provide overall engineering coordination for the Project.

• Coordinate engineering standards among the three US laboratories, and between the US LHC Accelerator Project and the LHC Project at CERN.

• Maintain the Design Standards Control Levels Document that specifies whether a component design must be reviewed by CERN or is within the jurisdiction of the US LHC Project (see Section 4.2.1).

• Establish and maintain the Technical Design Handbook that includes the requirements lists and specifications (see Section 4.2.2).

• Schedule and chair the systems Design Reviews (CDRs, EDRs, and PRRs, as discussed in Section 4.2.3), ensure that the official reports on the proceedings are generated, and that appropriate follow-up action, if required, is taken.

• Implement the Configuration Management Plan and the associated change control procedures described in this PMP (see Section 5).

• Implement Quality Assurance procedures across the entire Project (see Section 4.2.10).

• Establish the Project Acceptance Plan in conjunction with the PM (see Section 4.2.9).

• Serve as a member of the Inter-Laboratory Steering Committee.

• Chair the Inter-Laboratory Engineering Committee (see Section 3.2.5).

3.3.4 Project Cost and Schedule Manager

The Project Cost and Schedule Manager (CSM) reports to the PM and maintains the official Project planning documents and Project status. The CSM has the following responsibilities:

• Prepare and maintain the Project WBS.

• Establish and maintain the Project Cost and Schedule Control System, consistent with DOE guidelines.

• Establish and head the Project Cost and Schedule Group, consisting of cost and schedule coordinators from each lab.

• Establish the mechanisms and coordinate the monthly reporting of Project cost, schedule, and technical status to PMO from the WBS Level 3 Managers via the Laboratory Project Managers.

• Prepare all budget planning documents.

• Audit Project financial reports.

• Serve as member of the Inter-Laboratory Steering Committee.

It is anticipated that each laboratory will have an equivalent position to the CSM. The laboratory CSMs will provide similar cost and schedule functions for their respective institutions and are expected to be in regular contact with the PMO CSM.

3.3.5 Laboratory Project Managers

The Laboratory Project Managers (LPMs), are responsible for planning and coordinating the technical activities within their respective laboratories for the US LHC Accelerator Project. Each LPM is assigned by the manager of the organizational element at that laboratory in which primary Project responsibility resides (see Section 3.2.3) with the concurrence of the PM. The LPM reports to the PM for Project related matters, but is also responsible to the manager of the responsible organizational element at that laboratory for the performance of work on the Project.

The responsibilities of each LPM are:

• Provide overall coordination for the part of the Project taking place in his respective laboratory.

• Assign the Level 3 Managers at his laboratory with the concurrence of the PM.

• Coordinate, organize and supervise the work and delegate responsibility and authority as appropriate to the Level 3 Managers at his laboratory.

• Ensure that the cost and schedule plan for the WBS elements at his laboratory are submitted to the PM consistent with the DOE budget cycle.

• Ensure that annual work authorization proposals are submitted to the PM on behalf of and subject to the approval of his laboratory Director, or designee, for the WBS elements at his laboratory (see Section 6.3).

• Ensure that monthly reports of his laboratory's project cost, schedule and technical status on behalf of and subject to the approval of his laboratory Director, or designee, are submitted to the PMO.

• Ensure that all WBS Level 3 variances are reported to the PM and help in creating a remedial action plan.

• Ensure that the deliverables from his laboratory are properly documented.

3.3.6 Accelerator Physics Coordinator

Generally, the responsibility for delivery of specific elements in the WBS is divided along laboratory lines to make the projects easier to manage in the multi-institutional collaboration. This is not the case for the Accelerator Physics tasks (WBS 1.4) that generally cross institutional boundaries. In this case, an Accelerator Physics Coordinator shall be appointed to manage the appropriate activities throughout the collaborating laboratories. The AP Coordinator is considered a member of the Project Office and serves as an advisor to the PM and the LPMs in developing and managing the AP program at the three laboratories.

3.3.7 WBS Level 3 Managers

WBS Level 3 Managers (L3Ms) are responsible for the day-to-day coordination and progress of the WBS Level 3 task to which they are assigned. The L3Ms at each laboratory report to the LPM at their laboratory. The L3Ms for accelerator physics at each laboratory also report for technical matters to the Accelerator Physics Coordinator. The WBS to Level 3 is shown in Appendix 1 and the managers currently assigned to each Level 3 task are shown in Appendix 4.

The L3M responsibilities include:

• Perform cost and schedule control management at the WBS Level 3 consistent with management responsibilities, organization structure, and commonly accepted practices at the laboratory where the work is being performed.

• Report the status of budgets and schedules to the PM, through the LPM, on a monthly basis.

• Report variances in his WBS Level 3 task to the LPM and PM, and jointly work out a remedial action plan.

• Initiate change requests as outlined in Section 5.

• Ensure that the EM is kept up-to-date on the Technical Design Handbook chapters relevant to the work in his WBS task (see Section 4.2.2).

• Approve all subcontracts and purchases within his WBS task.

3.4 Project Communications

3.4.1 Informal Communications

The US LHC Accelerator Project is conducted as a team effort involving organizational elements from the DOE, the US Laboratory Collaborations, 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 each laboratory and among the US laboratories and CERN should be exchanged frequently among the participants to accomplish 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. It is the responsibility of the LPM at each collaborating laboratory to coordinate informal communications and ensure their proper distribution within his laboratory.

3.4.2 Formal Communications

Formal communication of Project business will flow through appropriate Project management channels (up through the WBS Levels), culminating in a signed document filed in the PMO. Action on, and transmittal of, formal communications must be performed promptly. Therefore, it is anticipated that on most issues, informal communications will have occurred prior to formal communications, minimizing surprise and maximizing success.

All formal communications will be maintained by the PMO, such that the only official versions will be those distributed through the PMO. The most up-to-date versions of controlled drawings, budgets, schedules, milestones and specifications for the Project will also be maintained by the PMO as they become official. The PMO will also maintain a list and disposition of all action items that result from regular Project meetings. It is the responsibility of the PMO to inform appropriate individuals of action items that have been assigned to them for resolution.

4 WORK PLAN

4.1 Work Description

4.1.1 Research and Development Program

While some of the components and systems are relatively straightforward from an engineering perspective, or represent incremental extensions of existing technology, other systems push the state-of-the-art. Therefore, a program of Research and Development (R&D) has been initiated to develop these new components and systems that the Project will provide for the LHC.

At present the specific R&D tasks recognized in the Project are:

- Construction of a series of 2-m long model high-gradient quadrupoles for the Interaction Regions.
- Tests on helium flow in the long heat exchangers that will provide the 1.9 K refrigeration for the Interaction Region quadrupoles.
- Construction of one full-scale Interaction Region quadrupole in a prototype cryostat.
- Construction of two 3-m long model twin-aperture beam separation dipoles.
- Development of the parameters and optimization of the manufacturing of superconducting cable for the main LHC magnets.

4.1.2 Technical Systems

The technical systems to be built, all in collaboration with CERN, are four final focus systems at the IRs and specialized magnets for the RF straight section. The work to be done by the US national laboratories is specified in the Implementing Arrangement and is described in detail in the US LHC Accelerator Project Technical Design Handbook discussed in Section 4.2.2.

4.1.3 Technical Support to CERN

The US Project will also supply technical support to CERN in the areas of superconductor cable development and testing and in accelerator physics. The latter will concentrate on, but is not limited to, support of the design and fabrication of US-provided hardware for the LHC. The support work specifically to be done by the US national laboratories is specified in the Implementing Arrangement and is described in detail in the US LHC Accelerator Project Technical Design Handbook discussed in Section 4.2.2.

4.2 Work Management Methodology

4.2.1 Design and Engineering Standards Control Levels

For each technical component or system, Standard Control Levels will be established that will specify which technical specifications and designs must be reviewed and approved by CERN, and which remain under the auspices of the US Project. For those which remain under the control of the US Project, Standard Control Levels will be established which specify the level within the project at which technical specifications and designs must be reviewed and approved. Descriptions and agreements of these Control Levels for each component will be maintained by the EM in a Standard Control Levels Document. This will become a controlled document following formal approval, such that changes can only be made through a Change Control Board action (see Section 5).

The technical equipment and systems will be designed by the scientific and engineering staffs of the collaborating laboratories. The designs will be reviewed by Design Review Boards (see Section 4.2.3) convened by the PM and chaired by the EM, or by CERN, as dictated by the Control Levels specified for that component.

4.2.2 Technical Design Handbook (Requirements Document and Component Specifications)

The highest level specifications for deliverables to be constructed by the US Laboratory Collaboration are called out in the Implementing Arrangement. The US LHC Accelerator Project in consultation with CERN will establish detailed performance specifications for all of the technical components and systems and document these in the US LHC Accelerator Project Technical Design Handbook. This document contains the system requirements and specifications to be met in the succeeding engineering designs. The Technical Design Handbook is an officially controlled document in the Project that will be the responsibility of the EM to maintain with the appropriate input from the LPMs and L3Ms. CERN involvement in the control of the TDH is specified in the Implementing Arrangement.

4.2.3 Technical Design Reviews for Major Project Systems

The deliverable for each element at the Level 3 WBS is defined as a Major Project System. Each of these systems has a set of requirements and specifications defined in the Technical Design Handbook. Prior to the start of fabrication, there will be a series of Design Reviews to ensure the adequacy of the engineering design of each Major Project System. These reviews will also address the proper functioning and integration of the components into the LHC, the budget impact of the procurement or fabrication method proposed, the schedule and the program plan. These reviews will be as follows: (a) Conceptual Design Review (CDR), Engineering Design Review (EDR), and Production Readiness Review (PRR). Work on a Major Project System cannot progress to the next phase until each successive design review is successfully completed.

