DRAFT

Statement of Work
for the
Cornell-Brookhaven ERL Test Accelerator
(C-Beta)

A collaboration between Cornell University and Brookhaven National Laboratory

July 24, 2016

1 Project Summary and Objective

Project Title:	Design, Construction and Demonstration of a Prototype Energy Recovery Linac
Project Funding and Duration	$25,000,000; 38 months
Sponsor:	New York State Energy Research and Development Authority 17 Columbia Circle Albany, NY 12203
Sponsor Contact:	Mark R. Torpey, Director Technology and Business Innovation Mark.Torpey@nyserda.ny.gov (518) 862-1090 x3316
Lead Performing Organization:	Brookhaven National Laboratory Upton, NY
Oversight Board Chair	Berndt Mueller, Assoc. Laboratory Director Nuclear and Particle Physics Brookhaven National Laboratory
Project Manager	Stephen Peggs Collider-Accelerator Department peggs@bnl.gov (631) 344-3104
Project Principal Investigator	Dejan Trbojevic Collider-Accelerator Department trbojevic@bnl.gov (631) 344-3078

BNL scientists and their collaborators at Cornell University will design and test an Energy Recovery Linear Accelerator (ERL) prototype, the Cornell-Brookhaven ERL Test Accelerator (C-Beta). This prototype ERL addresses one of the major risks to successful implementation of the eRHIC design that Brookhaven National Laboratory (BNL) will propose for an Electron-Ion Collider (EIC).

C-Beta will confirm the ability of a multi-turn ERL to recover most of the energy in the high-energy electron beam of an EIC. Successful demonstration will ensure that the electric power requirements of the eRHIC design are within acceptable limits, with respect to operating costs and reuse of existing power infrastructure at BNL.

2 Background

2.1 An Electron-Ion Collider: The nation's next large science facility

The U.S. Department of Energy (DOE) is the federal agency with the mission to explore basic science questions about the nature of matter. DOE has designed, constructed and operated a series of large research accelerator facilities to pursue this mission. The next accelerator facility to be considered for construction by the DOE Office of Nuclear Physics is an Electron-Ion Collider.

Several stages of review are required to realize such a major facility. First is the recommendation by the Nuclear Physics community of the type of new facility that is needed. The Nuclear Science Advisory Committee (NSAC) was charged by the Secretary of Energy to make such a recommendation for nuclear science. In 2015 NSAC recommended, as its highest priority, an Electron-Ion Collider for the next major research facility. An excerpt from the NSAC recommendation to DOE's Office of Science states:

> **"We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB."**
>
> *Excerpt from The 2015 Long Range Plan for Nuclear Physics, page 4, prepared by the Nuclear Science Advisory Committee.*

Also from the NSAC recommendation:

> *"The EIC was designated in the 2007 Nuclear Physics Long Range Plan as "embodying the vision for reaching the next QCD frontier." In 2013 the NSAC Subcommittee report on Future Scientific Facilities declared an EIC to be "absolutely essential in its ability to contribute to the world-leading science in the next decade." The strong and worldwide interest in a U.S.-based EIC has been rapidly growing. Countries such as China, France, India, Italy, and Japan have expressed strong interest in collaborating on the physics, the detector, and the accelerator technologies. Now is the time to realize the EIC in the U.S."*
>
> *Excerpt from The 2015 Long Range Plan for Nuclear Physics, page 40, prepared by the Nuclear Science Advisory Committee.*

The second step, following the NSAC recommendation, is for the National Academy of Sciences (NAS) to empanel a review group. An NAS panel was charged in April 2016 and is expected to issue its recommendation in around October 2017. This panel will provide a scientific review of the EIC and recommend whether an EIC will appropriately meet DOE's basic science mission need of investigating the fundamentals of matter.

If the NAS panel recommends an EIC, the Department of Energy will then begin the process of determining an appropriate site and team to design, construct and operate the EIC for the term of its scientific mission. That mission is expected to last at least 20 years.

eRHIC is the EIC design that BNL is proposing to construct at its site in Upton, NY, with an ERL at its heart. The C-Beta ERL is a small-scale prototype of the large-scale eRHIC ERL.

2.2 eRHIC – Brookhaven Lab's EIC Design

The typical design for an Electron-Ion Collider has two rings where beams of electrons and ions circulate in separate rings, and in opposite directions. These beams pass through each other at specified points resulting in collisions between electrons and ions. Specialized detectors capture these collision events, enabling the ability to “see into” the most basic structure of the ion. Figure 1 shows a diagram of BNL’s eRHIC design, including one ring for ions, two rings for electrons, and two collision point detectors.

