Project Execution Plan
for the Lattice QCD Computing Project (LQCD)

at
Brookhaven National Laboratory, Brookhaven, New York
Fermi National Accelerator Laboratory, Batavia, Illinois
Thomas Jefferson National Accelerator Facility, Newport News, Virginia

For the U.S. Department of Energy
Office of Science
Offices of High Energy and Nuclear Physics

Date approved:

December 2005

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Change Log: Project Execution Plan for the
Lattice QCD Computing Project (LQCD)

Revision No.	Pages Affected	Effective Date

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1 INTRODUCTION

The development and operation of a large scale dedicated computing facility capable of sustaining thirteen teraflops (10^{12} floating point operations per second, or TFlops) for the study of quantum chromodynamics (QCD) will play an important role in expanding our understanding of the fundamental forces of nature and the basic building blocks of matter. The hardware will be housed at Brookhaven National Laboratory (BNL), Fermi National Accelerator Laboratory (FNAL) and Thomas Jefferson National Accelerator Facility (TJNAF/JLab), and operated as a single distributed computing facility, which will be available to lattice gauge theorists at national laboratories and universities throughout the United States. The project will start in Fiscal Year (FY) 2006 and be completed in FY 2009. The total cost is estimated to be $9.2 million. The President's FY 2006 budget requested $2.5 million to begin the project.

Over the past six years members of the United States (U.S.) lattice gauge theory community have worked together to plan the computational infrastructure needed for the study of QCD. Virtually all members of the community have been involved in this effort. Research and development performed during this period has provided the groundwork for the construction of production hardware beginning in FY 2006. With support from the Department of Energy's (DOE) High Energy Physics (HEP), Nuclear Physics (NP), Advanced Scientific Computing Research (ASCR), and Scientific Discovery through Advanced Computing (SciDAC) Programs, prototype hardware has been designed, constructed and tested, and the software needed to use it effectively has been developed. Historically, by taking advantage of simplifying features of lattice QCD calculations, as has been done in designing the prototype hardware, it has been possible to build computers for this field that have significantly better price/performance than commercial machines. Two tracks for the construction of massively parallel computers for QCD have been studied. One involves the design and fabrication of key components, while the other makes use of carefully chosen commodity parts. The latest example of the former is the QCD on a Chip (QCDOC), which was designed by lattice gauge theorists at Columbia University in collaboration with colleagues at IBM. The design incorporates the central processing unit (cpu), memory and communication on a single chip. As part of the research and development effort a 12,288 QCDOC was recently constructed at BNL. The operation of the QCDOC for use by U.S. lattice gauge theorists will be an important component of the current project. In the commodity track, prototype clusters optimized for the study of QCD have been developed and tested at FNAL and JLab under a grant from the DOE's SciDAC program, as well as with the support of these labs' base programs. This work indicates that commodity clusters are the hardware of choice for the project in FY 2006. The guiding principle will be to build or purchase whatever hardware best advances the science at each stage of the project. To support the selection of hardware, research and development on specialized systems and evaluation of commercial computers will continue under the lattice gauge theory SciDAC grant. Further development of software and algorithms under the SciDAC grant will provide additional support for this project.

In the remainder of this Project Execution Plan (PEP) the relevance of the project to the DOE mission is described, and its technical scope, management organization, schedule, cost scope, and change control are set out.

2 MISSION NEED

The Lattice QCD (LQCD) Computing Project directly supports the mission of the DOE's High Energy Physics (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 Nuclear Physics (NP) Program "to foster fundamental research in nuclear physics that will provide 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 DOE'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.

The lattice QCD computational infrastructure effort, of which this project is the culmination, was reviewed in February 2003 by a panel of physicists and computer scientists chaired by Frank Wilczek. Among its conclusions were that "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 the DOE fund dedicated computer hardware for lattice QCD 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.

3 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. This class of computing requires machines capable of sustaining at least on the order of a TFlops for days or weeks at a time. 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 each capable of sustaining at least on the order of 100 gigaflops (10^9 floating point operations per second, or GFlops) for days at a time, with a total aggregate computing capacity of on the order of TFlops.

3.1 Computational Requirements

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

Lattice QCD clusters are composed of hundreds to thousands of interconnected processors. For TFlop scale machines, each processor must be capable of sustaining on the order of 1 GFlops on the fundamental kernels. Memory bandwidths of 2-4 gigabytes/sec (10^9 bytes per second, or GBytes/sec) 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 tens to hundreds of megabytes/sec (10^6 bytes per second, or MBytes/sec) per processor are required, using message sizes of order 1000 bytes in size.

3.2 I/O and Data Storage Requirements

During vacuum configuration generation, data files specifying each representative configuration must be written to storage. These files are of order 1 to 10 Gbytes in size, with a new file produced every few hours. The average input/output (I/O) rate required for configuration storage is modest, of order 1 MBytes/sec. However, high peak rates are desired, to minimize the delays in computation while configurations are written to external storage. The storage volumes required for configurations are of order tens of terabytes. 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 are 16 times larger than the corresponding gauge configuration. Often, eight or more propagators are calculated for each gauge configuration. However, because of the large computational resources needed to generate them, they are often written to external storage for later reuse. Because many independent analysis streams can run on a given lattice QCD machine, substantial aggregate I/O rates (hundreds of MBytes/sec) are required during the loading of configurations and the storage of results.

3.3 Data Access Requirements

In the first years of the investment, configurations will typically be generated at the BNL QCDOC facility, and analysis computing will be performed at either of the FNAL and JLab cluster facilities, or on the BNL QCDOC. Configuration generation will also occur on clusters once their capability is sufficient. Archival storage of configurations will utilize robotic tape facilities at FNAL and JLab. Facile movement of files between the three sites will be required. The aggregate size of the files moved between sites will be of order one terabytes per year (10^{12} bytes per year, or Tbyte/year) in the first two years of the project, increasing to order 10 Tbyte/year in the last two years of the project.

4 TECHNICAL SCOPE

The LQCD Computing project consists of the purchase of high performance parallel computers, as well as the operation of these systems, the existing SciDAC prototype clusters, and the existing QCDOC system at BNL. In each year of this project, new systems will purchased. The systems purchased in FY 2006 will be tightly coupled clusters. These clusters will be installed at FNAL and JLab. For details about the FY 2006 purchases, see "Deliverables" below. In FY 2007 through FY 2009, one system will be purchased in each year. By the end of June of each year, the project will present for external review the plan for the next fiscal year's purchase. These plans will describe the architecture of the proposed system. The plans will also specify the site (FNAL or JLab). The performance goals for the systems in each year of the project are discussed in the "Deliverables" section.

In the subsequent years of this project, alternatives to tightly coupled clusters may prove more cost effective. The alternatives are commercial supercomputers, such as a successor to the IBM BlueGene/L supercomputer. Because more cost effective alternatives do not currently exist, for the purposes of defining the cost and schedule of this project we have made the assumption that tightly coupled clusters will be built in FY 2007-2009. This assumption is conservative because clusters will enable us to meet the project's milestones even if the commodity market does not advance as rapidly as it has in recent years. Should superior alternatives emerge, the project will adopt the most cost effective design and modify the schedule and budgets accordingly; this would enable the project to surpass the planned milestones, allowing U.S. physicists to accelerate the rate of scientific accomplishments.

4.1 Computing Systems - Nodes and Networks

Lattice QCD clusters consist of multiple commodity computers interconnected with high performance networks. The most cost effective processor and network will be used in each year's system design. Evaluations of available processors and networks will be part of this project but will also leverage the prototyping work done within the LQCD SciDAC project (prototype clusters).

