Project Execution Plan
for the
SC Lattice QCD Computing Project Extension
(LQCD-ext)

Unique Project (Investment) Identifier: 019-20-01-21-01-1032-00

Operated at
Brookhaven National Laboratory
Fermi National Accelerator Laboratory
Thomas Jefferson National Accelerator Facility

for the
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Office of Science
Offices of High Energy and Nuclear Physics

Version 0.2

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LQCD-ext Project Execution Plan
Change Log

Revision No.	Description / Pages Affected	Effective Date
	Preliminary Project Execution Plan	
0.0	Preliminary PEP updated	April 15, 2009
1.0	Updated Preliminary PEP in response to recommendations from the CD-1 review. Affected sections: 4.1, 6.3, 6.4.1, and 8.4.	June 29, 2009
	Project Execution Plan	
0.0	Document upgraded from "preliminary" state. Revisions made throughout document.	08/07/2009
0.1	Fixed typo in Section 1 (DOE O 413.3A). Updated Section 6.4 to clarify that the budget profile matches the anticipated budget profile, and to clarify that the cost of host site services such as networking, cyber security, and financial management support are not in-kind contributions, but are covered by project funds through the assessment of overhead charges. Revised Level 1 Cost Threshold in Table 7, Summary of Change Control Thresholds.	09/10/2009
0.2	Modified signature sheet – replaced Gene Henry with Timothy Hallman; revised Vicky White title. Modified org chart in Figure 2 to reflect change in V. White title. Corrected BNL organization name in Section 5.1.8. Updated the *Introduction* and *Historical Background* sections to reflect that CD-2/3 approval was obtained in October 2009.	04/09/2010

Table of Contents

1 INTRODUCTION

This document describes the plan and related methodologies to be followed while executing the Lattice Quantum Chromodynamics (LQCD) computing facility project for the period FY2010 through FY2014. The plan has been prepared in accordance with DOE Order O413.3A, *Program and Project Management for the Acquisition of Capital Assets* (dated 7-28-06) and DOE Guidance G 413.3-14, *Information Technology Project Guide* (dated 9-12-08).

Continuing the acquisition and operation of dedicated hardware for the study of lattice QCD through FY 2014 will be an extension of the initial LQCD computing project, which concluded at the end of FY2009. The LQCD computing project extension (LQCD-ext) meets the planning, budgeting, and reporting criteria for an OMB Exhibit 300 major IT investment. The official name of this capital asset is "SC Lattice Quantum Chromodynamics Computing (LQCD)" and the Unique Project (Investment) Identifier is 019-20-01-21-01-1032-00. Exhibit 300 business cases have been prepared and submitted for Budget Years (BY) 2010 and 2011.

2 HISTORICAL BACKGROUND

The development and operation of a large scale computing facility dedicated to the study of quantum chromodynamics (QCD) plays an important role in expanding our understanding of the fundamental forces of nature and the basic building blocks of matter.

Since 2000, members of the United States lattice gauge theory community have worked together to plan the computational infrastructure needed for the study of QCD. In February 2003, the lattice QCD computational infrastructure effort was reviewed by a panel of physicists and computer scientists chaired by Frank Wilczek. One of its conclusions was: "The scientific merit of the suggested program is very clearly outstanding." Since then the High Energy Physics Advisory Panel (HEPAP) and the Nuclear Science Advisory Committee (NSAC) have both recommended that DOE funds should be allocated for dedicated computer hardware for lattice QCD simulations because of the importance of the calculations to their respective fields. Thus, the scientific need for this project has been validated by leading experts in high energy and nuclear physics.

With support from the DOE High Energy Physics (HEP), Nuclear Physics (NP), Advanced Scientific Research (ASCR) and SciDAC programs, prototype hardware was designed, constructed and tested. In addition, the software needed to effectively use the hardware was developed. By taking advantage of simplifying features of lattice QCD calculations, these R&D efforts demonstrated that it is possible to build computers for this field with significantly better price/performance than commercial machines.

Two tracks for the construction of massively parallel computers for QCD were studied. One involved the design and fabrication of key components, while the other made use of carefully chosen commodity parts. During the 6-year development phase (2000 to 2005), the QCD on a Chip (QCDOC) machine was designed and developed by lattice gauge theorists at Columbia University in collaboration with colleagues at IBM. The design incorporates CPU, memory and communication on a single chip. Based on the above design, a 12,288-chip QCDOC was constructed at Brookhaven National Laboratory (BNL).

In parallel, commodity-component-based prototype clusters optimized for the study of QCD were developed and tested at Fermilab (FNAL) and Thomas Jefferson National Accelerator Facility (JLab) under a grant from the SciDAC program, as well as with support from the laboratory base programs. Research and development performed during the first six years of this period provided the groundwork for the Lattice QCD computing project.

Based on the progress made during the above-described period, an OMB 300 IT investment project was initiated in early 2005. The proposed project was reviewed and received final approval in August 2005. The project was baselined at the same time. The LQCD computing project began in October 2006 and ended on September 30, 2009. The project was executed as planned and all performance milestones and metrics were met.

In 2008, the Lattice QCD Executive Committee submitted a proposal outlining the scientific justification to extend the project until the end of FY2014. The proposal was formally reviewed by a panel of nuclear and high energy experimentalists and theorists, as well as computer scientists, on January 30-31, 2008 and the results summarized in a written report dated March 3, 2008. The review resulted in a strong endorsement of the proposed plans. As a result, the extension project was reviewed following the Critical Decision process as outlined in DOE O 413.3A. CD-3, Approval to Start Construction, was granted on October 29, 2009.

3 JUSTIFICATION OF MISSION NEED

The Lattice QCD Computing Project Extension directly supports the mission of the DOE’s SC HEP program “to explore and to discover the laws of nature as they apply to the basic constituents of matter and the forces between them," and of the DOE's NP program "to foster fundamental research in nuclear physics that provides new insights and advance our knowledge on the nature of matter and energy...". The Project also supports the Scientific Strategic Goal within the DOE Strategic Plan to "Provide world-class scientific research capacity needed to: advance the frontiers of knowledge in physical sciences...; or provide world-class research facilities for the Nation's science enterprise."

To fulfill their missions the HEP and NP Programs support major experimental, theoretical and computational programs aimed at identifying the fundamental building blocks of matter and determining the interactions among them. Remarkable progress has been made through the development of the Standard Model of High Energy and Nuclear Physics. The Standard Model consists of two quantum field theories: the Weinberg-Salam Theory of the electromagnetic and weak interactions, and QCD, the theory of the strong interactions. The Standard Model has been enormously successful. However, our knowledge of it is incomplete because it has been difficult to extract many of the most interesting predictions of QCD. To do so requires large-scale numerical simulations within the framework of lattice gauge theory. The objectives of these simulations are to fully understand the physical phenomena encompassed by QCD, to make precise calculations of the theory's predictions, and to test the range of validity of the Standard Model. Lattice simulations are necessary to solve fundamental problems in high energy and nuclear physics that are at the heart of the Department of Energy's large experimental efforts in these fields. Major goals of the experimental programs in high energy and nuclear physics on which lattice QCD simulations will have an important impact are to: 1) verify the Standard Model or discover its limits, 2) understand the internal structure of nucleons and other strongly interacting particles, and 3) determine the properties of strongly interacting matter under extreme conditions, such as those that existed immediately after the "big bang" and are produced today in relativistic heavy-ion experiments. Lattice QCD calculations are essential to the research in all of these areas.

4 PROJECT DESCRIPTION

The LQCD Computing Project Extension is part of the DOE SC HEP and NP programs to accomplish SC strategic goal (SG) 6 (Deliver computing for the frontiers of science) and DOE SGs 3.1 (Scientific Breakthroughs) & 3.2 (Foundations of Science). QCD is the theoretical framework for large experimental programs in HEP & NP, and its properties can only be determined through large scale computer simulations. The LQCD Computing Project identified the need to dedicate hundreds of teraflop-years of sustained integrated computing power to the study of QCD, and other strongly coupled gauge theories expected to be of importance in the interpretation of experiments planned for the LHC. To achieve the FY10 delivered integrated capacity goal of 18 TF/s-yr, the LQCD-ext project will utilize the QCDOC supercomputer located at the Brookhaven National Laboratory and the LQCD clusters located at the Fermi National Accelerator Laboratory and Thomas Jefferson National Accelerator Facility, along with the hardware to be acquired in FY10 in this project. To achieve delivered integrated capacity goals in subsequent years, the LQCD project will utilize the LQCD clusters located at the FNAL and JLab along with planned annual hardware procurements and deployments. Details regarding the acquisition strategy are contained in the *Acquisition Strategy for the Lattice QCD Computing Project Extension.*

The HEP, NP, and ASCR (Advanced Scientific Computing Research) funded SciDAC-1 and SciDAC-2 LQCD software projects provide highly optimized LQCD codes and the SciDAC-2 project is developing new algorithms that will increase the cost effectiveness of the hardware acquired by this investment. The current LQCD investment project was scheduled to end in FY09. Due to management decision, the LQCD investment is being extended through FY2014. The investment provides funds for the acquisition and operation of new hardware, and for the operation of the existing QCDOC supercomputer and LQCD clusters through the end of their life cycle. These systems run physics applications built using optimized LQCD libraries developed by the SciDAC projects.