For systems which do not require significant R&D to prove the design, the EDR and the PRR may be combined into a single review. Determination as to whether or not this is appropriate will be made by the EM based on the recommendation of the CDR committee and subject to approval by the PM.

Depending on the nature and scale of the WBS level 3 task in question, there may be one series of reviews for the system as a whole, or several sets of reviews may be held corresponding to different sub-systems.

The CDR is generally conducted once the basic engineering design has been established. For a system to pass the CDR, it must be demonstrated that the engineering design is feasible and that an adequate R&D program has been planned to develop and prove the design.

The EDR will be conducted when most of the R&D is complete and the engineering design has been finalized. For a system to pass the EDR, it must be demonstrated that all of the technical and engineering challenges have been adequately addressed allowing the design and purchase of parts and tooling for full-scale prototypes and production deliverables to proceed.

The PRR will occur after final proof-of-design is complete, i.e., after prototypes are delivered and tested successfully, etc. It will occur before the final production of the deliverables for the LHC. The PRR must include a strategy for fabrication or procurement, quality assurance, and a component test plan.

Each of the above reviews will be conducted by a committee of experts assigned by the PM and will be chaired by the EM or a person designated by the EM with the concurrence of the PM. It is anticipated that the committee participants reviewing a particular Major Project System will remain the same throughout the three Design Reviews for that system. The EM will recommend to the PM when a Major Project System is ready for its next review phase. It is the responsibility of the EM to issue a report at the end of each phase of the Design Review process detailing the technical designs, committee recommendations, and action items.

Participation by CERN in the review process is specified in the Implementing Arrangement.

4.2.4 Construction, Fabrication, Assembly, and Testing

Fabrication of technical components and systems will be done both in-house, utilizing the three national laboratories' capabilities, and by outside vendors working under subcontracts with one of the laboratories. Assembly will be done predominantly by each laboratory's staff under the direction of the appropriate WBS Manager and according to the schedule discussed in Section 2.4.2.

4.2.5 Make-Buy Decisions

A procurement plan must be developed for each hardware deliverable, and this plan may involve one or more make-buy decisions. The make-buy decision will be based on a preference for providing hardware on a least-cost basis, giving due regard to such considerations as quality, capability, and schedule. In general, work remains within the laboratories if it requires close engineering or scientific supervision, interaction between many trades or shops, involves elements or procedures not familiar to outside shops, or is dependent on capabilities unique to the laboratories. Otherwise, the fabrication will be opened to bids from outside vendors.

For the major hardware deliverables, a formal Procurement Plan will be written. The Procurement Plan must specify the fabrication and procurement strategy, and present the basis for the decision as to the level of in-house versus outside fabrication and procurement. The strategies employed may include build-to-specification or build-to-print procurement for the entire deliverable, procurement of major sub-assemblies with in-house final assembly, or in-house fabrication with procurements limited to materials and parts. The strategy presented must be consistent with the make-buy policies at the laboratory that is responsible for the work. The Procurement Plan must be approved by the PM before funds are committed for fabrication of the hardware deliverables.

4.2.6 Major Procurements and Subcontracts with Industry

To the extent practicable, outside purchase or fabrication subcontracts will be awarded on a fixed-price competitive bid basis. Purchase requisitions will be processed through the normal procurement channels of the particular purchasing laboratory following appropriate approval. The PM must be notified in advance of all purchases exceeding $25,000, and must approve all purchases above $100,000. These purchases will normally have been identified in the Procurement Plan.

4.2.7 Inspection During Fabrication

Each member of the WBS Line Management is responsible for adherence to specifications, plans, and standards for all components and systems, for final assembly, and for in-house and vendor procurements for items within his or her area of responsibility. Project staff members or experts drawn from other organizations will perform on-site inspections of work in progress. When appropriate, inspection visits will be made to vendor shops and industrial firms fabricating or preparing components or instruments for the Project. The responsible WBS Manager must be sure that the allowance for such visits is part of each procurement contract.

4.2.8 Systems Acceptance Testing

The planning for final testing and acceptance of individual components and systems is the responsibility of the WBS Manager for that deliverable, or the Quality Assurance staff to whom that responsibility has been delegated (see Section 4.2.10). When the deliverable is a Major Project System (WBS Level 3 deliverable), a written acceptance or testing plan will be produced, describing the nature of the tests to be performed and the criteria for successful completion. This plan will be reviewed and approved as part of the PRR for that System.

4.2.9 The Project Acceptance Plan

The primary responsibility for the generation of the Systems Acceptance Plan involving all components and systems over the whole Project lies with the PM, working in conjunction with the EM. This plan, designated as the Project Acceptance Plan, is a compilation of the written acceptance plans for all of the WBS level 3 deliverables described in Section 4.2.8. It will describe the acceptance tests to be carried out before release of the Major Project Systems (WBS Level 3 deliverables) from the laboratories or subcontractors where the components are being assembled. The on-site activities will be defined by a work list with delivery dates and responsible personnel assigned to each task. Procedures for approval of the Systems Acceptance Plan and changes thereto by CERN are specified in the Implementing Arrangement.

4.2.10 Quality Assurance Program

Each of the US laboratories has its own Quality Assurance (QA) systems and procedures, with specific implementations within the responsible organizational element. The QA programs for each component of the US Project will be developed within the context of the relevant laboratory's normal QA program and procedures. The system-specific QA plan must be approved by the PM with concurrence by CERN as specified in the Implementing Arrangement. Existence of an approved QA program at the appropriate level will be a criterion for the successful completion of each of the technical design reviews specified in Section 4.2.3.

The Engineering Manager has the principal responsibility within the US Project for ensuring that adequate QA programs are implemented for each Level 3 deliverable at each laboratory, that adequate communication between the US participants and CERN takes place in developing these programs, and that the concurrence procedures with CERN specified in the Implementing Arrangement are followed. The EM must approve all QA plans before they are submitted to the PM for approval.

4.2.11 Safety Requirements and Reviews

Any of the equipment manufactured in the US laboratories as part of the US LHC Accelerator Project that will be operated in one of the laboratories for acceptance testing or other reasons must satisfy all of the safety requirements and pass all of the required safety reviews at the laboratory where it is operated.

Equipment provided for installation and operation in LHC must conform to CERN safety standards and their designs must be approved through CERN safety review procedures as specified in the Implementing Arrangement.

4.2.12 ES&H Analysis and Compliance

It is the policy of the US LHC Accelerator Project not to make, handle, use, transport, or dispose of a product unless it can be done safely and in an environmentally sound manner. All work activity done in the US laboratories as part of the US LHC Accelerator Project will be subject to all of the host laboratory's Environment, Safety and Health (ES&H) regulations and will be under that laboratory's authority in this regard. Similarly, work done at CERN as part of the US Project will be subject to CERN regulations and authority with respect to ES&H.

5 CHANGE MANAGEMENT AND CONTINGENCY MANAGEMENT

5.1 Change Management

Changes to the technical, cost and schedule baselines will be controlled using the process shown in Figure 1 and in Tables 1, 2, and 3. Table 1 defines the control thresholds for changes to the technical, cost and schedule baseline. The required approvals corresponding to each change control level are defined in Table 2. The schedule baseline is controlled through controlled baseline schedules for each WBS level 3 task (see Section 2.4) and milestones, whose levels are defined in Table 3. Change management is a prime responsibility of the PM. A Change Control Board (CCB), as defined in Section 5.3, advises the PM on all proposed changes at level 3 or above.

All changes in technical scope or performance, cost, or schedule at the levels defined in Table 1 must be documented by a written Baseline Change Request (BCR). Change requests must originate in the PMO or at the lowest applicable level below that. The change request should include a description of the proposed change, with appropriate backup documentation included directly in the BCR, attached or referenced; an evaluation of the impact of the proposed change on other parts or aspects of the US LHC Accelerator Project and the LHC Project as a whole; and the proposed course of action.

The change request must initially be submitted for action at the lowest applicable level. If approval is denied at that level, a copy of the request, together with the reasons for denial, is returned to the requestor, and a copy is filed. If the change is approved at that level, a copy of the request with the approval indicated, together with any qualifications or further analysis or documentation generated in considering the request, is returned to the requestor, and copies are sent to the person at the next higher control level and to the Project Office.

If final approval is within the authority of the person at this level, the process ends, except that the person at the next higher control level may review the change to ensure proper application of the procedure and consistency of the change with the goals and boundary conditions of the Project. If consideration at the next higher control level is required, then the process is repeated at that level.

Interaction between the US Project and CERN is the responsibility of the US LHC Accelerator Project Manager (PM), and all official communications with CERN concerning change control decisions as outlined here will proceed through the PM. Certain changes, shown as Level 3.1 in Table 1, require CERN approval. Changes to these items must be approved by the PM, following recommendation of the CCB, before being submitted to CERN for approval. It is the responsibility of the PM to obtain CERN approval for changes to these items before giving final approval to the changes, allowing the proposed change to be acted upon or to be forwarded to DOE for its consideration. The PM must also keep CERN informed of the status of change control decisions made by DOE on level 1 and level 2 items, and of changes made at level 3.2 and below as appropriate.

The scope of work of the US LHC Accelerator Project is fully specified in the Implementing Arrangement, which must be amended according to provisions contained therein if the work scope changes.

Each laboratory must have internal procedures for controlling changes at levels lower than those specified here. The level of formality of these procedures should be appropriate to the level of complexity of the task controlled. The change control system may be audited by the Project Manager at his discretion.