During the last four years, from 2001-2005, the SciDAC Lattice Gauge Computing project has evaluated the performance of all of the currently available commodity processors, and has built a number of prototype clusters based on gigabit Ethernet, Myrinet, and Infiniband networking equipment. At the present time, the most cost effective commodity computers for these calculations are systems based on Intel ia32 processors. The most cost effective high performance network fabric for future systems is Infiniband. By December 2005, as part of the SciDAC project, FNAL will bring into production a 512-node prototype cluster based on 3.2 gigahertz (GHz) Pentium 640 processors, Peripheral Component Interconnect Express (PCI-Express) motherboards, and an Infiniband fabric.

In FY 2006, FNAL and JLab will each construct clusters. JLab will construct a 256-node cluster similar to the FNAL 2005 Infiniband cluster, i.e., based on a single processor-socket PCI-Express motherboards, Intel Pentium processors, and Mellanox Infiniband hardware; through the construction and operation of this cluster, JLab will acquire expertise in Infiniband networks. The JLab cluster will be funded through a combination of SciDAC, laboratory, and project monies. FNAL will construct an Infiniband cluster of approximately 1000 processors, funded through a combination of SciDAC and project monies. This cluster will be built to cost, with the precise processor count depending upon the pricing of the commodity computers.

Based on current vendor roadmaps and benchmarking, the suitable processors for the FY 2006 FNAL cluster will be Intel Pentium or Xeon. These processors differ in memory bandwidth, floating-point performance, chipset support, and cost. The cost effectiveness of each will vary according to their performance, the pricing of the available motherboards, symmetric multiprocessing (SMP) scaling efficiency, and the cost of the high performance network.

To support the large node count of the clusters, the network fabric design will require the use of cascaded switches. Because Infiniband provides bandwidth in excess of the amount required to balance calculations with communications on lattice QCD codes, full bisection bandwidth designs will not be required. In such designs, half of the switch ports of each leaf switch are used to connect to the spine switches, and half of the ports connect to compute nodes. In oversubscribed designs, the ratio of node connections to spine connections is greater than one to one. The amount of oversubscription that will minimize the price to performance ratio for the FY 2006 clusters will be determined on the FNAL 2005 cluster.

For FY 2007 and later, evaluations of commodity processors and networks will determine the most cost effective components. We will also evaluate commercial supercomputers, such as the successor to the IBM BlueGene/L, and Raytheon Toro. As part of the project's annual external review, the preliminary plan for the next fiscal year's purchase will be presented.

We anticipate that the useful life of the computer nodes will be three and one-half years. The high performance networks, however, may be useful for up to seven years. Consequently, it may be cost effective in the third year of the project to reuse Infiniband equipment purchased at FNAL in 2005, and in the fourth year to reuse the network fabric purchased in FY 2006.

4.2 Operations

The operation of the lattice QCD systems will involve physical facilities (buildings, power, cooling), system administration, hardware and software maintenance, configuration management, cyber security, data storage, and data movement.

FNAL, JLab, and BNL will each operate physical facilities in support of the lattice QCD systems. In FY 2006, FNAL will refurbish an existing computer room to supply sufficient power and cooling for two-thirds of the systems that will be developed at FNAL during the project; the remaining one-third of the systems will be housed in a second room that was refurbished in 2005. JLab will use a new computer facility, to be completed in early 2006, to house the lattice QCD systems. The QCDOC built in 2005 at BNL is housed in a refurbished computing room.

As part of the SciDAC Lattice Gauge Computing project, libraries and application programming interfaces (API's) were developed which allow high level physics codes to run without modification (after recompilation) on the different hardware platforms available - QCDOC, Myrinet and Infiniband clusters, gigabit Ethernet mesh clusters and commercial supercomputers. At each site, one or more versions of the SciDAC libraries will be deployed. SciDAC project personnel will be responsible for building and verifying the correctness of these libraries. Project personnel will be responsible for the configuration management of the libraries and the associated utilities.

Archival storage of physics data will utilize tape robots and hierarchal mass storage systems at FNAL and JLab. Tape media and, as necessary after FY 2006, tape drives will contribute to the operational costs supported by the project.

On a periodic basis, currently twelve months, U.S. collaboration members will be allocated computing time at one or more of the three sites by the Scientific Program Committee. Specific physics projects will often utilize two of the three sites to take advantage of the specific characteristics of each. For example, in FY 2006, the FNAL and JLab clusters will likely be used to analyze configurations generated on the QCDOC. Efficient movement of physics data between the sites will be essential.

4.3 Deliverables

In each year, the LQCD project will develop or purchase high performance parallel computing systems, as well as operate the systems developed in the previous years. In the first three years, the project will also operate the SciDAC prototype clusters. Each computing system will be operated for up to 3.5 years after commissioning. Table 1 below shows the performance goals for the systems operated by the project in each year. The performance figures give the average sustained throughput in TFlops of the Dirac inverter in the Domain Wall Fermion (DWF) and Improved Staggered (asqtad) formulations. The integrated performance figures specify the aggregate computing performance available for scientific calculations on all of the systems operated by the project, integrated over the year. These integrated performance figures include the effects of the new deployments only being available for part of the year.

Table 1 – Performance of New System Deployments, and Integrated Performance

	FY 2006	FY 2007	FY 2008	FY 2009
Performance of new system, TFlops (for FY 2006, figure is sum of JLab and	2.0	3.1	4.2	3.0

FNAL clusters)				
Delivered integrated performance (JLab + FNAL + QCDOC), TFlops-yr	6.0	9.2	12	15

In FY 2006, clusters will be constructed at both FNAL and JLab. The JLab cluster will be similar to the 2005 FNAL SciDAC Infiniband cluster, using PCI Express motherboards supporting single Intel Pentium processors, and an Infiniband fabric based on Mellanox host channel adapters and switches. This cluster will reuse the software configuration (Infiniband drivers and libraries, SciDAC application libraries) used on the FNAL cluster. The FNAL cluster will use Infiniband-connected systems based on dual processor PCI-Express motherboards, using Intel dual core Xeon processors. Further details are given in Table 2.

Table 2 – FY 2006 Purchases

Location:	**JLab**	**FNAL**
Node Type	Intel Single Processor	Intel Dual Processor
Node Count	128	400
Network	Infiniband 4X	Infiniband 4X
Performance	0.2 TFlops	1.8 TFlops
Release to Production	June 30, 2006	Sept.30, 2006

4.4 Alternative Analysis

In FY 2006, an alternative acquisition would be to purchase commercial supercomputers, rather than clusters. Commercial supercomputers could be procured that come closest to having the architecture, I/O, memory, disk space, etc., that is optimal for LQCD computing. Because of the special architecture of the IBM BlueGene/L, these systems run LQCD much more cost-effectively than typical general purpose supercomputers. They would therefore appear to be the commercial machines of choice. However, the current BlueGene/L is estimated to run LQCD codes at $2 per sustained megaflops (10^6 floating point operations per second, or MFlops). In comparison, the planned clusters are estimated to cost $0.80 per sustained MFlops.

5 MANAGEMENT ORGANIZATION

This section describes the management organization for the LQCD Computing project as defined for the development, construction, and final operation. It provides for the management of the major hardware subprojects – deployment and operation at BNL, FNAL and JLab. The management plan also facilitates the involvement of the scientific community that will be the ultimate users of the infrastructure. Figure 1 outlines the proposed management structure.

