

U.S. Large Hadron Collider (U.S. LHC) Construction

**Project Execution Plan
(PEP)**

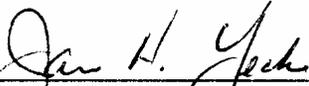
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**U.S. Department of Energy
and
U.S. National Science Foundation**

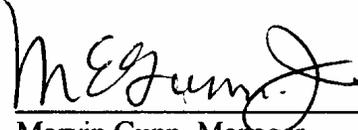
**U.S. LARGE HADRON COLLIDER CONSTRUCTION
PROJECT EXECUTION PLAN**

Submitted by:

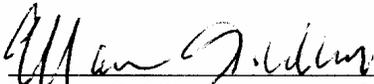
U.S. LHC PROJECT OFFICE

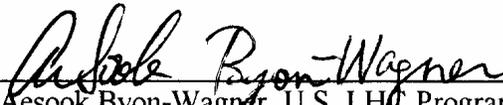

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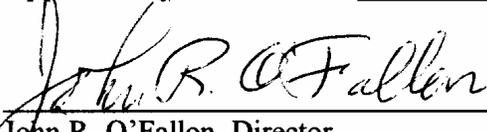
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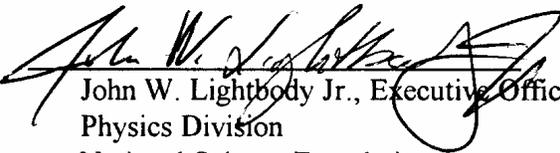

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ACRONYM LIST

ATLAS	<u>A Toroidal LHC ApparatuS</u>
BNL	Brookhaven National Laboratory
CERN	The European Laboratory for Particle Physics
CH	Department of Energy Chicago Operations Office
CMS	Compact Muon Solenoid
DOE	Department of Energy
ES&H	Environmental, Safety, and Health
Fermilab	Fermi National Accelerator Laboratory
GeV	Billion Electron Volts (giga electron volts)
HEP	High Energy Physics
HEPAP	High Energy Physics Advisory Panel
IA	Implementing Arrangement
IPA	Intergovernmental Personnel Act
JOG	Joint Oversight Group
LBNL	Lawrence Berkeley National Laboratory
LHC	Large Hadron Collider
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act
NSF	National Science Foundation
PEP	Project Execution Plan
PMP	Project Management Plan
SC	Department of Energy Office of Science
SSC	Superconducting Super Collider
TEC	Total Estimated Cost
TeV	Trillion Electron Volts (tera electron volts)
TPC	Total Project Cost
U.S.	United States
U.S. ATLAS	U.S. participation in the ATLAS detector
U.S. CMS	U.S. participation in the CMS detector
U.S. LHC	U.S. participation in the LHC
U.S. LHC Accelerator	U.S. participation in the LHC machine
WBS	Work Breakdown Structure

1. Introduction

The European Laboratory for Particle Physics, CERN, in collaboration with the U.S. and other non-Member States, has undertaken construction of a new high energy physics research facility, the Large Hadron Collider (LHC) at its laboratory site outside Geneva, Switzerland. This facility will include the LHC accelerator and two very large, general purpose detectors, ATLAS (A Toroidal LHC Apparatus) and CMS (Compact Muon Solenoid). The accelerator is designed to collide two counter rotating proton beams, at a center-of-mass collision energy of 14 TeV, the highest in the world. The products of these collisions will be detected and recorded by ATLAS and CMS, which are being built by large international collaborations of universities and laboratories including many in the U.S. CERN has responsibility for construction and operation of the LHC accelerator. In addition, CERN is contributing to the construction of, and is providing coordination and administrative support for, the ATLAS and CMS detectors and their research program.

The U.S. high energy physics community, acting through various advisory committees and national studies, has conveyed to the U.S. Department of Energy (DOE) and the U.S. National Science Foundation (NSF) that participation of U.S. high energy physicists in the LHC scientific program is required to provide access for the U.S. to the high energy frontier. U.S. participation in the LHC will maintain the U.S. as a world leader in this area of science. In response to this, and after extensive reviews and in close coordination and consultation with other elements of the Administration and with the Congress, the DOE and NSF have jointly negotiated and signed an agreement and protocols with CERN for U.S. participation in construction of the LHC accelerator and in the international collaborations for design, fabrication and operation of the ATLAS and CMS detectors that will carry out the LHC scientific program. The U.S. participation in the construction of the LHC accelerator and in the design and fabrication of the ATLAS and CMS detectors is hereinafter referred to as the U.S. LHC Construction Project. U.S. participation in the international scientific program is hereinafter referred to as the U.S. LHC Research Program.

The U.S. LHC Construction Project consists of those day-to-day activities specifically required for the U.S. participating universities and national laboratories to execute the construction and delivery of the scientific and technical components ("deliverables") agreed to by the DOE, NSF, and CERN. The U.S. LHC Research Program consists of those activities related to active participation in the operation of the detectors and subsequent analysis and publication of the physics results from the experiments. Collectively, the U.S. LHC Construction Project and the U.S. LHC Research Program constitute the U.S. LHC Program. The NSF and DOE have chosen to treat these activities as a single overall program, subject to the normal review and oversight procedures of each agency for its respective components.

DOE and NSF responsibilities for the U.S. involvement in the construction of the LHC machine and experiments are set forth in three documents. The International Cooperation Agreement Concerning Scientific and Technical Cooperation on the Large Hadron Collider Activities of December 8, 1997, hereinafter called the International Agreement, defines the U.S. responsibilities common to all parts of the LHC Construction activities. The Experiments Protocol Concerning Scientific and Technical Cooperation on the Large Hadron Collider ATLAS and CMS Detectors of December 19, 1997, hereinafter called the Experiments Protocol, describes DOE and NSF responsibilities to the detector projects. Finally, only DOE has responsibilities for U.S. participation in the LHC accelerator construction, and these are set forth in the Accelerator Protocol of December 19, 1997, hereinafter called the Accelerator Protocol. The lines of authority and responsibilities for the management of the U.S. LHC Construction Project are described in the U.S. LHC Construction Project Execution Plan (PEP).

1.1 Purpose and Structure

DOE and NSF have executed a Memorandum of Understanding (MOU) that defines the relationship between the two agencies relative to programmatic coordination of U.S. participation in LHC construction Activities, Appendix 1. The MOU establishes a Joint Oversight Group (JOG) as the highest level of joint U.S. LHC Program management. As defined in the MOU, the U.S. LHC Project Execution Plan (PEP) for the construction program is the governing document for the management structure from the JOG through the U.S. ATLAS, U.S. CMS and U.S. LHC Accelerator Projects. The specific management arrangements for these projects are described in their individual Project Management Plans that are incorporated herein as Appendices.

The PEP describes: mission need and justification; scope, goals and risks; management structure; management systems; and environment, safety, and health requirements. It is structured as a base document with appendices. The base document establishes the general approach for project execution. The appendices are divided into two parts. Part 1 includes the DOE/NSF MOU (which includes the International Agreement and Experiments and Accelerator Protocols) along with tables of U.S. LHC Governing Documentation and Key Personnel. Part 2 includes the Project Management Plans for the U.S. LHC Construction Project.