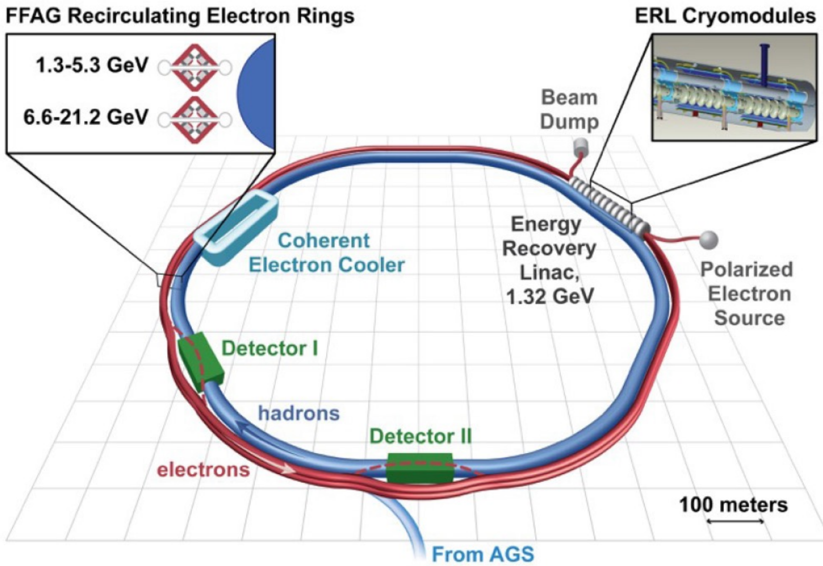

Figure 1: eRHIC schematic showing an electron beam facility (in red) colliding with the existing RHIC ion beam (blue) at two interaction point detectors.

BNL has presented a novel design with electrons passing only once through each detector, after being accelerated on a relatively small number of passes through a linear accelerator (linac). This electron beam is significantly brighter than the more conventional design in which electron beams circulate for many million of turns. After collision, the energy in each bunch is (almost) fully recovered in the same linac, by also using it for deceleration. This design produces a much higher rate of electron-ion collisions, expanding the range of scientific investigations at the same time as greatly reducing the electric power consumption of the facility.

Although several ERLs already exist, the type of ERL that makes the eRHIC design both highly energy efficient and cost effective (a multi-pass ERL with permanent magnet FFAG recirculation arcs) needs to be tested with a prototype.

2.3 Collaboration between Brookhaven and Cornell University

Cornell University, a BNL Core University, joins BNL in designing and testing the C-Beta ERL, in a collaboration that includes Cornell faculty researchers with expertise in key areas of the ERL design.

The ERL concept was invented at Cornell. For over a decade, the development of this New York State invention has been a primary focus of research at the Cornell Laboratory for Accelerator-Based Sciences and Education (CLASSE). This development effort included the construction of components that are ready for integration into the C-Beta accelerator, including a high performance photo-injector to produce the electron beam, and a high efficiency superconducting linac.

Using Cornell’s existing facilities, equipment and infrastructure reduces the C-Beta cost by about $30M, compared to configuring space for construction and testing at BNL.

3 Project Benefits

Continuing New York State leadership in nuclear physics and accelerator science.

Multi-pass ERL technology is potentially instrumental in bringing the eRHIC project to Long Island, attracting the world's best and brightest nuclear physicists and accelerator scientists. It will foster the development of fundamental science capabilities, industrial partnerships, and a highly educated workforce — thus promoting the status of New York State, Stony Brook University, Brookhaven National Laboratory and Cornell University as world leaders in the field.

Generating the discoveries to build next-generation technology companies, especially those based on energy-focused technologies.

The eRHIC project will spur the development of new, next-generation technologies — including innovative accelerator and detector systems, large data management and analysis tools — enabling spin-off applications into national security, finance, cancer therapy, and nuclear medicine. Examples already established or under development include: a linear accelerator that recovers the energy used to accelerate ions and greatly reduces operating costs; new compact superconductor magnets that shrink the size and cost of particle-beam-delivery systems used for precision cancer treatment; and the continued cost-effective production of important isotopes used for medical diagnosis and treatment.

Leveraging a multi-billion-dollar investment in New York State.