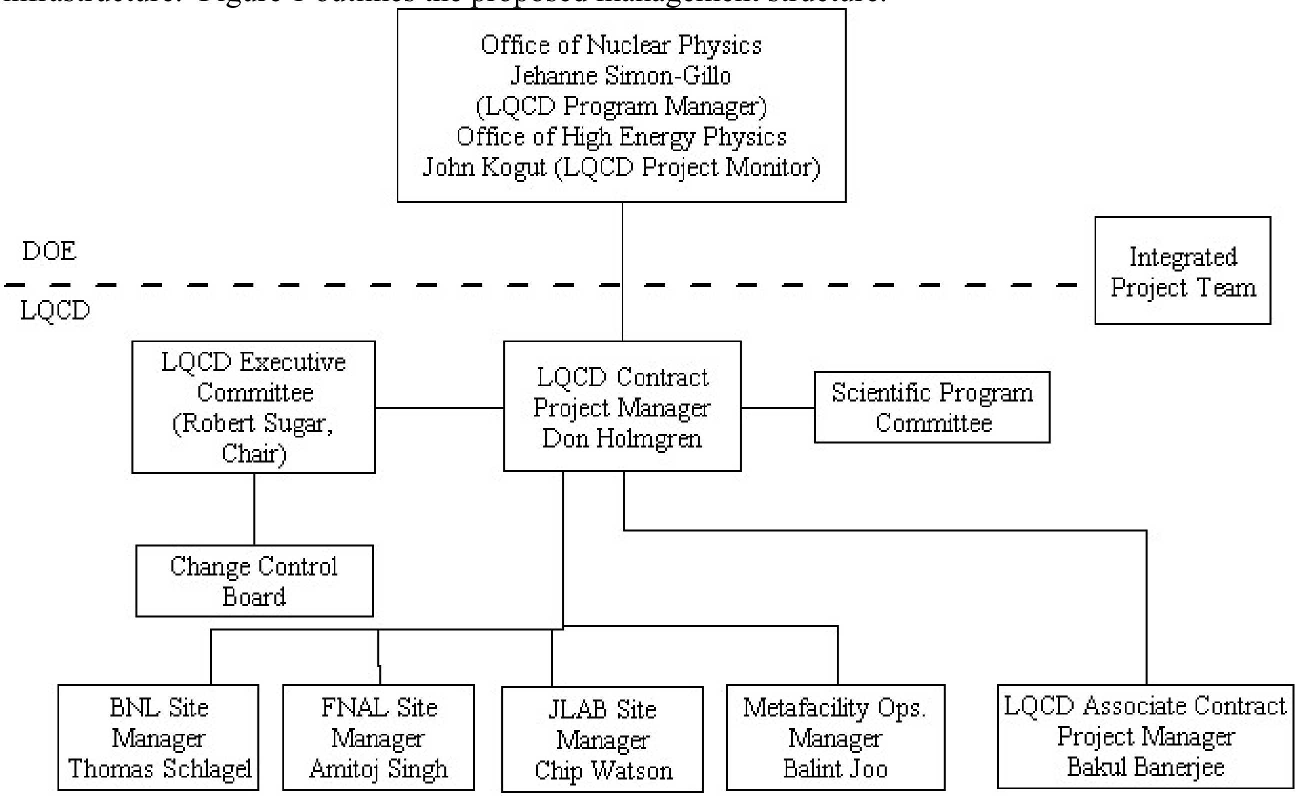


Figure 1. Management Organization Chart for the LQCD Computing Project. Vertical lines indicate reporting relationships. Horizontal lines indicate advisory relationships.

5.1 Project Management Responsibilities

5.1.1 Department of Energy Program Manager

Within DOE's Office of Science (SC), the Office of Nuclear Physics (ONP) has overall DOE responsibility for the LQCD Computing project. Dr. Jehanne Simon-Gillo is the LQCD Program Manager in the ONP. The LQCD Program Manager will be assisted by the LQCD Project Monitor. John Kogut of the Office of High Energy Physics (OHEP) is the LQCD Project monitor.

The LQCD Program Manager responsibilities include:

- Provide programmatic direction for LQCD
- Function as DOE headquarters point of contact for LQCD matters
- Oversee LQCD progress and help organize reviews as necessary
- Budget funds for LQCD
- Control changes to the LQCD baselines in accordance with the PEP

5.1.2 Contractor Project Manager

A Contractor Project Manager (CPM), responsible for the overall management of the project, will manage project execution at the highest level. This person is responsible for insuring that the project is well defined (via a work breakdown structure) and tracked (via milestones), and is the key interface to DOE for financial matters, reporting, and reviews of the project. As the top manager of the project, the CPM has significant budgetary control, and is in the approval chain for all major project commitments and procurements. The CPM will be Don Holmgren (FNAL). The CPM is equivalent to the Contractor Investment Manager defined in the Office of Management and Budget (OMB) Exhibit 300
Responsibilities

- prepares detailed planning documents for the project, including a work breakdown structure (hierarchical list of tasks, with each task defined at a level that can be externally reviewed, and with sites and individuals responsible for those tasks well identified; resource loaded so that costs can be predicted and earned value calculated), and a set of project milestones to rigorously track progress
- prepares and approves proposed budgets consistent with the detailed planning documents
- provides final approval for the project of all major (> $50 thousand) procurements
- prepares quarterly and/or annual project status / progress reports
- provides internal project oversight and review, 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
- establishes and manages a project change control mechanism

Interactions

- reports to the project Program Manager
- serves as a point of contact with DOE on matters related to budget and schedule of all funded activities

5.1.3 Associate Contractor Project Manager

The CPM will be assisted by the Associate Contractor Project Manager (ACPM). This person is responsible for maintaining the project work breakdown structure (WBS) and all other controlled documents related to management of the project. The Associate Contractor Project Manager will track expenditures and progress in achieving milestones. The Associate Contractor Project Manager will be Bakul Banerjee (FNAL).

Responsibilities

- assists the CPM in the preparation of detailed planning documents for the project, including a work breakdown structure, and a set of project milestones to rigorously track progress
- maintains the project WBS and other project management documents
- maintains the project schedule
- assists in the preparation of proposal budgets consistent with the detailed planning documents
- prepares of budget and milestone tracking information for input into the quarterly and/or annual project status / progress reports
- develops of a project web site, containing (pointers to) information on the project, schedules of meetings, repository of project documents, etc.

Interactions

- reports to the CPM
- works with the Metafacility Operations Manager and the Site Managers to gather budget and performance data for tracking the project and for preparing quarterly and/or annual reports

5.1.4 Site Managers

The hardware deployment and operations subproject at each host laboratory (BNL, FNAL, and JLab) will be headed by a Site Manager (SM), who will have significant authority at his/her site for delivering a significant computational resource to the community. The Site Manager 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, the host laboratory, and the work performed at that host laboratory.

The SM has authority to reallocate project resources within the laboratory to accomplish the assigned scope and tasks. This person is responsible to provide sufficient details of major procurements to the CPM to facilitate a review and approval for use of funds. The SM will have direct management control over that site's budget each year, with major procurements subject to approval by the CPM. All procurements are subject to host site management procedures and approvals. The site managers are Thomas Schlagel at BNL, Amitoj Singh at FNAL, and Chip Watson at JLAB.

Responsibilities

- specific hardware selection consistent with the project plan
- hardware procurement and deployment
- site operations and user support
- assist in preparation of detailed planning documents for the site sub-project, including:
    - a work breakdown structure (hierarchical list of tasks, with each task defined at a level which can be externally reviewed, and with sites and individuals responsible for those tasks well identified), and
    - a set of site project milestones for that site to rigorously track progress
- preparation of site budgets consistent with the detailed planning documents
- preparation of monthly status reports, including expenditures and effort, for the section of the WBS covering their site
- preparation of site quarterly and/or annual project status / progress reports
- internal site project oversight and review, 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
- preparation of materials for external oversight
- software deployment consistent with the project plan
- implementing the user allocations determined by the Scientific Program Committee
- obtaining necessary approvals from laboratory management
- coordination of resources contributed by the laboratory

Interactions

- reports to the Contractor Project Manager
- works closely with the Contractor Project Manger, the Associate Contractor Project Manager, the Metafacility Operations Manager, 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 of that site's portion of the national hardware infrastructure

5.1.5 Metafacility Operations Manager

The Metafacility Operations Manager (MFOM) will head the deployment and operation of the software necessary to seamlessly operate the three sites as a coherent metafacility. Necessary software will be developed in other projects (including the LQCD SciDAC project, and the International Lattice Data Grid (ILDG) activity), and will be integrated under the oversight of the MFOM, working in collaboration with the Site Managers.

