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

Unique Project (Investment) Identifier: 019-20-01-21-02-1032-00

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

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Office of Science
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SC Lattice QCD Computing Project Extension II (LQCD-ext II)

Version 1

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LQCD-ext II Project Execution Plan
Change Log

Revision No.	Description / Pages Affected	Effective Date
	Preliminary Project Execution Plan	
0.0	Preliminary PEP developed.	02/17/2014
0.1	Updated values in Table 1 and Appendices C & D to reflect revised forecast for deployed Tflop/s and delivered Tflop-s/yrs.	02/21/2014
	Project Execution Plan	
0.0	Document upgraded from "preliminary" state. Revisions made throughout document. Initial document release. Presented at CD-2/3 Review.	07/07/2014
1.0	Updated signature page, org charts and other areas of document to reflect various personnel changes.	1/8/2015
1.1	Implemented text changes approved in Dec 2014 DOE Monthly Call. Updated the SVA Report reference to "Cyber Security Plan". Removed DRAFT watermark. Updated committee membership in Appendix B. Add id's to App. C & D entries.	5/8/2015
1.2	Integrated PEP Addendum (July 5, 2015), BNL and FNAL staff and org changes. Updated for consistency with CR16-01 and the 3-Sites FY-Straddle scenario.	5/24/2016

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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 FY2015 through FY2019. The plan has been prepared in accordance with DOE Order O413.3B, *Program and Project Management for the Acquisition of Capital Assets* (dated 11-29-10).

The official name of this capital asset investment is "SC Lattice Quantum Chromodynamics Computing (LQCD)" and the Unique Project (Investment) Identifier is 019-20-01-21-02-1032-00. The LQCD computing project was initially funded from FY2006 through FY2009. In 2009, a proposal to extend the project through FY2014 was reviewed following the DOE Critical Decision (CD) process. The LQCD Computing Project Extension (LQCD-ext) received CD-3 approval on October 29, 2009 and was funded for the period FY2010-2014. In 2013, a proposal to continue the computing project through FY2019 was submitted and reviewed. The proposed next phase of the computing project (LQCD-ext II) received CD-0 approval on September 9, 2013 and CD-1 approval on April 21, 2014. If fully approved, LQCD-ext II will continue to deploy and operate dedicated computing hardware from FY2015 through FY2019 using the same hardware deployment and operations methodology, and the management and oversight structure, that has been used since FY2006. The methodology and oversight structure has resulted in the project successfully meeting all performance goals and milestones, and more importantly, in providing the US Lattice Quantum Chromodynamics (USQCD) scientific community with dedicated computing facilities to achieve its scientific goals.

The LQCD computing project was initially classified as an OMB Exhibit 300 IT investment project. In August 2010, the OMB Exhibit 300 investment classification criteria were modified and the LQCD computing project was re-classified as an OMB Exhibit 53 project. The LQCD-ext II project continues to meet the planning, budgeting, and reporting criteria for an OMB Exhibit 53 IT investment, therefore this classification remains intact.

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 Offices of High Energy Physics (HEP), Nuclear Physics (NP), Advanced Scientific Computing Research (ASCR), and the SciDAC program, 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 machines built for general purpose use on a wide range of applications.

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 incorporated 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 outlined in DOE O 413.3A, which was the version in effect at the time. CD-3, Approval to Start Construction, was granted on October 29, 2009. The project was baselined after this approval and project execution began in FY10. Following the original project execution model, LQCD-ext project managers used this document as the primary management tool. The LQCD-ext computing project ended on September 30, 2014. The project executed as planned and all performance milestones and metrics were met or exceeded.

In 2009, funds from the American Recovery and Reinvestment Act of 2009 (ARRA) were provided through the DOE SC Office of Nuclear Physics to support a parallel project to deploy and operate additional computing resources for LQCD calculations. The scope of the LQCD-ARRA project included two hardware deployments and four years of operations. The addition of the LQCD-ARRA project impacted the deployment plans for the LQCD-ext project. The LQCD-ext FY2010 cluster was to have been deployed at JLab. However, when the LQCD-ARRA project was initiated, a collective decision was made to deploy resources obtained through the LQCD-ARRA project at JLab and to deploy the FY2010 LQCD-ext cluster at Fermilab. In addition, the LQCD-ARRA project was managed separately from, but in coordination with, the LQCD-ext project. Whereas the LQCD-ext project office was located at Fermilab, the LQCD-ARRA project was managed through JLab.

By mid-2012, the LQCD-ARRA project had met or exceeded all performance goals and so the DOE requested that the LQCD-ARRA project be closed out and ongoing operation of the computing systems obtained through the LQCD-ARRA project be merged with LQCD-ext operations. Beginning in October 2012, the LQCD-ext project took over the responsibility for the operations and maintenance of the LQCD-ARRA clusters.

In 2013, the USQCD Executive Committee submitted a proposal outlining the scientific justification to extend the project through the end of FY2019. Following an initial scientific review of the written proposal, CD-0, Approval of the Mission Need Statement, was granted on September 9, 2013. The proposal was then formally reviewed by a panel of nuclear and high energy experimentalists and theorists, as well as computer scientists, on November 8, 2013 and the results summarized in a written report that was approved January 29, 2014. The science review resulted in a strong endorsement of the proposed plans. Following the DOE Critical Decision (CD) process, a CD-1 review of the project was held on February 25, 2014 and the results summarized in a written report. CD-1, Approve Alternative Selection and Cost Range, was granted on April 21, 2014. The LQCD-ext II project continued through the DOE Critical Decision process as outlined in DOE O413.3B. A CD-2/3 review took place on July 10, 2014, and CD-2/3 approval was granted on 8/28/2014.

Following the original project execution model, LQCD-ext II project managers will continue to use this document as the primary management tool. The LQCD-ext II computing project is scheduled to begin in October 2014 and is scheduled to end on September 30, 2019.

A significant change in the IT investment classification of the LQCD computing project occurred in August 2010. The DOE Office of the Chief Information Officer (OCIO) determined that it was appropriate to raise the threshold for mandatory IT investment classification and reporting to $25 million (PY, CY, and BY) beginning with the BY 2012 IT reporting cycle. An e-mail containing this decision and guidance was distributed to the DOE IT Council on August 26, 2010 to ensure that the initial BY2012 IT portfolio was adjusted to reflect this change prior to OMB submission.

Since the LQCD-ext project budget profile fell beneath the revised threshold, the project status was downgraded to a non-major IT investment because it no longer fit the criterion for a Major investment. Accordingly, the project was reclassified from an OMB Exhibit 300 project to an OMB Exhibit 53 project. The LQCD-ext Federal Project Director formally notified the LQCD-ext Contractor Project Manager of the change in classification through an e-mail dated August 27, 2010.

Although the formal IT investment classification of the LQCD computing project has changed, the project continues to be managed through OHEP and ONP using the same management and oversight structure that has been in place since project inception. Performance milestones that had been documented in the OMB Exhibit 300 business case are now incorporated in the appendices of this document. The project will adhere to all OMB Exhibit 53 reporting requirements and will coordinate reporting through the Federal Project Director.

3 JUSTIFICATION OF MISSION NEED

The LQCD computing project 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-ext II computing project is a part of the DOE Office of Science HEP and NP programs to enable scientific discovery through advanced scientific computing. QCD is the theoretical framework for large experimental programs in HEP and NP, and its properties can only be determined through large scale computer simulations. The LQCD-ext II 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. At the beginning of the project in FY15, LQCD-ext II will utilize the LQCD clusters located at the Fermi National Accelerator Laboratory (FNAL) and Thomas Jefferson National Accelerator Facility (JLab), and the LQCD IBM

BlueGene/Q half-rack operated at Brookhaven National Laboratory (BNL). These resources will provide an estimated total sustained computing capacity on LQCD calculations of 195 TF/s. These systems run physics applications built using optimized LQCD libraries developed by the SciDAC-1, SciDAC-2, and SciDAC-3 LQCD projects and funded by HEP, NP, and ASCR (Advanced Scientific Computing Research). In addition to providing highly optimized LQCD codes, the SciDAC-3 project is developing new algorithms that will further increase the cost effectiveness of the hardware acquired by this investment. This investment provides funds for the acquisition and operation of new hardware and for the operation of the existing hardware through the end of their life cycle.

