Project Execution Plan

for the

Lattice QCD ARRA Computing Project

at the

Thomas Jefferson National Accelerator Facility
Newport News, Virginia

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

March 2010
Revision 1

Project Execution Plan
for the
Lattice QCD ARRA Computing Project
at the
Thomas Jefferson National Accelerator Facility
March 2010

CONCURRENCES:

__________________ ________
Chip Watson Date
Contractor Project Manager
Thomas Jefferson National Accelerator Facility

__________________ ________
Roy Whitney Date
CIO, Jefferson Lab

__________________ ________
George Fai Date
Program Manager for
Nuclear Theory
Office of Nuclear Physics

__________________ ________
Helmut Marsiske Date
Program Manager for
Nuclear Physics Instrumentation
Office of Nuclear Physics

APPROVED:

__________________ ________
Jehanne Gillo Date
Director
Facilities and Project Management Division
Office of Nuclear Physics
Office of Science

Change Log: Project Execution Plan for the
Lattice QCD ARRA Computing Project

Revision Number	Pages Changed	Effective Date
0	Entire document	January 2010
1	5-8, 13-14	March 2010

Table of Contents

1 INTRODUCTION

This Project Execution Plan (PEP) describes the technical scope, schedule, cost, management organization, and control processes for the Lattice Quantum ChromoDynamics (LQCD) American Recovery and Reinvestment Act (ARRA) Computing Project at the Thomas Jefferson National Accelerator Facility (Jefferson Lab), a project to deploy and operate a significant dedicated computing resource for LQCD calculations. This resource will play an important role in expanding our understanding of the fundamental forces of nature and the basic building blocks of matter.

The computing hardware will be housed at Jefferson Lab, and will be available to lattice gauge theorists at national laboratories and universities throughout the United States. The project starts in FY 2009 and will be completed in FY 2013, and includes hardware procurements and four years of operations. The total project cost is $4.965 million, funded by the American Recovery and Reinvestment Act (ARRA) of 2009.

The major performance goal for the project is to deploy resources capable of an aggregate of at least 60 Teraflops of performance sustained in key LQCD kernels, specifically the matrix inversion routines for 3 numerical approaches for solving LQCD: asqtad (a-squared-tadpole), clover, and domain wall. As a point of reference, this metric is typically 20% of the Linpack performance for a large machine.

Over the past six years members of the United States 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. With support from the Department of Energy (DOE) Offices of High Energy Physics (HEP), Nuclear Physics (NP), and Advanced Scientific Computing Research (ASCR) with its Scientific Discovery through Advanced Computing (SciDAC) program, prototype systems, both custom hardware and customized commodity, have been deployed, and the software needed to exploit them has been developed.

Historically, by taking advantage of simplifying features of lattice QCD calculations, it has been possible to build computers for this field that have significantly better price/performance than typical high end supercomputers or even high end clusters. The guiding principle has been to build or purchase whatever hardware best advances the science. To support the selection of hardware, software research and development on specialized systems and evaluation of commercial computers has been done under the lattice gauge theory SciDAC grant. Further ongoing 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 the project's technical scope, management organization, schedule, cost scope, and change control are set out.

2 MISSION NEED

The LQCD ARRA Computing Project directly supports the mission of the DOE's Nuclear Physics 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...[and] provide world-class research facilities for the Nation's science enterprise."

The Standard Model consists of two quantum field theories: the Weinberg-Salam Theory of the electromagnetic and weak interactions, and Quantum ChromoDynamics (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 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.

3 FUNCTIONAL REQUIREMENTS

3.1 Computational Requirements

Two classes of computing are done for lattice QCD. 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. Multiple ensembles with varying lattice spacing and quark masses are generated, and sets of ensembles are generated using several different numerical approaches. This class of computing requires machines capable of sustaining tens of Tflops for days or weeks at a time.