The MFOM directly manages a small amount of manpower to diagnose problems and to coordinate with external projects involved in software development, and works with the SMs to execute the metafacility operations WBS items. This person reports to the CPM. The MFOM is Bálint Joó (JLab).

Responsibilities

- specific software selection and deployment coordination consistent with the project plan
- meta facility operations and user support
- assist in preparation of detailed planning documents for the meta facility sub-project, including
  - a work breakdown structure (hierarchical list of tasks, with each task defined at a level which can be externally reviewed, and with sites and individuals responsible for those tasks well identified), and
  - a set of project milestones to rigorously track progress
- preparation of budget consistent with the detailed planning documents
- preparation of quarterly and/or annual sub-project status / progress reports
- internal sub-project oversight and review, ensuring that funds are being expended according to the sub-project plan, and identifying weaknesses in the execution of the plan which need to be addressed
- preparation of materials for external oversight
- implementing the user allocations determined by the Scientific Program Committee

Interactions

- reports to the Contractor Project Manager
- works closely with the Associate Contractor Project Manager, the Contractor Project Manager and the Site Managers both to assist in defining milestones and infrastructure deployment schedules, and to ensure a high level of coherency across the project

5.1.6 Integrated Project Team

The LQCD Integrated Project Team (IPT) is composed of the DOE Program Manager, DOE HEP and NP Program Managers, DOE Project Monitor, a DOE ASCR Consultant, representatives from DOE Site Offices at BNL, FNAL, and JLab, the Contract Project Manager, the Associate Contract Manager, the BNL, FNAL, and JLab site managers, and the Metafacility Operations Manager. The list of names is given in Appendix A. Members of the team will meet monthly and on an as-needed basis. The LQCD Program Manager will chair the IPT.

5.1.7 LQCD Executive Committee

The charter of the LQCD Executive Committee is to provide leadership in developing the computational infrastructure needed by the United States lattice gauge theory community to study QCD, the theory of the strong interactions of subatomic physics. The Executive Committee has responsibility for setting scientific goals, determining the computational infrastructure needed to achieve these goals, developing plans for creating the infrastructure, obtaining funds to carry out these plans, and overseeing the implementation of them.

Current members of the Executive Committee are expected to serve for the duration of the project. If a vacancy occurs, it will be filled by a vote of the remaining members of the Executive Committee. The current members are Richard Brower (Boston U.), Norman Christ (Columbia University),Michael Creutz (BNL), Paul Mackenzie (FNAL), John Negele (Massachusetts Institute of Technology (MIT)), Claudio Rebbi (Boston University), Stephen Sharpe (University of Washington), Robert Sugar (University of California, Santa Barbara, Chair) and David Richards (JLab).

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
- has responsibility for the national lattice gauge theory community's SciDAC grant and will provide coordination between work done under that grant and in the current project
- appoints the members of the Scientific Program Committee
- appoints three or more members of the Control Change Board

5.1.8 Spokesperson

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

Responsibilities

- determines scientific goals and required computational infrastructure together with the Executive Committee
- chairs Executive Committee
- serves on Change Control Board

Interactions

- principal point of contact for DOE on scientific matters related to the project
- presents the project's scientific objectives to DOE, its review committees and its advisory committees
- liaison between the Executive Committee and the Contractor Project Manager, relating the Executive Committee's priorities to the Contractor Project Manager, and transmitting the Contractor Project Manager's progress reports to the Executive Committee

5.1.9 Change Control Board

The Change Control Board (CCB) is composed of the Contractor Project Manager, the Chairman of the LQCD Executive Committee (chair), the FNAL Computing Division Head, the JLab Chief Information Officer, the BNL Information Technical Division Director, and a scientific consultant appointed by the chair. The purpose of this committee is to assure that the changes to the project are managed with the primary focus on the advancement of the scientific goals of the project. The CCB must approve all changes resulting in cumulative increases of more than $125 thousand at WBS level 2, or a delay of more than 1 month of any level 1 milestone, or a delay of more than 3 months of any level 2 milestone. The CPM will present such changes to CCB for approval before executing any changes. All changes approved by CCB will be reported to DOE.

Responsibilities

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

Interactions

- gathers input from the project participants and the user community about project scope changes

5.1.10 Scientific Program Committee

The charter of the Scientific Program Committee is to assist the Executive Committee in providing scientific leadership for the LQCD Infrastructure Effort. The Program 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 all of the hardware that will be operated under the LQCD Computing Project: the SciDAC prototype clusters, the QCDOC, and the new hardware that will be acquired under the project. The Committee has instituted the following allocation process. Once a year it solicits proposals for use of the computational resources that will be available to the user community during the allocation period. The Committee reviews the proposals, and makes preliminary allocations based on its reviews. It then organizes an open meeting of the user community to discuss the proposals and the preliminary allocations. The Committee makes final allocations following this meeting. The three site managers and the MFOM are responsible for executing these allocations. The objective of this process is to achieve the greatest scientific benefit from the resources through broad input from the community. This process has been used to make the initial allocations of resources on the QCDOC computer and on the SciDAC prototype clusters. 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. Five such meetings have been held to date.

Members of the Scientific Program Committee are appointed by the Executive Committee. The current members are expected to serve for the duration of the project. If a vacancy occurs, it will be filled by the Executive Committee. The current members are Robert Mawhinney (Columbia University), Andreas Kronfeld (FNAL), Colin Morningstar (Carnegie Mellon University), John Negele (MIT), Claudio Rebbi (Boston University, Chair), Stephen Sharpe (University of Washington), Doug Toussaint (University of Arizona) and Frank Wilczek (MIT).

Responsibilities

- organizes annual meeting of the users community
- solicits proposals for using LQCD computational resources
- allocates computing resources

5.2 Interaction of the Laboratory Management and Project

Management of the collaborating laboratories, namely, BNL, FNAL, and JLab provides various supports to the project. Management authorities for DOE and upper management of the laboratories are described in Figure 2.