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

Project funds will be 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 computing hardware brought online during the LQCD, LQCD-ext, and LQCD-ARRA computing projects. Project funds will also be used for the procurement and operation of new computing systems 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 10 Tflop/s on jobs lasting at least 2 hours. The total memory required for such jobs will be at least 100 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 0.5 Tflop/s on jobs lasting at least one hour. The total memory required by such jobs will be up to 2 TBytes. Further, the total aggregate computing capacity of such systems by the end of the second year of the project must be at least 176 Tflop/s. Note that this total includes 127 Tflop/s of capacity provided by systems from the current LQCD-ext project, with an additional 49 Tflop/s of capacity provided by systems procured during the first two years of the LQCD-ext II project. During the course of the final two years of the project, all requirements (sustained performance and required memory) for both classes of lattice QCD computing will at least double.

Depending on funding and the needs of the scientific community, one or two new systems will be deployed per year during the period FY2016-FY019; there will be no deployment of new hardware in FY2015. “System” denotes a cluster or other hardware of uniform design; typically both a conventional and an accelerated cluster may be deployed in a given year, counting as two new systems even though a single procurement activity may be utilized. Table 1 shows the planned total computing capacity of the new deployments and planned delivered (integrated) performance. Currently the project uses effective Tflop/s-yrs as the metric for delivered computing capacity on GPU-accelerated clusters; this unit is based on the observed increase of throughput on a set of benchmark production codes running on accelerated hardware relative to equivalent calculations performed on conventional hardware. In all discussions of performance, unless otherwise noted, the specified figure reflects an average of the sustained performance of domain wall fermion (DWF) and highly improved staggered quark (HISQ) algorithms; for accelerated systems, the specified figure is an effective sustained performance rating based on the speedup of DWF, HISQ, and anisotropic clover production codes relative to the performance of the equivalent non-accelerated programs.

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

	FY 2015	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**
Planned computing capacity of new deployments (Original Baseline) Tflop/s	0	49	66	134	172
Planned computing capacity of new deployments (CR16-01) Tflop/s	0	98	45	126	112
Planned delivered performance (Original Baseline) Tflop/s-yr	180	135	165	230	370
Planned delivered performance (CR16-01) Tflop/s-yr	180	164	190	241	340

Performance of New System Deployments, and Integrated Performance (DWF+HISQ averages used). Integrated performance figures assume an 8000-hour year. The capacity and delivered performance figures shown in each year sum the conventional (Tflop/s and Tflop/s-yr) and accelerated (effective Tflop/s and effective Tflop/s-yr) resources deployed and operated. All deployment figures assume that the annual hardware budget is split 50%-50% between accelerated hardware. CR16-01 includes an allocation on the BNL Institutional Cluster that is “deployed” in FY16.

In each year of the project, the hardware that best accomplishes the scientific goals for LQCD calculations will be purchased. Each system acquired by the LQCD-ext II project will be operated for a minimum of 4 years. Since FY2011, the project has determined that two deployments, consisting of conventional and GPU-accelerated Infiniband clusters, best optimize the scientific capabilities of the portfolio of hardware operated by the LQCD-ext project for existing hardware choices and for current software. The split between these types of clusters is determined as part of the annual acquisition planning process and is based upon a number of factors, including cost effectiveness, availability of software, demand, and scientific impact.

In FY2012, the project added the procurement of an IBM BlueGene/Q supercomputer to the annual deployment mix. As in past years, for each annual hardware acquisition going forward, the LQCD-ext II project team will consider alternative hardware designs suitable for LQCD computing that may become available.

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 capability, but rather by either bandwidth to main memory, or by the delays imposed by the network fabrics interconnecting the processors.

LQCD computing 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 Gflop/sec in single precision 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 200 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 10 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 1.4 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 400 TB. 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 may be as high as 300 Mbytes/sec for a fraction of the duration of the job. The mix of jobs on a given cluster may be manipulated through the use of the batch system to preclude saturation of the I/O system.

4.4 Data Access Requirements

Configuration generation is performed at the BNL LQCD BG/Q 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 is at least 200 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 LQCD Federal Project Director and conducted as part of the annual DOE 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-ext II 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 document: *Acquisition Strategy for the Lattice QCD Computing Project Extension II*.

4.6 Operations

The operation of LQCD 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.

In addition to hosting the dedicated LQCD computing hardware, the three host laboratories operate physical facilities in support of the LQCD systems. The LQCD-ext II 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, SciDAC-2, and SciDAC-3 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: conventional and GPU-accelerated 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 BNL, FNAL and JLab. Tape media and, as necessary, tape drives are procured using operational funds allocated to the project.

On a periodic basis, USQCD 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 may utilize two of the three sites to take advantage of the specific characteristics of each. For this reason, efficient movement of physics data between sites is essential.

The planned lifecycle for computing hardware operated by the LQCD-ext II project team is 4 years after commissioning. Specific systems may be operated beyond 4 years if the project team determines that continued operation is cost-effective for the project and host institution. 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 Office of Science, the DOE Offices of High Energy Physics and Nuclear Physics, and the laboratories hosting LQCD computing facilities. Members of the USQCD collaboration are key customers of the LQCD computing facilities. These include laboratory and university researchers, as well as post-docs and students. Their feedback will be provided throughout the project through the USQCD Executive Committee and spokesperson.

5 MANAGEMENT STRUCTURE AND INTEGRATED PROJECT TEAM

This section describes the management organization for the LQCD-ext II computing project and defines 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 II project is shown in Figure 1. Solid lines indicate reporting relationships; dashed lines represent advisory relationships.