The second class of jobs, the analysis phase, uses thousands 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, analysis computing can rely on multiple machines or partitions each capable of sustaining 1% of the performance of the largest jobs (i.e. hundreds of Gflops), with a total aggregate computing capacity of tens of Tflops.

In summary, to meet the requirements of 60 Tflops, it is sufficient to have (for example) of order 150 machine partitions, each with of order 400 Gflops performance. It is the purpose of this project to address this second class of jobs.

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. During the analysis stage, 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 in an ensemble. 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 in order to sustain 60 Tflops.

3.3 Network Requirements

Configuration files will be generated at supercomputing centers, and transferred to Jefferson Lab. This represents a very modest network bandwidth requirement, less than 1 Gbit/s. The larger propagator files will typically be generated and consumed at the same site (Jefferson Lab in this case) and so do not represent a large wide area network bandwidth requirement.

4 TECHNICAL SCOPE

The LQCD ARRA Computing Project consists of the purchase of a large aggregate high performance computing resource, plus ~4 years of operations. The resource will be deployed in two phases, with the first phase funds committed by the end of FY 2009, and the second phase committed in FY 2010.

4.1 Computing Systems - Nodes and Networks

Recent dedicated USQCD computing resources have been of a single common architecture: a cluster of x86 based servers interconnected with an Infiniband fabric. Each year the nodes have gotten faster as CPUs have increased in core count. Every two years the network has increased in speed by a factor of two, starting with Single Data Rate (SDR) Infiniband in 2005, growing to Quad Data Rate (QDR) available in 2009. The software for exploiting these systems is mature, and the cost effectiveness of this approach is sufficient to meet the milestones of the project.

An interesting disruptive technology has appeared which yields significantly increased performance per dollar, and that is the use of Graphics Processing Units (GPUs) as compute accelerators. One of the reasons for splitting the procurement into two phases is to allow the software maturity for exploiting GPUs to grow as the number of GPUs is expanded.

Other credible alternatives to these two architectures are not known at the time of the project proposal, but would be considered if any appeared prior to procurements being initiated.

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.

The computers will be installed in the existing Data Center at Jefferson Lab, which has adequate space and cooling, but will need some additional power conditioning (UPS) plus the installation of new circuits. This additional power provisioning is a part of the project. Space charges and electricity charges will be absorbed by the laboratory as part of overhead or in-kind contributions from the laboratory.

Archival storage of physics data will utilize the existing Jefferson Lab tape library, an additional contribution by the laboratory. Tape media and, as necessary, tape drives and even expansion of the tape library, will be expenses associated with the science exploitation of this computational resource, but are not included as operational costs of the project. Media will be covered by the LQCD-extension project, and tape library expansion (if necessary) will be covered by the laboratory as part of routine operating expenses for all of Scientific Computing. This partitioning of responsibilities has been agreed to by all parties.

On a periodic basis, currently twelve months, US collaboration members will be allocated computing time by the USQCD Scientific Program Committee. This committee allocates time in an integrated fashion for the supercomputers (including DOE Incite awards), the LQCD National Computing Project facilities, and this new LQCD ARRA computing facility.

4.3 Deliverables

In the first 15 months of the project, there is a deliverable of 60 deployed teraflops, a hardware deployment of approximately $3.5 million across two phases.

Each year the LQCD ARRA Computing Project will have a deliverable of integrated running time measured in Teraflops-years, corresponding to running the resources from the target date of production running with an uptime of 90%. Operations funded by this project will continue through the end of FY2013, or approximately 3.5 years. Over the life of the project, this will be 50 Tflops-years of integrated performance. The resource will be rolled out during FY 2010, and so the target integrated running will be lower that year (eight months for the Phase 1 portion, and four months for the Phase 2 portion).

	FY 2010	FY 2011	FY 2012	FY 2013
Delivered integrated performance, Tflops-yr	15.2	55	55	55

Table 1 – Annual Integrated Sustained Performance

In this calculation, GPU cards are assumed to be contributing performance for 50% of a job's running time. Some applications will exploit them at a higher level, up to 90%, and some at a lower level, as low as 10%. This factor of 2 degradation in performance is intended to take into account Amdahl's Law's impact on the performance. Thus the project will deliver more than 60 Tflops of potential performance: 100 TFlops in GPUs, and 10 TFlops in conventional cluster nodes.