The hardware is housed at BNL, FNAL and JLab, and operated as a single distributed computing facility. Within this distributed system, each facility installation is managed locally by the host laboratory. The distributed computing facility is available to lattice gauge theorists at national laboratories and universities throughout the United States.

Project funds are used to support the operation of existing hardware and the procurement and deployment of new computing hardware to meet performance requirements and metrics. In particular, project funds will be used to support the operation of the QCDOC machine through

FY10; commodity clusters brought online during the LQCD computing project; and new commodity clusters as they are brought online.

4.1 Functional Requirements

Two classes of computing are done on lattice QCD machines. In the first class, a simulation of the QCD vacuum is carried out, and a time series of configurations, which are representative samples of the vacuum, are generated and archived. Several ensembles with varying lattice spacing and quark masses are generated. For the planned scientific program in the first two years of this project, this class of computing requires machines capable of sustaining at least 2.75 Tflop/s on jobs lasting approximately 2 hours. The total memory required for such jobs will be at least 30 GBytes. The second class, the analysis phase, uses hundreds of archived configurations from each ensemble to calculate quantities of physical interest. A wide variety of different quantities can be calculated from each ensemble. These analysis computations also require large floating-point capabilities; however, the calculations performed on individual configurations are independent of each other. Thus, while configuration sequence generation requires single machines of as large computing capability as practical, analysis computing can rely on multiple machines. For the planned scientific program in the first two years of this project, these analysis jobs will require systems capable of sustaining at least 2.0 Tflop/s on jobs lasting approximately 1 hour. The total memory required by such jobs will be at least 600 GBytes. Further, the total aggregate computing capacity of such systems by the end of the second year of the project must be at least 34 Tflop/s. Note that this total includes 12 Tflop/s of capacity provided by systems from the current LQCD project, with an additional 23 Tflop/s of capacity provided by systems procured during the first two years of the LQCD-ext project. During the course final three years of the project, all requirements (sustained performance and required memory) for both classes of lattice QCD computing will at least double.

Throughout this project, at most five independent systems dedicated to LQCD computing will be deployed, one per year in each of FY2010-FY014. The goals for aggregate sustained performance on LQCD applications for each of these deployments are given in Table 1.

Table 1: Annual Capacity Deployment Goals for Aggregate Sustained Performance on LQCD Applications

	FY 2010	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**
Planned computing capacity of new deployments, Tflop/s	11	12	24	44	57
Planned delivered performance (JLab + FNAL + QCDOC), Tflop/s-yr	18	22	34	52	90

Each acquisition will deploy a system that best meets the scientific goals planned by the USQCD community. The typical system will consist of a commodity cluster with a high performance interconnect. However, in each acquisition any other suitable hardware will be considered, such as the IBM BlueGene family, customized commodity hardware, and traditional supercomputer hardware. Each system acquired by the LQCD-ext project will be operated for a minimum 4-year period.

4.2 Computational Requirements

The fundamental kernels of both configuration generation and analysis are SU(3) algebra. This algebra uses small, complex matrices (3x3) and vectors (3x1). SU(3) matrix-vector multiplication dominates the calculations. For single precision calculations, these multiplications require 66 floating-point operations, 96 input bytes, and 24 output bytes, a 1.82:1 byte-to-flop ratio. Double precision calculations have a 3.64:1 byte-to-flop ratio. The four dimensional space-time lattices used in lattice QCD calculations are quite large, and the algorithms allow very little data reuse. Thus, with lattices spread over even hundreds of processors, the local lattice volumes exceed typical cache sizes. On modern processors, the performance of these fundamental kernels is limited not by the floating-point capacity, but rather by either bandwidth to main memory, or by the delays imposed by the network fabrics interconnecting the processors.

Lattice QCD clusters are composed of thousands of interconnected processor cores. For the most demanding problems in the planned scientific program, each processor core must be capable of sustaining at least 2.5 Gflop/sec on the fundamental kernels. Memory bandwidths of 4 GBytes/sec per processor core are necessary to sustain such floating-point rates. Depending on the size of the local lattice, which depends upon the number of processors used for a calculation, sustained network communication rates of at least 250 MBytes/sec per processor core are required, using message sizes of at least 10 Kbytes in size.

4.3 I/O and Data Storage Requirements

During vacuum configuration generation, data files specifying each representative configuration must be written to storage. For the planned scientific program in the first two years of the project, these files are at least 30 GBytes in size, with a new file produced every two hours. Thus the average I/O rate required for configuration storage is modest at only 4 Mbytes/sec. However, higher peak rates of at least 100 Mbytes/sec are desired, to minimize the delays in computation while configurations are written to or read from external storage. The total storage volume required for configurations generated in the first two years of the project is at least 200 TBytes. Because configurations are computationally costly to generate, archival-quality storage is mandatory.

During the analysis stage, hundreds of configurations must be loaded into the machines. The propagation of quarks must be calculated on each configuration. This requires the numerical determination of multiple columns of a large sparse matrix. The resulting "propagators" are combined to obtain the target measurements. Propagator files for Clover quarks, for example, are 16 times larger than the corresponding gauge configuration. Often, eight or more propagators are calculated for each gauge configuration. To minimize the time for writing to and subsequently reading from scratch storage space, the sustained I/O rate for each independent analysis job during the first two years of the project should be at least 300 Mbytes/sec.

4.4 Data Access Requirements

Configuration generation is performed at the BNL QCDOC facility and at the DOE Leadership Computing Facilities. Configurations are also imported from other external facilities. Archival storage of these configurations utilizes robotic tape facilities at FNAL and JLab. The project maintains software to provide facile movement of files between the three sites. The aggregate size of the files moved between sites during the first two years of the project will be at least 100 TBytes per year.

4.5 Hardware Acquisition Plan

In each year of the project, additional systems will be procured and deployed using the most cost-effective hardware as determined by anticipated usage, scientific requirements, and planned performance milestones. As part of the annual procurement cycle, available hardware will be benchmarked and compared against scientific requirements and planned milestones. An alternatives analysis will be performed to determine the most cost-effective solution for a given year, and an acquisition plan will be developed and presented to an external review committee for review and concurrence. These reviews will be organized by the DOE Federal Project Manager for this investment project and conducted as part of the project annual progress review. Historically, these reviews have been held in May, for procurements planned in the following fiscal year.

The procurement of new computing hardware will be done in accordance with the procurement policies and procedures of the laboratory that will host the new system. All procurements will utilize a multi-step process that includes the issuance of Requests for Information (RFIs) and Requests for Proposals (RFPs). Procurement documentation will clearly define performance requirements and specifications. Purchase contracts will be awarded to the winning vendor based on a set of pre-defined selection criteria designed to ensure "best-value" procurements. Upon receipt and installation, each new system will undergo a series of rigorous acceptance tests to verify performance against specified requirements. The system must successfully pass all acceptance tests before final payment is made to the vendor. In the event that a system fails to pass specific acceptance tests, negotiations will be conducted between the LQCD Project Office, project technical staff, host laboratory procurement office, and vendor to mitigate and successfully resolve discrepancies between required and actual performance.

Full details of the acquisition planning and procurement process, as well as a description of the minimum set of acceptance tests required to verify system performance, are contained in the following project documents: *Acquisition Strategy for the Lattice QCD Computing Project Extension* and *Alternatives Analysis for the Lattice QCD Computing Project Extension.*

4.6 Operations

The operation of lattice QCD computing facilities includes system administration, system performance monitoring (e.g., capacity utilization and system availability), physical infrastructure monitoring (e.g., power and cooling), hardware and software maintenance, configuration management, cyber security, data storage, and data movement.

The three host laboratories operate physical facilities in support of the lattice QCD systems. The LQCD-ext site managers work closely with their respective facility personnel to make sure that plant infrastructure needs are met in a cost-effective manner. Although project personnel work closely with facilities personnel to ensure that project needs are met, no project funds are used for physical plant improvements or repairs.

As part of the SciDAC and SciDAC-II Lattice Gauge Computing projects, libraries and application programming interfaces (API's) have been developed that allow high level physics codes to run without modification (after recompilation) on the different hardware platforms available: QCDOC, Infiniband clusters, and commercial supercomputers. At each site, one or more versions of the SciDAC libraries are maintained to support this diverse hardware base. SciDAC project personnel are responsible for building and verifying the correctness of these libraries. Project personnel are responsible for the configuration management of the libraries and the associated utilities.

Archival storage of physics data utilizes tape robots and hierarchal mass storage systems at FNAL and JLab. Tape media and, as necessary, tape drives are procured using operational funds allocated to the project.

On a periodic basis, US collaboration members apply to and receive from the Scientific Program Committee allocations of computing time at one or more of the three sites. Specific physics projects often utilize two of the three sites to take advantage of the specific characteristics of each. For this reason, efficient movement of physics data between the sites is essential.

The FNAL and JLab clusters are operated for up to 4 years after commissioning. Operation of the QCDOC is planned through FY 2010. The project decommissions individual systems when they are no longer cost effective to operate.