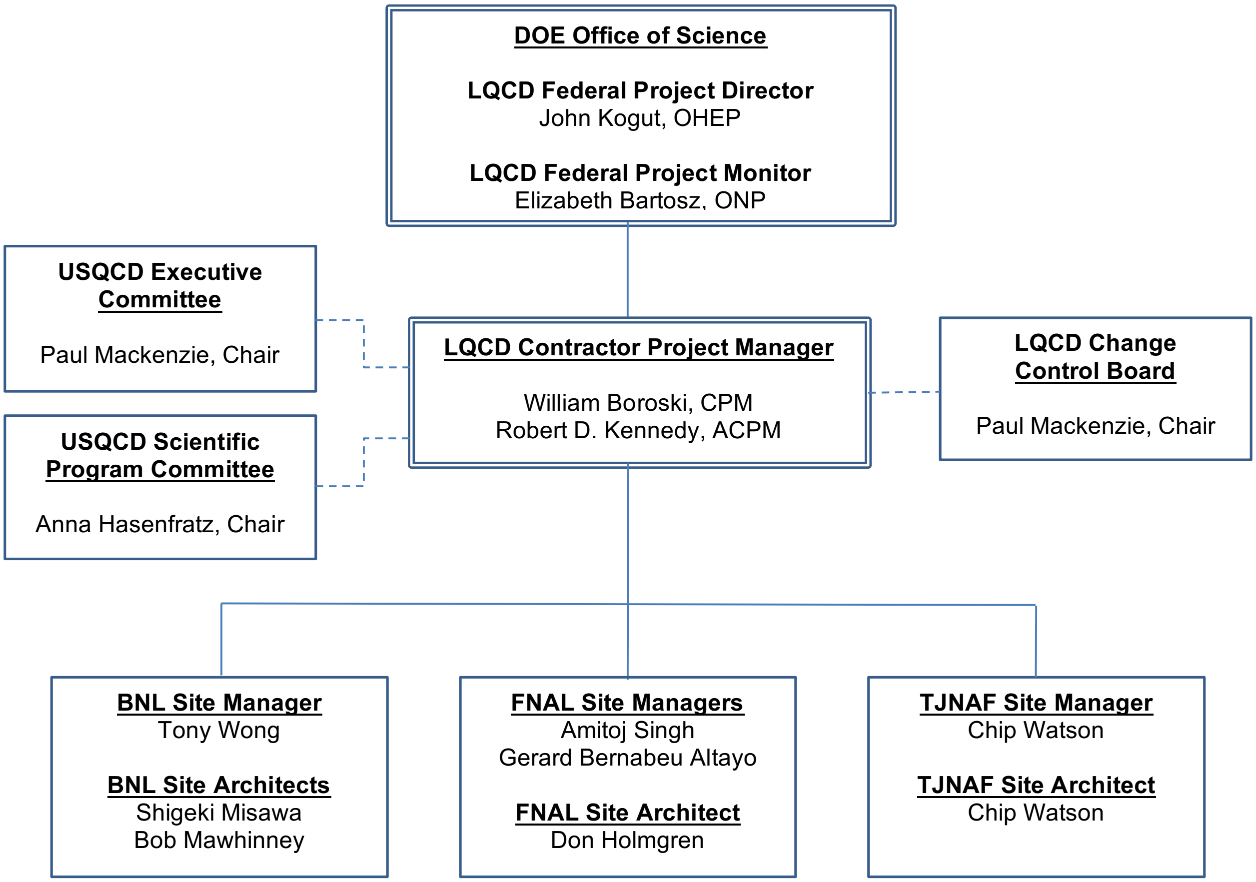

Figure 1: Management Organization Chart for the LQCD-ext II Computing Project.

5.1 Roles and Responsibilities

5.1.1 LQCD Federal Project Director

Overall management and oversight is provided by the DOE Office of Science, through the Offices of HEP and NP. The LQCD Federal Project Director 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 Federal Project Director is John Kogut, from OHEP; he is a certified DOE Level 1 Qualified IT Project Manager. The LQCD Project Monitor is Elizabeth Bartosz, from ONP.

Specific responsibilities of the Federal Project Director include the following:

- Provide programmatic direction for the LQCD-ext II project.
- Serve as the primary point of contact to DOE SC headquarters for LQCD matters
- Oversee LQCD-ext II progress and help organize reviews as necessary
- Budget funds for LQCD-ext II and act as the key contact to the project office during the preparation of annual OMB Exhibit 53 submissions and 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 Federal Project Director 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 Contractor Project Manager is Bill Boroski from Fermilab. He is a certified DOE Level 1 Qualified 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 II computing facilities.
- Provide support to the LQCD Federal Project Director in the preparation of annual OMB Exhibit 53 Budget Year (BY) submissions in accordance with DOE and OMB guidance and schedules.
- Gather and summarize financial information for the monthly progress reports to the LQCD Federal Project Director and Project Monitor.
- Present monthly progress reports to the LQCD Federal Project Director and Project Monitor. These reports cover project cost and schedule performance, performance against established key performance metrics, review of annual acquisition strategies and progress against deployment plans, and other significant issues related to project execution as appropriate.
- Prepare and submit to DOE 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 of the Contractor Project Manager:

- Reports to the LQCD Federal Project Director.

- Serves as the primary point of contact with DOE SC, through the LQCD Federal Project Director, on matters related to budget and schedule for all funded activities.
- Interacts with host laboratory senior management regarding project-related matters.
- Provides direction and oversight to LQCD Site Managers on project-related matters.
- Interacts with the Chair of the USQCD 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 preparing and tracking the project WBS and schedule; managing the Risk Management Plan; and gathering and analyzing performance data from the host laboratories. Performance data includes actual expenditures, progress towards milestones, and other relevant performance data. The ACPM assists with the creation of various management documents and maintains other controlled documents as appropriate. The Associate Contractor Project Manager is Robert D. Kennedy from Fermilab.

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. Included in the WBS are key project tasks and performance milestones that allow for the tracking of progress and expenditures against the baseline plan.
- Prepares and manages the Risk Management Plan and Risk Register. Coordinates periodic risk assessments and updates with the LQCD project team.
- Prepares and manages other technical and controlled documents as requested.
- Monitors and reports on activities related to project performance assessment.
- Assists in the preparation of annual financial plans consistent with the detailed planning documents and ensures that funds received by the host laboratories are in accordance with annual financial plans.
- Assists in the preparation of OMB Exhibit 53 submission documents.
- Develops and maintains project-management-related communications including the project web site and the repository of project documents, etc.
- Leads the annual user survey process, which includes preparing the survey, analyzing and reporting on survey results, and preparing annual user survey reports.
- Assists with the annual reviews.

Interactions of the Associate Contractor Project Manager:

- Reports to the CPM
- Works with the Site Managers to coordinate the development of project documents, make updates to the Risk Management Plan and Risk Register, and gather budget and other data for tracking performance against plan.
- Works with the LQCD Federal Project Director in the CPM's absence.

5.1.4 Site Managers

Steady-state operations and new hardware deployment 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 their host laboratory to accomplish their 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 their site's LQCD budget, 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 II computing facilities at his/her site. This includes providing adequate user support to the USQCD community
- Ensure 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 II computing resources at the host site including the monitoring and reporting of system performance metrics such as uptime and usage.
- Implement and monitor user allocations as 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 projects and the International Lattice Data Grid (ILDG) project.
- Participate in the hardware selection process for deployments at his/her site, representing their host laboratory facilities and operations capabilities..
- Lead the hardware deployment activities at his/her site.
- Assist in the annual budget planning and allocation process, and in the preparation of detailed planning documents, 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 the CPM and ACPM
- Prepare materials for external oversight and reviews and participate in external review activities, as necessary.

Interactions of the Site Manager:

- 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 Site Architects

The Site Architect (SA) is responsible for technical design and architecture at their host site. The Site Architect assists the Site Manager on strategic issues, monitoring, and reviews, but does not have day-to-day operations responsibilities.

Specific site architect responsibilities include the following:

- Leads the hardware selection activities at their host laboratory, working with the Site Manager who represents the host laboratory facilities and operations capabilities.
- Leads the architectural design effort at their host laboratory, working with the Site Manager who represents the host laboratory facilities and operations capabilities.
  - o This design covers computing, storage, networking, monitoring, facilities (space, power, cooling), and integration of these components into a holistic system.
- Establishes performance goals and benchmarks for LQCD systems located at or to be located at their site.
- Assist the SM in the monitoring and assessment of actual performance versus planned performance.
- Assist the CPM to document and communicate:
  - o Hardware selection information for acquisition planning (target audience is Executive Committee)
  - o Performance goals and benchmarking information for allocation process (target audience is Scientific Program Committee)

Interactions of the Site Architect:

- Reports to the CPM
- Works closely with the ACPM, Site Managers, and other Site Architects both to assist in defining milestones, and to ensure a high level of coherency across the project.

5.1.6 Integrated Project Team

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

The full IPT meets on an as-needed basis, however subsets of the IPT meet on a regular basis. For example, monthly meetings are held between the Federal Project Director, Project Monitor, CPM and ACPM to review progress against goals and milestones. The CPM, ACPM and Site Managers meet bi-weekly to review project performance on a more detailed, technical level. These meetings often involve planning for subsequent deployments and sharing lessons learned. Site Architects participate in these meetings as well when they involve acquisition planning, architectural design, or other Site Architect responsibilities, or at least every other bi-weekly meeting as a touchpoint.

5.1.7 USQCD Executive Committee

The charter of the USQCD 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 II Change Control Board (CCB). In addition to the chair, 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 user community.

Members of the Executive Committee rotate at the rate of around one per year. Around half of the members of the Executive Committee are expected to remain during the lifetime 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
- Oversees the national lattice gauge theory community's SciDAC grants and provides coordination between the work done under those grants 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.

5.1.8 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 USQCD Executive Committee
- Chairs the USQCD Executive Committee

Interactions of the Spokesperson:

- 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

5.1.9 Scientific Program Committee

The charter of the Scientific Program Committee (SPC) is to assist the Executive Committee in providing scientific leadership for the LQCD 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 II 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 LQCD-ext II Site Managers are responsible for executing these allocations. The objective of this process is to achieve the greatest scientific benefit from the dedicated computing 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 committee chair rotates every two years. Current members have staggered terms of four years. When a vacancy occurs, the open slot is filled by the Executive Committee. The current membership of the SPC is shown in Appendix B.