The U.S. LHC PEP serves three basic functions. First, it describes the project management and execution processes for the U.S. LHC Construction Project. As approved by the JOG, the PEP constitutes the authorizing document for the method of project execution and therefore has precedence. Second, the PEP establishes the project baselines (technical, cost, and schedule) against which project execution will be measured. Changes to project execution will be evaluated in terms of baseline impacts, and approved by appropriate levels of management as described in this document. Third, the PEP serves as the primary reference document for all levels of the project team. Project requirements, policies and procedures flow from the PEP.

1.2 Approval and Revisions

The Joint Oversight Group (JOG) Co-chairs approve the PEP and subsequent changes. Approval of the Project Management Plans for the U.S. LHC Construction Project and the project baselines rests with the JOG. Changes to the PEP will be processed and approved by the appropriate management levels and submitted to the JOG for final approval.

2. Project Need

2.1 Mission Need

U.S. participation in the LHC is required to provide access for the U.S. High Energy Physics program to the high energy frontier in order to maintain the U.S. as a world leader in this area of science.

In the early 1980's, the high energy physics community determined that continued progress over the long term would require a much higher energy accelerator facility than the existing 1 TeV facility at Fermilab. This was the genesis of the Superconducting Super Collider (SSC) in the U.S. and the LHC in Europe. When Congress terminated the SSC in October 1993, the LHC became the only new facility able to address many of the critical questions in the field. It will provide a factor-of-seven advance in the energy frontier, presently being explored with the 1-TeV beams of the Fermilab Tevatron collider. The primary physics goals of the LHC include:

1. The Question of Mass What is the origin of the different particle masses, and in particular how do the Z and W particles acquire masses around 91 and 80 GeV, respectively, while the related photon remains massless? This question is the basis of the search for the Higgs boson that is thought to be responsible for particle masses.
2. The Question of Flavor Why is there such a proliferation of quark and lepton species, and what explains their bizarre pattern of masses and couplings to the W, including the appearance of Charge-Parity (CP) violation? This question is the basis for understanding the dominance of matter over antimatter in the universe.
3. The Question of Unification Can the gauge theories of the electroweak interactions (the theory of the force that governs radioactive decay) be combined with quantum chromodynamics (the theory of the strong nuclear interactions) in a Grand Unified Theory (GUT), and perhaps with gravity in a Theory of Everything? This is the basis for the search for supersymmetry.

In summary this program will impact our understanding of the relation of mass, fundamental forces, and the structure and origin of the universe. The LHC will be

sensitive to a variety of possible new particles and phenomena not predicted by the Standard Model, including new W and Z bosons or additional quark or lepton species.

Following the cancellation of the SSC, a High Energy Physics Advisory Panel (HEPAP) subpanel on **Vision for the Future of High-Energy Physics**, chaired by Professor Sidney D. Drell, was asked for recommendations on the direction of the U.S. HEP program. One of its recommendations was that the U.S. “should continue to be among the leaders in the worldwide pursuit of the fundamental questions of particle physics” and should continue its tradition of success in this field through a strong U.S. program that includes “significant participation in the LHC accelerator and detectors, both to provide research opportunities at the energy frontier and to ensure that U.S. physicists remain integrated in the international high-energy physics community.”

Since that time HEPAP and NSF Special Emphasis panels have reiterated its support for U.S. participation in the LHC on several occasions. In February 1998 a HEPAP subpanel, chaired by Professor Frederick Gilman, strongly endorsed the physics goals of the LHC and U.S. participation in the accelerator project and in the ATLAS and CMS experiments.

2.2 Justification

NSF and DOE are the principal sources of support for the nation’s elementary particle physics. The U.S. high energy physics community, acting through various advisory committees and national studies, has conveyed to the DOE and NSF that participation of the U.S. in the LHC scientific program is required to provide access for the U.S. to the high energy frontier. In response to this advice and after extensive reviews, and in close coordination and consultation with other elements of the Administration and with the Congress, the DOE and NSF have jointly negotiated agreements with CERN for U.S. participation in the LHC program. On December 8, 1997, DOE, NSF, and CERN signed an International Co-operation Agreement Concerning Scientific and Technical Co-operation on Large Hadron Collider Activities. An Accelerator Protocol and an Experiments Protocol concerning Scientific and Technical Cooperation on the LHC construction and on the ATLAS and CMS Detectors were subsequently signed on December 19, 1997. These agreements provide the principal justification for the U.S. LHC Construction Project and the U.S. LHC Research Program.

3. Project Description

3.1 Project Scope

The U.S. LHC Construction Project is defined by the goods and services to be provided to CERN for the LHC Project under the terms of the International Cooperation Agreement between CERN, DOE and NSF. In accordance with the Agreement and Protocols, DOE is solely responsible for providing funding of \$200 million for goods and services for the LHC accelerator construction. In addition, DOE and NSF are responsible for providing funding of \$250 million and \$81 million, respectively, for goods and

services toward the fabrication of the ATLAS and CMS detectors. The DOE contribution of \$450 million is budgeted from FY 1996 through FY 2007, and the NSF contribution of \$81 million is budgeted from FY 1999 through FY 2003.

The DOE contribution to the LHC accelerator consists of items provided by U.S. National Laboratories and reimbursement for CERN direct purchases from U.S. industrial firms. The scope of these contributions is addressed in the Accelerator Protocol (Appendix 1) and, in detail, in the Implementing Arrangement to the Accelerator Protocol. The Implementing Arrangement is an appendix to the U.S. LHC Accelerator Project Management Plan (Appendix 2.A).

The DOE and NSF contributions to the LHC experiments consist of components and systems for the ATLAS and CMS detectors provided by the collaborating U.S. universities and national laboratories. The scope of these contributions is addressed in the Experiments Protocol (Appendix 1), and, in detail, in Memoranda of Understanding for each experiment. These Memoranda of Understanding are between CERN, as host laboratory, and the Institutes/Funding Agencies of the ATLAS and CMS collaborations. DOE and NSF have chosen not to sign these MOUs but to send a letter to CERN endorsing the sets of deliverables agreed to by the U.S. ATLAS and U.S. CMS collaborations.

3.2 Goals and Risks

The primary goal of U.S. scientific and technical cooperation on the LHC is to maintain the excellence of the U.S. high energy physics program by providing U.S. high energy physicists access to science at the energy frontier. The U.S. participation in the LHC will provide U.S. physicists with access to the LHC research program. The timely construction of the LHC will maintain the research momentum in the field of high energy physics established over the past decades.

The U.S. participation in the LHC presents a significant opportunity for U.S. scientists and engineers to stay at the cutting edge of accelerator and detector technology, providing positive impacts on many fields of science, not just particle physics. Such involvement will significantly contribute to the training of the next generation of U.S. physicists, and should help pave the way for even larger scientific collaborations in the future. In addition, the U.S. ATLAS and CMS collaborations have a common goal to actively promote educational programs associated with the discoveries to be made at the energy frontier. The intended audiences for these educational activities are the general public, secondary school students, undergraduates, and primary school teachers.