4.7 Major Interfaces

As noted earlier, BNL, FNAL, and JLab are the primary participating laboratories. Memoranda of Understanding (MOU) will be established between the project and each host laboratory to define the relationships and expectations between these laboratories and the project.

4.8 Key Stakeholders

Key stakeholders include the DOE SC OHEP and NP, as well as the laboratories hosting LQCD-ext computing facilities. Members of the USQCD collaboration are key customers of the LQCD-ext computing facilities. These include laboratory and university researchers, as well as post-docs and students. Their feedback is incorporated throughout the duration of the project through the LQCD Executive Committee and the spokesperson.

5 MANAGEMENT STRUCTURE AND INTEGRATED PROJECT TEAM

This section describes the management organization for the LQCD-ext computing project, along with roles and responsibilities for key positions. The management structure is designed to facilitate effective communication between the project management team and the project's key stakeholders. The organization chart for the management and oversight of the LQCD-ext project is shown in Figure 1. Solid lines indicate reporting relationships; dashed lines represent advisory relationships.

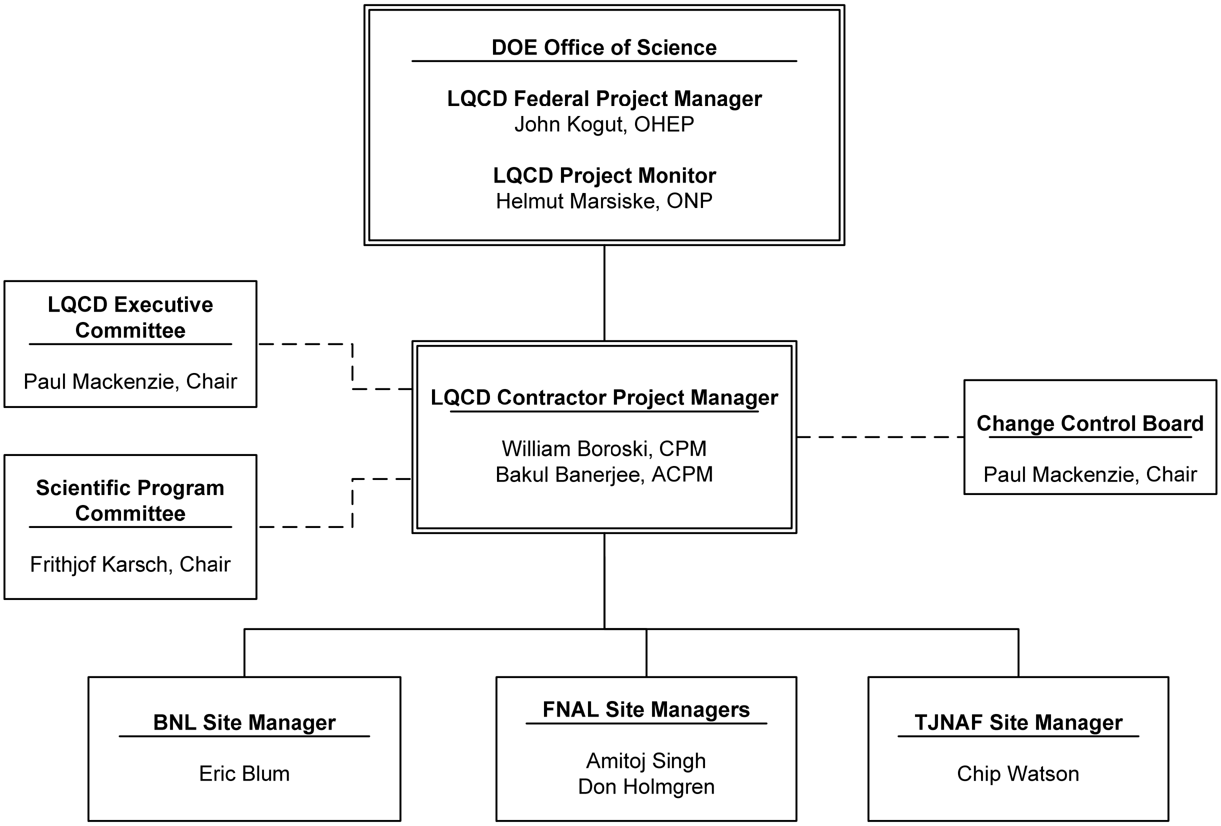

Figure 1: Management Organization Chart for the LQCD-ext Computing Project.

5.1 Roles and Responsibilities

5.1.1 LQCD Project Manager

Overall management and oversight is provided by the DOE Office of Science, through the Offices of HEP and NP. Since this project meets the criteria for an OMB Exhibit 300 major IT investment, the OMB requires that this project be managed by a qualified project manager. Since the total project cost is less than $20 million, the Federal Project Manager must be certified as a Level-1 IT Project Manager.

The LQCD-ext Federal Project Manager is appointed from either OHEP or ONP. To ensure all stakeholder needs are met, a Project Monitor is also appointed from the other SC office. The LQCD-ext Project Manager is John Kogut, from OHEP; he is a Certified Level 1 IT Project Manager. The LQCD-ext Project Monitor is Helmut Marsiske, from ONP.

Specific responsibilities of the Project Manager include the following:

- Provide programmatic direction for the LQCD-ext project.
- Serve as the primary point of contact to DOE SC headquarters for LQCD matters
- Oversee LQCD-ext progress and help organize reviews as necessary
- Budget funds for LQCD-ext and act as the key contact to the project office during the preparation of the OMB Exhibit 300 submissions and quarterly progress reports.
- Control changes to the approved project baseline in accordance with the change control process defined later in this document.

5.1.2 Contractor Project Manager

The LQCD Contractor Project Manager (CPM) is responsible for the overall management of the project. This person is the key interface to the LQCD Project Manager for financial matters, reporting, and reviews of the project. The CPM has significant budgetary control and is in the approval chain for all major project commitments and procurements. The OMB also requires that the Contractor Project Manager be certified as a Level-1 IT Project Manager.

The Contractor Project Manager is Bill Boroski from Fermilab. He is a certified Level 1 IT Project Manager.

Specific responsibilities for the Contractor Project Manager include the following:

- Provide management and oversight for all planning, deployment, and steady-state activities associated with project execution.
- Ensure that critical project documents exist and are kept up-to-date, such as the Project Execution Plan, Risk Management Plan, Acquisition Plan, Alternatives Analysis, and Certification & Accreditation Documentation.
- Develop and maintain a work breakdown structure (WBS) with tasks defined at a level appropriate to successfully manage the project, and that can be externally reviewed. The WBS should include project milestones at a level appropriate to track project progress.
- Establish and maintain MOUs with the DOE laboratories hosting LQCD-ext computing facilities.
- Prepare annual OMB Exhibit 300 Budget Year (BY) submissions in accordance with DOE and OMB guidance and schedules.
- Prepare and submit DOE quarterly progress reports that cover project cost and schedule performance, as well as performance against established key performance metrics.
- Presents monthly progress reports to the LQCD Project Manager and Project Monitor.
- Prepare annual operating budgets and financial plans consistent with the project plan and performance objectives, and manage project costs against the approved budget. .
- Provide final approval for the project of all major (> $50K) procurements

- Provide internal project oversight and reviews, ensuring that funds are being expended according to the project plan, and identifying weaknesses in the execution of the project plan which need to be addressed.
- Establish and manage a project change control process in accordance with the requirements contained later in this document.

Interactions

- Reports to the LQCD Project Manager
- Serves as the primary point of contact with DOE SC on matters related to budget and schedule for all funded activities.
- Interacts with senior management at the host laboratories regarding project-related matters.
- Provides direction and oversight to the LQCD-ext Site Managers on project-related matters.
- Interacts with the Chair of the LQCD Executive Committee and the Chair of the Scientific Program Committee to ensure collaboration needs are being met.

5.1.3 Associate Contractor Project Manager

The CPM is assisted by the Associate Contractor Project Manager (ACPM). The CPM delegates to the ACPM many activities, including preparation and tracking of the project WBS and schedule; and the gathering and analysis of performance data from the host laboratories. Performance data includes actual expenditures, progress towards milestones, and other relevant performance data as defined in the OMB Exhibit 300 business case.. The ACPM assists with the creation of various management documents and maintains other controlled documents as appropriate.

The Contractor Project Manager is Bakul Banerjee from Fermilab. She is a certified Level 1 IT Project Manager.

Specific responsibilities of the ACPM include the following:

- Prepares detailed planning documents for the project, including the overall project WBS and WBS sections specific to each subproject. Including in the WBS are key project tasks and performance milestones., and expenditure including the tracking of the progress
- Assists in the preparation of proposal budgets consistent with the detailed planning documents and ensures that funds received are allocated in accordance with annual financial plans.
- Assists in the preparation of OMB Exhibit 300 BY submission documents.
- Gathers and summarizes financial information for the monthly reports to the DOE Project Manager and Project Monitor; and for the DOE quarterly progress reports according to the guidance received from OMB
- Prepares other technical and administrative controlled documents and performance activities related to project performance monitoring and measurement.

- Develops and maintains project-management-related communications including the project web site and the repository of project documents, etc.
- Assists with the annual reviews.