An eRHIC in New York will result in a further multi-billion-dollar investment. eRHIC will bring more than $700 million in DOE capital investments for construction, followed by an operating budget of nearly $200 million per year for up to two decades of scientific operations. Securing a commitment to the eRHIC project will also help ensure the continued operations of RHIC over the next 5-7 years, before the transition to the new facility, with similar levels of annual funding. On balance, the benefit to the state is estimated to be at least $3 billion over two decades.

Accessing top global talent, training next generation scientists and engineers

The project offers unique education and workforce development opportunities for students and young researchers at BNL and Cornell University, not only in the fields of accelerator science and engineering, but also in other associated high-tech areas. The construction of the technical components of the project and the necessary infrastructure at Cornell University will stimulate the local economies and create jobs on Long Island and in upstate New York. Companies across New York State can access this global talent pool, which has the experience to solve their toughest problems.

Enhancing major user facilities at BNL

This investment will be managed to make all of the Lab's science programs, including the user facilities, more competitive and agile. The broader partnership with NYSERDA is directed toward finding solutions to energy distribution and storage problems, for example, using the High-Energy X-ray Diffraction (HEX) Beamline for Materials Engineering and Battery Research at NSLS-II and the energy materials and systems testing capabilities at the Center for Functional Nanotechnology (CFN). Success in these areas will influence the overall scientific productivity of all BNL programs and facilities, attracting significant follow-on investments from the DOE and industry over the next decade in "big data", science and engineering facilities.

Enabling ERL-based research at CLASSE

ERL development at CLASSE was originally inspired by the potential of a high energy ERL X-ray source. In the meantime, the potential applications of ERL's have expanded to include an electron ion collider such as eRHIC and high throughput, high precision photolithography. The development of a high power ERL like C-Beta is the next step on the path toward realizing the full potential of the ERL concept.

Once the NYSERDA program for C-Beta is complete, it will have a variety of other uses. One is accelerator physics itself, where C-Beta is an ideal tool for the study of nonlinear beam dynamics, ERL phenomenology, or beam instrumentation. Many aspects of these uses are suitable thesis topics for graduate students in Cornell's world-renowned graduate program in accelerator physics. The C-Beta beam could also be used to produce very hard X-rays with energies of more than 100 keV, augmenting the capabilities of Cornell's CHESS national X-ray user facility. Finally, C-Beta's intense electron beam offers opportunities in particle and nuclear physics, such as a search for dark photons that could probe new regions of parameter space.

4 Technical Approach

Energy efficiency is required in order to affordably meet the full set of scientific expectations of the Electron-Ion Collider. BNL proposes to achieve energy efficiency by recovering the energy initially stored in the high-energy electron beam, through the use of a multi-pass Energy Recovery Linac with permanent magnet FFAG recirculation arcs. While simpler ERLs have been constructed and operated before, *the eRHIC ERL design needs to be tested with a prototype.*

The required performance criteria for the C-Beta prototype ERL have been established and are summarized in Table 1. Achieving these Key Performance Parameters will ensure that an ERL-based eRHIC design will achieve high energy efficiency.

Table 1: Key Performance Parameters (KPPs) and design parameters for C-Beta.

Parameter	**Unit**	**KPP**	**Design**
Electron beam energy	MeV		150
Electron bunch charge	pC		123
Gun current	mA	1	40
Bunch repetition rate (gun)	MHz		325
RF frequency	MHz	1300	1300
Injector energy	MeV		6
RF operation mode			CW
Number of ERL turns		1	4
Energy aperture of arc		2	4

4.1 Leveraging Specialized Facilities and Expertise at Cornell University

Cornell scientists possess unique expertise with high intensity electron beams and superconducting radio frequency (SRF) systems, which, together with the BNL scientists, will ensure the successful design, construction, installation and commissioning of this test-ERL.

Scientists and engineers at Cornell University pioneered the concept of an Energy Recovery Linac. For many years they have pursued the development of an ERL-based Free Electron Laser (FEL). They have built and successfully operated an intense 6 MeV electron source and injector. A 70 MeV superconducting RF linac cryomodule has been constructed and successfully tested without beam, with beam testing to follow in the first half of 2017. This existing equipment is ideally suited to be the basis for a prototype test-ERL.

Cornell University also has sufficient high bay area and associated infrastructure to enable the prototype to be completed with the additional construction and installation of a permanent magnet FFAG recirculation arc. C-Beta will be installed in a repurposed extracted-beam hall, L0E, in Wilson laboratory at Cornell. This facility provides the basic infrastructure required to test the 4-turn ERL, including utility connections, support infrastructure, shielding and controls.