5.2 Contingency Management

The Project contingency is defined as the difference between the TPC and the baseline EAC at WBS level 1, and this contingency is held as a single fund. Contingency funds are allocated by the DOE-PM. As required by the change control procedure given in Section 5.1, requests for contingency allocation must be approved by the PM, following recommendation of the CCB, before being submitted to the DOE-PM.

5.3 Change Control Board

The PM will establish a Change Control Board to make recommendations on changes that affect the Project baseline cost, schedule and technical specifications. The Change Control Board consists of the members of the Inter-Laboratory Steering Committee (see Section 3.2.4) plus additional members that may be appointed by the PM. The DOE-PM and members of the PAG will be invited to participate as observers. The CCB will be chaired by the PM unless he designates another member as the chair. The Board will meet at regular intervals, typically concurrent with Inter-Laboratory Steering Committee meetings, unless there are no pending actions. Meetings may be held in person, or by video teleconference. A record of the disposition of all requests placed before the Change Board will be kept by the PMO. Notices of approval or denial of proposed changes will be distributed to the relevant L3Ms and to CERN by the PMO, and official budgets and schedules will be modified as appropriate.

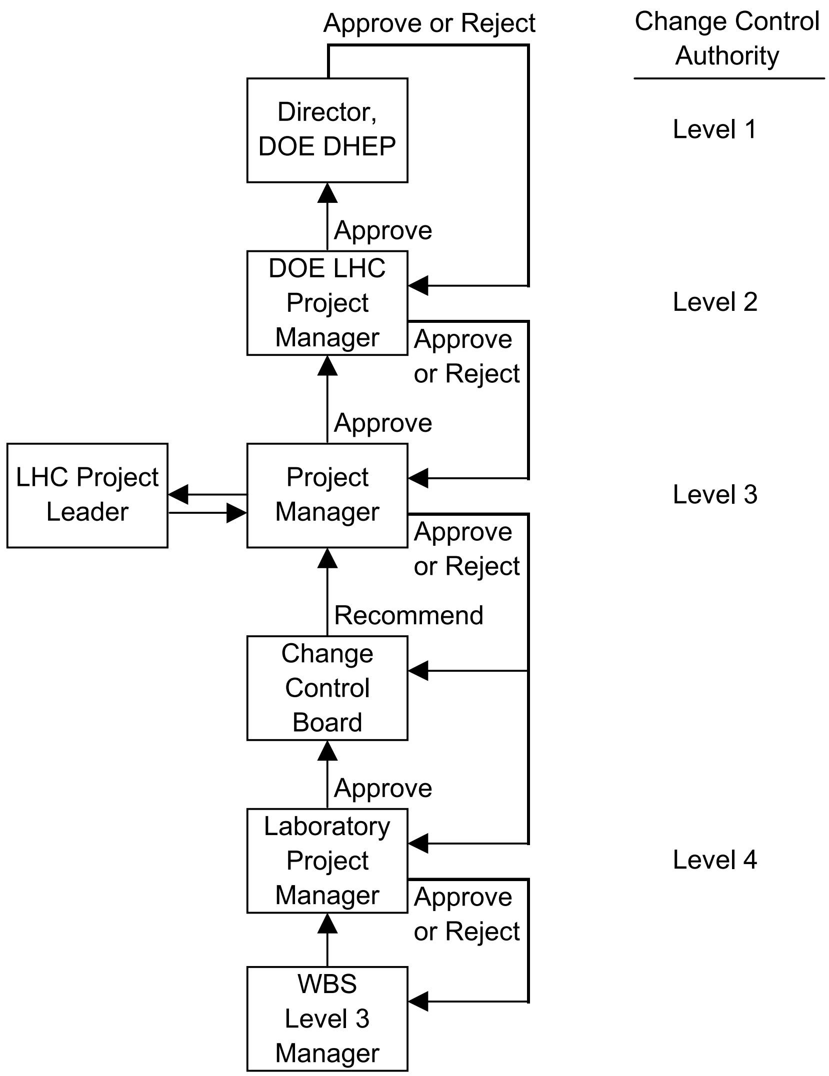


Figure 1. US LHC Accelerator Project change control process.

Table 1
US LHC Accelerator Project Change Control Thresholds

	Director, DOE OER (Level 0)	Joint Oversight Group (Level 1)	DOE LHC Project Manager (Level 2)	US LHC Accelerator Project Manager (Level 3)	Laboratory Project Manager (Level 4)
Technical	1) Any change that requires modification to the US-CERN Agreement or the Accelerator Protocol (PEP Appendices A and C).	1) Initial baseline list of deliverables specified in the WBS level 3 descriptions in the Implementing Arrangement (PMP Annex II). 2) Any reduction in the baseline list of deliverables specified in the WBS level 3 descriptions in the Implementing Arrangement (PMP Annex II).	1) Any change in the baseline list of deliverables specified in the WBS level 3 descriptions in the Implementing Arrangement (PMP Annex II).	3.1) CERN approval required: 1) Initial baseline list of deliverables specified in the Implementing Arrangement and any changes thereto. 2) Functional specifications. 3) Interfaces between US-provided equipment and other LHC equipment. 4) Designs as specified in the Technical Design Handbook. 3.2) CERN approval not required: 1) Interfaces between equipment in different WBS level 3 tasks. (Ref. PMP Appendix 1.) 2) Interfaces between equipment provided by different US Labs. (Ref. Implementing Arrangement - PMP Annex II).	1) All technical changes not controlled at higher levels.
Schedule	1) Any change that requires modification to the US-CERN Agreement or the Accelerator Protocol (PEP Appendices A and C).	1) Any change in level 1 milestones specified in PMP Appendix 5.	1) Any change in level 2 milestones specified in PMP Appendix 5.	3.1) CERN approval required: 1) Any changes in level 1, 2 or 3 milestones with milestone number suffix "C," specified in PMP Appendix 5. 2) >20% change number of SC wire or cable tests in any year specified in "Superconductor Testing at BNL under US-LHC Accelerator Project" 3.2) CERN approval not required: 1) Any changes in level 3 milestones without milestone number suffix "C," specified in PMP Appendix 5. 2) Initial set of level 4 milestones specified in "US LHC Accelerator Project Laboratory Milestones." 3) Any change in laboratory baseline schedules (Ref. US LHC Accelerator Project Laboratory Baseline Schedules.)	1) Any change in level 4 milestones for the appropriate laboratory specified in "US LHC Accelerator Project Laboratory Milestones."
Cost	1) Any change that requires modification to the US-CERN Agreement or the Accelerator Protocol (PEP Appendices A and C).	1) Any change in the TPC specified in PMP Appendix 6. 2) Any change in the TPI specified in PMP Appendix 6.	1) Any change in the WBS level 2 cost baseline specified in PMP Appendix 6. 2) Any contingency usage.	3.2) CERN approval not required: 1) Any change in the cost baseline at WBS level 3 specified in PMP Appendix 6. 2) Initial cost baseline at WBS level 4 specified in "US LHC Accelerator Project Cost Summary." 3) Any change in laboratory cost baselines specified in PMP Appendix 6.	1) Any changes in the cost baseline at the appropriate laboratory at WBS level 4 which do not change the WBS level 3 or laboratory cost baselines.

Table 2
Change Control Authority Levels

Control Level	Required Approval
0	Director, DOE Office of Energy Research
1	Joint Oversight Group
2	DOE-LHC Project Manager
3	US LHC Accelerator Project Manager, based on recommendation of the Change Control Board. Additional approval of LHC Project Leader (or designee) and CERN official contact person for items indicated as "CERN approval required" in Table 1.
4	Laboratory Project Manager approval Notification required to US LHC Accelerator Project Manager and Change Control Board for listed schedule and cost items.

Note: Changes must be approved at all lower applicable levels before being forwarded to the next higher level for consideration.

Table 3
Milestone Levels

<u>Level 1 milestones</u>

CERN approval required:
- Major decision points concerning the goals or scope of the Project.

CERN approval not required:
- Project start and completion dates.

<u>Level 2 milestones</u>

CERN approval required:
- The delivery to CERN of completed equipment that will be installed in LHC.

CERN approval not required:
- The start and completion of major phases of a WBS level 3 task.

<u>Level 3 milestones</u>

CERN approval required:
- The delivery to CERN of other equipment.
- The delivery from CERN to the US Project of devices, components or material that will be incorporated in US-built systems or equipment.
- The establishment of specifications that are under level 3.1 change control.

CERN approval not required:
- The delivery of equipment or components by one US laboratory to another.
- The start and completion of major phases of a WBS level 3 task.
- The completion of an intermediate number of production deliverables.
- The establishment of specifications that are under level 3.2 change control.
- Project-level technical reviews.

<u>Level 4 milestones</u>

CERN approval not required:
- The completion of significant intermediate phases of a WBS level 3 task.
- Laboratory-level or WBS level 3 internal technical reviews.
- Other milestones that aid in tracking the progress of WBS level 3 tasks, as determined by the Laboratory Project Manager with the concurrence of the US LHC Accelerator Project Manager.

6 FUNDS MANAGEMENT, WORK AUTHORIZATION, AND PROJECT CONTROL SYSTEM

6.1 Introduction

This Section deals with the authorization for project funds to be expended and the accounting practices that will apply following the commitment or expenditure of funds that have been made. The line of cost account management will function along the same lines as the WBS management structure shown in Appendix 4. A computer-based Project Control System will track expenditures, such that the up-to-date status of the Project Budget can be determined and the cost and schedule performance of each WBS level 3 task can be calculated.

6.2 Funds Management

Funds will be made available to the DOE in support of the US LHC Accelerator Project on an annual basis following passage of appropriation legislation by the US Congress. These funds will be provided to the laboratories through the DOE Financial Plan only upon written authorization from the PM to DHEP, and with the approval and concurrence of the DOE-LHC PM. Included in the initial recommendation will be the amount of funds to be allocated that year for reimbursing CERN for the purchase of US industrial goods as specified in Article IV of the Accelerator Protocol.