Interactions

- Reports to the CPM
- Works with the Site Managers to gather budget and performance data for tracking the project and to preparing quarterly and/or annual reports

5.1.4 Site Managers

New hardware deployment and steady-state operations activities at each host laboratory are led by a designated Site Manager (SM) who is located at that site. Each SM has significant authority at his/her site over the resources necessary to deliver the appropriate level of computing resources to the USQCD community. The SM is responsible for developing and executing the corresponding components of the WBS, and making sure that appropriate commitments by the host laboratory are obtained and carried out. The SM is the primary interface between the CPM, ACPM, the host laboratory, and the individuals associated with the work to be performed at that host laboratory.

The SM has the authority to reallocate project resources within the laboratory to accomplish the assigned scope and tasks, in consultation with the CPM. The SM provides sufficient details of major procurements to the CPM to facilitate review and approval for the use of funds. The SM has direct management control over that site's budget each year, with major procurements subject to approval by the CPM. All procurements are subject to host site management procedures and approvals.

Specific site manager responsibilities include the following:

- Provide day-to-day management and oversight of the LQCD-ext computing facilities at his/her site. This includes providing adequate user support to the USQCD community. This also includes ensuring that project funds are being expended according to the project plan and identifying weaknesses in the execution of the project plan that need to be addressed.
- Obtain necessary resources and approvals from laboratory management and coordinate resources contributed by the laboratory
- Provide technical oversight of the LQCD-ext computing resources at the host site including the monitoring and reporting of system performance metrics such as uptime and usage. The SM also implements the user allocations determined by the Scientific Program Committee.
- Deploy software consistent with the project plan for the integration of necessary software developed by other projects such as the LQCD SciDAC-2 project and the International Lattice Data Grid (ILDG) project.

- Lead the hardware selection process for deployment at his/her site, in a manner consistent with the project hardware procurement and deployment, and in consultation with the CPM and partner site managers.
- Assist in the annual budget planning and allocation process, and in the preparation of detailed planning documents for the site sub-project, including the WBS and performance milestones at a level appropriate for external review
- Track progress of site-specific project milestones.
- Prepare and submit monthly status reports, including expenditures and effort, to CPM and ACPM
- Provide necessary information on quarterly progress reports
- Prepare materials for external oversight and reviews and participate in external review activities, as necessary.

Interactions

- Reports to the CPM
- Works closely with the ACPM and other Site Managers both to assist in defining milestones and infrastructure deployment schedules, and to ensure a high level of coherency across the project
- Oversees all staff responsible for deployment and operation activities at their respective site.

5.1.5 Integrated Project Team

The LQCD-ext Integrated Project Team (IPT) is composed of the LQCD Federal Project Manager, LQCD Project Monitor, CPM, ACPM, and Site Managers from the host laboratories. The LQCD Project Manager chairs the IPT. The current membership of the IPT is given in Appendix A.

The full IPT meets on an as-needed basis. Subsets of the IPT meet on a monthly basis. For example, monthly meetings are held between the Federal Project Manager, Project Monitor, CPM and ACPM to review progress against goals and milestones. The CPM, ACPM and Site Managers meet monthly to review project performance on a more detailed, technical level. These meetings often involve planning for subsequent deployments and sharing lessons learned.

5.1.6 LQCD Executive Committee

The charter of the Lattice QCD Executive Committee is to provide leadership in developing the computational infrastructure needed by the United States lattice gauge theory community to study Quantum Chromodynamics (QCD), the theory of the strong interactions of subatomic physics. The Executive Committee is responsible for setting scientific goals, determining the computational infrastructure needed to achieve these goals, developing plans for creating the infrastructure, securing funds to carry out these plans, and overseeing the implementation of all of the above. The Executive Committee advises the CPM regarding scientific priorities and the computing resources needed to accomplish them. The Executive Committee appoints the

Scientific Program Committee, which allocates the project's computational resources. The chair of the Executive Committee is also the chair of the LQCD-ext Change Control Board (CCB). In addition, the Executive Committee nominates a second scientist to serve on the CCB. The role of Executive Committee members on the CCB is to represent the interests of the users.

Current members of the Executive Committee are expected to serve for the duration of the project. If a vacancy occurs, it is filled by a vote of the remaining members of the Executive Committee. Appendix B contains a list of the current members of the Executive Committee.

Responsibilities

- Sets the scientific goals and determines the computational infrastructure needed to achieve them
- Establishes procedures for the equitable use of the infrastructure by the national lattice gauge theory community
- Arranges for oversight of progress in meeting the scientific goals
- Arranges regular meetings of the national lattice gauge theory community to describe progress, and to obtain input
- Manages the national lattice gauge theory community's SciDAC grant and provides coordination between the work done under that grant and in the current project
- Appoints the members of the Scientific Program Committee
- Represents the interests of the user community by appointing two members to serve on the CCB.

5.1.7 Spokesperson

The Chair of the Executive Committee serves as the Scientific Spokesperson for the project.

Responsibilities

- Determines scientific goals and required computational infrastructure together with the LQCD Executive Committee
- Chairs the LQCD Executive Committee

Interactions

- Principal point of contact to DOE on scientific matters related to the project
- Presents the project's scientific objectives to the DOE, its review committees and its advisory committees
- Liaison between the Executive Committee and the CPM, relating the Executive Committee's priorities to the CPM, and transmitting the CPM's progress reports to the Executive Committee

5.1.8 Change Control Board

The Change Control Board (CCB) is composed of the Contractor Project Manager, the Chairman of the LQCD Executive Committee (chair), the FNAL Chief Information Officer, the JLab Chief Information Officer, the BNL Information Technology Division Director, and a scientific consultant appointed by the chair. The purpose of this committee is to assure that the changes to the project are managed with the primary focus on the advancement of the scientific goals of the project. All changes approved by CCB will be reported to the DOE SC through the LQCD-ext Federal Project Manager. The role of the CCB in the change control process is defined in detail in Section 7, Change Control.

Responsibilities

- Evaluates feasibility, cost, and impact of proposed changes to the project that result in more than a minimal cost or schedule change.

Interactions

- Gathers input from the Executive Committee, project participants, and the user community about proposed project changes.
- Advises the CPM on recommended actions for change requests.

5.1.9 Scientific Program Committee

The charter of the Scientific Program Committee is to assist the Executive Committee in providing scientific leadership for the Lattice QCD infrastructure development efforts. This committee monitors the scientific progress of the effort, and provides leadership in setting new directions.

The Scientific Program Committee is charged with allocating time on the integrated hardware resources operated within the scope of the LQCD-ext computing project. This committee has instituted the following allocation process. Once a year, proposals are solicited for the use of computational resources that are available to the user community during the allocation period July 1 to June 30. The Committee reviews the proposals and makes preliminary allocations based on its reviews. An open meeting of the user community is then held to discuss the proposals and the preliminary allocations. The Committee makes final allocations for each site following this meeting. The three site managers are responsible for executing these allocations. The objective of this process is to achieve the greatest scientific benefit from the resources through broad input from the community. The committee is also charged with organizing an annual meeting of the user community to review progress in the development of the infrastructure and scientific progress achieved with the infrastructure, and to obtain input on future directions.

Members of the Scientific Program Committee are appointed by the Executive Committee. The current members are expected to serve for the duration of the project. If a vacancy occurs, the open slot is filled by the Executive Committee. See Appendix B for names of the current members.

5.2 *Interaction of Host Laboratory Management*

Line management within the three host laboratories (BNL, FNAL, and JLab) provides support to the project in a number of ways, including management and infrastructure support. Management authorities for DOE and senior management of the laboratories are shown in Figure 2.