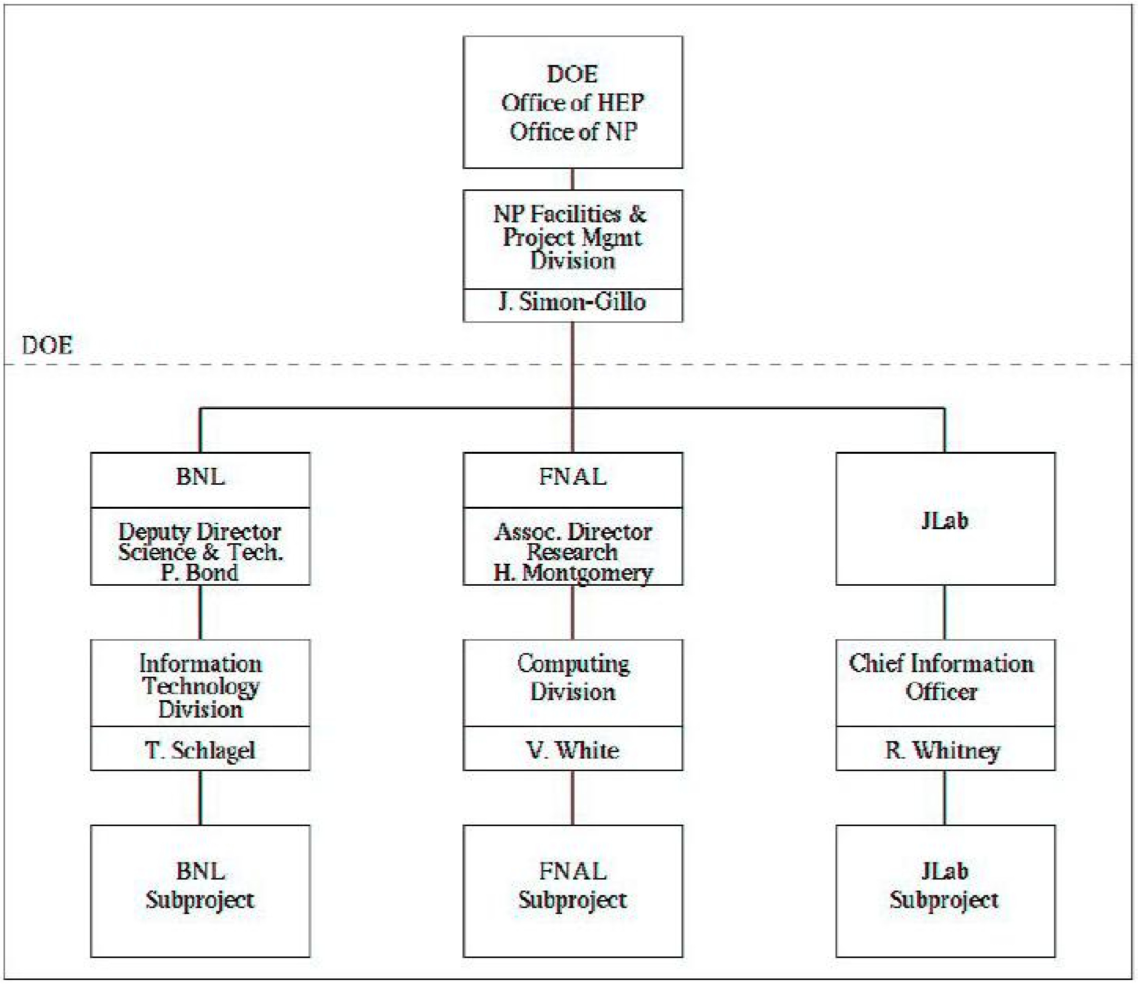


Figure 2: LQCD and Laboratory management

6 SCHEDULE AND COST MANAGEMENT

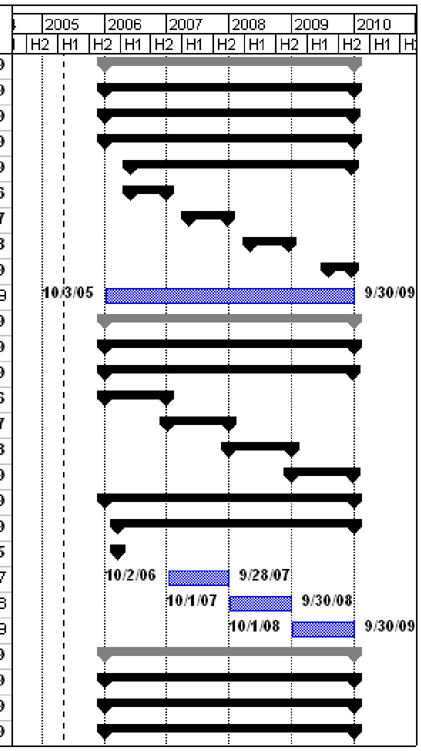
The LQCD Computing project is categorized as an OMB 300 development, modernization, and enhancement (DME) project, with an associated steady state (SS) component. The project is organized into a WBS for purposes of planning, managing and reporting project activities. Work elements are defined to be consistent with discrete increments of project work and the planned method of project control. Figure 3 shows a high level schedule of the key elements of the project. LQCD has three major WBS Level 2 components based on the facilities at each participating laboratory, FNAL, JLab, and BNL, spanning the period from October 2005 to September 2009. Under the Level 2 components there are Level 3 components:

Planning: Includes all project management activities at FNAL

Acquisition: Includes all acquisition and deployment of the LQCD facility at three laboratories. This component has two distinct, but overlapping, phases, prototyping and production phases, as noted in the details of WBS.
Operations: Includes deployment and site operation of the facility to serve the LQCD researchers. It also includes the MetaFacilities management tasks conducted by the MetaFacilities manager and site managers for each laboratory.

Figure 3 – High level schedule of the LQCD project.

Unique ID	WBS	Task Name	Duration	Start	Finish
940	1	**LQCD_FNAL.mpp**	**1008 d**	**10/3/05**	**9/30/09**
26009	**1.01**	**FNAL**	**1008 d**	**10/3/05**	**9/30/09**
26010	**1.01.01**	**LQCD FNAL site deployment**	**1001 d**	**10/3/05**	**9/21/09**
26089	**1.01.02**	**LQCD FNAL site operation**	**1008 d**	**10/3/05**	**9/30/09**
26080	**1.01.03**	**LQCD equipment purchases**	**898 d**	**3/6/06**	**9/16/09**
26090	**1.01.03.1**	**PO FNAL - FY06**	**143 d**	**3/6/06**	**9/25/06**
26097	**1.01.03.2**	**PO FNAL - FY07**	**159 d**	**2/5/07**	**9/18/07**
26098	**1.01.03.3**	**PO FNAL - FY08**	**161 d**	**2/5/08**	**9/16/08**
26099	**1.01.03.4**	**PO FNAL- FY09**	**98 d**	**5/4/09**	**9/16/09**
26087	1.01.04	LQCD project management	1008 d	10/3/05	9/30/09
939	2	**LQCD_JLab.mpp**	**1008 d**	**10/3/05**	**9/30/09**
20277	**2.01**	**JLAB**	**1008 d**	**10/3/05**	**9/30/09**
20257	**2.01.01**	**LQCD JLAB site deployment**	**1006 d**	**10/3/05**	**9/28/09**
20354	**2.01.01.1**	**FY06 JLAB - Procure and deploy systen**	**247 d**	**10/3/05**	**9/29/06**
20355	**2.01.01.2**	**FY07 JLAB - Procure and deploy systen**	**246 d**	**10/3/06**	**9/28/07**
20358	**2.01.01.3**	**FY08 JLAB - Procure and deploy systen**	**250 d**	**10/3/07**	**9/29/08**
20361	**2.01.01.4**	**FY08 JLAB - Procure and deploy systen**	**257 d**	**10/3/08**	**9/28/09**
20336	**2.01.02**	**LQCD JLAB site operation**	**1007 d**	**10/3/05**	**9/30/09**
20337	**2.01.03**	**LQCD JLAB equipment purchases**	**957 d**	**12/15/05**	**9/30/09**
20338	**2.01.03.1**	**PO - FY06**	**1 d**	**12/15/05**	**12/15/05**
20339	2.01.03.2	PO - FY07	247 d	10/2/06	9/28/07
20340	2.01.03.3	PO - FY08	253 d	10/1/07	9/30/08
20341	2.01.03.4	PO - FY09	261 d	10/1/08	9/30/09
941	3	**LQCD-BNL.mpp**	**1007 d**	**10/3/05**	**9/30/09**
14581	**3.01**	**BNL**	**1007 d**	**10/3/05**	**9/30/09**
14631	**3.01.01**	**LQCD BNL site operation**	**1007 d**	**10/3/05**	**9/30/09**
14632	**3.01.02**	**LQCD BNL equipment purchases**	**1007 d**	**10/3/05**	**9/29/09**



6.1 Project Milestones

The Level 1 project milestones defined in the project WBS are shown in Table 3. Each laboratory will report the status of completion for each project milestone to the CPM on a monthly basis. Any significant changes to milestone schedules will be processed according to the change control procedure.