5 Technical and Budget Timelines

5.1 Technical Timeline

The 40-month technical timeline shown in Table 2 is a high-level summary of the schedule of the Work Breakdown Structure (WBS). If funding begins in October 2016, then project completion will occur in February 2020. The timeline includes two "go/no go" milestones, at months 10 and 18.

The first "go/no go" occurs after beam has been accelerated through the Main Linac Cryomodule (MLC). The MLC, which is already on the floor of the L0E experimental hall, has already been commissioned without beam, surpassing all of its performance goals. The MLC will be moved into its final location for beam testing that will be completed in August 2017, even in the absence of NYSERDA funding.

The second "go/no go", in month 18, occurs after the Fractional Arc Test (FAT) that will see beam also pass through an initial configuration of one combiner-separator and a prototype girder containing 8 hybrid permanent magnets, and all associated systems and diagnostics. The FAT commissions as much C-Beta equipment as is practically possible before making a final commitment to constructing and assembling the rest of the accelerator.

Table 2 Technical timeline showing major milestones after funding start date.

Technical milestone	Months	Comment
NYSERDA funding start date	0	Estimate: Oct 2016
Prototype girder	6	
Spreader and combiner production approved	8	
Prototype girder testing complete	8	PM production approved
Beam through Main Linac Cryomodule	10	Go/no go 1
Fractional Arc Test: Beam through MLC + prototype girder	18	Go/no go 2
Girder production run complete	25	
Final assembly and pre-beam commissioning	28	
Single pass, x2 energy scan	32	
Single pass, Energy Recovery	36	Key parameters achieved
Four pass with Energy Recovery (low current)	38	
Project completion	40	Estimate: Feb 2020

5.2 Budget Timeline

The project deliverables that are summarized in Table 3 are associated with budget increments attached to each deliverable. This budget timeline is consistent with the technical timeline of Table 2. The final deliverable (D11) results in a successfully commissioned and tested prototype 4-pass ERL. A brief description of each deliverable follows. Each deliverable is self-contained, with all project management and physics support included.

Table 3 Deliverables and budget timeline, with completion month since the beginning of funding.

Index	Deliverable	Completion month	Cost $M
D01	Engineering design	3	2.0
D02	Infrastructure preparation	5	1.4
D03	SRF injector, linac RF components, RF controls	8	1.7
D04	Cryogenic equipment	8	0.8
D05	Shielding and safety systems	11	1.2
D06	Hybrid permanent magnets	11	3.9
D07	Power and instrumentation	14	3.1
D08	Vacuum system and beam transport	17	2.6
D09	Beam spreader-combiners (Turns 2-4)	23	3.5
D10	Final assembly and installation	26	2.3
D11	Commissioning and testing	38	2.5

D01: Engineering design

Complete 80% of the engineering design of the whole project, including all system-wide design. A key part of this design is the layout for the 4-turn ERL with FFAG return loop. The detailed engineering design regarding specifics for each component or subsystem is included within the subject task, D02 – D09.

D02: Infrastructure preparation

Preparation of Cornell's existing high-bay extracted-beam facility L0E for use by the project. Existing electrical and cryogenic infrastructure will be modified, as necessary, for the prototype ERL. This includes moving all necessary equipment into the test facility, including the ERL gun with its laser system, Injector Cryomodule, ERL merger, Main Linac Cryomodule, and beam stop.

D03: Superconducting Radio Frequency injector, linac RF components, RF controls

Upgrade and install the existing SRF Injector and linac. Procure and install linac radio frequency (RF) components and the necessary controls to operate the RF system, the laser systems and the diagnostic systems.

D04: Cryogenic equipment

Procure cryogenic equipment for SRF Injector and linac. Install all cryogenic equipment, controls and diagnostics.

D05: Shielding and safety systems

Procure radiation shielding material and components of the personnel protection system. Establish the safety protocols and ensure all safety standards are met. Configure and install all required shielding and measurement systems. Some existing shielding and equipment will be provided from existing BNL capabilities. All necessary equipment protection systems will be designed, procured, and installed.

D06: Hybrid permanent magnets

Procure and assemble all hybrid permanent magnets for the recirculation arc.

D07: Power and instrumentation

Procure and assemble all power supplies and beam instrumentation equipment. Procure all equipment for first pass beam spreader and combiner.

D08: Vacuum system and beam transport

Procure and assemble all beam vacuum chambers, vacuum pumps, and girders. The magnets and vacuum chambers will be installed on the accelerator girders. Those girder sub-assemblies will be installed in the test facility.