5 MANAGEMENT ORGANIZATION

This section presents the management organization for the LQCD ARRA Computing Project. The management plan also facilitates the involvement of the scientific community that will be the ultimate users of the infrastructure. The figure below shows the management structure.

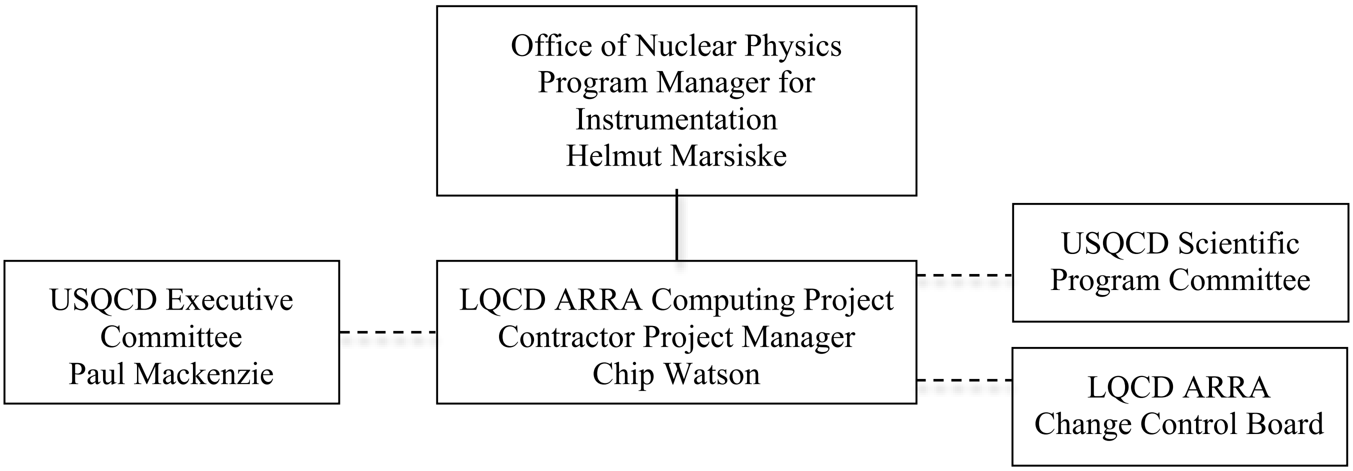

Figure 1. Management Organization Chart for the LQCD Computing Project. Vertical lines indicate reporting relationships. Horizontal lines indicate advisory relationships.

5.1 Department of Energy Program Manager

Within DOE's Office of Science (SC), the Office of Nuclear Physics (NP) has overall DOE responsibility for the LQCD ARRA Computing Project. Helmut Marsiske is the Program Manager for Instrumentation in the Office of Nuclear Physics.

The DOE Program Manager responsibilities include:

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

5.2 Contractor Project Manager

The Contractor Project Manager, responsible for the overall management of the project, manages project execution. This person is responsible for insuring that the project is well defined (via a work breakdown structure, WBS) and tracked (via milestones), and is the key interface to the Department of Energy for financial matters, reporting, and reviews of the project. As the manager of the project, the Contractor Project Manager has significant budgetary control, and is in the approval chain for all major project commitments and procurements. The Contractor Project Manager will be Chip Watson. This person will be referred as CPM in all project documents.

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 individuals responsible for those tasks well identified, 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 (> $50K) 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 DOE Program Manager
- serves as a point of contact with DOE on matters related to budget and schedule of all funded activities

5.3 USQCD Committees

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). This responsibility spans the current project and other QCD computing projects and computing allocations. The Executive Committee has responsibility for setting scientific goals, determining the computational needs to achieve these goals, developing plans for creating the infrastructure, obtaining funds to carry out these plans, and overseeing the implementation.