The actual scope of the U.S. LHC Construction Project will be based on maximizing the value of the U.S. contribution to the LHC within authorized funding. The U.S. contributions to the LHC accelerator and detectors will involve state-of-the-art technology that in some cases is a modest extension of existing capabilities. Potential sources of schedule risk include potential reductions in the authorized funding profile for

U.S. LHC activities and deviation from the published schedules for ATLAS, CMS, and the LHC machine.

The responsibility for the success of the LHC program rests with CERN. In accordance with the Agreement, the U.S. is represented in key management bodies at CERN. These relationships, described in section the DOE/NSF MOU, provide opportunities for the U.S. to assess progress on the LHC and to resolve issues that present risk to the program.

3.3 Resource Plans

In accordance with the International Agreement and Protocols, DOE is solely responsible for providing funding of \$200 million for goods and services for the LHC accelerator construction. In addition, DOE and NSF are responsible for providing funding of \$250 million and \$81 million, respectively, for goods and services toward the fabrication of the ATLAS and CMS detectors. For the U.S. LHC Construction Project, the DOE contribution of \$450 million is budgeted from FY 1996 through FY 2007 and the NSF contribution of \$81 million is budgeted from FY 1999 through FY 2003. The U.S. has formally agreed to these fixed contributions as per the International Agreement. Table 1 provides profiles for U.S. LHC Construction Project funding, both the original and current (FY02) profiles, as well as the profile revision needed to support the baseline change in U.S. LHC Construction project completion .

Additional resources for the U.S. LHC Research Program are required to enable participation in LHC accelerator commissioning and in the LHC ATLAS and CMS experiments, as provided for in the framework of the International Agreement. These resources are analagous to the pre-operational and operational phases of a new research facility, and are complementary to the funding provided for the U.S. LHC Construction Project. DOE and NSF have consulted with the U.S. LHC collaborations to develop long-range funding profile and mechanisms for implementing this Research Program. Within the U.S. LHC Research Program, DOE will have primary responsibility for funding national laboratory-based activities, such as regional centers for computing located at the U.S. Host Laboratories. DOE and NSF will continue their traditional program support of activities at U.S. universities participating in the LHC Collaborations, and will be jointly responsible for other needed CERN-based and University-based support activities.

Table 1 U.S. LHC Construction Project Funding (\$M)

	<i>FY96</i>	<i>FY97</i>	<i>FY98</i>	<i>FY99</i>	<i>FY00</i>	<i>FY01</i>	<i>FY02</i>	<i>FY03</i>	<i>FY04</i>	<i>FY05</i>	<i>FY06</i>	<i>FY07</i>	<i>Total</i>
Original													
DOE	6.00	15.00	35.00	65.00	70.00	70.00	70.00	65.00	54.00	0	0	0	450.00
NSF	0	0	0	22.15	15.90	16.37	16.86	9.72	0	0	0	0	81.00
Total	6.00	15.00	35.0	87.15	85.90	86.37	86.86	74.72	54.00	0	0	0	531.00
Current¹													
DOE	6.00	15.00	35.00	65.00	70.00	58.87	49.00	60.00	60.00	31.13	0	0	450.00
NSF	0	0	0	22.15	15.90	16.37	16.86	9.72	0	0	0	0	81.00
Total	6.00	15.00	35.00	87.15	85.9	75.24	65.86	69.72	60.00	31.13	0	0	531.00
Revised²													
DOE	6.00	15.00	35.00	65.00	70.00	58.87	49.00	60.00	48.80	31.71	7.44	3.18	450.00
NSF	0	0	0	22.15	15.90	16.37	16.86	9.72	0	0	0	0	81.00
Total	6.00	15.00	35.00	87.15	85.90	75.24	65.86	69.72	48.80	31.71	7.44	3.18	531.00

¹ As of end of FY02

² As of the CD-4 rebaseline of FY03

4. Project Management Structure

4.1 Management Approach

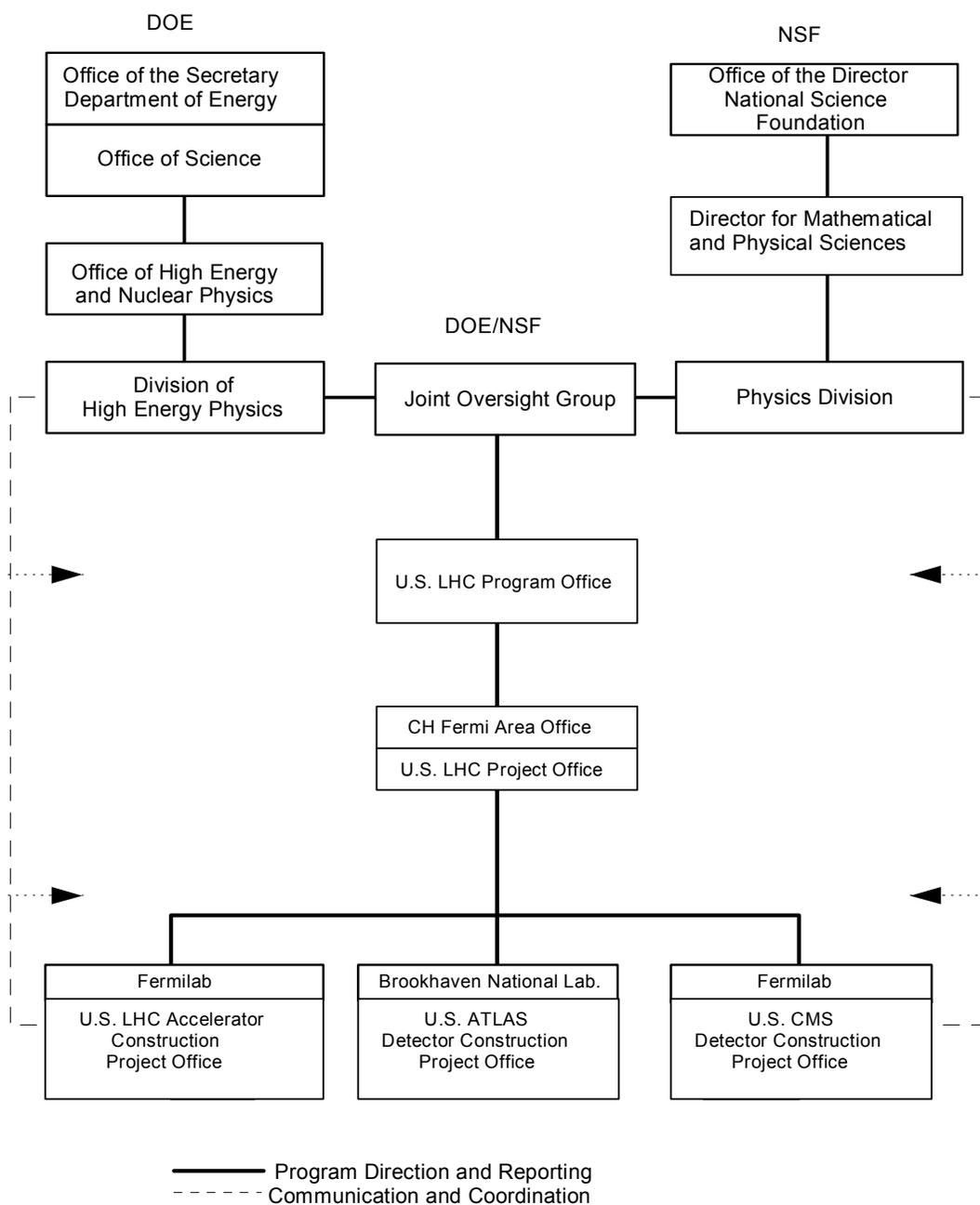
This document describes the primary management roles and responsibilities for the U.S. LHC Program from the highest level of joint U.S. LHC program management, the Joint Oversight Group (JOG), through and including the project offices of the U.S. LHC Projects. Each of these projects has its own individual project management plan included in the Appendices. The relationship of the U.S. Construction Project with CERN is defined in the International Co-operation Agreement (the Agreement) and protocols and described in section the DOE/NSF Memorandum of Understanding.