5.1.10 Change Control Board

The purpose of the Change Control Board (CCB) is to assure that changes to the project are managed with the primary focus on the advancement of the scientific goals of the project.

Responsibilities

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

Interactions of the Change Control Board:

- 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.

The role of the CCB in the change control process is defined in detail in Section 7, Change Control. All changes approved by CCB will be reported to the DOE SC through the LQCD-ext Federal Project Director as appropriate.

The CCB is composed of the Contractor Project Manager, the Chair of the USQCD Executive Committee (chair), the FNAL CIO, the JLab CIO, the BNL CIO, and a scientific consultant appointed by the spokesperson with the concurrence of the Executive Committee. The current membership of the CCB is shown in Appendix C.

5.2 Project Communications

In addition to the interactions defined under Roles and Responsibilities, the following formal communications touchpoints are to occur annually, as appropriate:

Touch Point and Timing	Attendees	Actions and Goals
Early Acquisition Planning	CPM, Executive Committee	CPM leads discussion of acquisition planning, timeline. Goal: Concurrence on scope, non-technical considerations as input.
Late Acquisition Planning	CPM, Site Architects, Executive Committee	CPM presents acquisition plan. Goal: Concurrence on proposed acquisition plan.
Early Allocations Process	CPM, Site Architects, Scientific Program Committee	CPM presents performance benchmarks, deployed capacity. Goal: Address questions from SPC related to their Allocations process.
Late Allocations Process	CPM, Site Managers, Scientific Program Committee	SPC presents allocations including expectations for Class B, C allocations in coming year. Goal: Address questions from Site Managers related to their monitoring of allocations.

5.3 Interaction with 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. The primary flow of communication regarding LQCD-ext II project matters between the DOE Federal Project Director and laboratory management is through the LQCD-ext II Project Office.

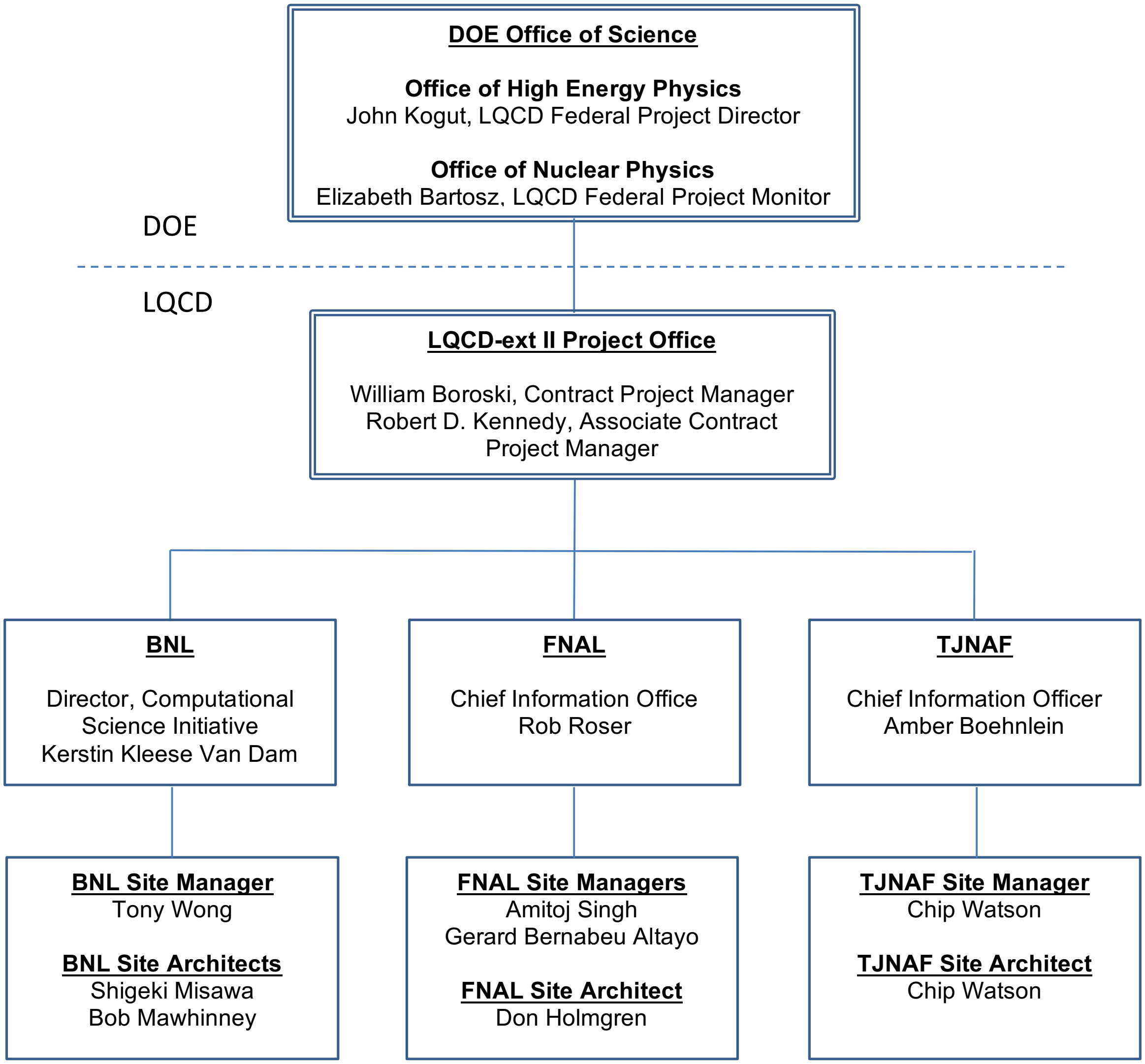

Figure 2: LQCD and Laboratory Management

6 COST AND SCHEDULE MANAGEMENT

6.1 Project Scope

The scope of the LQCD-ext II project includes the operation of the LQCD BG/Q computer at BNL, the operation of existing clusters at JLab and FNAL, and the acquisition and operation of new systems in FY2015-2019. Existing systems will be operated through end of life as determined by cost effectiveness (typically 4-5 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 II computing project is categorized as an OMB Exhibit 53 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-ext II 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:

> **Steady-State Operations**: Includes all activities associated with steady state operation of the LQCD-ext II computing facilities at the three host laboratories. The budget associated with Operations supports labor for operations and maintenance activities, a modest level of travel support, and funds for M&S purchases such as replacement parts, spare disk, tape, etc.
>
> **New Hardware Deployment**: Includes all activities associated with developing the acquisition strategy and plan for annual computing system hardware procurements; and all activities associated with the annual receipt and deployment of new computing system and storage hardware. Planning activities typically include gathering vendor roadmap information, performing benchmarking tests, preparing procurement documents, etc. Deployment activities occur from the time new hardware arrives at the site until it is released for production use. Typical activities include vendor delivery coordination, unit acceptance tests, system installation, system acceptance tests, release in friendly user mode and analysis of results, and preparations for production release. The budget associated with New Hardware Deployments includes labor costs for planning and deployment activities and equipment costs for new hardware.
>
> **Project Management**: Includes all activities associated with project management and oversight, as described above. The budget associated with Project Management supports salary costs for the Contractor Project Manager and Associate Contractor Project Manager, as well as a modest amount for travel and miscellaneous project office expenses.

Before the beginning of each fiscal year, a WBS is developed for the work to be performed in the coming year, with bases 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 developed and maintained using Microsoft Project.

Project milestones are defined in the project WBS. Site Managers report the status of completion for each project milestone to the ACPM 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 Federal Project Director and Project Monitor. These milestones are also defined and tracked in the project WBS. The target levels for new computing capacity deployed and aggregate computing delivered are defined in Appendix D - Computing Facility Performance Metrics.