The financial resources required to perform the scope of work to be carried out by each of the three laboratories will be determined by the PM. Identification of these resources will be made before the beginning of each fiscal year to effect transfers of funds efficiently with minimal interruption of work. It is anticipated that not all of the annual funds will be initially allocated. At mid-year, and at the beginning of the fourth quarter, additional allocations will be made at the recommendation of the PM with the concurrence of the DOE-PM. The mid-year and fourth quarter recommendations may also include adjustments to the recommended amounts allocated for industrial purchases. Any funds not explicitly allocated by the first of August of any given fiscal year, including funds for industrial purchases (as specified in the Accelerator Protocol, Article IV), will be allocated to the Lead Laboratory, Fermilab.

6.3 Work Authorization

To assure that funds are transferred in a timely manner to meet future expenditures and procurements, the PM will prepare Work Authorizations (WAs) for the work to be performed in a given fiscal year by the first of August of the preceding fiscal year. The WAs will authorize work at specific amounts identified at Level 3 of the WBS, with specific amounts allocated at each of the three laboratories. The WA will include a description of the authorized scope of work to be performed and the fiscal year funding amount for each WBS level 3 task, with specific amounts allocated to each laboratory.

Each laboratory will have specific accounts corresponding to the WBS elements authorized by the WA, and a list of authorized Cost Account Managers (CAMs), who will have signature authority over specific accounts. The PM must approve the list of CAMs at each laboratory, although it is anticipated that in most cases the L3Ms will also serve as CAMs.

The process of creating the WAs begins with a proposed scope of work and budget submitted to the PM, through the local LPM, by each L3M. It is the responsibility of the appropriate LPM to ensure that these proposals are completed in a timely fashion in order to meet the first of August deadline for submissions to the DOE.

6.4 Project Control System and Performance Measurement

The Project Cost and Schedule Manager will maintain the official Project budgets and schedules using commercially available software. Status information on each WBS level 3 task is sent to the CSM by L3Ms, via the LPMs, on a monthly basis. This status includes the estimated percent complete of each lowest-level task in the approved baseline schedule, the current and project inception to date expenditures, and the current value of open commitments, reported at a WBS level assigned by the PM (typically level 4 or 5). The status information is analyzed with respect to the baseline schedule and cost estimate to prepare a cost performance report using standard earned value techniques.

The Budgeted Cost of Work Scheduled (BCWS) is the time-phased budget that represents the value of the work planned to be accomplished through a given time. As work is completed, budget associated with this work is "earned" as Budgeted Cost of Work Performed (BCWP) or earned value. The actual cost of the resources consumed in performing the work is represented by the Actual Cost of Work Performed (ACWP). The difference between BCWP and ACWP is the cost variance. The difference between BCWP and BCWS is the schedule variance expressed in dollar terms. The current values and time histories of these indices are computed on a monthly basis and cost performance reports are provided to the PM, the LPMs and the L3Ms for analysis. Significant variances, defined by percentage or dollar thresholds to be set by the PM being exceeded, must be formally analyzed and, if necessary, corrective action plans must be developed jointly by the responsible L3M and LPM and the PMO.

7 PROJECT REPORTING AND REVIEW

7.1 Status Reporting within the Project

The LPM at each laboratory submits a Monthly Status Report to the PMO on the work performed by that laboratory. The reports are submitted by the 17th of the month following that on which the report is made. These reports have a similar format to the Quarterly Project Status Reports submitted by the PMO to the DOE, as discussed below, but with greater detail being included. The report includes: (a) Narrative for each level 3 task describing the work done, giving details concerning levels 4 or 5 (depending on the reporting level assigned by the PM) subtasks on which there was activity during the month. The report includes commentary and analysis as necessary on deviations from the technical, cost or schedule baseline and discussion of any perceived difficulties that might appear in the future. (b) Status of expenditures and open commitments at the WBS level assigned by the PM. (c) The level of effort on each task at the assigned reporting level. (d) Milestone status. (e) Major procurement (>$25K each) status and plans. (f) Percent complete on each lowest level task in the baseline schedule for each WBS level 3 task to allow the calculation of earned value. These reports will become part of the Official Project Record and information abstracted from them will be included in the Quarterly Reports to the DOE.

7.2 Status Reporting to the DOE

The PMO prepares Quarterly Project Status Reports which are submitted to the DOE. These reports are submitted to the DOE-PM within four weeks following the end of the quarter being reported. The report includes: (a) Short narrative of the overall project status, (b) Short description of the technical status of each WBS Level 3 element, (c) Cost performance status, with tables including BCWS, BCWP and ACWP for each WBS Level 3 task and graphs to display their trends, (d) Funds status showing usage of funds allocated to date and a projection of when additional funds will be required, (e) Milestone status report, (f) Major procurement status and plans, and (g) Discussion of major accomplishments and analysis of outstanding issues.

7.3 Meetings and Reviews

7.3.1 Meetings with DOE

The PM and the DOE-PM meet bi-weekly to discuss project status, and these meetings normally include a conference with the DOE-PGM or a member of his staff.

7.3.2 Reviews by DOE

The DOE-DHEP will hold semi-annual reviews on the progress of the Project. These reviews will be called by and report to the Director of DOE-DHEP, who will choose the committee chairmanship and membership and approve the agenda. These meetings will generally include a detailed discussion of budget and schedule performance and technical progress in the Project, though special concerns may be brought forward for more detailed discussion. It will be a joint responsibility of the DOE-PM and the PMO to provide the necessary support for these meetings. The LHC Project Leader or his designee will be informed of and invited to all such reviews.

The DOE-PM may also hold reviews on the progress in the Project. The DOE-PM will choose the committee chairmanship and membership, as well as set the agenda. These meetings will generally be called to resolve special issues as they arise, though they may include a detailed discussion of budget and schedule performance and technical progress in the Project. It will be a joint responsibility of the DOE-PM and the PMO to provide the necessary support for these meetings. Comments resulting from the review will become recommendations made to the DOE-PM, who will be responsible to distribute them and to track any action items. The LHC Project Leader or his designee will be informed of and invited to all such reviews.

7.3.3 Meetings with CERN

All formal communication between the US Project and CERN proceeds through the PMO. The PM travels to CERN several times per year and meets there with the LHC Project Leader or his designee to report on the status and progress of the US Project and to discuss issues related to it.

CERN is kept informed of the status and progress of the US Project via monthly video teleconferences involving all three US laboratories, as well as through other forms of informal communication such as those listed in Section 3.4.2 and in the Implementing Arrangement.

7.3.4 Reviews by CERN

CERN participation in US Project Technical Design Reviews (see Section 4.2.3) and procedures for CERN review of the US Project or components of it are specified in the Implementing Arrangement.

7.3.5 Internal Project Meetings and Reviews

As part of the normal process of assessment of Project progress, the PM may convene a panel of experts to evaluate the program at any of the collaborating laboratories. These reviews will not replace any of the Project formal technical reviews (CDRs, EDRs or PRRs) and resulting comments will be recommendations made to the PM.