The U.S.-CERN collaboration in construction of the LHC and its detectors poses a unique management challenge, both internationally and nationally, for the U.S. program in high energy physics. To meet that challenge, the DOE and NSF have established, through an Interagency Memorandum of Understanding, a unique joint agency organization to provide the necessary oversight to ensure effective management of the U.S. activities in support of the collaboration.

Overall Federal responsibility for programmatic management resides in the DOE-NSF Joint Oversight Group (JOG) which was created by the Memorandum of Understanding. The members of the JOG are Federal employees from the two respective agencies whose responsibility is to oversee the NSF and DOE supported LHC activities. As detailed below, the JOG will be supported by the U.S. LHC Program Office located at DOE and NSF Headquarters and a U.S. LHC Project Office located at the DOE Fermi Area Office that resides at Fermi National Accelerator Laboratory (Fermilab).

The specific technical and managerial expertise to design and produce the U.S. in-kind contributions resides at universities and the national laboratories participating in the U.S. LHC Collaboration. DOE and NSF have appointed Fermilab to be the Host Laboratory for U.S. participation in the CMS detector collaboration, and Brookhaven National Laboratory (BNL) to be the Host Laboratory for U.S. participation in the ATLAS detector collaboration. In their roles as Host Laboratories, BNL and Fermilab provide both management and technical oversight for the U.S. ATLAS and CMS projects, and support for the respective managers of these projects. The managers of these projects are to be drawn from the staffs of the National Laboratories or the participating universities. Fermilab also serves as the lead laboratory for the U.S. LHC Accelerator Project. The U.S. LHC Accelerator Project Manager is to be a Fermilab employee who is responsible for technical coordination and management of the LHC accelerator hardware to be provided by a collaboration comprised of BNL, Fermilab, and the Lawrence Berkeley National Laboratory (LBNL). The line management organization is shown in Figure 4.1, U.S. LHC Construction Project Organization, and described in detail in subsequent sections of this PEP. The figure also depicts representative lines of communication and coordination between project participants. It is recognized that the success of the three U.S. LHC projects depends on both the clear definition of a line management organization and on the frequent communication and coordination that traditionally takes place between the funding agencies and their research institutions.

**Figure 4.1
U.S. LHC Construction Project Organization**



The details of the U.S. ATLAS, U.S. CMS and U.S. LHC Accelerator project organizations are contained in their respective Project Management Plans.

4.2 Joint Oversight Group

The Joint Oversight Group (JOG) has the responsibility to see that the U.S. LHC Program is effectively managed and executed so as to meet the commitments made to CERN under the International Agreement and its Protocols. The JOG provides programmatic

guidance and direction for the U.S. LHC Construction Project and the U.S. LHC Research Program and coordinates DOE and NSF policy and procedures with respect to both. The JOG approves and oversees the implementation of the U.S. LHC Project Execution Plan (PEP) and the individual Project Management Plans (PMPs) which are incorporated into the PEP.

Specific responsibilities of the JOG are:

1. approval of the initial scope, cost, and schedule baselines and subsequent changes to the baselines at Level 1 of the Work Breakdown Structure (WBS) for the U.S. LHC Projects;
2. approval of the PEP and the attendant project management plans and any modifications thereto;
3. formal concurrence on the assignment of DOE and NSF employees to the positions of the U.S. LHC Program Manager, Associate U.S. LHC Program Manager, and U.S. LHC Project Manager;
4. formal concurrence on the assignments of designated university staff or DOE national laboratory staff as managers of the U.S. LHC Program activities ;
5. ensuring that technical, cost, schedule and management reviews are conducted in a timely and effective manner;
6. reviewing plans, budgets, and status reports;
7. reviewing the DOE and NSF funding plans to assess their impact on the optimal execution of the objectives of the U.S. LHC Program;
8. monitoring developments in the LHC Program and its related activities at CERN;
9. reporting to senior NSF and DOE officials on major developments in, and external events affecting, the U.S. LHC Program; and,
10. identifying and forward issues to the U.S. Co-Chair of the Cooperation Committee and to other DOE and NSF officials, as appropriate.

In addition to the joint oversight functions described above, the JOG shall identify and resolve those issues that cannot be resolved at lower levels of the management structure. Those issues that cannot be resolved at the JOG level will be referred to individuals within the NSF and DOE as are appropriate to the issue at hand. The JOG shall also perform such other activities as it deems appropriate and are within its programmatic responsibilities.

The JOG is co-chaired by the Director of the DOE Division of High Energy Physics and the Director of the NSF Division of Physics. They report, respectively, to the Associate Director for High Energy and Nuclear Physics at the DOE and the Assistant Director for Mathematical and Physical Sciences at the NSF. Either Co-Chairs may delegate authority within the agency. In the event of such delegation, the other Co-Chair shall be formally notified in writing.

Membership in the JOG is by mutual agreement of the Co-Chairs and shall be limited to Federal employees and Intergovernmental Personnel Act (IPA) appointees. While meetings of the JOG may be limited to the Co-Chairs, they will typically include the U.S.

LHC Program Manager, the Associate U.S. LHC Program Manager, the U.S. LHC Project Manager, appropriate staff from DOE's Office of High Energy and Nuclear Physics and NSF's Division of Physics, and appropriate university and laboratory leadership involved in the execution of the U.S. LHC Program.

The JOG will meet at least semi-annually. In the event that the JOG cannot meet, the duties of the JOG can be discharged by the mutual agreement of both co-chairs. Those agenda items for JOG meetings that require separate agency review will be identified approximately one month prior to the JOG meeting date.

4.3 U.S. LHC Program Office

Program management activities are considered to be those which would normally be carried out by NSF and DOE program divisions separately in preparing and defending budget requests within the agencies, to the Executive Branch, and before the Congress; in the allocation of funds within the government, to universities or to national laboratories; and in oversight of the activities funded.

The U.S. LHC Program Office is established to carry out the management functions set forth in the MOU, this PEP, and the PMPs. The program office is staffed by Federal employees or IPA appointees assigned by the DOE and NSF. As the DOE has been designated "lead agency" for the U.S. LHC Program, the U.S. LHC Program Manager that heads the program office will generally be a DOE employee. The Associate U.S. LHC Program Manager will generally be an NSF employee.