Table 2: Level 1 Milestones

No.	Level 1 Milestone	Fiscal Year
1	Computer architecture planning for the FY16 procurement complete & reviewed	Q3 2015
2	Procurement and deployment of zero teraflops (sustained – *Conventional Resources*) in FY15 (no deployment in FY15 is planned, but this placeholder will account for any change in budget profile)	Q3 2015
3	Target level of aggregate *Conventional Resources* computing delivered in FY15	Q4 2015
4	Target level of aggregate *GPU-accelerated Resource* computing delivered in FY15	Q4 2015
5	Computer architecture planning for the FY17 procurement complete & reviewed	Q3 2016
6	Procurement and deployment of *Conventional Resources* in FY16	Q4 2016
7	Procurement and deployment of *Accelerated Resources* in FY16	Q4 2016
8	Target level of aggregate *Conventional Resource* computing delivered in FY16	Q4 2016
9	Target level of aggregate *GPU-accelerated Resource* computing delivered in FY16	Q4 2016
10	Computer architecture planning for the FY18 procurement complete & reviewed	Q3 2017
11	Procurement and deployment of *Conventional Resources* in FY17	Q3 2017
12	Procurement and deployment of *Accelerated Resources* in FY17	Q3 2017
13	Target level of aggregate *Conventional Resource* computing delivered in FY17	Q4 2017
14	Target level of aggregate *GPU-accelerated Resource* computing delivered in FY17	Q4 2017
15	Computer architecture planning for the FY19 procurement complete & reviewed	Q3 2018
16	Procurement and deployment of *Conventional Resources* in FY18	Q4 2018
17	Procurement and deployment of *Accelerated Resources* in FY18	Q4 2018
18	Target level of aggregate *Conventional Resource* computing delivered in FY18	Q4 2018
19	Target level of aggregate *GPU-accelerated Resource* computing delivered in FY18	Q4 2018
20	Procurement and deployment of *Conventional Resources* in FY19	Q3 2019
21	Procurement and deployment of *Accelerated Resources* in FY19	Q3 2019
22	Target level of aggregate *Conventional Resource* computing delivered in FY19	Q4 2019
23	Target level of aggregate *GPU-accelerated Resource* computing delivered in FY19	Q4 2019

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 computing system purchase and deployment.

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

Level 2 Milestones
Preliminary System Design Document prepared
Request for Information (RFI) released to vendors
Request for Proposal (RFP) released to vendors
Request for Proposal (RFP) responses due
Purchase subcontract awarded
Approval of first rack
Remaining equipment delivered.
Successful completion of Acceptance Test Plan
Release to "Friendly User" production testing
Release to full production

Progress against all milestones is tracked and reported by the LQCD-ext II Project Office.
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. Progress against Level 1 and Level 2 milestones is discussed with the DOE Federal Project Director and Project Monitor during monthly project conference calls.

6.4 Total Project Cost

The total project cost for LQCD-ext II is $14 million. The project is jointly supported by the DOE SC Offices of HEP and NP. The HEP and NP planning budgets for LQCD-ext II are shown in Table 4.

Table 4: $14 million Planning Budget for LQCD-ext II (in millions)

	FY15	**FY16**	**FY17**	**FY18**	**FY19**	**Total**
HEP	1.00	2.00	2.00	2.00	2.00	9.00
NP	1.00	1.00	1.00	1.00	1.00	5.00
Total	**2.00**	**3.00**	**3.00**	**3.00**	**3.00**	**14.00**

Project funds will be used to procure and deploy new systems, and provide labor support for steady-state operations (e.g., site management, system administration, hardware support, and deployment of LQCD software) and project management. 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 the scope of the LQCD-ext II 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. The project contributes to the pool of funds at each site used to cover these costs, through the assessment of overhead charges by each host site in accordance with standard laboratory policies.

Table 5 shows the LQCD-ext II budget profile for the $14 million budget in terms of planning, acquisition, and steady-state operations. The "Operations & Maintenance" budget provides funds for labor and M&S costs associated with steady-state operations and maintenance. The "New Hardware Deployment" budget provides funds for labor costs associated with deployment planning and new system deployments, as well as equipment funds for new computing and storage hardware procurement. The "Project Management" budget provides funds for labor costs associated with project management activities, and a modest level of travel and M&S for miscellaneous project expenses.

Table 5: Obligation Budget Profile by Spending Category ($K)

Category	FY15	FY16	FY17	FY18	FY19	Total
Operations & Maintenance	1,836	1,760	1,701	1,579	1,540	8,415
New Hardware Deployment	-	1,021	1,055	1,205	1,218	4,500
Project Management	118	135	139	144	148	685
Management Reserve	46	83	105	72	94	400
Total	2,000	3,000	3,000	3,000	3,000	14,000
Planning Budget Guidance	2,000	3,000	3,000	3,000	3,000	14,000

Figure 3 shows the obligation budget distribution by spending category. The planned distribution across categories is based on experience gained during the prior 8+ years of deployments and operations.

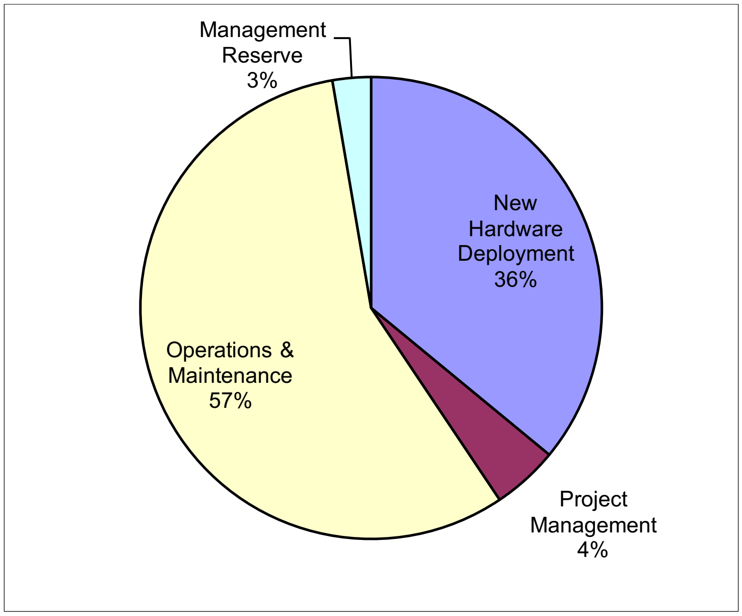

Figure 3: LQCD-ext II Total Project Budget Fraction by Spending Category

Table 6 shows the obligation budget profile in terms of commonly-recognized expenditure types, by fiscal year. The personnel budget covers system administration, engineering and technical labor, site management, and project management. All labor cost estimates are based on fully-loaded average labor rates at the host laboratories and have been inflated using an annual escalation rate of 3%. The compute/storage hardware budget covers compute system acquisitions (computers, network hardware, etc.) plus storage hardware. Indirect charges will be applied according to agreements established between the project and the host laboratories and documented in approved MOUs. Project funds allocated to support travel and non-essential M&S expenses have been kept to a minimum, with budgeted levels based on and consistent with past operating experience.

Table 6: Obligation Budget Profile by Expenditure Type (in $K)

Expenditure Type	**FY15**	**FY16**	**FY17**	**FY18**	**FY19**	**Total**
Personnel	1,654	1,778	1,971	1,724	1,792	8,919
Travel	17	17	17	18	18	87
M&S	283	300	148	122	122	975
Compute/Storage Hardware	-	823	759	1,064	974	3,619
Management Reserve	46	83	105	72	94	400
Total	2,000	3,000	3,000	3,000	3,000	14,000
Planning Budget Guidance	2,000	3,000	3,000	3,000	3,000	14,000

Figure 4 shows the proportional cost breakdown by these expenditure types. Given the planning budget profile, approximately 30% of the total budget will be allocated to new compute and storage hardware. The largest fraction of the budget is allocated to support personnel working on the project. The level of personnel support required is based on a detailed staffing model that has been used successfully during the LQCD-ext project and refined for the LQCD-ext II project.