APPENDICIES

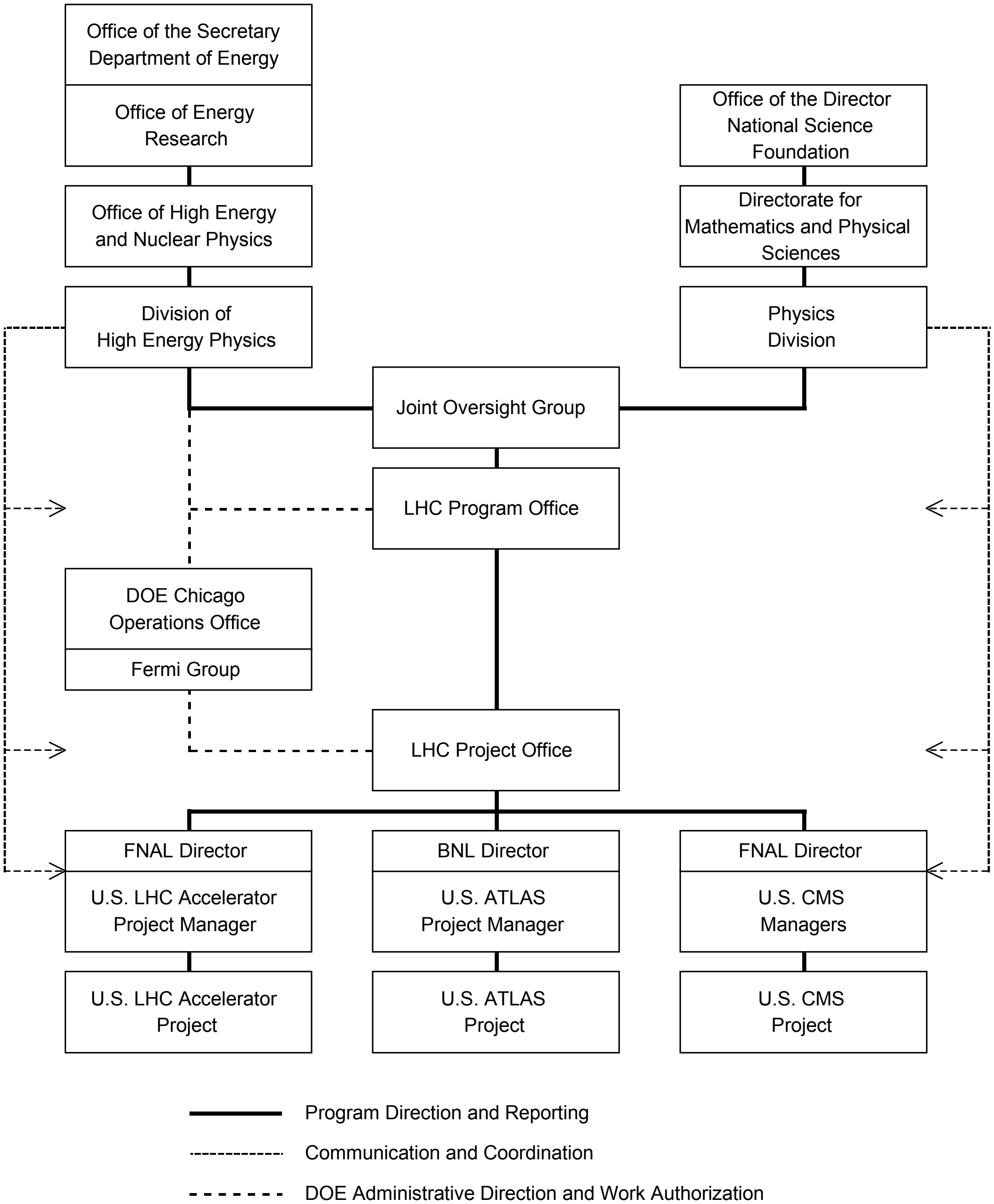
Management Structure

Appendix 1
US LHC Accelerator Project
Work Breakdown Structure (WBS) to 3rd Level

WBS	Task	Responsible Laboratory
1	US PART OF THE LHC ACCELERATOR PROJECT	
1.1	INTERACTION REGIONS	
1.1.1	Interaction Region Quadrupoles	FNAL, LBNL
1.1.2	Interaction Region Dipoles	BNL
1.1.3	Interaction Region Cryogenic Feed Boxes	LBNL
1.1.4	Interaction Region Absorbers	LBNL
1.1.5	Interaction Region Layout and Integration	FNAL
1.2	RF REGION	
1.2.1	RF Region Dipoles	BNL
1.2.2	(Reserved for RF Region Quadrupoles*)	
1.3	SUPERCONDUCTING WIRE AND CABLE	
1.3.1	Superconducting Wire and Cable Testing	BNL
1.3.2	Superconducting Cable Production Support	LBNL
1.4	ACCELERATOR PHYSICS	BNL, FNAL, LBNL
1.5	PROJECT MANAGEMENT	
1.5.1	US LHC Accelerator Project Management	FNAL
1.5.2	BNL LHC Accelerator Project Management	BNL
1.5.3	FNAL LHC Accelerator Project Management	FNAL
1.5.4	LBNL LHC Accelerator Project Management	LBNL

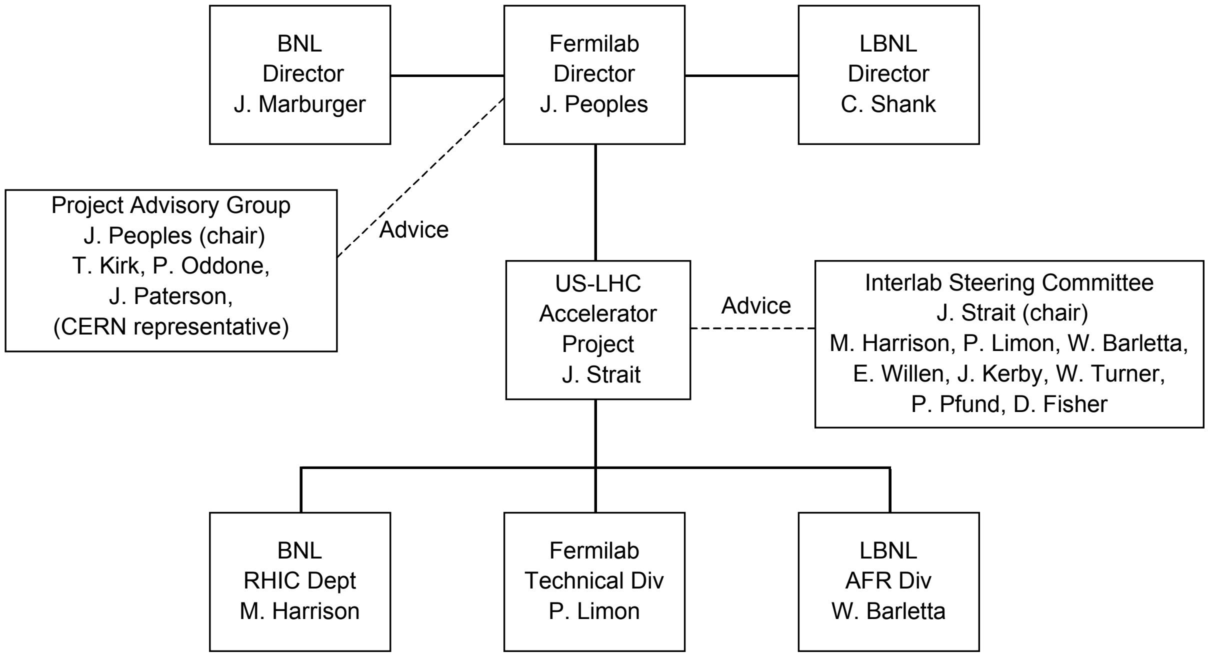
* The RF region quadrupoles are not currently part of the Project, but may be added by mutual agreement with CERN if resources allow.

Appendix 2
US LHC Projects oversight organizational relationships



Appendix 3

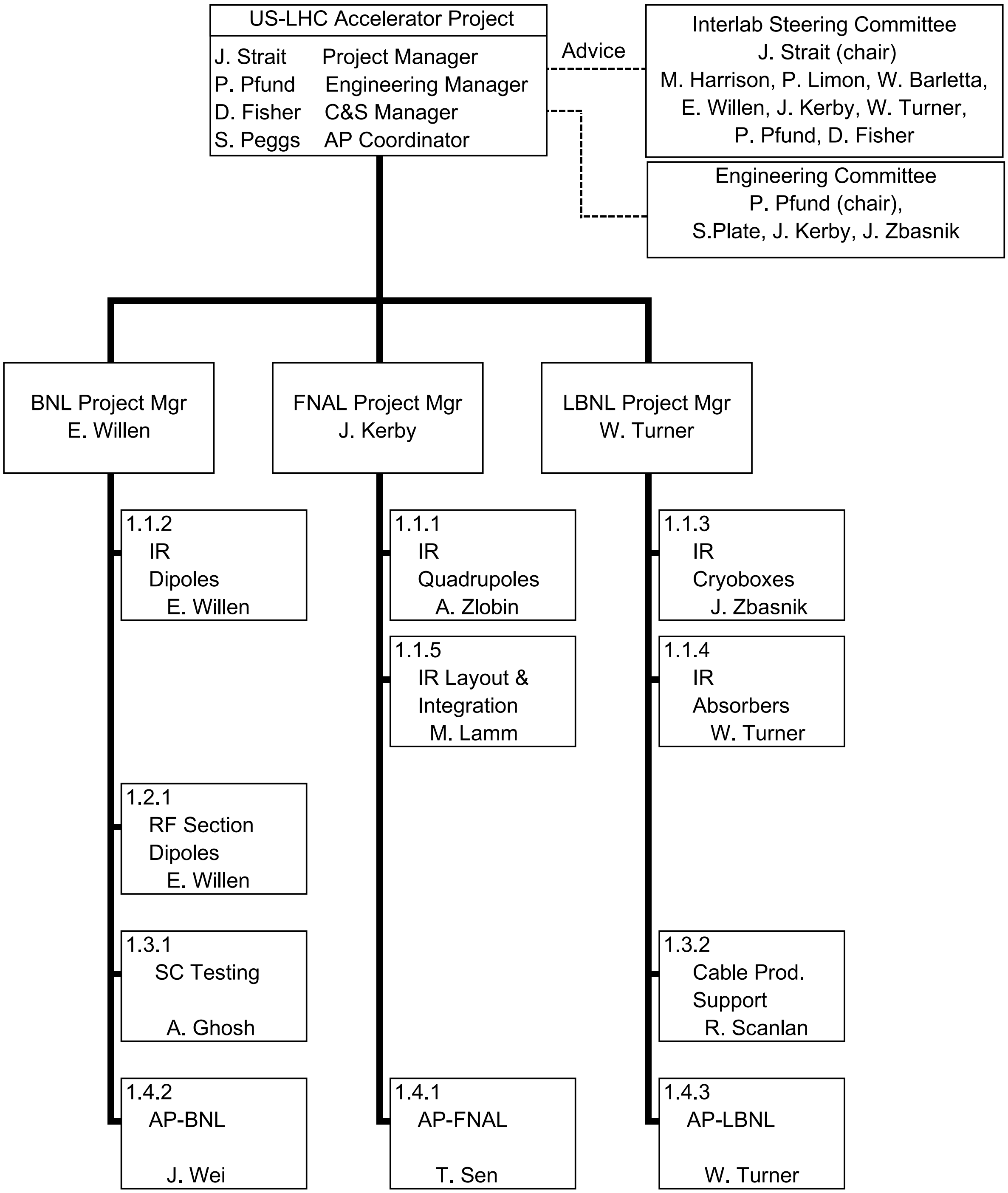
Organizational relationships among BNL, Fermilab, LBNL laboratory management