D09: Beam spreader-combiners (Turns 2-4)

Procure and assemble all equipment for the beam spreaders and combiners for the ERL turns 2, 3, and 4. Existing diagnostic systems will be installed to optimize the beam emittance, optics and trajectory.

D10: Final assembly and installation

Final assembly and installation of all equipment.

D11: Commissioning and testing

C-Beta commissioning is accomplished in this task, first with low intensity beam for one pass, then low intensity beam through all four passes, and finally with high intensity beam through all passes. The necessary authorizations to commission and operate the system will be obtained before any testing is begun. The goal of commissioning is to reach the Key Performance Parameters in Table 1. Once the KPP are achieved, additional operation and testing will be undertaken toward the design parameters.

Figure 2 presents the same deliverable and budget timeline in graphical form, showing the eleven deliverable milestones plus the on-going Project Management Task. The schedule shown assumes a June 1, 2016 funding start date. It will be shifted to the actual project start date once the true date is established and funding is available.

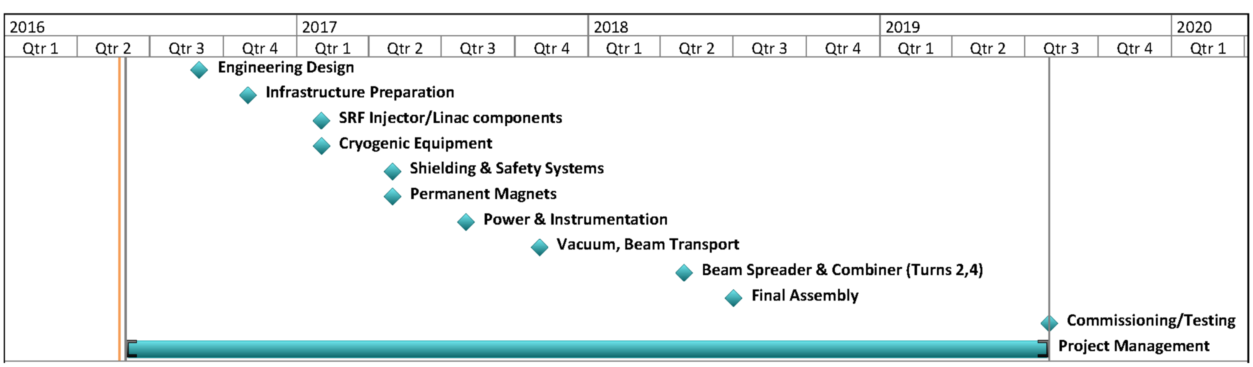

Figure 2: C-Beta deliverables and budget timeline milestones. [TABLE NEEDS UPDATING TO REFLECT AN OCT 2016 START DATE.]

6 Project Management and Oversight

BNL has established a project management and oversight structure to ensure operational and strategic management as well as oversight of all project activities. Effective mechanisms will be put in place for external advice and to review the technical and financial performance of the project. These mechanisms are described in this section. A summary diagram of the project management structure is presented in Figure 3.