Table 3 – Level 1 Milestones

Milestone	Fiscal Years
FY07 computer architecture planning complete and reviewed	Q3 2006
Procurement and deployment of systems totaling 2.0 Teraflops (sustained)	Q4 2006
6 Teraflops-years computing delivered	Q4 2006
FY08 computer architecture planning complete and reviewed	Q3 2007
Procurement and deployment of systems totaling 3.1 Teraflops (sustained)	Q3 2007
Additional 9 Teraflops-years computing delivered	Q4 2007
FY09 computer architecture planning complete and reviewed	Q3 2008
Procurement and deployment of systems totaling 4.2 Teraflops (sustained)	Q3 2008
Additional 12 Teraflops-years computing delivered	Q4 2008
Procurement and deployment of systems totaling 3.0 Teraflops (sustained)	Q3 2009
Additional 15 Teraflops-years computing delivered	Q4 2009

6.2 Project Scope

The scope of the LQCD project is the operation of the QCDOC computer at BNL, the operation of the existing SciDAC clusters at JLab and FNAL, including equipment purchased during the final year of SciDAC (July 2005 – June 2006), the acquisition of clusters at JLab and FNAL in FY 2006 and their operation, and the acquisition of new systems in FY 2007 – FY 2009 with project funds and their operation. The QCDOC will be operated throughout the project (FY 2006 – FY 2009). The existing SciDAC clusters will be operated until end of life, as determined by cost effectiveness (approximately 3.5 years). All new systems acquired during the project will be operated from purchase to the end of the project.

LQCD will fund labor for system administration, hardware support, and site 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 scope of the project.

6.3 Cost Scope

The total cost for LQCD is $9.2 million. Figure 4 shows the cost breakdown summary for equipment (hardware, or HW) and labor (Full Time Equivalent (FTE)) for the LQCD in actual year dollars. Equipment costs include system acquisitions (computers, networks) plus storage (disk, tape media). Labor costs include system administration, engineering and technical labor, site management, and project management. Indirects will be applied according to agreements between the project and the host laboratories. All labor estimates have been inflated using escalation rates of 4%.

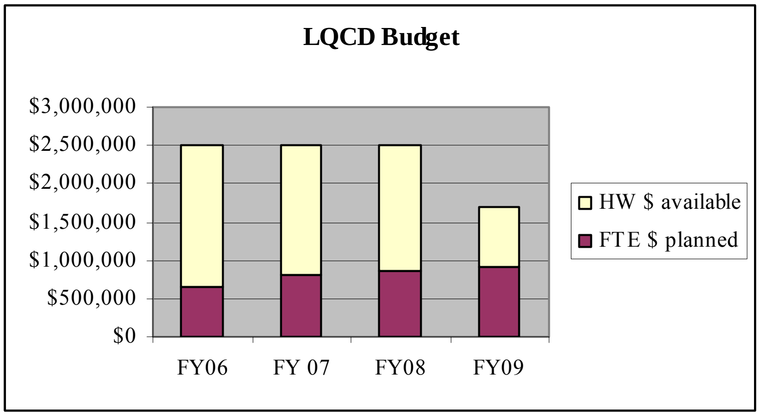


Figure 4: LQCD Project Funding Profile

6.3.1 Costing and Funding Profile

The LQCD Computing project will be funded by DOE-HEP and DOE-NP as shown in Table 4. A cost summary for FY 2006 is shown in Table 5. The ONP and OHEP held a Technical, Cost and Schedule Review of LQCD at the Laboratory for Nuclear Science at the Massachusetts Institute of Technology (MIT/LNS) in May 2005. The review was chaired by ASCR. The OMB-300 submission for the project and the PEP was assessed by this independent committee.

Table 4 - Cost Breakdown by DOE Program Office

Fiscal Year	**DOE-NP Funding**	**DOE-HEP Funding**
2006	$0.5M	$2.0M
2007	$0.5M	$2.0M
2008	$0.5M	$2.0M
2009	$0.5M	$1.2M
Project Total	$2.0M	$7.2M

Table 5 – Cost Summary for FY 2006

WBS	Name	Total Cost K$	HEP Funding K$	NP Funding K$
1.01	FNAL	1850	1850	
1.01.01	LQCD FNAL site deployment			
1.01.01.01	FY06 FNAL- Procure and deploy system	128	128	
1.01.02	LQCD FNAL site operation (FY06 only)	64	64	
1.01.03	LQCD FNAL equipment purchases			
1.01.03.1	PO FNAL - FY06	1548	1548	
1.01.04	LQCD project management	110	110	
2.01	JLAB	428		428
2.01.01	LQCD JLAB site deployment			
2.01.01.1	FY06 JLAB - Procure and deploy system	66		66
2.01.02	LQCD JLAB site operation (FY06 only)	82		82
2.01.03	LQCD JLAB equipment purchases			
2.01.03.1	PO - FY06	280		280
3.01	BNL	222	150	72
3.01.01	LQCD BNL site operation (FY06 only)	202	130	72
3.01.02	LQCD BNL equipment purchases			
3.01.02.01	PO BNL - FY06		20	
	Total FY06 project cost	2500	2000	500

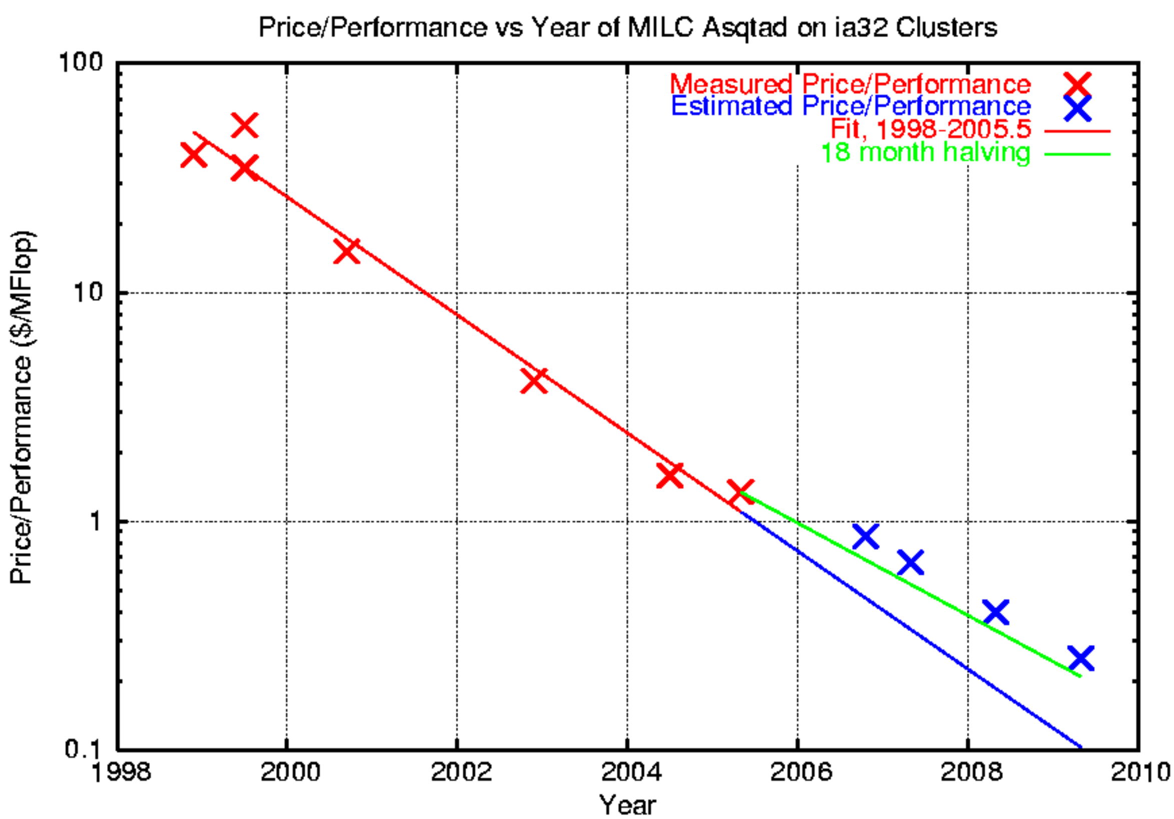
6.3.2 Procurement Strategy

In each year, the Lattice QCD project will either construct tightly coupled clusters, or purchase commercial supercomputers, choosing the most cost effective solution available at the time. Each of these annual developments of new computing systems will be “built-to-cost”. That is, a fixed budget will be determined for each year for computer hardware, with the precise number of processors procured determined by purchase price of systems and network equipment in that year. Variation in purchase price of these components from the estimates used in the budget will result in greater or lesser computing capability from the estimated value. Variation in performance of the components from the estimates will also result in greater or lesser computing capability. The resulting performance risk is managed by the fact that the scope of the project is fluid; small negative variances in available computing capability and/or capacity will result in schedule delays in completing scientific computing projects. Large negative variances will prevent the completion of computing goals; these will trigger review and modification of the LQCD scientific program, such as through changes or elimination of allocations of computing resources to specific projects.
The risk of large performance variances is minimized through the use of conservative projections in the estimated costs and performance of each future system development. Allocations of computing resources, and the planning of the LQCD scientific program, will be based upon these conservative estimates.