The U.S. LHC Program Office has the overall responsibility for day-to-day program management of the U.S. LHC Program. In this capacity, it reports directly to the JOG and acts as its executive arm. The office is jointly responsible with the U.S. LHC Project Office for preparation and maintenance of the PEP, and interfaces with the DOE Division of High Energy Physics and the NSF Division of Physics, which are the respective agency offices charged with the responsibility to oversee the U.S. LHC Program. The Program Manager and Associate Program Manager are responsible for the coordination between the agencies of the joint oversight activities described in the MOU and this PEP. In particular, the Program Office will arrange for appropriate agency clearances of the PEP, PMPs, and other documents as may be required, as well as the accomplishment of project reviews as charged by the JOG or as deemed necessary for effective program management. These reviews will be held at least annually. In addition, the Program Office will coordinate: interactions with the Congress in response to official inquiries, testimony, or discussion; initiatives in education; public outreach activities; and, release of public information.

Specific responsibilities of the U.S. LHC Program Office are:

1. coordinating project needs with DOE Headquarters and NSF;
2. providing programmatic guidance and direction to the U.S. LHC Project Office;
3. ensuring that DOE and NSF funding is distributed to the U.S. LHC projects on a timely basis;

4. concurrence on the assignment of a Federal employee as the U.S. LHC Construction Project Manager, and on the assignments of university or DOE national laboratory staff as the managers of the U.S. LHC Program activities;
5. reviewing and recommending approval of project planning documents including the PEP and the attendant PMPs and any modifications thereto;
6. reviewing and recommending approval of project baselines and subsequent changes to the baselines at Level 1 of the Work Breakdown Structure for the U.S. LHC Projects;
7. concurrence on the funding allocations to universities and laboratories proposed by the managers of the U.S. LHC Program activities;
8. conducting technical, cost, schedule and management reviews of the U.S. LHC Projects in a timely and effective manner;
9. ensuring adequate project reporting to meet DOE and NSF program requirements;
10. providing staff support and serve as the executive secretary to the JOG;
11. ensuring joint agency concurrence on all Program Office responsibilities. Items where concurrence is not achieved will be referred to the JOG;
12. serving as the primary interface with the U.S. LHC Project Manager on a day-to-day basis; and,
13. identifying and recommending solutions to the JOG for those issues that could not be resolved at lower levels.

4.4 U.S. LHC Project Office

The DOE Chicago Operations Office (CH) has the contract management responsibility for DOE's performance based management contracts with Fermilab and BNL, which are the host/lead laboratories for the U.S. LHC projects. The Fermi Area Office and Brookhaven Area Office are the responsible DOE offices on site at Fermilab and BNL that provide the day-to-day DOE oversight of these laboratories. The Fermi Area Office is to be the home of the U.S. LHC Project Office. The Fermi Area Office Manager will delegate to the U.S. LHC Project Manager the authority for day-to-day implementation and direction of the project. The Fermi Area Office Manager will provide support from Fermi Area Office staff when necessary and appropriate. NSF personnel may be added to the U.S. LHC Project Office as appropriate.

The U.S. LHC Project Office is established to carry out the management functions set forth in the MOU, this PEP, and the PMPs for each of the U.S. LHC Construction Projects. The project office is staffed by Federal employees or IPA appointees assigned by the DOE and NSF. As the DOE has been designated "lead agency" for the U.S. LHC Program, the U.S. LHC Project Manager that heads the project office will generally be a DOE employee.

The U.S. LHC Project Office, led by the U.S. LHC Project Manager, provides day-to-day project management and support for the U.S. LHC Projects. The U.S. LHC Project Office receives guidance and direction from the U.S. LHC Program Office and serves as the day-to-day contact for the DOE and NSF on issues specific to each of the U.S. LHC Projects.

Specific responsibilities of the U.S. LHC Project Office are:

1. reviewing and recommending approval of project planning documents including the U.S. LHC Construction Project Execution Plan (PEP) and the attendant project management plans (PMP)s and any modifications thereto for each of the three U.S. LHC projects;
2. reviewing and recommending approval of project baselines and evaluating project performance against such baselines;
3. implementing procedures for baseline management and control and approving changes to the baselines at Level 2 of the Work Breakdown Structure and recommend changes or corrective action to Level 1 baselines;
4. control contingency for the three U.S. LHC projects within levels established in the project management plans;
5. define the expectations for the project management systems for the U.S. LHC Construction projects;
6. conduct regular reviews of the U.S. LHC Construction projects and participate in U.S. ATLAS, U.S. CMS, and U.S. LHC Accelerator reviews as appropriate;
7. participate in and provide support for the U.S. LHC Program Office peer reviews and reviews by oversight committees;
8. maintain close contact with the participating universities and national laboratories to assist in expediting the activities of the U.S. LHC Construction projects;
9. ensure compliance by the individual U.S. LHC Projects with DOE, NSF, and CERN requirements as appropriate, e.g., ES&H and contracting regulations;
10. identify and arbitrate unresolved issues within the individual project organizations;
11. prepare quarterly reports and such other reports on the status of the U.S. LHC Construction projects for DOE and NSF management as required in this Project Execution Plan and applicable DOE and NSF agency requirements;
12. manage all of the project office documentation; and,
13. keep DOE and NSF management informed on significant project issues and events in a timely manner.
14. provide assistance and coordination on the planning for the U.S. LHC Research Program.

4.5 U.S. CMS Detector Construction Project

4.5.1 Fermilab

The DOE and NSF have jointly assigned management oversight responsibility for the U.S. CMS detector project to the Fermi National Accelerator Laboratory (Fermilab). The Fermilab Director has the responsibility to ensure that the detector effort is soundly managed, that technical progress proceeds in a timely way, that technical or financial problems are identified and properly addressed, and that an adequate management organization is in place and functioning. The Fermilab Director may delegate certain responsibilities and authorities to a duly appointed Fermilab staff member. The Director or his designee is responsible for day-to-day management oversight of the project; the U.S. CMS Project Office reports to him.

Specific responsibilities of the Fermilab Directorate are:

1. acting on recommendations of the U.S. CMS Collaboration, appoint the U.S. CMS Construction Project Manager, subject to the concurrence of the Joint Oversight Group;
2. establish an advisory structure external to the U.S. CMS project for the purpose of monitoring both management and technical progress for all U.S. CMS activities;
3. ensure that the Construction Project Manager has adequate staff and support, and that U.S. CMS management systems at Fermilab are matched to the needs of the project;
4. consult regularly with the U.S. CMS Construction Project Manager to ensure timely resolution of management challenges;
5. review and concur on the international Memoranda of Understanding with CERN that specifies U.S. CMS project deliverables funded by DOE and NSF;
6. review and concur with the institutional Memoranda of Understanding for the U.S. CMS collaborating institutions that specify the deliverables to be provided and the resources available for each institution;
7. ensure that accurate and complete project reporting to the DOE and NSF is provided in a timely manner; and,
8. review and approve Level 3 baseline changes as prescribed in the U.S. CMS Project Management Plan.