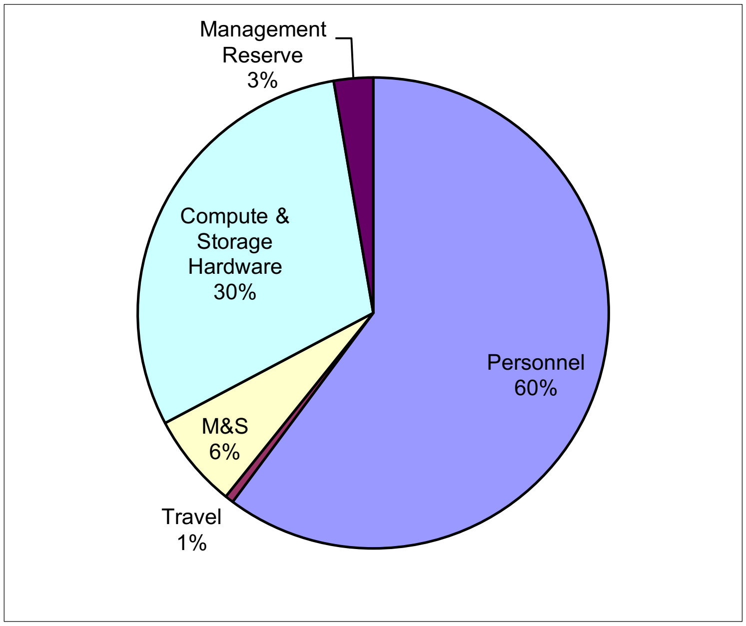

Figure 4: LQCD-ext II Total Project Budget Fraction by Expenditure Type

Figure 5 shows in graphical form the data presented in Table 7. 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.

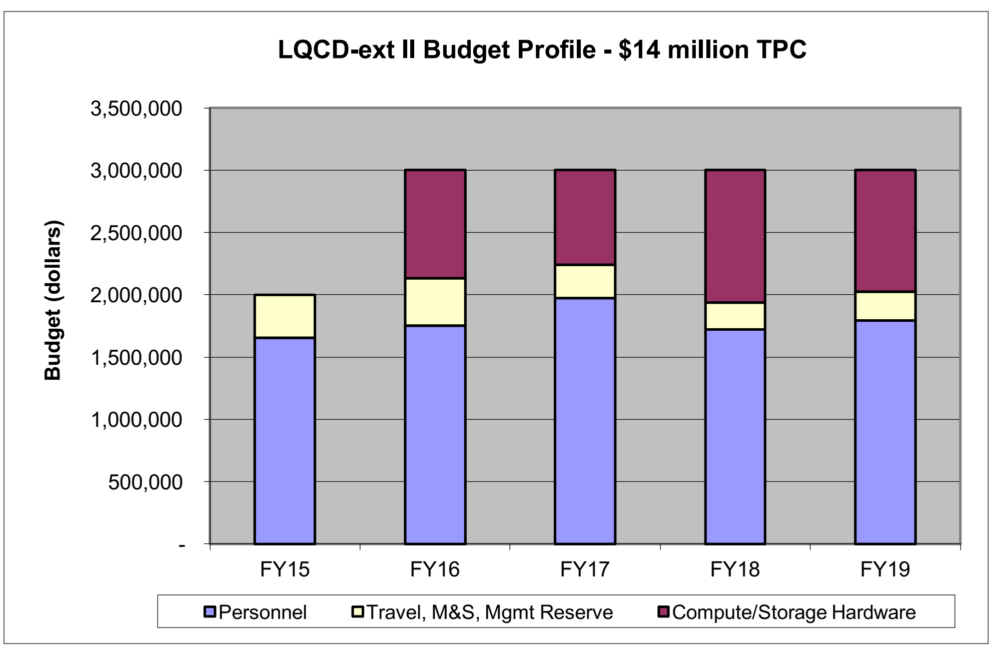

Figure 5: LQCD-ext II Project Budget Profile by Fiscal Year

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. This has proven to be more than adequate in the first 9 years of this computing project.

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 Director and Project Monitor during the monthly progress report and noted during the annual DOE progress review.

6.4.2 *Steady State Life Cycle Cost*

Part of the steady state life cycle costs will be funded by the project, specifically, the effort required for the administration and maintenance of the systems (~2-3 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 also be retired as they reached their projected lifetimes (typically 4-5 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.

6.4.3 *Deployment Performance Contingency*

Table 7 shows the planned budget for compute and storage hardware. In each year of the LQCD-ext II project, the project will choose the most cost effective computing hardware 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 7: Compute Hardware Budget (in $K)

Fiscal Year	Compute Hardware	Storage Hardware	Total
FY15	-	-	-
FY16	772	50	823
FY17	719	39	759
FY18	1,009	55	1,064
FY19	896	78	974
Total	3,396	223	3,619

All LQCD-ext II project hardware procurements will utilize firm fixed-price contracts. Given annual fixed compute equipment budgets, the precise number of processors procured will be determined by the 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 USQCD 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 USQCD scientific program, will be based upon these conservative estimates.

Figure 6 shows historical price/performance data for FY09 through FY14. The blue diamonds are the price/performance figures for the conventional clusters. The black diamond shows the projection from May 2013 of the price/performance for the FY14 conventional cluster. The magenta diamonds are the actual price/performance for the FY14 conventional cluster with and without the added costs for expanded memory and an extension of warranty to five years. The magenta star near 2013 is the price/performance for the GPU-accelerated cluster "12k". The black star is the projection from May 2013 of the price/performance of the FY14 GPU-accelerated cluster. The magenta stars near 2015 are the actual price/performance for the FY14 GPU-accelerated cluster with and without the added cost for an extension of warranty to five years.

The actual FY14 conventional cluster price/performance was higher than projected for a variety of reasons. Prior to 2013, AMD and Intel competed strongly for the high performance computer (HPC) market, but since 2013 AMD has not significantly improved its processor products. During the same period Intel has improved processors for HPC clusters, but has not needed to price the products aggressively or to bring them to market at the same rate as in prior years. New algorithms and workflows introduced starting in 2012 have increased the requirement for memory per compute node; this results in a higher cost per node with no improvement in performance as measured by the project's inverter benchmarks. Finally, because the FY15-FY19 budget profile allows for less deployment of new equipment compared to the LQCD-ext project, the LQCD-ext II project will operate systems for a longer period of time; to support these longer operations, extended warranties (five years) were included in the purchase contracts for the FY14 conventional and GPU-accelerated clusters. However, according to vendor roadmaps, the Moore's Law effects of higher gate densities will continue during LQCD-ext II. For the purpose of extrapolating future price/performance figures, the project assumes that the exponential trend (black line) observed in FY09 through FY13 will continue, except with the slip observed in the FY14 conventional cluster purchase (green line). The planned LQCD-ext II conventional cluster purchases are shown as red diamonds, plotted at the planned deployment dates. If the green price/performance trend holds, we expect to achieve the better price/performance values along the green fit line. The separation of the red diamonds in the plot from the green trend line is the project's performance contingency for conventional hardware. We assume the same trend line slope for the accelerated hardware (magenta line) as is used for the conventional hardware. The separation of the red stars from the magenta line is the project's performance contingency for accelerated hardware. 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.

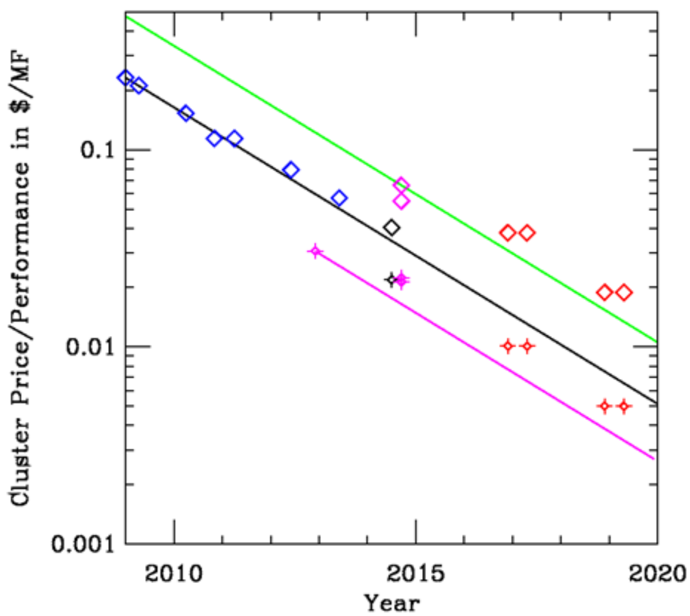

Figure 6: Development of Performance Contingency

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

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. The table in Appendix C shows the cost and work performance metrics for the LQCD-ext II project. The table in Appendix D lists all facility performance metrics for the entire LQCD-ext II project. The metrics in these tables are associated with a $14 million project budget. The values in these tables will be revised once the final project funding profile is approved.