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 committee. The current chair is Paul Mackenzie of FNAL.

Responsibilities

- sets the scientific goals and determines the computational needs 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

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

Responsibilities

- chairs Executive Committee
- serves on Change Control Board

Interactions

- principal point of contact for the Department of Energy on scientific matters related to the project
- presents the project's scientific objectives to the Department of Energy, 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

The charter of the Scientific Program Committee is to assist the Executive Committee in providing scientific leadership for the Lattice QCD 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 project, as well as other resources shared by the USQCD Collaboration. 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 objective of this process is to achieve the greatest scientific benefit from the resources through broad input from the community. The Committee is also charged with organizing an annual meeting of the user community to review progress in the development of the infrastructure and scientific progress achieved with the infrastructure, and to obtain input on future directions.

Members of the Scientific Program Committee are appointed by the Executive Committee. The current members are expected to serve for the duration of the project. If a vacancy occurs, it will be filled by the Executive Committee. The current chair is Frithjof Karsch (BNL).

Responsibilities

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

5.4 Change Control Board

The Change Control Board (CCB) is composed of the Contractor Project Manager (representing the project), the Chairman of the USQCD Executive Committee (representing the users), and the Jefferson Lab Chief Information Officer (representing the host institution). The purpose of this committee is to assure that changes to the project are managed with the primary focus on the advancement of the scientific goals of the project. The CCB acts on change requests according to the procedures described in section 7 below.

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

5.5 Interaction of Host Laboratory Management and the Project

Management of the host laboratory, Jefferson Lab, provides oversight and supplemental support to the project including all line management duties such as staffing, safety, etc. Management authorities for DOE and senior upper management of the host laboratory are shown in Figure 2.

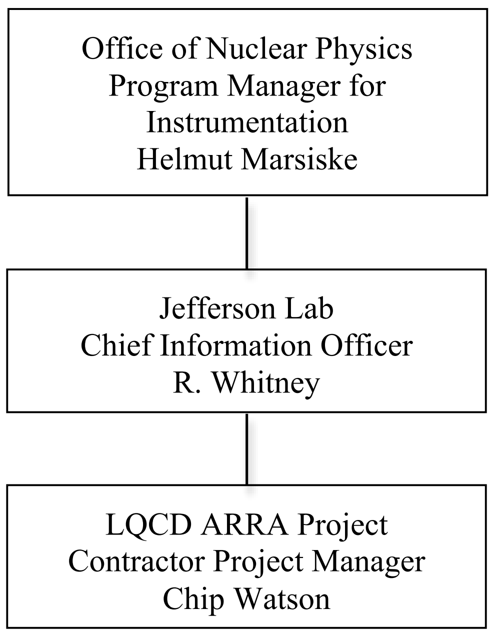

Figure 2. Management Authorities Chart for the LQCD Computing Project.

6 SCHEDULE AND COST

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. LQCD has three major WBS Level 1 components:

Planning: Includes all project management activities
Deployment: Includes all site preparation, acquisition and deployment of the LQCD ARRA resources in two phases.
Operations: Includes operation of the facility to serve the LQCD researchers for the four years of the project.

6.1 Project Milestones

The Level 1 project milestones defined in the project WBS are shown in Table 2. Any significant changes to milestone schedules will be processed according to the change control procedure.

Milestones	Date
Project Start	6/10
Issue Request for Proposal (RFP) for disk and compute clusters	8/10
Place order for disk cluster and first compute cluster	9/10
Begin early use on first cluster	12/09
Production running on first cluster	1/10
Place order for Phase 2a Infiniband cluster	1/10
Begin early use of Phase 2a Infiniband cluster	4/10
Place order for Phase 2b next generation GPU cluster	4/10
Production running on Phase 2a Infiniband cluster	5/10
Complete Annual Peer Review of LQCD program (June of each year)	6/10
Begin early use of Phase 2b next generation GPU cluster	8/10
Production running on all resources	9/10

Table 2 – Level 1 Milestones

6.2 Budget

The total project cost for the LQCD ARRA Computing Project is $4.965 million. Equipment costs include system acquisitions (computers, networks), storage (disk), and power provisioning / conditioning (UPS, circuits). Labor costs include system administration, engineering and technical labor, and project management. Indirect costs will be applied according to Jefferson Lab standards. All labor estimates have been inflated using escalation rates of 4%.