4.5.2 U.S. CMS Project Office

The U.S. CMS Construction Project Manager leads the U.S. CMS Project and serves as head of the Project office that resides at Fermilab. The U.S. CMS Construction Project Manager is appointed by the Fermilab Director subject to concurrence of the Joint Oversight Group. He/she serves as the Level 1 manager and has the primary responsibility of completing the project within the approved scope, within budget, and on schedule. He/she is also responsible to ensure that the project's technical goals support the planned physics program and that those goals are achieved.

Specific responsibilities of the U.S. CMS Construction Project Manager are :

1. represent the U.S. CMS Project in interactions with CMS, CERN, and DOE/NSF;
2. appoint, after consultation with the U.S. CMS Collaboration, the U.S. CMS subsystem managers;
3. working with Fermilab, establish a project office with appropriate staff services;
4. develop the project scope and integrated cost and schedule plans consistent with available funding and ensure that the project scope is congruent with the international CMS Memorandum of Understanding with CERN;
5. prepare annual funding requests to the DOE and NSF and recommend funding allocations to the U.S. CMS institutes;
6. prepare institutional memoranda of understanding for the U.S. CMS collaborating institutions and annual Statements of Work for each institution;
7. complete the U.S. CMS scope of work on schedule and within the authorized budget as described in the approved U.S. CMS project baseline documents;

8. prepare and approve Level 3 baseline changes as prescribed in the U.S. CMS Project Management Plan; and,
9. ensure that all elements of the project conform to applicable U.S. and CERN ES&H and Quality Assurance requirements.

4.6 U.S. LHC Accelerator Construction Project

4.6.1 Fermilab

The DOE has selected Fermilab as the Lead Laboratory for the U.S. LHC Accelerator Project. Fermilab has management oversight responsibility for the U.S. LHC Accelerator Project composed of a collaboration of Fermilab, BNL, and LBNL. The Fermilab Director has the responsibility to ensure that the U.S. LHC Accelerator Project is soundly managed, that technical progress proceeds in a timely manner, that technical or financial problems are identified and properly addressed, and that an adequate management organization is in place and functioning. This oversight responsibility is exercised in consultation with the Directors of the other laboratories so as to ensure that the goals of the Project as a whole are achieved at all three laboratories.

Primary responsibilities of the Fermilab Directorate are:

1. appoint the U.S. LHC Accelerator Project Manager, subject to the approval of the Joint Oversight Group;
2. establish an advisory structure external to the U.S. LHC Accelerator Project for the purpose of monitoring both management and technical progress;
3. ensure that the U.S. LHC Accelerator Project Manager has adequate staff and support, and that the management systems at Fermilab for the project are matched to the needs of the project;
4. consult regularly with the U.S. LHC Accelerator Project Manager to ensure timely resolution of management issues;
5. sign the Implementing Arrangement with CERN specifying deliverables to be provided by the U.S. LHC Accelerator Project funded by DOE;
6. review and concur in the U.S. LHC Accelerator Project Management Plan;
7. review and approve baseline changes as prescribed in the U.S. LHC Project Execution Plan and U.S. LHC Accelerator Project Management Plan; and,
8. ensure that accurate and complete project reporting to the DOE is provided in a timely manner.

4.6.2 U.S. LHC Accelerator Project Office

The U.S. LHC Accelerator Project Manager leads the U.S. LHC Accelerator Construction Project and serves as the head of the Project Office that resides at Fermilab. The U.S. LHC Accelerator Project Manager is appointed by the Fermilab Director subject to concurrence of the Joint Oversight Group and the Directors of the participating laboratories. The Project Manager 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.

The U.S. LHC Accelerator Project Manager is the primary interface for CERN and DOE/NSF. He/she is responsible for maintaining a national view and to work to achieve the goals of the project without bias among the participating laboratories.

Specific responsibilities of the U.S. LHC Accelerator Project Manager are:

1. provide general administration, planning, organization, and control on a day-to-day basis to complete the U.S. LHC Accelerator Project technical objectives on schedule and within the authorized budget;
2. prepare and recommend approval of the Implementing Arrangement as called for in the U.S.-CERN Accelerator Protocol and of the U.S. LHC Accelerator Project Management Plan;
3. establish design criteria for all project hardware and establish standards used to satisfy the project baseline technical requirements;
4. review and approve designs and specifications to satisfy project functional requirements and ensure that all elements of the project conform to applicable U.S. and CERN ES&H and Quality Assurance requirements;
5. ensure that an adequate project management control and reporting system is in place and functioning;
6. develop the project scope and integrated cost and schedule plans that are consistent with funding plans;
7. prepare and approve baseline changes as prescribed in the U.S. LHC Accelerator Project Management Plan;
8. prepare annual work authorizations for each WBS Level 3 task; and,
9. advise DOE on matters related to DOE payments to CERN for their purchases from U.S. vendors as specified in Article IV of the U.S.-CERN Accelerator Protocol.

4.7 U.S. ATLAS Detector Construction Project

4.7.1 Brookhaven National Laboratory

The DOE and NSF have jointly assigned management oversight responsibility for the U.S. ATLAS detector project to the Brookhaven National Laboratory (BNL). The BNL Director has the responsibility to ensure that the detector effort is soundly managed, that technical progress proceeds in a timely way, that technical or financial problems are identified and properly addressed, and that an adequate management organization is in place and functioning. The BNL Director may delegate certain responsibilities and authorities to the Associate Laboratory Director for High Energy and Nuclear Physics. The BNL Director or his/her designee is responsible for day-to-day management oversight of the project and the U.S. ATLAS Project Manager reports to him/her.

Primary responsibilities of the BNL Directorate are:

1. acting on recommendations of the U.S. ATLAS Collaboration, appoint the U.S. ATLAS Project Manager, subject to the concurrence of the Joint Oversight Group;

2. establish an advisory structure external to the U.S. ATLAS project for the purpose of monitoring both management and technical progress for all U.S. ATLAS activities;
3. ensure that the U.S. ATLAS Project Manager has adequate staff and support, and that U.S. ATLAS management systems at BNL are matched to the needs of the project;
4. consult regularly with the U.S. ATLAS Project Manager to ensure timely resolution of management challenges;
5. review and concur with the international Memoranda of Understanding with CERN that specifies the U.S. ATLAS project deliverables funded by DOE and NSF;
6. review and concur with the institutional Memoranda of Understanding for the U.S. ATLAS collaborating institutions that specify the deliverables to be provided and the resources available for each institution;
7. ensure that accurate and complete project reporting to the DOE and NSF is provided in a timely manner; and,
8. review and approve Level 3 baseline changes as prescribed in the U.S. ATLAS Project Management Plan.

4.7.2 U.S. ATLAS Project Office

The U.S. ATLAS Project Manager leads the U.S. ATLAS Project and serves as the head of the Project Office that resides at BNL. The U.S. ATLAS Project Manager is appointed by the BNL Director subject to concurrence of the Joint Oversight Group. The Project Manager provides project management and technical coordination for the U.S. ATLAS effort as defined in the U.S. ATLAS Project Management Plan.

