Excerpt from the
Mission-Need Statement for a U.S. Accelerator Project for the LHC

Office of High Energy Physics
Office of Science

A. Statement of Mission Need

The mission of the program in High Energy Physics (HEP) is to discover and explore the laws of nature that apply to the basic constituents of matter and their interactions. The core of the mission centers on investigations of properties of the elementary particles and how they reflect the symmetries and the development of space-time in our universe. This is an area of research that is fundamental to the advancement of science and technology as well as mankind's broader intellectual perspectives. The next frontier in particle physics is the Large Hadron Collider (LHC), which is to be completed during the summer of 2008 at the European Laboratory for Nuclear and Particle Research (CERN), located outside of Geneva, Switzerland. There, within a year, two beams of protons will be made to collide head-on with a center-of-mass energy of 14 TeV, and thereby provide data that will help clarify current puzzles and inadequacies in our conceptual formulation of the nature of the elementary particles and their interactions.

The LHC is a "discovery machine" constructed to respond to specific issues raised by the apparent failings of the otherwise very successful "standard model," which is the current theory of particle interactions. The development of the standard model is the most significant achievement of elementary-particle physics of the past 40 years. It has provided a framework for categorizing all observed phenomena within a formal "gauge" theory of electroweak and strong forces. Despite the fact that this model is remarkably consistent with observations, it is flawed in that it has many free parameters, and even more telling is that it becomes internally inconsistent beyond Teravolt energies (1 TeV = 10^9 electron volts). The LHC with beam energies seven times that of the Tevatron collider at Fermi National Accelerator Laboratory is expected to resolve this scientific conundrum through discovery of new kinds of particles or interactions at this "Terascale" range of energies.

Complex scientific enterprises such as the LHC require many years of detailed planning and construction, and a lengthy period of harnessing and analyzing of the accumulated data before the impact of the measurements can be fully gauged. Because of the cost of such scientific endeavors, these facilities are usually upgraded after some initial running period to provide significantly greater scientific reach and insight at relatively small marginal cost. In the past, such accelerator and detector upgrades have aimed to double luminosities every two years, before the facilities were finally closed. The mission of this

project is to participate and contribute to the LHC upgrade program. A multi-laboratory collaboration has submitted a proposal to the DOE listing possible U.S. contributions to the upgrade of the LHC accelerator complex. They provide relatively detailed perspectives on options based on U.S. interest as well as recognized U.S. expertise in accelerators. The U.S. contributions outlined in the upgrade proposal will enable a projected two- to three-fold increase in LHC luminosity, with the approved U.S. items assembled and ready for installation by the beginning of 2013, as currently envisioned by CERN.

B. Analysis in Support of Mission Need

A recent study by the National Academy of Sciences (EPP-2010, ISBN 0-309-10195-6) has recommended that U.S. participation in the LHC program, "including any well-motivated potential upgrades," be regarded as our nation's highest scientific priority for particle physics. CERN is already planning a luminosity upgrade for LHC operations at 14 TeV, and the project has gained financial support from CERN as well as additional support from the European Union. This phase of the upgrade is scheduled for completion in or about 2013. Any formal decisions on further upgrades, possibly to about 10^{35} events/cm^2/s, are expected in 2011, once sufficient scientific results from the LHC become available to justify the need for a further increase in luminosity. (See explanatory letter of January 14, 2008 from Robert Aymar, Director General of CERN, to Ray Orbach, and the website for a "Kickoff" to the upgrade: http://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=30583)

The goals of the currently proposed fabrication project are in full accord with those articulated in the Strategic Plan of the DOE Office of Science to "explore the fundamental interactions of energy, matter, time and space," as well as with its mission to "keep the U.S. at the forefront of intellectual leadership" (DOE/SC-0079, February 2004). These goals have been endorsed through internal as well as external reviews of the LHC research program, and were supported most enthusiastically by the EPP-2010 study conducted by the National Academy. For example, the first itemized finding of the EPP- 2010 report states: "The study of LHC physics will be at the center of the U.S. particle physics program during the coming decade," and the report's major action item proffers: "The highest priority for the U.S. national effort in elementary particle physics should be to continue to be an active partner in realizing the physics potential of the LHC experimental program." This envisions full participation in an upgrade of the LHC: "As potential upgrades to the detectors and the accelerator are motivated and defined through scientific results, the U.S. particle physics program should consider the provision of in- kind contributions as appropriate." The recent P5 subpanels of HEPAP concur. In its 2005 statement of the planning guidelines for the future of the field, the first item in the Panel's Roadmap states: "The LHC program is our most important near term project given

its broad science agenda and potential for discovery. It will be important to support the physics analysis, computing, maintenance and operations, upgrade R&D and necessary travel to make the U.S. LHC program a success. The level of support of this program should not be allowed to erode through inflation." The Panel has also indicated that "extending exploration of the energy frontier with the LHC accelerator and detector luminosity upgrades is *absolutely central*" to the field. The latest P5 report, released in June 2008, is equally clear about the centrality of the science of the LHC, and recommends that the LHC and its upgrades be given top priority under any financial scenario.