WBS	Name	Total Cost K$
1.	Project Planning and Management	101
2.	Deployment	
2.01	Site preparations	266
2.02	Phase 1 deployment	1,970
2.03	Phase 2 deployment	1,816
3.	Operations	
3.01	Year 1	127
3.02	Year 2	239
3.03	Year 3	229
3.04	Year 4	217
	Total Project Cost	**4,965**

Table 3 – Cost Summary by WBS with contingency

6.3 Procurement Strategy

The overall strategy for the computational resource is the same strategy as has been used by the LQCD National Computing Project: always procure or build the system which provides the best performance for the anticipated workload, under the constraints of what the software is capable of supporting. Following this strategy, it was clear in creating the LQCD ARRA Computing Project that the compute resource would be some combination of an Infiniband cluster and a cluster of GPU enabled nodes.

As described above, the project has been divided into two procurement phases, with three types of components planned for the computational system: Infiniband cluster nodes, GPU cluster nodes, and file storage nodes.

For the Infiniband cluster, the target job performance was set at about 1% of the performance now being achieved on leadership class machines doing configuration generation, as described in section 3.1 above.

The split between a standard Infiniband cluster and a cluster of GPU enabled nodes will be driven by software maturity. The fraction going into GPUs in the first phase will be smaller than the percentage going into GPUs in the second phase. As software maturity increases, more and more of the USQCD workload can be moved to GPUs, which yield higher performance per dollar spent. In light of the performance opportunity of GPUs, the procurement was intentionally split into two phases to allow software maturity to rise, while still delivering a significant increase in USQCD capacity as quickly as possible in Phase 1.

Disk server capacity and performance requirements were projected based upon a roughly five and a half fold increase from 3.6 Tflops sustained to 20 Tflops sustained at Jefferson Lab. Budget was set assuming $1K / Terabyte at the bandwidth needed. Compute performance will now be 3x larger, but disk cost is about 2.5x smaller, so the disk capacity can almost be scaled with performance.

All procurements are firm fixed price, acquiring as much performance or capacity as can be obtained within budget (build to cost).

6.4 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 (~ 1.2 FTE). The same process for estimating this level of effort is used for the LQCD-extension project, and is based firmly upon many years of experience. Other operational costs of the LQCD ARRA computing facility, such as power and cooling, will be contributed by the host laboratory. Total estimated power and cooling costs are ~ $300K per year. The costs of decommissioning of the resources at end of life are not included in the project cost. The hardware is likely to have residual value exceeding the decommissioning costs so that this is not an outstanding obligation.

7 CHANGE CONTROL

Changes to the technical, cost and schedule baselines will be controlled using the thresholds described in Table 4, below.

All changes that include or exceed Level 2 approval thresholds are to be documented by the Contractor Project Manager. For changes exceeding Level 2, the Contractor Project Manager will document the change using a Change Request (CR) form and transmit the CR to the Change Control Board (CCB, section 5.4 above) with recommendations. If the request exceeds the Level 1 threshold, the CCB will submit the CR to the DOE Program Manager for approval or rejection of the request.

The CCB must approve all changes resulting in a shift of more than $200,000 between equipment and labor budgets, or movement of more than $200,000 between WBS Level 2 subprojects, or any one month or greater delay of a level 1 WBS milestone. The Contract Project Manager will present such changes to CCB for approval before executing any changes. All changes approved by CCB will be reported to DOE. Changes that result in any increase in the total project cost or a 3-month or greater delay in a level 1 WBS milestone or a change that could adversely affect project performance specifications must in addition be approved by DOE prior to executing the change.