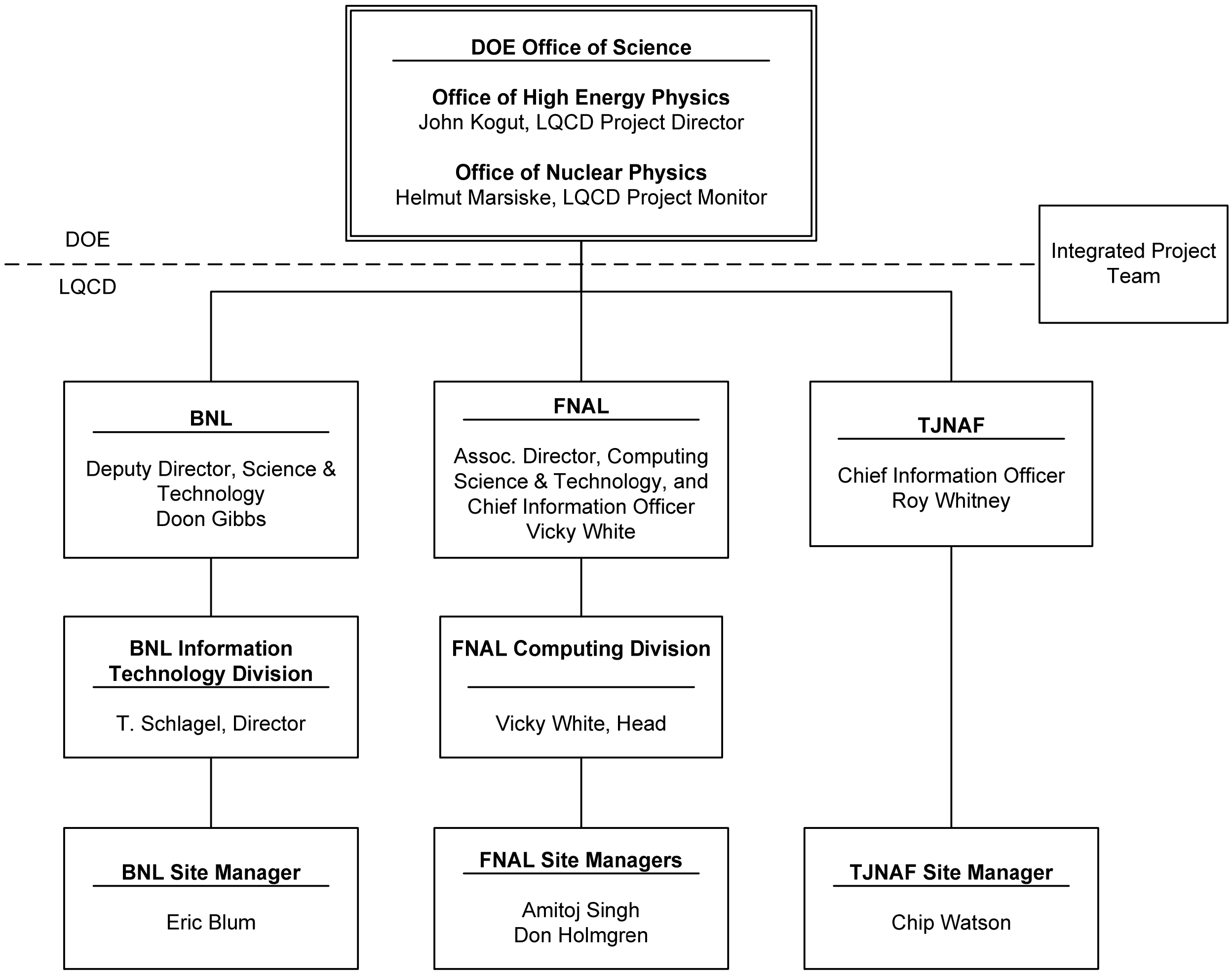

Figure 2: LQCD and Laboratory management

6 COST AND SCHEDULE MANAGEMENT

6.1 *Project Scope*

The scope of the LQCD-ext project includes the operation of the QCDOC computer at BNL, the operation of existing clusters at JLab and FNAL, and the acquisition and operation of new systems in FY 2010-FY2014. The QCDOC will be operated through the end of FY10. Existing clusters (7n at JLab, Kaon and J-Psi at Fermilab) will be operated through end of life, as determined by cost effectiveness (approximately 4 years). All new systems acquired during the project will be operated from purchase through end of life, or through the end of the project, whichever comes first.

6.2 Work Breakdown Structure

The LQCD-ext computing project is categorized as an OMB 300 mixed life-cycle investment, with both development/modernization/enhancement (DME) and steady state (SS) components. Project work is organized into a Work Breakdown Structure (WBS) for purposes of planning, managing and reporting project activities. Work elements are defined to be consistent with discrete increments of project work and the planned method of project control. The LQCD project plan has three major WBS Level 2 components based on the work performed at each participating laboratory (BNL, FNAL, and JLab). Under the Level 2 components are the following Level 3 components:

> **Planning**: Includes all activities associated with developing the acquisition plan for a given annual compute hardware procurement, including gathering vendor roadmap information, performing benchmarking tests, preparing procurement documents, etc.. Also includes all project management activities performed by the project office. The budget associated with planning includes labor costs associated with procurement planning and project management, as well as a modest amount for travel and miscellaneous project office expenses.
>
> **Acquisition**: Includes all activities associated with the annual receipt and deployment of new compute hardware, from the time new hardware arrives at the site until it is released to production use. The budget associated with Acquisition includes labor costs for deployment activities and equipment costs for new hardware.
>
> **Operations**: Includes all activities associated with steady state operation of the LQCD-ext computing facilities at the three host laboratories. The budget associated with Operations support labor for operations and maintenance activities, a modest level of travel support, and funds for M&S purchases such as replacement parts, spare disk, etc.

Before the beginning of the fiscal year, a detailed WBS, including WBS dictionary, is developed for the work to be done for the investment during that year, with basis of estimates derived from past purchase records and effort reports. The WBS is developed with the concurrence of the three Site Managers. Once defined, the WBS is baselined and a process for reporting status against the baseline is initiated. The WBS is typically developed using Microsoft Project.

Project milestones are defined in the project WBS. Each laboratory reports the status of completion for each project milestone to the CPM on a monthly basis. Any significant changes to milestone schedules are processed according to the change control procedure described later.

6.3 Project Milestones

Table 2 shows the Level 1 project milestones that are tracked by the DOE Office of Science and reported to the OMB through the Exhibit 300. These milestones are also defined and tracked in the project WBS.

Table 2: Level 1 Milestones

Level 1 Milestones	Fiscal Year
Computer architecture planning for the FY11 procurement complete & reviewed	Q3 2010
18 Teraflops-years aggregate computing delivered in FY10	Q4 2010
Procurement and deployment of 11 teraflops (sustained) in early FY11	Q1 2011
Procurement and deployment of 12 teraflops (sustained) in mid FY11	Q2 2011
Computer architecture planning for the FY12 procurement complete & reviewed	Q3 2011
22 Teraflops-years aggregate computing delivered in FY11	Q4 2011
Computer architecture planning for the FY13 procurement complete & reviewed	Q3 2012
Procurement and deployment of 24 teraflops (sustained) in FY12	Q3 2012
34 Teraflops-years aggregate computing delivered in FY12	Q4 2012
Computer architecture planning for the FY14 procurement complete & reviewed	Q3 2013
Procurement and deployment of 44 teraflops (sustained) in FY13	Q3 2013
52 Teraflops-years aggregate computing delivered in FY13	Q4 2013
Procurement and deployment of 57 teraflops (sustained) in FY14	Q3 2014
90 Teraflops-years aggregate computing delivered in FY14	Q4 2014

In addition to these Level 1 milestones, the WBS contains lower level milestones that provide the means for tracking progress at a more granular level. Table 3 contains an example of the type of Level 2 milestones contained within the WBS that are associated with each annual machine purchase and deployment.

Progress against all milestones is tracked and reported by the LQCD Project Office. Progress against Level 1 milestones is reported quarterly through the OMB Exhibit 300 reporting process. Progress against Level 2 milestones is discussed monthly with the DOE Federal Project Manager and Project Monitor, during monthly project status conference calls.

Site Managers at each host laboratory report the status of completion for each project milestone to the Project Office on a monthly basis. Any significant changes to milestone schedules will be processed according to the change control procedure.

Table 3: Example of Level 2 Milestones in the WBS
associated with each Hardware Procurement

Level 2 Milestones
Preliminary System Design Document completed
Request for Information (RFI) released to vendors
Request for Proposal (RFP) released to vendors
Purchase subcontract awarded
Approval of first rack.
Delivery of remaining equipment
Successful installation and completion of Acceptance Test Plan
Release to "Friendly User" production
Release to full production

6.4 Total Project Cost

The total project cost (TPC) estimate for LQCD-ext is $18.15 million. The budget profile has been developed in accordance with guidance from the DOE SC Offices of HEP and NP, and has been constructed to match the anticipated funding profile.

Project funds will be used to procure and deploy new systems, and provide labor support for steady-state operations, including site management, system administration, hardware support, and deployment of meta-facility software. All labor for scientific software support as well as the scientific needs of users will be paid by laboratory contributions and by the SciDAC project. Software development is not in scope of the project.

Each host site will continue to contribute in-kind support to the project in the form of infrastructure facilities and equipment, such as suitable computer room space, utility costs for power and cooling, and mass storage facilities. Each host site also provides administrative and technical support and services to the project in areas such as environment, safety, and health (ES&H), cyber security, disaster planning and recovery, networking, procurement, financial management services, and administrative support. Project funds are used to cover these costs through the assessment of overhead charges by each host site in accordance with standard laboratory policies.

Table 4 shows the budget profile in terms of planning, acquisition, and steady-state operations. The "Planning" budget provides for labor costs associated with deployment planning and project management activities, and for miscellaneous project office expenses. The "Acquisition" budget provides funds for labor costs associated with new system deployments, as well as equipment funds for new hardware procurements. The "Operations & Maintenance" budget provides funds for labor and M&S costs associated with steady-state operations and maintenance.

Table 4: Obligation Budget Profile by Exhibit 300 Summary of Spending Categories ($K)

Category	FY10	FY11	FY12	FY13	FY14	Total
Planning	52	54	57	59	61	283
Acquisition	1,887	1,997	2,203	2,825	2,627	11,539
Subtotal	1,939	2,051	2,260	2,884	2,688	11,822
Operations & Maintenance	1,061	1,199	1,340	1,216	1,512	6,327
Total	3,000	3,250	3,600	4,100	4,200	18,150

Figure 3 shows the proportional cost breakdown for the estimated total project cost for the 5-year project, by expenditure category. The planned distribution across expenditure types is based on experience gained during the first four years of deployments and operations, and reflects the goal of minimizing the amount of project funds used to support travel and non-essential M&S expenses.