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-ext II 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, level of funding, and the in-kind support provided to the project by the host laboratories.

The LQCD-ext II 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 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. Every month the CPM reports on the overall cost, schedule and technical performance to the Federal Project Director and Project Monitor.

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 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 9.

No formal change control action is required for changes that do not exceed Level-1 thresholds. Site Managers are authorized to make changes below Level-1 thresholds and are required to inform the CPM of the change. Changes below Level-1 do not have to be documented on Change Request (CR) Forms.

The Contractor Project Manager (CPM) is authorized to approve Level-1 changes. The initiator of a Level-1 change request must submit a completed CR form to the CPM for review and approval. A sample CR form is included as Appendix E.

The CCB is authorized to approve Level-2 changes. The initiator of a Level-2 change must submit a completed CR form to the CPM for review and approval. 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 will either: 1) reject the request; 2) return the CR to the CPM with a request for additional information; or 3) approve the CR.

The Federal Project Director is authorized to approval Level-3 changes. Level-3 changes are typically prepared and submitted by the CPM to the CCB for consideration. If the CCB approves the change, the CR is transmitted to the Federal Project Director for consideration. The Federal Project Director 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.

The Acquisition Executive is authorized to approve Level-4 changes. If the CCB approves the change, the CR is transmitted to the Federal Project Director for consideration. If the Federal Project Director approves the change, the CR is transmitted to the Acquisition Executive with recommendations for further action.

Table 9: Summary of Change Control Thresholds

Change Control Level	Approver	Cost Threshold	Schedule Threshold	Technical Scope/ Performance Threshold
Level 4	Acquisition Executive	Any increase in Total Project Cost Or Change of > $250K in budget distribution between DME and SS O&M costs	6-month or more increase in a Level 1 milestone date	Changes to scope that affect mission need and/or performance requirements
Level 3	Federal Project Director	Change of ≥ $125K in budget distribution between DME and SS O&M costs 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 2	Change Control Board	Change of < $125K in budget distribution between DME and SS O&M costs 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 1	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%

The CPM is responsible for notifying the Scientific Program Committee (SPC) of all schedule and technical scope change requests that exceed Level-1 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 advice 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-ext II 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

8.1 Security Management

LQCD 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 II Project Office maintains copies of 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 JLab). 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.

8.2 Privacy Management

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

8.3 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 USQCD Executive Committee and LQCD-ext II 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 II Risk Management Plan. The Risk Management Plan is reviewed and updated whenever changing conditions warrant a review and revision of the risk register. The Risk Management Plan is also reviewed on a periodic basis to review the status of identified risks and to consider the potential existence of new risks. 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 following document: *Risk Management Plan for the LQCD Computing Project Extension II*. 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, the project 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 the 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-ext II computing facility partially mitigates the risk of natural disasters. Additionally, the 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.

8.4 Quality Assurance

The LQCD-ext II project 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." Project personnel follow quality control procedures established at the three host laboratories. In addition, the project has put into place various methodologies to monitor and improve quality, as described in the following document: *Quality Assurance Plan for the LQCD Computing Project Extension II*. All new hardware is 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.

8.5 Project Oversight

The LQCD-ext II Project Office prepares a monthly progress report and a monthly meeting is held to inform the Federal Project Director and Project Monitor of cost, schedule and technical performance, along with other issues related to project execution.

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

The LQCD-ext II project is a collaborative effort among three DOE-sponsored laboratories with stringent environment, safety, and health (ES&H) policies and programs. The LQCD-ext II project integrates ES&H into all phases of the project (planning, acquisition, operations and maintenance) using appropriate procedures defined by the participating laboratories. All individuals supported by project funds follow procedures specific to the host laboratory at which they work.

The LQCD-ext II project follows the five core functions associated with integrated safety management:

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.

Line management at 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 personnel assigned to the LQCD-ext II project 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 is documented as needed using appropriate safety documentation guidelines for the laboratory. Also, laboratory personnel receive specific training required 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 the host 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 II 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 II computing facilities will be coordinated and/or conducted by the host laboratory.

Appendix A: Integrated Project Team

LQCD Federal Project Director (HEP)	John Kogut (chair)
LQCD Project Monitor (ONP)	Elizabeth Bartosz
Contractor Project Manager (CPM)	Bill Boroski
Associate CPM (ACPM)	Rob Kennedy
BNL Site Manager	Tony Wong
BNL Site Architects	Shigeki Misawa, Bob Mawhinney
FNAL Site Manager	Amitoj Singh, Gerard Bernabeu Altayo
FNAL Site Architect	Don Holmgren, Amitoj Singh
TJNAF Site Manager	Chip Watson
TJNAF Site Architect	Chip Watson
USQCD Executive Committee Chair	Paul Mackenzie

Appendix B: Committees and Members

USQCD Executive Committee

Richard Brower (Boston U.), Norman Christ (Columbia U.), Will Detmold (MIT), Frithjof Karsch (BNL), Julius Kuti (UCSD), Paul Mackenzie (Chair, FNAL), Kostas Orginos (William & Mary), David Richards (TJNAF), Martin Savage (U. Washington), and Robert Sugar (UCSB)

USQCD Scientific Program Committee

Tom Blum (U. Conn.), Will Detmold (MIT), Steve Gottlieb (Indiana U.), Anna Hasenfratz (Chair, Colorado), Kostas Orginos (William & Mary), Robert Petreczky (BNL), Ruth Van de Water (Fermilab)

LQCD Change Control Board

Bill Boroski (Contractor Project Manager), Steve Gottlieb (Indiana U.), Paul Mackenzie (Chair, USQCD Executive Committee), Kerstin Kleese Van Dam (BNL), Rob Roser (FNAL), Amber Boehnlein (TJNAF)

Appendix C: Cost and Schedule Performance Metrics

ID	Description of Activity	DME, SS, MR	Total Cost		Current Baseline (07/10/2014)			
			Planned Cost ($M)	Actual Cost ($M)	Planned Start Date	Actual Start Date	Planned Completion Date	Actual Completion Date
1	FY15 SS - Aggregate sustained computing delivered to USQCD community. Goals levels: KPI # 1 for *Conventional Resources* KPI # 2 for *Accelerated Resources*	SS	$1.954		10/01/2014		09/30/2015	
2	FY16 DME Procurement and deployment of new sustained computing capacity. Goals levels: KPI # 7 for *Conventional Resources* KPI # 8 for *Accelerated Resources*	DME (FY16 DME + FY15 MR)	$1.067 ($1.021 + $0.046)		10/01/2015		08/30/2016	
3	FY16 SS - Aggregate sustained computing delivered to USQCD community. Goals levels: KPI # 9 for *Conventional Resources* KPI #10 for *Accelerated Resources*	SS	$1.896		10/01/2015		09/30/2016	
4	FY17 DME Procurement and deployment of new sustained computing capacity. Goals levels: KPI #15 for *Conventional Resources* KPI #16 for *Accelerated Resources*	DME (FY17 DME + FY16 MR)	$1.138		10/01/2016		06/30/2017	
5	FY17 SS - Aggregate sustained computing delivered to USQCD community. Goals levels: KPI #17 for *Conventional Resources* KPI #18 for *Accelerated Resources*	SS	$1.840		10/01/2016		09/30/2017	
6	FY18 DME Procurement and deployment of new sustained computing capacity. Goals levels: KPI #23 for *Conventional Resources* KPI #24 for *Accelerated Resources*	DME (FY18 DME + FY17 MR)	$1.311		10/01/2017		08/30/2018	
7	FY18 SS - Aggregate sustained computing delivered to USQCD community. Goals levels: KPI #25 for *Conventional Resources* KPI #26 for *Accelerated Resources*	SS	$1.723		10/01/2017		09/30/2018	
8	FY19 DME Procurement and deployment of new sustained computing capacity. Goals levels: KPI #31 for *Conventional Resources* KPI #32 for *Accelerated Resources*	DME (FY19 DME + FY18 MR)	$1.290		10/01/2018		06/30/2019	
9	FY19 SS - Aggregate sustained computing delivered to USQCD community. Goals levels: KPI #33 for *Conventional Resources* KPI #34 for *Accelerated Resources*	SS	$1.688		10/01/2018		09/30/2019	
10	FY19 Management Reserve	MR	$0.094		10/01/2018		09/30/2019	
	Total		**$14.000**		**10/1/2015**		**09/30/2019**	