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 to be kept by the Contractor Project Manager as part of the project documentation. If approval is denied, a copy of the CR, together with the reasons for denial, is to be filed.

Level	**Cost**	**Schedule**	**Technical Scope**
DOE Program Manager (Level 0)		> 1-month delay of a Level 1 milestone date	Change of any WBS element that could adversely affect project performance specifications
LQCD ARRA CCB (Level 1)	A cumulative increase of more than $200K in WBS Level 2	> 1-month delay of a Level 1 milestone date	Any deviation from technical deliverables that does not affect expected project performance specifications.
LQCD ARRA Contractor Project Manager (Level 2)	Any increase of > $50K in the WBS Level 2	> 1-month delay of a Level 2 milestone date	Technical design changes that do not impact technical deliverables.

Table 4: Summary of Change Control Thresholds

8 SAFETY AND RISK MANAGEMENT

8.1 Environment, Safety and Health

8.1.1 Integrated Safety Management (ISM) Plan

Environment, safety and health (ES&H) will be integrated into all phases of planning, acquisition and maintenance of the project using appropriate procedures defined by the host laboratory. The LQCD ARRA Computing Project will follow the five core functions of ISM:

- 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.

The line management of the laboratory retains supervisory authority of their personnel and responsibility for the safety of work at the laboratory. Line management will keep the Contractor Project Manager informed about their laboratory's management and ES&H organization structures. Any safety concerns by LQCD ARRA Project personnel are to be communicated to the LQCD ARRA Contractor Project Manager and to the line management where the concern occurs.

The Contractor Project Manager will work with safety officers at the laboratory to ensure that the specific hazards found in the project are documented according to plans and procedures of the 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. The Contractor Project Manager is responsible for verifying that the staff members have received appropriate training and that this training 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. The results and conclusions of these reviews, when applicable, will be documented.

8.1.2 NEPA

There is no direct construction activity associated with the project. From past experience at the three USQCD deployment sites covering a range of research and related activities, it is anticipated that the LQCD ARRA Project will be determined to be included under Categorical Exclusion.

8.1.3 Quality Assurance

The LQCD ARRA 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." LQCD ARRA will follow established quality control procedures of the host laboratory.

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 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 deployed. There is a modest contingency (10%) on labor and deployment costs other than the major procurement purchases. Out year operations are well known to an accuracy smaller than this. If deployment labor costs exceed this contingency, a small adjustment in the Phase 2 procurement could be done to compensate (most deployment costs occur prior to the Phase 2 award).

The performance risks associated with the planned computing and network systems are estimated to be low due to the successful R&D performed during the ongoing SciDAC project, and also due to the use of common off the shelf components whenever possible. The performance milestones are based primarily upon the performance of existing systems and by knowledge of near term new hardware. Contingency is built into the estimates of the performance of the systems that will be acquired during the project through the use of conservative estimates of vendor pricing.

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. Integration delay risks are low when new systems are based on components previously used on earlier LQCD clusters, specifically Infiniband clusters and file servers. Integration risks are higher for the GPU nodes, consequently determining the fraction of the procurement that goes into GPUs will include steps to estimate and reduce these risks.

8.3 Cyber Security

The LQCD ARRA Project resources will be installed in the Jefferson Lab Scientific Computing network enclave. This enclave has access control which makes it inaccessible directly from offsite, and has rules governing access from onsite. As described in the enclaves cyber security documentation, the compute nodes are in non-routed subnet(s), and access is only via interactive gateway notes. All nodes except the compute nodes are scanned for vulnerabilities daily, with a deeper scan conducted once a week. The systems are maintained according to Jefferson Lab cyber security policies, and the system will be operated under Jefferson Lab's Authority To Operate. Cyber monitoring of the scientific computing enclave is performed by the cyber security group; this service is an in-kind contribution from the laboratory.