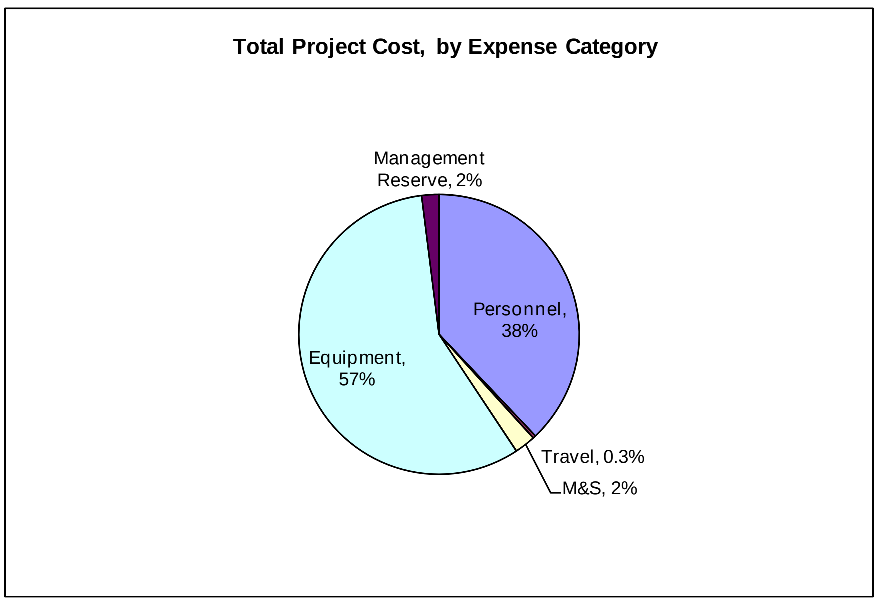

Figure 3: LQCD-ext Total Project Budget by Expenditure Type

Table 5 shows the obligation budget profile in terms of commonly-recognized expenditure types, by fiscal year. Personnel costs include system administration, engineering and technical labor, site management, and project management. All labor estimates have been inflated using escalation rates of 4%. Equipment costs include system acquisitions (computers, network hardware, etc.) plus storage (disk, tape media). Indirect charges will be applied according to agreements established between the project and the host laboratories and documented in approved MOUs.

Table 5: Obligation Budget Profile by Expenditure Type (in $K)

Expenditure Type	FY10	FY11	FY12	FY13	FY14	Total
Personnel	1,139	1,306	1,456	1,340	1,644	6,885
Travel	13	11	12	12	12	60
M&S	104	84	84	84	84	440
Equipment	1,684	1,779	1,974	2,589	2,379	10,405
Management Reserve	60	69	75	75	81	360
Total	3,000	3,250	3,600	4,100	4,200	18,150

Figure 4 shows in graphical form the data presented in Table 3. The travel, M&S, and management reserve budgets have been binned together for display purposes. Year-to-year fluctuations in the personnel budget profile are due to variations in the number of compute nodes in production in any given year. The staffing model is based on the number of nodes in operation in any given year, and so an increase in nodes results in increased system administration costs.

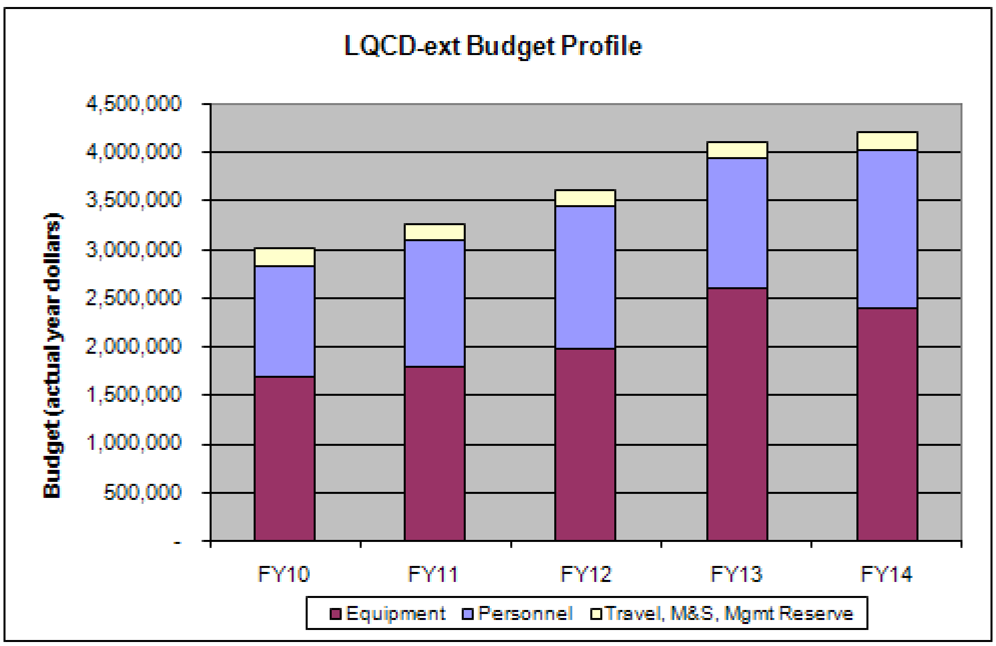

Figure 4: LQCD-ext Project Budget Profile by Fiscal Year

6.4.1 Management Reserve

Management reserve funds are used to cover the cost of unanticipated but required labor expenses that arise during the course of deploying new systems or supporting steady-state operations. Management reserve funds are allocated only after it is clear that the costs cannot be covered by adjusting priorities or rearranging work. Management reserve has been set at 20% of the unspent deployment personnel budget and 3% of the unspent steady-state operations personnel budget.

Unspent management reserve funds from the first two years of the project (FY10-11) will be carried forward to FY12. Beginning in FY12, unspent management reserve in any one year will be applied towards the new hardware procurement in the subsequent year, to maximize the computing resources provided to the user community.

Management reserve funds are controlled by the Contractor Project Manager. Any use of management reserve funds will be reported to the Federal Project Manager and Project Monitor during the monthly progress report and noted during the annual progress review process.

6.4.2 Funding and Costing Profile

The LQCD-ext computing project will be jointly funded by DOE-HEP and DOE-NP. As of this writing, the baseline funding and costing profile has not been finalized. Once finalized and approved as part of the Critical Decision process, the profile will be noted here and the project budget profile adjusted to accommodate the costing and funding profile.

6.4.3 Steady State Life Cycle Cost

Part of the steady state life cycle costs will be funded by the project, specifically, the manpower required for the administration and maintenance of the systems (~ 3-4 FTE). However, portions of the cost of the LQCD facility, such as power and cooling, will be contributed by the participating laboratories. After the end of the project, continued operation of all of the acquired systems would incur similar labor and utility costs; however, systems would be retired as they reached their projected lifetimes (3 to 4 years), decreasing the required out-year costs proportionally. The decommissioning of LQCD resources covers the disposal of standard electronic, computing, and network equipment, which must follow accepted standard procedures for disposal of these items. These decommissioning costs are not included in the project.

6.4.4 Deployment Performance Contingency

Table 6 shows the planned budget for compute and storage hardware. In each year of LQCD-ext project, we will either construct tightly coupled clusters, or purchase commercial supercomputers, choosing the most cost effective solution available at the time. Each of these annual developments of new computing systems will be "built-to-cost" in accordance with the approved budget.

Table 6: Compute Hardware Budget (in $K)

Fiscal Year	Compute Hardware	Storage Hardware	Total
FY10	1,600	84	1,684
FY11	1,690	89	1,779
FY12	1,875	99	1,974
FY13	2,460	129	2,589
FY14	2,260	119	2,379
Total	9,885	520	10,405

All LQCD-ext project cluster hardware procurements will utilize firm fixed-price contracts. Given annual fixed compute equipment budgets, the precise number of processors procured will be determined by purchase price of systems and network equipment in that year. Variation in purchase price of these components from the estimates used in the budget will result in greater or lesser computing capability from the estimated value. Variation in performance of the components from the estimates will also result in greater or lesser computing capability. The resulting performance risk is managed by the fact that the scope of the project is fluid; small negative variances in available computing capability and/or capacity may result in schedule delays in completing scientific computing projects. Large negative variances will prevent the completion of computing goals; these will trigger review and modification of the LQCD scientific program, such as through changes or elimination of allocations of computing resources to specific projects.

The risk of large performance variances is minimized through the use of conservative projections in the estimated costs and performance of each future system development. Allocations of computing resources, and the planning of the LQCD scientific program, will be based upon these conservative estimates.

Figure 5 shows historical price/performance data along with the price/performance that each new hardware purchase would need in order to meet project deployment goals shown in Table 1. Each of the purchases is plotted at the planned deployment date. If price/performance trends continue as they have since 2005, we expect to achieve the better price/performance values along the fit line. The separation of the blue diamonds in the plot from the trend line is the project's performance contingency. In each year, the project will build to cost in accordance with the approved baseline budget and we expect that the resulting computing capacity will be in excess of the project's "deployed TFlops" goal. This excess is the contingency.