Legend
DME = Development/Modernization/Enhancement; SS = Steady-State Operations; MR = Management Reserve

Notes:
1) Following project policy, unspent management reserve from one year is rolled into the hardware procurement budget for the following year. The DME planned costs in this table are based on the assumption that management reserve will not be used and will thus be available to augment the hardware budget.
2) Planned steady-state (SS) costs include Operations & Maintenance; and Project Management.

Appendix D: Computing Facility Key Performance Indicators (KPIs)

The metrics shown in the following table are associated with the $14 million project budget.

ID	Fiscal Year	Measurement Category	Measurement Indicator	Target	Actual Results	Rating
1	2015	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Conventional Resources*	88 TF-Yrs	Available in Q1 FY16	
2	2015	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Accelerated Resources*	92 TF-Yrs	Available in Q1 FY16	
3	2015	Responsiveness	% of tickets resolved within 2 business days	≥95%	Available in Q1 FY16	
4	2015	Security and Privacy	Frequency of vulnerability scans performed at each site on nodes visible from the Internet	Vulnerability scans performed at least weekly at each host site (minimum of 52 scans per year per site)	Available in Q1 FY16	
5	2015	Reliability and Availability	% of average machine uptime across all LQCD computing sites	≥95%	Available in Q1 FY16	
6	2015	Quality of Service Delivery	Customer satisfaction rating (Customers rate satisfaction with the service provided on a scale of 1 to 5)	≥92%	Available in Q1 FY16	
7	2016	Effectiveness	Additional computing resources deployed by the project, expressed as an average of the HISQ and DWF algorithm performances in TFlops. – *Conventional Resources*	≥13 TF	Available in Q4 FY16	
8	2016	Effectiveness	Additional computing resources deployed by the project, expressed as an average of the HISQ and DWF algorithm performances in TFlops. – *Accelerated Resources*	≥85 TF	Available in Q4 FY16	
9	2016	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Conventional Resources*	91 TF-Yrs	Available in Q4 FY16	
10	2016	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Accelerated Resources*	73 TF-Yrs	Available in Q4 FY16	
11	2016	Responsiveness	% of tickets resolved within 2 business days	≥95%	Available in Q1 FY17	
12	2016	Security and Privacy	Frequency of vulnerability scans performed at each site on nodes visible from the Internet	Vulnerability scans performed at least weekly at each host site (minimum of 52 scans per year per site)	Available in Q1 FY17	
13	2016	Reliability and Availability	% of average machine uptime across all LQCD computing sites	≥95%	Available in Q1 FY17	
14	2016	Quality of Service Delivery	Customer satisfaction rating (Customers rate satisfaction with the service provided on a scale of 1 to 5)	≥92%	Available in Q1 FY17	
15	2017	Effectiveness	Additional computing resources deployed by the project, expressed as an average of the HISQ and DWF algorithm performances in TFlops. – *Conventional Resources*	≥9 TF	Available in Q4 FY17	
16	2017	Effectiveness	Additional computing resources deployed by the project, expressed as an average of the HISQ and DWF algorithm performances in TFlops. – *Accelerated Resources*	≥36 TF	Available in Q4 FY17	
17	2017	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Conventional Resources*	73 TF-Yrs	Available in Q1 FY18	
18	2017	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Accelerated Resources*	117 TF-Yrs	Available in Q1 FY18	
19	2017	Responsiveness	% of tickets resolved within 2 business days	≥95%	Available in Q1 FY18	
20	2017	Security and Privacy	Frequency of vulnerability scans performed at each site on nodes visible from the Internet	Vulnerability scans performed at least weekly at	Available in Q1 FY18	

ID	Fiscal Year	Measurement Category	Measurement Indicator	Target	Actual Results	Rating
				each host site (minimum of 52 scans per year per site		
21	2017	Reliability and Availability	% of average machine uptime across all LQCD computing sites	≥95%	Available in Q1 FY18	
22	2017	Quality of Service Delivery	Customer satisfaction rating (Customers rate satisfaction with the service provided on a scale of 1 to 5)	≥92%	Available in Q1 FY18	
23	2018	Effectiveness	Additional computing resources deployed by the project, expressed as an average of the HISQ and DWF algorithm performances in TFlops. – *Conventional Resources*	≥26 TF	Available in Q4 FY18	
24	2018	Effectiveness	Additional computing resources deployed by the project, expressed as an average of the HISQ and DWF algorithm performances in TFlops. – *Accelerated Resources*	≥100 TF	Available in Q4 FY18	
25	2018	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Conventional Resources*	63 TF-Yrs	Available in Q1 FY19	
26	2018	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Accelerated Resources*	178 TF-Yrs	Available in Q1 FY19	
27	2018	Responsiveness	% of tickets resolved within 2 business days	≥95%	Available in Q1 FY19	
28	2018	Security and Privacy	Frequency of vulnerability scans performed at each site on nodes visible from the Internet	Vulnerability scans performed at least weekly at each host site (minimum of 52 scans per year per site)	Available in Q1 FY19	
29	2018	Reliability and Availability	% of average machine uptime across all LQCD computing sites	≥95%	Available in Q1 FY19	
30	2018	Quality of Service Delivery	Customer satisfaction rating (Customers rate satisfaction with the service provided on a scale of 1 to 5)	≥92%	Available in Q1 FY19	
31	2019	Effectiveness	Additional computing resources deployed by the project, expressed as an average of the HISQ and DWF algorithm performances in TFlops.- *Conventional Resources*	≥23 TF	Available in Q2 FY19	
32	2019	Effectiveness	Additional computing resources deployed by the project, expressed as an average of the HISQ and DWF algorithm performances in TFlops.- *Accelerated Resources*	≥89 TF	Available in Q2 FY19	
33	2019	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Conventional Resources*	73 TF-Yrs	Available in Q1 FY20	
34	2019	Scientific Program Support	TF-Yrs delivered towards the completion of the Scientific Program – *Accelerated Resources*	267 TF-Yrs	Available in Q1 FY20	
35	2019	Responsiveness	% of tickets resolved within 2 business days	≥95%	Available in Q1 FY20	
36	2019	Security and Privacy	Frequency of vulnerability scans performed at each site on nodes visible from the Internet	Vulnerability scans performed at least weekly at each host site (minimum of 52 scans per year per site)	Available in Q1 FY20	
37	2019	Reliability and Availability	% of average machine uptime across all LQCD computing sites	≥95%	Available in Q1 FY20	

Appendix E: 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 Director ______________________ 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 F: Controlled Documents

The set of documents submitted to DOE are designated as controlled project documents. These documents are tracked using DocDB, the Document Database Control system managed by the Fermilab Core 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 controlled documents, with formal version control and signature approval.

1. Project Execution Plan
2. Risk Management Plan
3. Quality Assurance Program
4. Acquisition Strategy
5. Annual Acquisition Plans
6. Certification and Accreditation Document
7. Cyber Security Plan (formerly called the Security Vulnerability Assessment Report)

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

1. Memoranda of Understanding
2. External project review reports