Specific responsibilities of the U.S. ATLAS Project Manager are:

1. represent the U.S. ATLAS Project in interactions with ATLAS, CERN, and DOE/NSF;
2. appoint, after consultation with the ATLAS Collaboration the U.S. ATLAS subsystem managers;
3. working with BNL, establish a project office with appropriate staff;
4. develop the project scope and integrated cost and schedule plans consistent with available funding and ensure that the project scope is congruent with the international ATLAS Memorandum of Understanding with CERN;
5. prepare annual funding requests to the DOE and NSF and recommend funding allocations to the U.S. ATLAS institutions;
6. prepare institutional Memoranda of Understanding for the U.S. ATLAS collaborating institutions and annual Statements of Work for each institution;
7. complete the U.S. ATLAS scope of work on schedule and within the authorized budget as described in the approved U.S. ATLAS project baseline documents;
8. prepare and approve Level 3 baseline changes as prescribed in the U.S. ATLAS Project Management Plan; and,
9. ensure that all elements of the project conform to applicable U.S. and CERN ES&H and Quality Assurance.

5. Management Systems

5.1 Project Management Systems

The U.S. LHC Accelerator, U.S. ATLAS, and U.S. CMS projects will each develop and implement project management systems. These project management systems are described in detail in Project Management Plans included in Part 2 of the appendices. The project management systems include project management techniques used to plan, authorize, and monitor U.S. work, and additional measures to address the communication and interface challenges presented by the fact that each of the three U.S. LHC Construction projects are not self-contained, but are parts of a much larger LHC project.

Each Project Management Plan (PMP) addresses: project objectives, organization and responsibilities, work breakdown structure, schedules and milestones, cost estimates, management and control, environment, safety and health, and interfaces with CERN and the international collaborations. The PMPs include provisions for review and revision as needed, to reflect new project developments or other agreements among the participants.

5.2 Monitoring, Assessment and Risk Management

Real time monitoring of the U.S. LHC activities occurs through the procedures established in the Project Management Plans for each project. A performance-based management system (Earned Value Management system) is used to monitor cost, schedule and performance goals. In addition to the day-to-day interaction of the line managers there are major mechanisms for periodic formal assessment of the U.S. LHC Construction Program. These mechanisms for assessment include meetings of the JOG, semi-annual reviews of the U.S. LHC projects conducted by the DOE Office of Science at the request of the JOG, U.S. LHC Project Manager's reviews, host/lead laboratory oversight activities, and internal reviews conducted by the laboratory and university project managers. The semi-annual DOE/NSF reviews are conducted using external senior technical and management experts to help determine project progress and make recommendations regarding areas of potential risk.

An important element of risk mitigation strategy is the establishment and careful, systematic management of project contingency and change control. Initial contingency analyses utilized uniform methodologies that considered technical, cost and schedule risks, as well as the judgement of project managers and subsystem managers. Factors considered include technical risk, schedule risk, manufacturing difficulties, design maturity, omissions and fluctuations in escalation rates, commodity prices and currency rates. Techniques employed in these analyses include: vendor quotes for materials and services, bottoms-up analysis of specific component/systems, historical costs scaled or extrapolated to the design, analogy to previously-built items of known costs and expert opinion, engineering judgement or parametric estimates where necessary. Internal project and technical management advisory entities also advise project management directly in areas such as change control and risk identification and mitigation during the project implementation life cycle.

The project performs on-going risk assessment and baseline management to manage risk where necessary, as well as quantitative risk assessment methods in some areas, e.g. to support revisions in Estimates to Completion. Another important factor that significantly mitigates and reduces potential risk to the government has been the establishment and adherence to a fixed cap on the Total Project Cost for construction, as established by International Agreement. An area of potential risk is the extension of the CERN LHC start-up schedule. This potential area of risk will be managed to minimize the impact on the U.S. Construction Project schedules and to assure no impact on the Total Project Cost. This is further discussed in section 5.5 on U.S. LHC Project Completion.

5.3 Reporting

The U.S. LHC Project Manager will prepare a Quarterly Progress Report addressing the status of the U.S. LHC Construction Program. The reports will include cost, schedule, and technical status information for each project and the Project Manager's assessment. These reports will be based on written reports prepared by the U.S. LHC Accelerator, U.S. ATLAS, and U.S. CMS project managers. The Quarterly Reports are prepared and distributed after the end of each fiscal quarter.

Requirements for routine reporting are to be documented in the Project Management Plans. Additional reporting requirements may be defined in response to specific management needs. DOE Headquarters requirements such as the Project Analysis and Reporting (PARS) system will be met as necessary. PARS reports will provide breakdown of earned value cost and schedule performance and other information as needed. Ad hoc reporting or requests for information are to be treated on a case-by-case basis and formally transmitted through the line management organization.

5.4 Project Baselines and Control Thresholds

The project baselines and control thresholds are defined in a hierarchical manner that provides change approval authority at the appropriate management level. The highest level of baseline change control authority is defined as Level 0. Changes at Level 0 are approved by the DOE Director of the Office of Science and the NSF Assistant Director for Mathematical and Physical Sciences. Changes below Level 0 are approved at the following levels: Level 1 - DOE/NSF Joint Oversight Group; Level 2 - DOE/NSF Project Manager; and Level 3 - Line managers in the appropriate Host/Lead Laboratories for the U.S. LHC Accelerator, U.S. CMS, and the U.S. ATLAS projects.

A Level 0 change is any change to the U.S. LHC Construction Program that requires a modification to the U.S.-CERN Agreement, the Accelerator Protocol, or the Experiments Protocol. Change control thresholds at Level 1 and Level 2 for the U.S. LHC Accelerator, U.S. CMS, and U.S. ATLAS Projects are shown in Tables 5.4.1 and 5.4.2. The change control thresholds and procedures at Level 3 and below are addressed in the Project Management Plans for each of the U.S. LHC projects.

Table 5.4.1, DOE/NSF Joint Oversight Group (Level 1)
Change Control Thresholds

	US LHC Accelerator	US CMS	US ATLAS
Technical	1) Initial baseline list of deliverables specified in the WBS Level 3 descriptions in the Implementing Arrangement [US LHC Accelerator PMP Annex II]. 2) Any reduction in the baseline list of deliverables specified in the WBS Level 3 descriptions in the Implementing Arrangement	Approve the technical baseline as described in US CMS PMP Appendix 2: Technical Baseline Document	Changes to the project purpose or goals. [US-CERN Agreement and Experiments Protocol]
Schedule	Any change in Level 1 milestones specified in US LHC Accelerator PMP Appendix 5.	Greater than six month change in a Level 1 milestone. [US CMS PMP Appendix 3: Baseline Schedule]	Greater than six month change in a Level 1 milestone. [US ATLAS PMP Appendix 4: Major Project Milestones]
Cost	1) Any change in the TPC specified in US LHC Accelerator PMP App. 6. 2) Any change in the TPI specified in US LHC Accelerator PMP App. 6.	Any change to the US CMS Total Project Cost (TPC)	Changes to the Total Project Cost. [US ATLAS PMP Table 6-1: Baseline Cost Estimate]