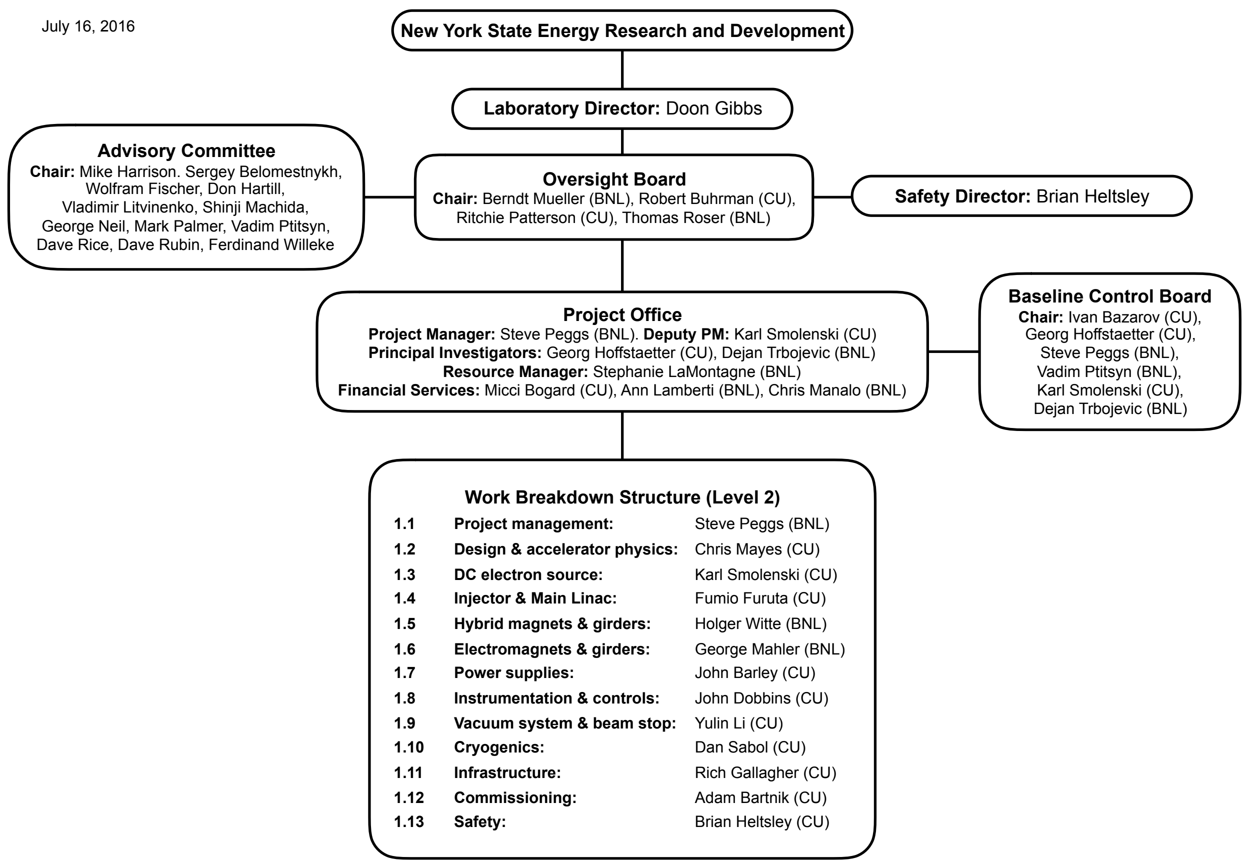

Figure 3: C-Beta project management structure

6.1 Oversight Board

The Oversight Board is responsible to ensure the success of the project, paying attention to ensure that timely funding, appropriate external scientific advice and clear decision making authority are available to the project. The Oversight Board chair is an employee of Brookhaven National Laboratory. The board is made up of two members each from Brookhaven Lab and Cornell University.

Dr. Berndt Mueller, Associate Laboratory Director for Nuclear and Particle Physics at Brookhaven Lab will serve as the Chair of the Oversight Board.

Other members of the Oversight Board include: Thomas Roser, Chair, Collider-Accelerator Department, BNL; Robert Buhrman, Senior Vice Provost for Research, Cornell University; and, Ritchie Patterson, Chair, Cornell Laboratory for Accelerator-Based Sciences and Education, Cornell University.

Example responsibilities of the Oversight Board include:

- Works with funders to secure timely access to project funding.
- Receives advice from the Advisory Committee about progress.
- Make changes to the Management Board or Advisory Committee, as needed.
- Reviews required project changes as outlined in Table 4.
- Reviews monthly reports from the Management Board and takes appropriate action.
- Approves construction start for each Task, as required.

6.2 Project Manager

The Project Manager works with the task leaders and other project management to ensure the long term and day-to-day success of the project. The Project Manager is accountable to the Oversight Board for performance of the project. The Project Manager seeks advice and recommendations from the project's Principal Investigators, as appropriate.

Stephen Peggs will serve as the Project Manager. Dr. Peggs is a long-time member of the Collider-Accelerator Department at BNL. Karl Smolenski from Cornell University will serve as the Deputy Project Manager.

Dr. Dejan Trbojevic, Brookhaven Lab, and Dr. Georg Hoffstaetter, Cornell University, will serve as the Project's co-Principal Investigators. These project Principal Investigators provide technical leadership and support project decision-making.