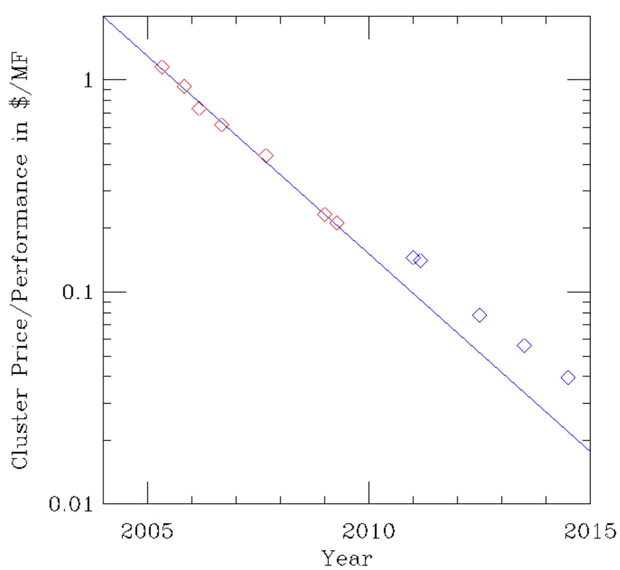

Figure 5: Development of Performance Contingency

A full description of the LQCD-ext project procurement strategy can be found in the following project document: *Acquisition Strategy for the Lattice QCD Computing Project Extension*.

6.5 Cost and Schedule Management Controls

Overall performance at three host laboratories is managed under the terms of the performance-based management contract with the DOE. Under these terms, laboratories are expected to integrate contract work scope, budget, and schedule to achieve realistic, executable performance plans. Following existing financial and operational procedures and processes at FNAL, BNL and JLab, the project has implemented methods of collecting and analyzing project performance data.

The LQCD project office, consisting of CPM and ACPM, is responsible for the overall management of the project and for implementing controls to ensure that cost, schedule, and technical performance requirements are met.

Memoranda of Understanding (MOU) are executed between the project and the participating laboratories that detail work scope, funding levels, and the in-kind support provided to the project by the host laboratories.

The project office has implemented a performance-based management system in which cost and effort data are collected from all three laboratories and analyzed on a monthly basis. Site managers are be responsible for tracking cost and schedule elements, and for reporting these to the ACPM monthly. The ACPM prepares and reviews monthly cost and schedule performance data against schedule, cost, and technical goals, and reports the result to the CPM. The CPM submits a monthly report on the overall cost, schedule and technical performance to the Federal Project Manager, Project Monitor, and other stakeholders.

Technical performance is monitored throughout the project to insure conformance to approved functional requirements. Design reviews and performance testing of the completed systems are used to ensure that equipment and systems meet functional requirements.

On a quarterly basis, the project office prepares a quarterly report on project performance per OMB guidance and submits the report to the Federal Project Manager for review and concurrence. Project performance is graded using a stop-light grading system (red, yellow, green). Significant deviations from performance objectives require the development of formal “Get-Well” corrective action plans.

On an annual basis, the DOE Office of Science organizes an external review of project performance. The review typically covers aspects of scientific, technical, cost, and schedule performance against goals. Results are recorded in a written report; all recommendations are carefully considered and implemented as appropriate. The Contractor Project Manager is responsible for preparing a document summarizing the project’s response to each recommendation.

7 CHANGE CONTROL

Changes to the technical, cost and schedule baselines are controlled using the thresholds and approval levels described in Table 7.

Table 7: Summary of Change Control Thresholds

Change Control Level	Approver	Cost Threshold	Schedule Threshold	Technical Scope/ Performance Threshold
Level 1	Acquisition Executive	Any increase in Total Project Cost Or Change of > $250K in budget distribution between DME and SS O&M costs as defined in Exhibit 300	6-month or more increase in a Level 1 milestone date	Changes to scope that affect mission need and/or performance requirements
Level 2	Federal Project Manager	Change of ≥ $125K in budget distribution between DME and SS O&M costs as defined in Exhibit 300 or Movement of allocated funds between laboratories	3-month or more delay of a Level 1 milestone date	Any modification in the technical performance baseline defined in a Level-1 milestone
Level 3	Change Control Board	Change of < $125K in budget distribution between DME and SS O&M costs as defined in Exhibit 300 or Cumulative increase of ≥ $125K over baseline budget for WBS Level 2 elements	> 1-month delay of a Level 1 milestone date or > 3-month delay of a Level 2 milestone date.	> 10% decrease from baseline of either the targeted computing capability increment (Tflop/s) or integrated delivery (Tflop/s-yrs) in a single project year.
Level 4	Contractor Project Manager	Any increase of ≥$25K over baseline budget for WBS Level 2 elements	> 1-month delay of a Level 2 milestone date	Any deviation from technical deliverables that negatively affects expected performance specifications by more than 5%

No formal change control action is required for changes that do not exceed Level 4 thresholds. Site Managers are authorized to make changes below Level-4 thresholds and are required to inform the CPM of the change. Changes below Level-4 do not have to be documented on Change Request (CR) Forms.

The Contractor Project Manager (CPM) is authorized to approve Level-4 changes. The initiator of a Level-4 change request must submit a completed CR form to the CPM for review and approval. A sample CR form is included as Appendix C.
All change requests that exceed Level-3 thresholds are first submitted to the CPM for approval, using a CR form. For these CRs, the CPM will either: 1) reject the request; 2) return the CR to the initiator with a request for additional information; or 3) approve the CR and transmit it to the CCB with recommendations for further action. The CCB is authorized to approve Level-3 changes.

For changes exceeding Level-3, the CCB will either: 1) reject the request; 2) return the CR to the CPM with a request for additional information; or 3) approve the CR and transmit it to the Federal Project Manager with recommendations for further action.

For changes exceeding Level-2, the Federal Project Manager will either: 1) reject the request; 2) return the CR to the CCB and/or CPM with a request for additional information; or 3) approve the CR and transmit it to the Acquisition Executive with recommendations for further action.

The CPM is responsible for notifying the Scientific Program Committee (SPC) of all change requests that exceed Level-4 thresholds. The SPC will review these CRs for potential scientific impact on the project and will advise the CPM accordingly. The CPM will factor the comments and advise of the SPC into the CR review and approval process.

For all approved change requests, a copy of the approved CR form, along with any qualifications, analysis, or documentation generated in considering the request, will be filed by the LQCD Project Office. One copy of the approved CR and supporting documentation will be provided to the CR initiator and one copy will be provided to the official at the next higher control level. The official at the next higher control level may review the granted change to ensure proper application of the procedure and consistency of the change with the goals and boundary conditions of the project.

For all denied changes, a copy of the CR form, along with the reasons for denial, will be filed by the Project Office. In addition, a copy of the CR Form and reason for denial will be provided to the CR initiator.

8 PROJECT MANAGEMENT/OVERSIGHT

8.1 Enterprise Architecture Management

The primary planning document for the project is the OMB Exhibit 300 business case document for the budgeting year. This document contains detailed tracking information on cost and schedule performance, performance toward project goals, security and privacy, alternative analysis and risk management. Since this is a major Federal IT investment, the project prepares a Performance Reference Model (PRM), mapping all “Measurement Indicators” to the corresponding "Measurement Area" and "Measurement Grouping" identified in the PRM. Other measures associated with the project are associated with the Service Component Reference Model (SRM) and Technical Reference Model (TRM). Details on Federal Enterprise Architecture are given at www.egov.gov.

8.2 Security Management

LQCD-ext computing systems are distributed over three different host laboratories. Each system becomes a part of a computing enclave of the particular host laboratory. Each computing enclave is protected according to the procedures implemented by the corresponding laboratory. During the deployment of a new hardware system, each Site Manager updates the site-specific security plan to include the new system. The LQCD-ext Project Office maintains the Certification and Accreditation documents for each participating laboratory.

Performance is monitored by the DOE site office at each laboratory, in accordance with the requirements specified in the contracts between the DOE and the respective contracting agencies (Brookhaven Science Associates (BSA) for BNL, Fermi Research Alliance (FRA) for FNAL, and Jefferson Science Associates, LLC (JSA) for TJNAF). These contracts include requirements for compliance with pertinent government (NIST 800-53) and DOE Computer Security policies (e.g. DOE O 205.1 Department of Energy Cyber Security Management Program). At each laboratory, contractor security procedures are monitored, verified, and validated by numerous external entities including: 1) DOE-OCIO, 2) DOE Office of Performance Management and Oversight Assessment, 3) the DOE-IG, and 4) external reviews.

8.3 Privacy Management

None of the LQCD-ext systems contain, process, or transmit personal identifying information. These systems are not a privacy system of records.

8.4 Risk Management

Within the project, risk management is viewed as an ongoing task that is accomplished by continuously identifying, analyzing, mitigating and monitoring risks that arise during the course of project execution. Risk is a measure of the potential of failing to achieve overall project objectives within the defined scope, cost, schedule and technical constraints. The purpose of risk analysis is not solely to avoid risks, but to understand the particular risks associated with the project and devise strategies for managing them.