October 1998

Appendix 4

The US LHC Accelerator Project organization



October 1998

APPENDICIES

Baseline Data

Appendix 5

Controlled Milestones to Level 3

US LHC Accelerator Project Level 1 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
1 - 1		Project Start	1 Oct 1995		1 Oct 1995
1 - 2 C		Decision as to whether or not the U.S. Project includes RF region quadrupoles	1 Jul 2001		
1 - 3		Project Completion	30 Sep 2005		
	Status: *Revised 1 July 1998* *Milestones 1-1 and 1-3 approved as part of the Project Baseline, 15 June 1998.* *Milestone 1-2C included and approved in the Implementing Arrangement 1 July 1998*				

US LHC Accelerator Project Level 2 Milestones

Milestone No.		Baseline Date	Forecast Date	Actual Date
	WBS 1.1 Interaction Regions			
2 -1.1- 1	Begin 1st inner triplet quadrupole model magnet	1 Jul 1997		1 Jul 1997
2 -1.1- 2	Complete inner triplet quadrupole model magnet program phase 1	1 Jun 1999		
2 -1.1- 3	Complete inner triplet quadrupole model magnet program phase 2	1 Jan 2000		
2 -1.1- 4	Complete tests of prototype HTS power leads	1 Jan 2000		
2 -1.1- 5	Begin absorber fabrication	1 Nov 2000		
2 -1.1- 6	Complete inner triplet quadrupole prototype magnet program	1 Dec 2000		
2 -1.1- 7	Begin interaction region beam separation dipole production assembly	1 Mar 2001		
2 -1.1- 8	Begin inner triplet feedbox fabrication	1 Mar 2001		
2 -1.1- 9	Begin inner triplet quadrupole production assembly	15 Apr 2001		
2 -1.1- 10	Complete 1st inner triplet quadrupole magnet	1 Nov 2001		
2 -1.1- 11 C	Delivery of D2 for IR8 left	1 Apr 2002		
2 -1.1- 12	Complete inner triplet feedbox fabrication	1 May 2002		
2 -1.1- 13 C	Delivery of all inner triplet system components for IR8 left (MQX, DFBX, D1)	1 Oct 2002		
2 -1.1- 14 C	Delivery of D2 for IR5 left	1 Nov 2002		
2 -1.1- 15	Complete absorber fabrication	1 Dec 2002		
2 -1.1- 16 C	Delivery of all inner triplet system components for IR8 right (MQX, DFBX, D1)	1 Jan 2003		
2 -1.1- 17 C	Delivery of D2 for IR8 right	1 Feb 2003		
2 -1.1- 18	Complete interaction region beam separation dipole production assembly	1 Mar 2003		
2 -1.1- 19 C	Delivery of all inner triplet system components for IR1 left (MQX,DFBX,TAS,TAN)	1 Jul 2003		
2 -1.1- 20 C	Delivery of D2 for IR2 right	1 Sep 2003		
2 -1.1- 21	Begin ionization chamber fabrication	1 Nov 2003		
2 -1.1- 22 C	Delivery of D2 for IR1 left	1 Dec 2003		
2 -1.1- 23 C	Delivery of all inner triplet system components for IR5 left (MQX,DFBX,TAS,TAN)	1 Jan 2004		
2 -1.1- 24 C	Delivery of D2 for IR5 right	1 Mar 2004		
2 -1.1- 25 C	Delivery of all inner triplet system components for IR5 right(MQX,DFBX,TAS,TAN)	1 Apr 2004		
2 -1.1- 26 C	Delivery of all inner triplet system components for IR2 right (MQX, DFBX, D1)	1 Apr 2004		
2 -1.1- 27 C	Delivery of all inner triplet system components for IR1 right(MQX,DFBX,TAS,TAN)	1 Jul 2004		

US LHC Accelerator Project Level 2 Milestones

Milestone No.		Baseline Date	Forecast Date	Actual Date
2 -1.1- 28 C	Delivery of D2 for IR1 right	1 Aug 2004		
2 -1.1- 29 C	Delivery of D2 for IR2 left	1 Sep 2004		
2 -1.1- 30	Complete inner triplet quadrupole production	1 Sep 2004		
2 -1.1- 31	Complete ionization chamber fabrication	15 Sep 2004		
2 -1.1- 32 C	Delivery of all inner triplet system components for IR2 left (MQX, DFBX, D1)	1 Oct 2004		
2 -1.1- 33	Interaction Region task complete	30 Sep 2005		
	WBS 1.2 RF Region			
2 -1.2- 1	Begin assembly of 1st dipole model magnet	1 Sep 1999		
2 -1.2- 2	Complete dipole model magnet program	1 Aug 2000		
2 -1.2- 3	Begin RF region beam separation dipole production assembly	1 Sep 2000		
2 -1.2- 4 C	Delivery of D3, D4 for IR4 right	1 Jan 2002		
2 -1.2- 5	Complete RF region beam separation dipole production assembly	1 Oct 2002		
2 -1.2- 6 C	Delivery of D3, D4 for IR4 left	1 Nov 2002		
2 -1.2- 7	RF Region task complete	30 Sep 2005		
	WBS 1.3 Superconducting Wire and Cable			
2 -1.3- 1	All cable production support equipment delivered to CERN	1 Mar 1999		
2 -1.3- 2	Complete SC testing facility upgrades	1 Jun 1999		
2 -1.3- 3	Series wire and cable testing complete	1 Oct 2004		
2 -1.3- 4	Superconducting Wire and Cable task complete	30 Sep 2005		

Level 2 Milestone Status:

Revised 7 October 1998

CERN controlled milestones included and approved in the Implementing Arrangement 1 July 1998.

Other milestones are under review.

Notes

1) CERN approval is required for milestones with suffix "C."
2) Delivery dates are set approximately 6 months before the installation date to allow for acceptance testing at CERN.
3) An inner triplet system consists of all of the equipment for one interaction region specified under WBS 1.1 (see the WBS dictionary in section II.B of the Implementing Arrangement) except the twin-aperture beam separation dipoles D2 and the instrumentation for the absorbers.

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.1.1 Interaction Region Quadrupoles				
3 -1.1.1- 1		Inner triplet quadrupole (MQX) cold mass conceptual design review	15 Oct 1996		15 Oct 1996
3 -1.1.1- 2		Begin 1st quadrupole model magnet	1 Jul 1997		1 Jul 1997
3 -1.1.1- 3		Quench heaters for model magnet program phase 1 delivered, LBNL to FNAL	1 Jun 1998		1 Jun 1998
3 -1.1.1- 4		Cable and wedges for model magnet program phase 1 delivered, LBNL to FNAL	1 Jun 1998		1 Jun 1998
3 -1.1.1- 5		MQX cryostat conceptual design review	15 Dec 1998		
3 -1.1.1- 6 C		MQX cold mass to cryostat interface specification approved	1 Mar 1999		
3 -1.1.1- 7		Complete model magnet program phase 1	1 Mar 1999		
3 -1.1.1- 8		Cable and wedges for model magnet program phase 2 delivered, LBNL to FNAL	1 Mar 1999		
3 -1.1.1- 9 C		MQXB field quality specifications approved	1 Jul 1999		
3 -1.1.1- 10 C		MQX functional specifications approved	1 Jul 1999		
3 -1.1.1- 11 C		MQX to correction coil interface specification approved	1 Jul 1999		
3 -1.1.1- 12 C		Inner triplet compensation and correction scheme approved	1 Jul 1999		
3 -1.1.1- 13		Start production of cable and wedges for prototype and production MQXB	1 Aug 1999		
3 -1.1.1- 14		Complete model magnet program phase 2	1 Oct 1999		
3 -1.1.1- 15 C		MQX alignment specifications approved	1 Nov 1999		
3 -1.1.1- 16 C		All MQX interface specifications approved	1 Nov 1999		
3 -1.1.1- 17		MQX Engineering Design Review	1 Dec 1999		
3 -1.1.1- 18 C		Delivery to FNAL of BPMs	1 Aug 2000		
3 -1.1.1- 19		Complete prototype magnet program	1 Oct 2000		
3 -1.1.1- 20		MQX Production Readiness Review	1 Oct 2000		
3 -1.1.1- 21		Begin assembly of first MQXB	1 Oct 2000		
3 -1.1.1- 22		Complete production of cable and wedges for production MQXB	1 Jan 2001		
3 -1.1.1- 23 C		Delivery to FNAL of 1st MQXA	1 May 2001		
3 -1.1.1- 24 C		Delivery to FNAL of 1st correction coil	1 Jul 2001		
3 -1.1.1- 25		Begin assembly of first MQXA	1 Aug 2001		
3 -1.1.1- 26		IR8 left MQX ready to deliver	1 Sep 2002		
3 -1.1.1- 27		IR8 right MQX ready to deliver	1 Dec 2002		
3 -1.1.1- 28		IR1 left MQX ready to deliver	1 Jun 2003		
3 -1.1.1- 29		IR1 right MQX ready to deliver	1 Oct 2003		
3 -1.1.1- 30		IR5 left and right MQX ready to deliver	1 Oct 2003		
3 -1.1.1- 31		IR2 left and right MQX ready to deliver	1 Feb 2004		
3 -1.1.1- 32		All spare MQX ready to deliver	1 Jul 2004		
3 -1.1.1- 33		Interaction Region Quadrupoles task complete	30 Sep 2005		