Conservative projections provide performance contingency for the project. This approach was reviewed at the Technical, Cost, and Schedule Review held at MIT/LNS in May 2006. Figure 5 from that review illustrates the approach. The graph shows the measured price to performance ratio ($/MFlops, red crosses) of lattice QCD clusters built at FNAL from 1999 through 2005 (the 1999 points include a cluster at Indiana University, and a cluster at Sandia National Laboratory). The blue line shows the fit to the measured points; the "Moore's Law" halving time of this fit is 15 months. The blue crosses represent the price/performance points used in the plan at the time of the review. The green line on the graph is an extrapolation from the measured FNAL FY 2005 Infiniband cluster price/performance using an 18-month halving time (18 months is the typical value cited for commodity processor Moore's Law performance increases). The project plan uses a slower, 21-month halving time to project the performance of clusters purchased in each year of the project.

The project plan bases the schedules for procurement and integration of systems on the experience gained at JLab and FNAL during the SciDAC project, as well as on more general experience at both labs with the integration of commodity computing hardware for experiments (large reconstruction and data acquisition farms). Additional schedule contingency has been added for the integration of systems based on new vendor architectures. For example, because the FY 2006 FNAL cluster purchase will use parts based on a new memory architecture ("fully buffered DIMMs"), the planned duration of the design through release to production phases is nine months, rather than the six months allocated to the JLab FY 2006 cluster.

Figure 5 – Development of Performance Contingency



A further mitigation of performance risk follows from the steady state operations at each project site of the older, existing systems; each system developed will be operated for three to four years. The computing performance available from any given system will be well known within months of initial production. At any given time, these established systems will represent more than half of the available computing capacity.

In each year, the project will operate the computing systems that were developed either during the project, or prior to the start of the project (the SciDAC prototype clusters at FNAL and JLab, and the QCDOC at BNL). Note that a series of clusters have been in production at JLab and FNAL producing scientific output since 2001, and that the QCDOC at BNL has been in production since September 2005. The manpower requirements for the operations of these systems, particularly the clusters, have been well established through these years of production. The amount of manpower required to provide end user support, and to maintain the systems, increases as the installed sizes of the systems at FNAL and JLab grow. The project will seek to operate these systems with the minimum effective manpower, attempting to maximize the scientific output by balancing the relative amounts of funding in each year for operations and for the development of new computing systems. At any given time, there will be a risk that insufficient user support, for example, will limit the scientific productivity of the systems. This risk will be managed by adjusting the balance between labor and equipment costs in every procurement cycle, relying on the experience gained in prior operations.

6.3.3 Steady State Life Cycle Cost

Part of the steady state life cycle costs will be funded by the project, specifically, the manpower required for the administration and maintenance of the systems (~ 2.5 FTE). However, portions of the cost of the LQCD facility, such as power and cooling, will be contributed by the participating laboratories. Total estimated power and cooling costs, based on current and escalated utility rates at BNL, FNAL, and JLab, range from ~ $340 thousand in FY 2005 to ~$780 thousand in FY 2009. This estimate is based on historical trend data at FNAL and JLab on the power consumption of the SciDAC prototype clusters; the BNL power and cooling cost estimate is based on measurement. After the end of the project, continued operation of all of the acquired systems and the QCDOC would require similar labor and utility costs; however, systems would be retired as they reached their projected lifetimes (3 to 4 years), decreasing the required outyear costs proportionally. The decommissioning of LQCD resources covers the disposal of standard electronic, computers and network equipment, which must follow accepted standard procedures for disposal of these items. These decommissioning costs are not included in the project.

6.3.4 Resource Utilization

The LQCD Computing WBS is loaded with two flavors of resource. Both DME and SS portions of the work and materials will be funded by the project, with some work contributions (system and scientific software support) of the SS portion funded by the base budgets of the three labs.

7 CHANGE CONTROL

Changes to the technical, cost and schedule baselines will be controlled using the thresholds described in Table 1.

All changes that include or exceed Level 2 approval thresholds should first be submitted to the Contractor Project Manager for approval, using a Change Request (CR) form. For changes exceeding Level 2, the CPM will endorse the request (i.e., recommend approval) to higher authority or reject the request. If endorsed, the CPM will then transmit the CR to the LQCD CCB with recommendations. If the request exceeds Level 1, the LQCD CCB will submit the CR to the DOE LQCD Program Manager for approval or rejection of the request.

If a change is approved, a copy of the approved CR, together with any qualifications or further analysis or documentation generated in considering the request is returned to the requestor, and copies are sent to the official at the next higher control level and to the LQCD project office for filing. If approval is denied, a copy of the CR, together with the reasons for denial, is returned to the requestor, and a copy is filed. 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.

Table 1: Summary of Change Control Thresholds

Level	Cost	Schedule	Technical Scope
LQCD Program Manager (Level 0)	Any increase in the total project cost	3-month or more delay of a Level 1 milestone date	Change of any WBS element that could adversely affect performance specifications
LQCD CCB (Level 1)	A cumulative increase of more than $125K in WBS Level 2	> 1-month delay of a Level 1 milestone date or > 3-month delay of a Level 2 milestone date	Any deviation from technical deliverables that does not affect expected performance specifications.
LQCD Contractor Project Manager (Level 2)	Any increase of > $25K in the WBS Level 2	> 1-month delay of a Level 2 milestone date	Technical design changes that do not impact technical deliverables.

8 ANALYSIS, ASSESSMENTS, AND PLANS

8.1 Environment, Safety and Health

8.1.1 Integrated Safety Management Plan

Environment, Safety and Health (ES&H) will be integrated into all phases of planning, acquisition and maintenance phases of the LQCD project using appropriate procedures defined by the participating laboratories. LQCD will follow the five core functions of the Integrated Safety Management (ISM) Plan.

- Define work and identify the potential hazards
- Analyze potential hazards and design the equipment or activities to appropriately mitigate or eliminate those hazards.

- Establish controls for hazards that cannot be eliminated through design features
- Perform work in accordance with the procedures
- Review the effectiveness of the hazard analyses and controls and provide feedback for improvement.

FNAL's ISM process is representative of the three laboratories' policies. The facility at FNAL will follow the FNAL's procedure titled "Laboratory Environment, Safety and Health Policy and Implementation." It is noted in the introduction of this document, "At FNAL, safety is important. It is the policy of this laboratory to protect the environment and all persons, be they employees or visitors, from accident or injury while they are on site. Nothing shall have a higher priority." The LQCD project will follow the Laboratory's ISM process.

The LQCD Computing project is a collaborative effort among three DOE sponsored laboratories with stringent ES&H policies and programs. Local ES&H and ISM policies will govern both local employees and visitors working at a particular site. Those working for the project will follow procedures specific to the laboratory and locations within the laboratory.

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

Site managers at each laboratory will 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 will be documented. Also, laboratory personnel will receive specific training required or recommended for project to perform their job in a safe and proper manner. Site managers are responsible for verifying that the staff members have received appropriate training and it is documented.