The final responsibility for risk management rests with the CPM, in consultation with the LQCD Executive Committee and site managers. However, effective risk management is a multi-step process that requires the continuous involvement of all project team members. The project team plans for and tracks the operational and financial risks associated with the project using the LQCD-ext Risk Management Plan. The Risk Management Plan is reviewed and updated whenever changing conditions warrant a review and revision of the risk register. At a minimum, the Risk Management Plan will be updated quarterly, in conjunction with the quarterly report process. During these reviews, the risk register is updated by adding and/or closing risks, and initiating and revising risk mitigations, as needed.

A full discussion of potential risks and mitigation strategies is contained in the Risk Management Plan. The following paragraphs provide a brief insight into some of the more salient risks associated with project execution, including cost overruns, failure to meet performance goals, and data loss due to catastrophic events.

Because of the build-to-cost nature of the project, LQCD has minimal risk of overrunning the approved project budget. Cost estimates are based in part on current and past procurements for the prototype computing systems, and on the actual cost of labor for deploying and operating the existing facilities. Actual costs are tracked monthly, allowing for prompt corrective action if necessary.

Notwithstanding, failure to properly manage project costs may impact our ability to deliver on key performance goals. Hardware cost variances result in adjustments to the size of the computing systems developed each year. Likewise, labor cost variances (.e.g., the need to change the level of systems admin or user support) results in adjustments in the allocation of funds between subsequent computing hardware and labor budgets. In either case, significant increases in hardware or labor costs could result in reductions in deployed computing capacity, system uptime, or other key performance metrics.

As documented in the Risk Management Plan, performance risks associated with computing and network system are estimated to be low due to successful R&D efforts and the use of off-the-shelf components whenever possible.

The distributed nature of the LQCD facility partially mitigates the risk of natural disasters. Additionally, the LQCD project employs a disaster recovery strategy for valuable data by storing data files redundantly at two different locations (e.g., FNAL and JLab). Although the equipment at each facility is not insured against disasters, standard disaster recovery protections are provided by each laboratory.

8.5 Quality Assurance

LQCD defines quality as the "fitness of an item or design for its intended use" and Quality Assurance (QA) as "the set of actions taken to avoid known hazards to quality and to detect and correct poor results." LQCD follows established quality control procedures established at the hosting laboratories. In addition, the project has put into place various methodologies to monitor and improve quality, as described in the *LQCD-ext Quality Assurance Plan*. All new hardware inspected for physical quality defects upon initial delivery. As new systems are brought on line, a series of tests are conducted to verify quality at the component and system level. Nodes are tested individually and then as a racked unit. Racks are then interconnected and tested. When various components of a new cluster have been tested, the cluster is release to "user-friendly mode" for a short period of more intense testing and use to verify operational readiness, before being turned over to full-production use. Other quality assurance processes include incoming inspection of replacement components, performance management, uptime monitoring, operations analysis, and user satisfaction surveys.

8.6 Project Oversight

The LQCD-ext project office prepares a monthly report for the DOE Office of Science and a monthly meeting is held to inform the Federal Project Manager and Project Monitor of cost, schedule and technical performance, along with other issues related to project execution. The project office also prepares and submits formal DOE Quarterly Reports based on OMB guidance.

To determine the health of the project and to provide guidance on project progress, an annual DOE Office of Science project review is held, generally in May. During this review, upcoming procurement strategies are presented and reviewed. Review results are presented in written form and transmitted to the Contractor Project Manager via the DOE Office of Science. The CPM is responsible for responding to all review recommendations.

9 ENVIRONMENT, SAFETY AND HEALTH

Environment, safety and health (ES&H) is integrated into all phases of planning, acquisition and maintenance phases of the LQCD-ext project using appropriate procedures defined by the participating laboratories.

LQCD-ext project follows the five core functions as described in the DOE guidelines.

1. Define work and identify the potential hazards
2. Analyze potential hazards and design the equipment or activities to appropriately mitigate or eliminate those hazards.
3. Establish controls for hazards that cannot be eliminated through design features
4. Perform work in accordance with the procedures
5. Review the effectiveness of the hazard analyses and controls and provide feedback for improvement.

The LQCD-ext computing project is a collaborative effort among three DOE-sponsored laboratories with stringent ES&H policies and programs. All individuals supported by project funds follow procedures specific to the host laboratory at which they work.

The line management of each laboratory retains supervisory authority of their personnel and responsibility for the safety of work performed. Line management keeps the CPM informed about their laboratory's management and ES&H organization structures. Any safety concerns by LQCD-ext personnel are to be communicated to the line management where the concern occurs and if appropriate, the employee's home laboratory or university.

Site managers at each laboratory work with safety officers at their Laboratory to ensure that the specific hazards found in the project are documented according to plans and procedures of the particular laboratory and mitigated appropriately. Information pertaining to these hazards are documented as needed using appropriate safety documentation guidelines for the laboratory. Also, laboratory personnel receive specific training required or recommended for project to perform their job in a safe and proper manner.

Applicable electrical and mechanical codes, standards, and practices are used to ensure the safety of personnel, environment, equipment and property. All equipment purchased from manufacturers must comply with Underwriters Laboratories Inc. or equivalent requirements, or reviewed for safety. The procurement of each new system or component is done under the guidance provided by the procurement organization of associated laboratory.

There is no direct construction activity under the direction and control of this project. Any facility upgrades or improvements involving construction activities will be managed by the host laboratory. The LQCD-ext project will comply with all necessary rules, regulations, policies and procedures related to working in or around construction areas. Any required NEPA reviews related to facility upgrades associated with LQCD-ext computing facilities will be coordinated and/or conducted by the host laboratory.

Appendix A: Integrated Project Team

LQCD (Federal) Project Manager (HEP)	John Kogut (chair)
LQCD Project Monitor (ONP)	Helmut Marsiske
Contractor Project Manager (CPM)	Bill Boroski
Associate CPM	Bakul Banerjee
BNL Site Manager	Eric Blum
JLab Site Manager	Chip Watson
FNAL Site Managers	Don Holmgren / Amitoj Singh
LQCD Executive Committee Chair	Paul Mackenzie

Appendix B: Committees and Members

LQCD Executive Committee

Richard Brower (Boston U.), Norman Christ (Columbia U.), Michael Creutz (BNL), Paul Mackenzie (Chair, FNAL), John Negele (MIT), Claudio Rebbi (Boston U.) David Richards (JLab), Stephen Sharpe (U. Washington), and Robert Sugar (UCSB)

LQCD Scientific Program Committee

Tom Blum (U. Connecticut), Chris Dawson (U. Virginia), Robert Edwards (JLab), Frithjof Karsch (Chair, BNL), Andreas Kronfeld (FNAL), Martin Savage (U. Washington), Junko Shigemitsu (Ohio State).

Appendix C: Sample Change Request Form

Log number (provided by project office): [BCA #]		
1) DATE: [date of origination]	2)Laboratory/WBS: [Highest level of WBS affected	3) ORIGINATOR:
4) WBS DESCRIPTION OF PRIMARY AFFECTED TASKS:		
5) TECHNICAL DESCRIPTION AND PRIMARY MOTIVATION OF CHANGE: [Attach in word doc]		
6) ASSESSMENT OF COST IMPACT (identify any change in resources needed as reflected in the WBS) Estimated M&S Cost Increase ($): Estimated Labor Cost Increase ($): Estimated scientific impact (high, medium, and low)		
7) ASSESSMENT OF SCHEDULE IMPACT AND AFFECTED MILESTONES (identify slip or stretch of work or change in plan): [Attach as WBS report]		
8) SECONDARY IMPACT AND OTHER COMMENTS:		
9) APPROVALS Level 1 – Acquisition Executive ______________________ Date __________ Level 2 – Federal Project Manager ______________________ Date __________ Level 3 - Chair, Change Control Board ______________________ Date __________ Level 4 - Contractor Project Manager ______________________ Date __________		
10) CCB Approvals O APPROVED O DISAPPROVED ______________________ Signature/date O APPROVED O DISAPPROVED ______________________ Signature/date O APPROVED O DISAPPROVED ______________________ Signature/date O APPROVED O DISAPPROVED ______________________ Signature/date O APPROVED O DISAPPROVED ______________________ Signature/date		

Appendix D: Controlled Documents

The set of documents submitted to DOE are designated as controlled project documents. These documents are tracked using the Document Database Control system managed by the Fermilab Computing Division. The LQCD document control area is password protected and only accessible by the IPT. Access requests should be made to the ACPM

The following are considered to be controlled documents, with formal version control and signature approval.

1. Project Execution Plan
2. Baseline Work Breakdown Structure
3. Risk Management Plan
4. Quality Assurance Program
5. System Description
6. Acquisition Strategy
7. Alternatives Analysis
8. Certification and Accreditation document
9. Security Vulnerability Assessment Report

In addition to controlled documents, the following documents are also stored in DocDB under limited access.

1. OMB Exhibit 300 submission documents
2. Memoranda of Understanding
3. LQCD monthly reports and DOE quarterly reports
4. External project review reports