Roles and responsibilities of the Project Manager include:

- Coordinates closely with the Deputy Project Manager (DPM).
- Manages the execution of the L2 subsystems for which BNL is the lead, especially WBS 1.1 (Project management).
- Oversees engineering design, procurement, fabrication, and assembly of the subsystems on which BNL is the lead institution, in coordination with the C-AD Chief Mechanical Engineer.
- Oversees delivery of BNL equipment for installation at Cornell, in coordination with C-AD Chief Mechanical Engineer.
- Validates labor charges at BNL.
- Provides a Quarterly Report to the Oversight Board, and maintains close communication with them.
- Appoints Level 2 managers and L2 or L3 Cost-Account Managers (CAMs), in consultation with the rest of the Management Board, and with consent from the C-AD chair.
- Works with CAMs to define the WBS structure and to establish intermediate milestones.
- Work with the CAMs, the C-AD chief engineer and the C-AD chair to identify staff for the project.
- Supports the DPM and BNL staff in maintaining the resource-loaded schedule and budget tracking.
- Ensures the preparation of drawings, specifications, procurement documents, installation and test instructions, and other documents to establish and record the project configuration, including as-built documentation.
- Ensures that project activities at BNL are conducted in a safe and environmentally sound manner, consistent with local DOE safety rules.
- Approves the use of contingency, schedule, and scope changes as per Table 4.
- Resolves resource conflicts within the Project.
- Monitors items of special concern.
- Presents the status of the project in meetings of the Advisory Committee.

- Maintains the database of the project's baseline-design parameters.

6.3 Advisory Committee

The Advisory Committee serves as a standing, external (to the project) advisory body that may be called upon by the Oversight Board or the Project Manager.

The Committee is made up of (about) 12 technical experts, mostly from Brookhaven National Laboratory and Cornell University. The Project Manager and Principal Investigators recommend candidates for the committee to the Advisory Committee Chair. Committee membership is recommended to the Oversight Board for approval by the Advisory Committee chair.

The Advisory Committee Chair is selected by the Oversight Board Chair, and must be a BNL staff member.

The Advisory Committee provides a written report to the Oversight Board on any matters it is requested to review.

The Advisory Committee shall be invited to visit the ERL Facility and project site at least once annually.

6.4 Task Leaders

Responsibility for meeting each of the eleven deliverables lies with the assigned Task Leader for each deliverable. These leaders represent Level 2 (L2) of the Work Breakdown Structure for the overall project. Task Leaders are accountable to the Project Manager for the performance of their L2 scope of work, budget and schedule.

Responsibilities of the L2 Task Leaders include:

- Manages the execution of the Task to ensure that it is completed within approved cost, schedule, technical scope and performance parameters, applicable.
- Oversees design, fabrication, installation, and construction of the subsystems within the Task scope.
- Provides a monthly Estimate at Complete and milestone status to the Project Manager.
- Validates labor charges.
- Ensures that task activities are conducted in a safe and environmentally sound manner. At BNL, that is ensuring all DOE and New York State requirements are observed. At Cornell, that includes CLASSE and Cornell safety requirements are met.

6.5 Baseline Control Board

The Baseline Control Board advises the Project Manager, Deputy Project Manager and the Principal Investigators when changes to the baseline-design parameters are requested. The Chair of the Board is from Cornell, but is not a member of the Management Board. Members of the Board include the Management Board plus at least one technical expert member from BNL. Members are recommended by the Board Chair and approved by the Project Manager. Wherever possible the Baseline Control Board Chair reaches decisions by consensus. The Advisory Committee may be consulted, as needed.

6.6 Project Office

The Project Office includes the Management Board, a resource manager from BNL, and financial services support from both BNL and Cornell. It tracks financial performance of the Project. It also coordinates with BNL Departments and Divisions, and Cornell University, to gather appropriate financial information.

The Project Office provides monthly financial reports. The Project Office is accountable to the Project Manager. It includes a representative from Cornell and the Cornell staff person responsible for project scheduling.

6.7 Change Control

Changes to the project parameters, scope, cost, and schedule will be controlled using the thresholds described in Table 4. Appropriate levels of the management structure will be alerted as soon as possible that an action needs to take place.

The Project Manager (PM) and the Deputy Project Manager (DPM) will specify contingences at least down to Level 3, in consultation with the Cost Account Managers. All contingencies are owned by the Management Board (PM, DPM and two Principal Investigators), and cannot be spent without its approval.

The most important system parameters, especially those that impact several subsystems, are maintained in the data bank of the baseline design. This includes in particular all system parameters that might be needed for simulations of accelerator performance or might impact accelerator operations.

Table 4: Change control thresholds: actions taken on different management levels.

Level	**Cost**	**Schedule and Risk**	**Technical Scope**
Oversight Board	Costs needs that surpass the total project cost	Project Milestones, Review Milestones, review scopes	Changes of Key Performance Parameters and design parameters
Management Board	Contingency allocations	L2 subsystem completion dates and risks	Baseline changes, after consultation with the Baseline Control Board
Project Manager & Deputy Project Manager	Allocations at L2 larger than $10k, without contingency	Milestone changes that do not affect L2 completion dates or risks	Changes that do not affect the baseline
Cost Account Managers	Allocations at L3 less than $10k, without contingency	Changes that do not affect L3 milestones	Changes that do not affect technical deliverables

6.8 Risk management

[A risk management discussion, and table, will be inserted here.]