Applicable electrical, mechanical, etc. codes, standards and practices, will be used to ensure the safety of personnel, environment, equipment and property and will be integrated into the project. Where these codes, standards and practices are in conflict, the most stringent or most appropriate will be selected. Reviews will assess compliance with these codes, standards and practices. All equipment purchased from manufacturers must comply with Underwriters Laboratories Inc. or equivalent requirements, or it will be reviewed for safety. Also, prior to initial operation, formal safety reviews will be held to establish operation readiness clearance for LQCD. The results and conclusions of these reviews, when applicable, will be documented.

8.1.2 National Environmental Policy Act

There is no direct construction activity associated with the project. However, an assessment of the need for a review of compliance with the National Environmental Policy Act of 1969 (NEPA) will be conducted before the beginning of the installation of equipment for the project. Necessary NEPA actions will be taken at the conclusion of that review. From past experience at the three sites covering a range of research and related activities, we anticipate that the LQCD project will be determined to be included under Categorical Exclusion.

8.1.3 Quality Assurance

LQCD defines Quality as the "fitness of an item or design for its intended use" and Quality Assurance (QA) as "the set of actions taken to avoid known hazards to quality and to detect and correct poor results." LQCD will follow established quality control procedures established at various laboratories. As a part of the annual self-assessment, CPM and ACPM will conduct a quality assurance assessment of the project.

8.2 Risk Assessment

Because of the build-to-cost nature of the project, LQCD has low risk of not completing on cost. The cost estimates are based in part on past procurements for the prototype computing systems, and on the actual cost of labor for deploying and operating the existing facilities. Hardware component cost variances will result in adjustments to the sizes of the computing systems developed each year. Labor cost variances, for example, the need to change the amount of user support, will result in adjustments of the division between subsequent equipment and labor budgets.

The performance risks associated with the planned computing and network systems are estimated to be low due to the successful Research and Development (R&D) performed during the development of the SciDAC prototype systems, and also due to the use of common off the shelf components (COTS) whenever possible. At project start, the performance of the existing SciDAC clusters and the QCDOC is well known; the FY 2006 Level 1 delivered performance milestone is based primarily upon the performance of these existing systems. Contingency is built into the estimates of the performance of the systems that will be acquired during the project through the use of conservative extrapolations from the performance of the newest SciDAC clusters; 21-month "Moore's Law" doubling times have been used, compared with the observed 15-month times on LQCD clusters built from 1999 through 2005.

The most important schedule risks are delays in releasing new systems to production after their procurement caused by difficulties in integrating the computer, network, and software subsystems, and delays resulting from slippage in vendor schedules for the release of new processors, networks, or other important subsystems (for example, memory architectures). Integration delay risks are low when new systems are based on components previously used on either SciDAC prototypes or on earlier project systems. Larger schedule contingencies are used when planned systems are based upon new components, technologies, or architectures.

The vacuum gauge configurations generated on the computing systems operated by this project have considerable value, as ensembles of configurations will be the result of several TFlops-yrs of computation. To protect against the risk of loss due to equipment failure or natural disaster, these gauge configuration data files will be redundantly stored at multiple locations (FNAL and JLab); they will also be duplicated in mass storage archives at the Lawrence Berkeley National Lab (LBNL NERSC) and at the National Center for Supercomputer Applications (NCSA).

9 PROJECT CONTROLS AND REPORTING SYSTEMS

The project will implement a Performance Based Management System (PBMS). Performance goals and measures are fully defined in the FY 2007 OMB 300 submission of the project. A detailed set of performance measures is listed in the section on Performance Reference Model (PRM) of the Federal Enterprise Architecture (FEA) of the above document.

The investment scope, schedule performance, and cost will be evaluated at pre-established intervals (no less than quarterly) using the industry-standard project management tools currently in place at FNAL. The project manager will identify, monitor, and assess accomplishments or deviations from baseline goals. The IPT will periodically review, assess, update and improve the project management plan to ensure that all key milestones and project cost estimates have been adequately adjusted for risk. In addition, operational analysis will be utilized to ensure that the investment is performing within baseline cost, schedule and performance goals.

Management processes for the investment will be designed according to the Guidance from the DOE M 413.3 and Project Management Institute (PMI) Guide to the Project Management Body of Knowledge (PMBOK) will be adopted as necessary. Overall performance at all three laboratories, namely, FNAL, BNL and JLab, is managed under the terms of the performance-based management contract with the DOE. Under the terms of the contract, laboratories are expected to integrate contract work scope, budget, and schedule to achieve realistic, executable performance plans. Following existing processes at FNAL, BNL and JLab, both financial and operational, the project will implement methods of collecting and analyzing data measured. Additionally, annual self-assessments, aligned with the annual DOE review, will be used at the investment level to assess and evaluate results and to improve performance.

Each site (FNAL, BNL and JLab) will have a SM dedicated to the project. The Project Manager will coordinate all project management activities with the Site Managers and MFOM and be responsible for reporting status to DOE. The Associate Contractor Project Manager will work with BNL and JLab financial and technical contacts to obtain necessary data from those sites.

A detailed WBS has been developed for the work to be done for the investment using Microsoft Project software, with basis of estimates derived from past purchase records and effort reports. Collaborating laboratories will execute Memoranda of Understanding (MOU) with the LQCD project. MOUs will include details of the contributions to the project by the laboratories. After the WBS is defined, it will be baselined and monthly status reporting process against the baseline will be initiated. Cost and percent completion data will be collected. FNAL uses Oracle-based Project Accounting system to capture actual costs for WBS items at certain predetermined levels. Data on the Actual Cost of Work Performed will be calculated from this system. Similar data will be collected from other laboratories and consolidated. This data will be used to create cost and schedule performance reports as well as necessary change requests and exception reports. The current investment project will deploy existing tools as deemed necessary. The budget planning and resource allocation process will be based on the financial management system of the respective laboratories, which in turn are based on DOE's general guidance. Details of fund management for the investment that includes both DOE's HEP and NP organizations will be established. The information pertinent to the investment will be detailed in the MOUs.

Site managers will be responsible for tracking cost and schedule elements, and for reporting these to the Associate Contractor Project Manager. This person will lead monthly cost and schedule performance reviews based on schedule, cost, and technical data, and will report the result to the CPM. A quarterly cumulative report will be submitted to the CPM, who will lead quarterly reviews of the overall cost, schedule and technical performance and report the results to the Federal Project Manager. The ONP and OHEP will conduct annual progress reviews with a committee of experts.

Each laboratory (FNAL, BNL, and JLab) will use its official accounting system as a basis for collecting cost data. Each SM and respective financial officer will work with the Associate Contractor Project Manager to establish a direct one-to-one relationship between each WBS element of Level 2 or higher and a separate account code under their accounting system. Site managers and the Associate Contractor Project Manager will define a common format of reporting data that can be consolidated into the master WBS.

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

10 PARTICIPATION OF OTHER INSTITUTIONS

For the LQCD project, FNAL, JLab and BNL are the primary participating laboratories. Memoranda of Understanding (MOU) will define the relationships and expectations between these laboratories and the project. Researchers from various universities are key customers of the computing systems developed during this LQCD Project. Their feedback will be incorporated throughout the duration of the project through the LQCD Executive Committee and the spokesperson.

11 Appendix A: LQCD Integrated Project Team

DOE LQCD Program Manager	Jehanne Simon-Gillo (chair)
DOE HEP Program Manager	Jeff Mandula
DOE NP Program Manager	Sid Coon
DOE LQCD Project Monitor	John Kogut
DOE ASCR Consultant	Dan Hitchcock
DOE BNL Site Office	Robert Gordon
DOE FNAL Site Office	Paul Philp
DOE JLab Site Office	Andrea Bethea
Contract Project Manager	Don Holmgren
Associate Contract Project Manager	Bakul Banerjee
BNL Site Manager	Tom Schlagel
JLab Site Manager	Chip Watson
FNAL Site Manager	Amitoj Singh
Metafacility Operations Manager	Bálint Joó
LQCD Executive Committee Chair	Robert Sugar