Table 5.4.2, DOE/NSF Project Manager (Level 2)
Change Control Thresholds

	US LHC Accelerator	US CMS	US ATLAS
Technical	1) Any change in the baseline list of deliverables specified in the WBS level 3 descriptions in the Implementing Arrangement. [US LHC Accelerator PMP Annex II]	Significant changes to the technical baseline as described in US CMS PMP Appendix 2: Technical Baseline Document	Changes to the baseline list of deliverables. [US ATLAS PMP Appendix 3: Initial Approved Scope of US Deliverables]
Schedule	1) Any change in Level 2 milestones specified in US LHC Accelerator PMP Appendix 5.	Greater than three month change in Level 2 milestone. [US CMS PMP Appendix 3: Baseline Schedule]	Greater than three month change in a Level 2 milestone. [US ATLAS PMP Appendix 5: Major Project Milestones].
Cost	1) Any change in the WBS level 2 cost baseline specified in US LHC Accelerator PMP App. 6. 2) Any contingency usage.	Cumulative changes greater than \$2.5 million to the US CMS cost baseline at WBS Level 2. [US CMS PMP Appendix 4: Cost Baseline]	Changes to the Level 2 Cost Baseline. [US ATLAS PMP Table 6-1 Baseline Cost Estimate]

5.5 U.S. LHC Construction Project Completion

U.S. LHC Construction Project completion is defined as completion of the DOE/NSF approved scope of deliverables. This scope was originally defined in the documents and letters referenced in Appendix 1.B., included in the DOE/NSF approved project management plans, and modified in accordance with the DOE/NSF approved change control process.

The International Cooperation Agreement between CERN and DOE and NSF concerning Scientific and Technical Co-operation on LHC Activities, along with the Accelerator and Experiments Protocols, all signed in December 1997, define the scope of U.S. Party's financial contribution to the LHC accelerator and the ATLAS and CMS experiments in construction. These agreements define a total contribution of \$531 million, \$200 million for the accelerator and \$331 million for the experiments. The U.S. elected to manage our contributions as three distinct activities: the U.S. LHC Accelerator Construction Project including the \$90 million in payments to U.S. industrial firms for items required to construct the LHC accelerator; the U.S. ATLAS Detector Construction Project; and the U.S. CMS Detector Construction Project. The original technical scope of these projects is defined in the references cited above. In each case the original scope of the projects is defined as a set of deliverables. As a consequence of this approach it is understood that the U.S. LHC Construction Project is complete when the deliverables defined for each project are complete and provided to CERN, consistent with the approved project scope. The U.S. LHC Accelerator Construction Project consistently defines the completion of deliverables as delivered and accepted at CERN. The U.S. ATLAS and U.S. CMS Detector Construction Projects define the completion of deliverables as equipment delivered to CERN and installed in a sub-detector or detector assembly, consistent with the U.S. responsibilities established in the project scope.

To meet this definition a two-phased project completion plan is to be executed, with a phase A and phase B. This is necessitated by an intrinsic U.S. dependency on the CERN/LHC schedule with regard to final underground detector installation, and areas of cutting edge technology where as-late-as-possible purchase or fabrication yield better capability per dollar (e.g. data acquisition and silicon systems). Phase A project completion represents the completion of nearly all U.S. project deliverables, including delivery and initial assembly or installation, short of those activities for which the U.S. must depend on the CERN/LHC completion schedule. The CERN/LHC-dependent activities represent only a small percentage (on the order of a few percent) of U.S. LHC project completion efforts, and is defined as phase B project completion. For each deliverable the expectation for completion (whether in phase A or phase B) is addressed in the definition of a completion milestone.

The U.S. construction projects typically do not include commissioning of accelerator components or sub-detectors. Commissioning and other pre-operations activities are considered to be elements of the U.S. LHC research program. The activities and functions included in the Research Program are preparation for operation of the detectors, development of the software required for data analysis, maintenance and operation of the detectors, analysis of the data, publication of the physics results from the experiments,

and related activities. The U.S. LHC Research Program will require additional resources for the laboratories and universities, analogous to the pre-operational and operational phases of a new research facility. These resources are complementary to the funding provided in Article VIII of the International Agreement.

The scope of deliverables for each project is modified in accordance with the change control process defined in the Project Management Plans for each project. It is understood that there may be additional changes to the scope of deliverables to maximize the value of the U.S. contribution to the construction of the LHC and the ATLAS and CMS experiments, within the \$531 million agreed upon for construction. The DOE/NSF designated Project Managers are responsible for assuring that all changes to the original project baselines are approved at the appropriate level and that CERN counterparts are properly informed.

6. Environment, Safety, and Health

U.S. LHC activities carried out at, or under the supervision of, U.S. institutions and national laboratories are subject to the Environmental, Safety, and Health (ES&H) policies and procedures of those specific institutions or laboratories. All DOE National Laboratories participating in the U.S. LHC Program have DOE-approved Integrated Safety Management Systems, which provides a framework for all work conducted at each laboratory. In addition, equipment provided for installation and operation in the LHC will conform to CERN safety standards, and equipment designs will be approved through CERN safety review procedures. The U.S. LHC Accelerator, U.S. CMS, and U.S. ATLAS project managers have overall responsibility for implementing these requirements for each of their respective projects.

Project specific details on ES&H requirements and implementation can be found in the U.S. LHC Accelerator, U.S. CMS, and U.S. ATLAS Project Management Plans, and in other project specific documents, such as: Memoranda of Understanding for each of the Experiments; the Implementing Arrangement to the Accelerator Protocol; and, the Institutional Memoranda of Understanding and Annual Statements of Work between the U.S. CMS and U.S. ATLAS project offices and their collaborating institutions.

The U.S. LHC Project is carried out at, or under the supervision of, U.S. universities and national laboratories. The effort includes activities at many different locations in existing facilities designed and built to carry out similar work. Most of the work is being performed under preexisting grant and contractual mechanisms. U.S. LHC Construction Project work at DOE National Laboratories is fully subject to the local DOE line ES&H management oversight and operational awareness mechanisms. Work at U.S. Universities is fully subject to OSHA and applicable state and federal external regulation and enforcement. Ongoing work on accelerator and detector component construction is covered by existing National Environmental Policy Act (NEPA) documentation established for work at each facility. If the scope of work changes and is not covered by existing NEPA documentation, work will be reviewed under existing procedures established by the cognizant office authorizing the work.

Operations of the LHC machine and detectors at CERN will be subject to applicable European requirements, regulation and enforcement in place at the time of LHC operations. CERN establishes and implements institutional ES&H policy, requirements and procedures to meet these requirements, and to effectively manage ES&H for accelerator and detector operations. The research collaborations follow these, and implement further ES&H policy, requirements and procedures specific to the experiment. The U.S. LHC Collaborations are fully subject to all applicable CERN, CMS or ATLAS ES&H policies, requirements and procedures.

APPENDICES

- 1.A. DOE/NSF MOU on U.S. Participation in the LHC Project at CERN**
- 1.B. U.S. LHC Governing Documentation and Key Personnel**
- 2.A. U.S. LHC Accelerator Project Management Plan**
- 2.B. U.S. ATLAS Project Management Plan**
- 2.C. U.S. CMS Project Management Plan**