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.1.2 Interaction Region Dipoles				
3 -1.1.2- 1		Beam Separation Dipole Conceptual Design Review (see Note 2)	1 Aug 1998		16 Jul 1998
3 -1.1.2- 2 C		D1,D2 field quality specifications approved	1 Feb 1999		
3 -1.1.2- 3 C		All D1,D2 functional and interface specifications approved	1 Jul 1999		
3 -1.1.2- 4		Superconducting wire for IR dipoles delivered by LBNL to BNL	1 Feb 2000		
3 -1.1.2- 5		Beam Separation Dipole Engineering Design Review (see Note 2)	1 Mar 2000		
3 -1.1.2- 6		Beam Separation Dipole Production Readiness Review (see Note 2)	1 Jun 2000		
3 -1.1.2- 7 C		Delivery by CERN to BNL of all CERN-provided D2 cryostat parts	1 Jul 2000		
3 -1.1.2- 8		Begin assembly of 1st D2	1 Dec 2000		
3 -1.1.2- 9		D2 production complete	1 Jan 2002		
3 -1.1.2- 10		Begin assembly of 1st D1	1 Feb 2002		
3 -1.1.2- 11		D1 production complete	1 Dec 2002		
3 -1.1.2- 12		Interaction Region Dipole task complete	30 Sep 2005		
	WBS 1.1.3 Interaction Region Cryogenic Feed Boxes				
3 -1.1.3- 1		Cryogenic Feed Box (DFBX) Conceptual Design Review	15 Dec 1998		
3 -1.1.3- 2 C		DFBX functional specification approved	1 Mar 1999		
3 -1.1.3- 3		DFBX interface specification review	1 May 1999		
3 -1.1.3- 4 C		DFBX interface specification approved	1 Jul 1999		
3 -1.1.3- 5		Complete tests of prototype HTS leads	1 Oct 1999		
3 -1.1.3- 6		DFBX Engineering Design Review	1 Jul 2000		
3 -1.1.3- 7		DFBX Production Readiness Review	1 Nov 2000		
3 -1.1.3- 8		Begin fabrication of 1st DFBX	1 Dec 2000		
3 -1.1.3- 9		IR1 and IR5 DFBXs ready to ship	1 Sep 2001		
3 -1.1.3- 10		IR2 and IR8 DFBXs ready to ship	1 Feb 2002		
3 -1.1.3- 11		Interaction Region Cryogenic Feed Box task complete	30 Sep 2005		

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.1.4 Interaction Region Absorbers				
3 -1.1.4- 1 C		TAN and TAS functional specifications approved	1 Jan 1999		
3 -1.1.4- 2 C		TAN and TAS interface specifications approved	1 Mar 1999		
3 -1.1.4- 3		TAN and TAS Absorber Conceptual Design Review	1 Mar 1999		
3 -1.1.4- 4		Instrumentation Conceptual Design Review	1 Mar 1999		
3 -1.1.4- 5 C		ISR jacks delivered to LBNL	1 May 1999		
3 -1.1.4- 6 C		z-placement of TAN approved	1 Jul 1999		
3 -1.1.4- 7 C		TAS support design approved	1 Jul 1999		
3 -1.1.4- 8		Interaction Region Absorber Engineering Design Review	1 Jul 2000		
3 -1.1.4- 9		Interaction Region Absorber Production Readiness Review	1 Jul 2000		
3 -1.1.4- 10		Begin fabrication of TAN and TAS components	1 Aug 2000		
3 -1.1.4- 11		Begin assembly of TAN and TAS	1 Sep 2001		
3 -1.1.4- 12		Instrumentation Engineering Design Review	1 Apr 2002		
3 -1.1.4- 13 C		Ionization chamber functional and interface specifications approved	1 Jul 2002		
3 -1.1.4- 14		Complete assembly of TAN and TAS	1 Sep 2002		
3 -1.1.4- 15		Instrumentation Production Readiness Review	1 Jul 2003		
3 -1.1.4- 16		Begin procurement and fabrication of instrumentation	1 Aug 2003		
3 -1.1.4- 17		Complete fabrication of instrumentation	1 Jul 2004		
3 -1.1.4- 18 C		Ionization chambers shipped to CERN	1 Oct 2004		
3 -1.1.4- 19		Interaction Region Absorber task complete	30 Sep 2005		

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.2.1 RF Region Dipoles				
3 -1.2.1- 1		Beam Separation Dipole Conceptual Design Review	1 Aug 1998		16 Jul 1998
3 -1.2.1- 2 C		D3,D4 field quality specifications approved	1 Feb 1999		
3 -1.2.1- 3 C		D3,D4 functional and interface specifications approved	1 Jul 1999		
3 -1.2.1- 4		Superconducting wire for IR dipoles delivered by LBNL to BNL	1 Feb 1999		
3 -1.2.1- 5		Begin assembly of 1st dipole model magnet	15 Jul 1999		
3 -1.2.1- 6		Complete cold test of 1st dipole model magnet	1 Dec 1999		
3 -1.2.1- 7		Beam Separation Dipole Engineering Design Review	1 Mar 2000		
3 -1.2.1- 8		Complete model magnet program	1 May 2000		
3 -1.2.1- 9		Beam Separation Dipole Production Readiness Review	1 Jun 2000		
3 -1.2.1- 10		Begin assembly of 1st D4	1 Jun 2000		
3 -1.2.1- 11 C		Delivery by CERN to BNL of all CERN-provided cryostat parts	1 Jul 2000		
3 -1.2.1- 12		D4 production complete	1 May 2001		
3 -1.2.1- 13		Begin assembly of 1st D3	1 Aug 2001		
3 -1.2.1- 14		First 2 D3s complete	1 Dec 2001		
3 -1.2.1- 15		D3 production complete	1 Jul 2002		
3 -1.2.1- 16		RF Region Dipole task complete	1 Nov 2003		

US LHC Accelerator Project Level 3 Milestones

Milestone No.			Baseline Date	Forecast Date	Actual Date
	WBS 1.3.1 Superconductor testing				
3 -1.3.1- 1 C		Complete superconductor testing facility upgrades	1 Jul 1999		
3 -1.3.1- 2 C		Begin pre-series testing	1 Mar 1999		
3 -1.3.1- 3 C		Begin series testing	1 Mar 2000		
3 -1.3.1- 4 C		Series testing complete	1 Oct 2004		
	WBS 1.3.2 SC Cable Production Support				
3 -1.3.2- 1 C		Deliver 4 Cable Measuring Machines (CMM) to CERN	1 Oct 1997		1 Oct 1997
3 -1.3.2- 2 C		Deliver powered Turkshead to CERN	1 Jul 1998		1 Jul 1998
3 -1.3.2- 3 C		Deliver eddy current flaw detector to CERN	1 Jul 1999		
3 -1.3.2- 4 C		Deliver spare CMM measuring heads to CERN	1 Jan 1999		

Level 3 Milestone Status:

Revised 9 October 1998

All level 3 milestones are under review

Notes

1) CERN approval is required for milestones with suffix "C."
2) Conceptual, Engineering and Production Readiness Reviews for the IR dipoles and for the RF dipoles are the same reviews. They are listed under the RF region dipole task, and duplicated under the IR dipole task for reference only.

Appendix 6
US LHC Accelerator Project Cost Estimate
Version 2.0 May 1998

WBS Level 2	WBS Level 3		Base Cost (K$) Level 1	Level 2	Level 3
1.1		Interaction Regions		42,147	
	1.1.1	Interaction Region Quadrupoles			26,664
	1.1.2	Interaction Region Dipoles			5,509
	1.1.3	Interaction Region Cryogenic Feed Boxes			4,924
	1.1.4	Interaction Region Absorbers			3,532
	1.1.5	Interaction Region Layout and Integration			1,518
1.2		RF Region		12,636	
	1.2.1	RF Region Dipoles			12,636
1.3		Superconducting Wire and Cable		10,608	
	1.3.1	Superconducting Wire and Cable Testing			9,511
	1.3.2	Superconducting Cable Production Support			1,097
1.4		Accelerator Physics		4,508	
	1.4.1	BNL Accelerator Physics			1,788
	1.4.2	FNAL Accelerator Physics			1,525
	1.4.3	LBNL Accelerator Physics			1,195
1.5		Project Management		14,175	
	1.5.1	US-LHC Accelerator Project			3,194
	1.5.2	BNL-LHC Accelerator Project			6,723
	1.5.3	FNAL-LHC Accelerator Project			2,271
	1.5.4	LBNL-LHC Accelerator Project			1,986
		Escalation		7,117	
		Estimate at Completion (EAC) (Then-year $)		91,191	
		Contingency		18,809	
		Total Project Cost (TPC)	110,000		
		Total Procurements from Industry (TPI)	90,000		
		Total US Contribution to the LHC Accelerator	200,000		

	Laboratory Totals (escalated, no contingency)			
	BNL			39,414
	FNAL			35,691
	LBNL			16,086

Appendix 7
Obligation Profile Plan
August 1998

Obligation Profile (FY1997 M$)	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	Total
BNL	0.819	2.143	4.131	5.535	4.024	6.663	5.169	5.027	2.655	36.167
FNAL	0.236	2.663	4.538	6.030	5.708	4.395	3.820	3.525	2.108	33.025
LBNL	0.513	1.044	1.844	1.553	2.416	3.565	2.240	1.090	0.616	14.882
Total	1.569	5.851	10.514	13.118	12.148	14.623	11.229	9.643	5.379	84.074

Obligation Profile (Then-year M$)	FY 1996	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	Total
BNL	0.797	2.143	4.214	5.776	4.312	7.326	5.837	5.835	3.174	39.414
FNAL	0.230	2.663	4.629	6.292	6.117	4.832	4.314	4.092	2.521	35.691
LBNL	0.500	1.044	1.881	1.620	2.589	3.920	2.530	1.265	0.736	16.086
Total	1.526	5.851	10.724	13.688	13.018	16.078	12.680	11.193	6.432	91.191

Appendix 8
Escalation Rates

Fiscal Year	Annual Inflation	Cumulative Escalation
1996		0.979
1997	2.1%	1.000
1998	2.0%	1.020
1999	2.3%	1.044
2000	2.7%	1.072
2001	2.6%	1.100
2002	2.7%	1.129
2003	2.8%	1.161
2004	3.0%	1.196

ANNEX I

Written Understanding between the US DOE and CERN

concerning

Payments for procurements from US industry

Department of Energy
Germantown, MD 20874-1290

December 19, 1997

Dr. Lyndon Evans
LHC Project Leader
European Organization for Nuclear
Research
CH - 1211
Geneva 23, Switzerland

Dear Dr. Evans:

Article IV ("Procurement from Industry") of the Accelerator Protocol to the Co-operation Agreement between CERN, the Department of Energy, and the National Science Foundation, hereafter referred to as the Protocol, provides for the payment by the Department of Energy (D.O.E.) for items to be procured by CERN from U.S. industry. Section 4.6 of the Protocol refers to a "separate, written understanding with CERN specifying payment provisions and such additional details as may be necessary . . . "

This letter together with the appropriate response from CERN constitute the written understanding referred to in the aforementioned Section 4.6.