7 Glossary

BNL	Brookhaven National Laboratory
BSA	Brookhaven Science Associates, contracted by DOE to operate BNL
C-AD	Collider-Accelerator Department, BNL
CAM	Cost Account Manager
C-Beta	Cornell-Brookhaven ERL Test Accelerator
CFN	Center for Functional Nanomaterials, a user facility at BNL
CHESS	Cornell High Energy Synchrotron Source
CLASSE	Cornell Laboratory for Accelerator-Based Sciences and Education
DOE	U.S. Department of Energy
DPM	Deputy Project Manager
EIC	Electron-Ion Collider
eRHIC	Brookhaven National Laboratory's design for an Electron-Ion Collider
ERL	Energy Recovery Linac
FAT	Fractional Arc Test
FEL	Free Electron Laser
FFAG	Fixed-Field Alternating Gradient
HEX	High-Energy X-ray diffraction beamline (at NSLS-II)
KPP	Key Performance Parameter
Linac	Linear Accelerator
L2, L3	Level 2 or 3 of the Work Breakdown Structure
MLC	Main Linac Cryomodule
NAS	National Academy of Sciences
NSAC	Nuclear Science Advisory Committee
NSLS-II	National Synchrotron Light Source II, at BNL
PI	Principal Investigator
PM	Project Manager
QCD	Quantum Chromo-Dynamics
RF	Radio Frequency
RHCI	Relativistic Heavy Ion Collider, at BNL
SBU	Stony Brook University
SC	U.S. Department of Energy's Office of Science
SRF	Superconducting Radio Frequency
WBS	Work Breakdown Structure

8 About Brookhaven National Laboratory

Established in 1947, Brookhaven National Laboratory (BNL) originated as a nuclear science facility. Today, BNL is a multi-purpose laboratory with a primary mission focus in the physical and energy sciences; and additional expertise in biological and climate sciences, energy technologies and national security. BNL brings strengths and capabilities to the Department of Energy (DOE) laboratory system to produce excellent science and advanced technologies, safely, securely, and environmentally responsibly, with the cooperation and involvement of the local, national, and scientific communities. With a longstanding expertise in accelerator science and technology, BNL conceptualizes, designs, builds, and operates major scientific facilities available to university, industry and government researchers, in support of its Office of Science (SC) mission. These facilities serve not only the basic research needs of the DOE, they also reflect BNL and DOE stewardship of national research infrastructure that is made available on a competitive basis to university, industry, and government researchers. While the Relativistic Heavy Ion Collider (RHIC) complex and the National Synchrotron Light Source (NSLS) are the two facilities that account for the majority of the ~4100 scientists/year served at BNL last year, the Center for Functional Nanomaterials (CFN) served 473 users, a record number. To date, seven Nobel Prizes have been awarded for discoveries made at the Laboratory.

BNL's strong partnerships with Stony Brook University (SBU), Battelle Memorial Institute, and the Core Universities[1] are important strategic assets in accomplishing the Lab's missions. Beyond their roles in Brookhaven Science Associates (BSA), which manages the Laboratory, Stony Brook and Battelle are key partners in all of BNL's strategic initiatives, from basic research to the commercial deployment of technology, and figure prominently in BNL's energy research and development (R&D) strategy. They also underpin the Lab's growing partnership in the Northeast, especially with New York State.

Since its founding in 1947, BNL has been an economic engine for Eastern Long Island and the New York metropolitan region. Its research facilities have been a magnet for technological development with participation of researchers from academia and industry from all over the US and the world. The Federal investment in the RHIC facility is over $2.5B and the recent investment in the NSLS-II that will eventually exceed $2.0B are evidence of the strong Federal support and national importance of BNL research and the scale of economic impact. This impact is expected to grow further with the build-out and maturation of NSLS-II and potential additional growth with the advent of the eRHIC facility being contemplated by the physics research community.

The technologies being developed at NSLS-II, CFN and other BNL facilities have high potential for near term commercialization that can leverage the technology development at BNL into regional economic impact and job creation. This project will synergistically enhance and expand these capabilities.

[1] Columbia, Cornell, Harvard, MIT, Princeton and Yale