C. Importance of Mission Need and Impact If Not Approved

The LHC will be the premier facility for particle physics over the next 10-20 years. CERN has decided that following an initial few years of operation, the upgrade components needed to extend the scientific reach of the facility will be installed in early 2013. This corresponds to the point in time at which marginal increases in science return start to take longer to achieve, thereby reducing the LHC cost-effectiveness due to longer operating times. A modest investment to increase the capabilities of the LHC in 2013 will ensure an increase in science productivity through 2016 commensurate with DOE's operational and research expenditures.

The entire program, including any future upgrades in luminosity, is in accord with the strategic goals of the DOE to advance scientific understanding at the fundamental level. It is anticipated that the initial LHC upgrade will be implemented with or without U.S. involvement. The rejection of the Accelerator Project would deny the opportunity for U.S. physicists to stay at the cutting edge of accelerator technology and cause an erosion of U.S. core competency in this area

As emphasized in the EPP 2010 study, this is the highest priority for the research program in particle physics, and lack of approval could for many reasons be detrimental to the future development of science in the U.S.

To maintain our full intellectual engagement and leadership at the energy frontier, and thereby fulfill DOE's strategic goals for science, the U.S. must participate in the LHC program. There is no alternative way of achieving this goal because multi-TeV energies, available only at the LHC, are required to probe the known limitations of the standard model. Participation in the upgrade would offer the U.S. the opportunity to benefit from its previous investment in the LHC, and enable it to continue developing novel techniques and analysis tools leading to additional important discoveries expected from the upgrade. Just as previous upgrades of the Tevatron Collider at Fermilab and of SLAC are providing greater insight into the physics of the present scientific frontier, so too will the LHC upgrade assure a more thorough exploration of the LHC energy frontier. The

rejection of the Accelerator Project would exclude the U.S. from this cost-effective way of pursuing the physics at the next energy frontier, and thereby diminish the training and career development opportunities of future generations of U.S. scientists. Our dropping out of the LHC program would likely affect the image of U.S. leadership in international scientific projects and would also threaten any future construction of major international HEP accelerator facilities within the U.S.

D. Constraints and Assumptions

1. Operational Limitations

There are currently no foreseen operational limitations concerning the effectiveness, capacity, technology or organization of the project. The criteria for reliable operations of the LHC accelerator, solely a CERN responsibility, will be established from the experience gained in the upcoming years of operation at lower luminosity.

Adequate technical and human resources are available at DOE laboratories, collaborating universities, and industrial firms to plan and execute this project on a competitive basis.

E. Applicable Conditions and Interfaces

The components authorized for the project are to be delivered to the CERN site for installation and commissioning by CERN. An appropriate U.S. laboratory will be selected for hosting the U.S. accelerator contributions, and be responsible for coordinating the needs of the U.S. project. U.S. laboratories participating in the project will negotiate with CERN separate MOUs for their individual deliverables to the LHC luminosity upgrade.

F. Resource Requirements and Schedule

The following profile has been estimated only for planning purposes. Neither the profile nor the schedule has been approved. The estimated cost of the project can be expected to change when the scope of the LHC upgrade and the degree of U.S. participation is fully determined. Changes in any proposed scope and schedule will impact the cost profile. The project would be funded as a Major Item of Equipment.

The table below shows the preliminary schedule for Critical Decisions for the Upgrade.

Preliminary Critical Decisions

CD-0 Approve Mission Need	1st quarter FY 2009
CD-1 Approve Alternative and Cost Range	2nd quarter FY 2009

CD-2 Approve Performance Baseline	4th quarter FY 2009
CD-3 Approve Start of Construction	2nd quarter FY 2010
CD-4 Approve Start of Operations	2nd quarter FY 2013

G. Development Plan

Following an affirmative decision for U.S. participation, the development strategy will be based on the CERN schedule and the negotiated scope of U.S. involvement in the upgrade. The DOE will support and oversee the U.S. activities that will concentrate initially on the R&D needs for meeting the goals for U.S. deliverables that will be specified in MOUs with CERN. Experienced international and U.S. management teams will integrate the developed technologies into robust designs that will achieve their goals at minimum cost, risk and time to completion.