1. Unless otherwise indicated, correspondence related to Article IV of the Protocol should be between the Director, Division of High Energy Physics, D.O.E., or his designee, and the CERN Director General or his designee; the Director General has designated the LHC Project Leader to be responsible for this matter. This does not preclude informal contacts between staff.

2. CERN shall provide to D.O.E. copies of the solicitations, as released, for procurements planned under Article IV of the Protocol, and copies of award documents for all selected vendors including anticipated delivery and payment schedules.

3. In accordance with sections 4.1, 4.3 and 4.4 of the Protocol, CERN shall provide to DOE certifications, filled in by U.S. industrial firms that have been selected by CERN, certifying that these firms are U.S. firms, and that they will supply U.S. domestic end products to CERN.

4. CERN shall provide copies of vouchers or other documentation indicating in U.S. dollars payments to selected and approved U.S. vendors which will serve as the basis for authorizing refund payments to CERN. If a request for payment exceeds the funding available in a particular U.S. government fiscal year, a partial payment may be made with the balance of the payment to be made in a future fiscal year.

5. Payments to CERN will be in the form of deposits in U.S. dollars to a bank account to be opened by CERN at Bankers Trust Company, 280 Park Avenue, New York, NY 10017, after signature of the Co-operation Agreement.

6. Before the beginning of each U.S. Government fiscal year, CERN and the D.O.E. shall hold consultations regarding the financial expenditures and budget allocations to be made by the Parties in relation to their commitments under Article IV of the Protocol. These consultations shall include consideration of any projected shortfall in the D.O.E. payments to CERN at the end of each U.S. government fiscal year.

7. To that end, CERN will supply, at least annually, information on the funding which will be needed for planned purchases under Article IV of the Protocol. The D.O.E. will supply, at least annually, information on the funding which will be made available under the provisions of Article IV of the Protocol. This will ordinarily be at the beginning of the U.S. Government fiscal year. In response, CERN will provide a plan for utilization of these funds indicating vendor, amount, and timing of payments.

Sincerely,

John R. O'Fallon

John R. O'Fallon
Director
Division of High Energy Physics

Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

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Division of High Energy Physics
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Germantown, MD 20874-1290
United States of America

Votre référence/Your reference:
Notre référence/Our reference: DG/DI/LE/eb/97-26

Geneva, 19th December 1997

Dear Dr. O'Fallon,

I am in receipt of your letter dated 19 December 1997 which reads as follows:

"Article IV ("Procurement from Industry") of the Accelerator Protocol to the Co-operation Agreement between CERN, the Department of Energy, and the National Science Foundation, hereafter referred to as the Protocol, provides for the payment by the Department of Energy (D.O.E.) for items to be procured by CERN from U.S. industry. Section 4.6 of the Protocol refers to a "separate, written understanding with CERN specifying payment provisions and such additional details as may be necessary...".

This letter together with the appropriate response from CERN constitute the written understanding referred to in the aforementioned Section 4.6.

1. Unless otherwise indicated, correspondence related to Article IV of the Protocol should be between the Director, Division of High Energy Physics, D.O.E., or his designee, and the CERN Director General of his designee; the Director General has designated the LHC Project Leader to be responsible for this matter. This does not preclude informal contacts between staff.
2. CERN shall provide to D.O.E. copies of the solicitations, as released, for procurements planned under Article IV of the Protocol and copies of award documents for all selected vendors including anticipated delivery and payment schedules.
3. In accordance with sections 4.1, 4.3 and 4.4 of the Protocol, CERN shall provide to DOE certifications, filled in by U.S. industrial firms that have been selected by CERN, certifying that these firms are U.S. firms and that they will supply U.S. domestic end products to CERN.
4. CERN shall provide copies of vouchers or other documentation indicating in U.S. dollars payments to selected and approved U.S. vendors which will serve as the basis for authorizing refund payments to CERN. If a request for payment exceeds the funding available in a particular U.S. government fiscal year, a partial payment may be made with the balance of the payment to be made in a future fiscal year.

5. Payments to CERN will be in the form of deposits in U.S. dollars to a bank account to be opened by CERN at Bankers Trust Company, 280 Park Avenue, New York, NY 10017, after signature of the Co-operation Agreement.

6. Before the beginning of each U.S. Government fiscal year, CERN and the D.O.E. shall hold consultations regarding the financial expenditures and budget allocations to be made by the Parties in relation to their commitments under Article IV of the Protocol. These consultations shall include consideration of any projected shortfall in the D.O.E. payments to CERN at the end of each U.S. government fiscal year.

7. To that end, CERN will supply, at least annually, information on the funding which will be needed for planned purchases under Article IV of the Protocol. The D.O.E. will supply, at least annually, information on the funding which will be made available under the provisions of Article IV of the Protocol. This will ordinarily be at the beginning of the U.S. government fiscal year. In response, CERN will provide a plan for utilization of these funds indicating vendor, amount and timing of payments."

I am pleased to confirm to you that CERN is agreeable to the understanding contained in the above letter.

Sincerely,

Lyndon Evans
LHC Project Leader
European Organization for Nuclear Research

ANNEX II

Implementing Arrangement
to
The Accelerator Protocol
between
The European Organization for Nuclear Research (CERN)
and
The United States Department of Energy
concerning
Scientific and Technical Cooperation on the Large Hadron Collider

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 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

Implementing Arrangement to the Accelerator Protocol
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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

Implementing Arrangement to the Accelerator Protocol
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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 applicable)	CERN LHC Document No. (if applicable)	Created	Page
N/A	TIS-TE-MB-98-74	14-DEC-98	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.

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.

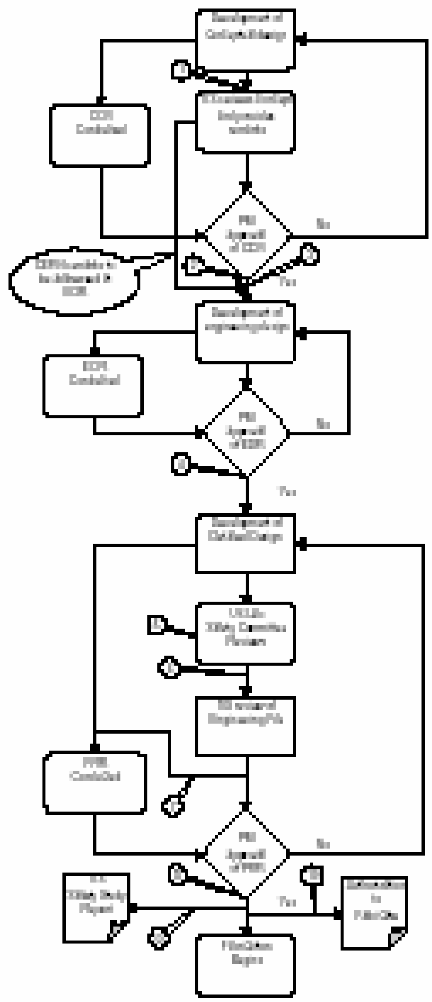
III. General Approach

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

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

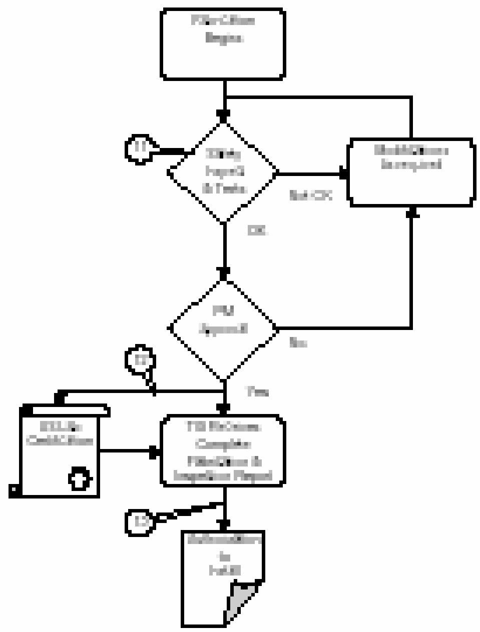
4. The US Project will provide TIS-TE with a copy of the official report documenting the EDR.
5. The safety structure of the relevant US Lab will monitor and assess the detailed design and the fabrication, inspection, and quality assurance plans to be followed.
6. Prior to the PRR the US Project will 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:

Helmut Schönbacher — Date
Head, Technical Inspection
and Safety Commission, CERN

Lyndon Evans — Date
Director
LHC Project Leader, CERN

Michael Harrison — Date
RHIC Associate Project Director
(Collider), BNL

Maurizio Bona — Date
Head, TIS-TE Group
CERN

Thomas Taylor — Date
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LHC Project Safety Officer,
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Research Division Head, LBNL

James Strait — Date
US LHC Accelerator Project
Manager, Fermilab