Independent Committee Report

on

CD-3A for the Electron Ion Collider

October 30, 2023

EIC CD-3A Director's Review Committee Report

Introduction

At the request of James Yeck, Electron Ion Collider (EIC) Project Director, a Director's Review of the EIC Project was held at Brookhaven National Laboratory on October 10-12, 2023, to assess the project's readiness for the DOE Critical Decision-3A (CD-3A) Independent Project Review (IPR), scheduled for November 14-16, 2023.

The charge for the EIC CD-3A Director's Review is provided in Appendix 1. The EIC Director's Review committee consisting of 31 subject-matter experts was divided into seven subcommittees as detailed in Appendix 2. Each subcommittee had a chair to guide the compilation of comments in the subcommittee report. The primary materials reviewed by the committee included management presentations, draft DOE documentation and a large number of supporting documents. EIC review materials can be obtained by contacting James Yeck, or Alyssa Petrone, EIC Project Chief of Staff.

Members of the EIC project team presented the project's management, planning, cost, schedule and technical features (accelerator design and beam dynamics, accelerator systems, detector systems, infrastructure, ES&H), a detailed long-lead CD-3A procurement package and the plans to deliver and manage the procurements, as well as an overall status of the EIC project including project risks and potential risk mitigations.

This document is the final report of the EIC CD-3A Director's Review for the EIC, and contains top-level answers to the charge questions assigned to each subcommittee, as well as individual subcommittee reports organized into findings, comments, and recommendations.

Figure 1 – The EIC Project team and Director's Review Committee on October 10, 2023.

Summary Remarks

The 2015 NSAC Long Range Plan committee recommended the EIC as the next major nuclear physics facility for the US Nuclear physics program, with luminosity up to $10^{34}cm^{-2}s^{-1}$ and center of mass energy in the range of 20 - 100 GeV initially, and highly spin polarized electrons, protons, and light ion beams. The EIC will provide unprecedented capability for understanding the interaction of elemental quarks and gluons that form the basic structure of atoms and nuclei.

The committee commends the project team on the outstanding progress on the technical design since CD-1. The BNL and JLab teams have the requisite experience and are working very effectively for this stage of the project. A well-focused R&D effort has resulted in converged accelerator and detector designs that provide a firm basis for technical subsystem requirements. The project is on track to deliver a CD-2 design by the planned time frame. The committee has confidence in the team's ability to address the remaining technical challenges.

Overall the committee strongly endorses the CD-3A package and finds that the project is ready to take this step. The CD-3A package is strategically advantageous for the project, particularly with respect to reducing risks associated with supply chain issues and vendor uncertainty. The selected LLPs are appropriate, and with the exception of one LLP which is scheduled for a January FDR, these systems have reached a sufficient level of design maturity for procurement. The scope, cost, and impact of an early procurement are well understood, and the contingency for the CD-3A package is sufficient (~35%).

There is significant potential for improvement in the communication of the CD-3A package to stakeholders, and in particular to the upcoming OPA review committee. Specifically, the technical plenary talks should increase their focus on CD-3A project management aspects (scope, cost, and schedule) in order to demonstrate ownership as the team moves into execution. A concise and compelling argument for the CD-3A package should be made by highlighting the integrated project cost/schedule with and without the 3A package; the same comparison can be made for project risks. The CD-3A breakout presentations would benefit from a greater degree of consistency in format with common project-oriented elements such as scope, cost, schedule, risk, etc. To this end a presentation template is advised.

Following this theme, as the project matures from the R&D/design phase into execution, the team must pivot to a more project-oriented approach to measuring and reporting progress based on tractable quantitative measures. For instance, the readiness for CD-2 should be tracked against a firm set of metrics such as % of design reviews completed. All WBS owners should consistently make use of project tools at their disposal when tracking and communicating progress.

While the ESH&Q scope is sufficiently mature for this stage of the project, it currently does not flow down well through the technical presentations. It is important to demonstrate strong and consistent integration between the ESH&Q team and the technical teams. With regard to the upcoming CD-3A scope, it would be useful to include ESH&Q considerations for each LLP.

Finally, the committee is concerned that the marginally low project contingency (~31%) combined with the TPC near the top of the CD-1 Cost Range leaves little room for the project to address emergent technical issues that are arising and will likely continue to arise in the future. At the upcoming IPR, the project should be prepared to discuss the plan to define a level of risk-based contingency that would support the baseline.

The project is ready for CD-3A.

Committee Responses to Charge Questions

1. *Is the project team effectively executing the work?* **Yes, the BNL and JLab teams are working effectively to execute the EIC Project.** *Are technical issues appropriately and proactively being addressed?* **Yes, technical issues are being addressed effectively.** *Are the proposed CD-3A long-lead procurements appropriate?* **Yes.**

2. *Are the cost and schedule estimates credible?* **Yes, cost and schedule estimates are well developed for this stage of the project. Selected Control Account drilldowns demonstrated the CAMs have adequate knowledge of their estimates and can defend them appropriately.** *Do they include adequate scope, cost, and schedule contingency?* **Scope contingency is light (~$100M), cost contingency is also on the low side for this stage of the project. Schedule contingency is adequate.** *Are the estimates for the proposed CD-3A long-lead procurements appropriate and can these procurements be properly tracked?* **Yes, the CD-3A cost estimates are sound as demonstrated by selected drilldowns. Some additional CAM training on EVMS will be necessary in the near term. The procurement team is experienced and presented systems for properly tracking procurements.**

3. *Is environment, safety, and health (ES&H) and quality being properly addressed given the project's current stage of development?* **Yes, however some documents (e.g. Hazard Analysis Report) need updating prior to the CD-3A OPA review, others need to be completed (e.g., Code of Record). Traveler tool needs a decision and the Non-Conformance Reporting process should be finalized.**

4. *Is the project being properly managed? Are risks being effectively managed? Is the management team in place to successfully execute the CD-3A scope?* **Yes, the BNL and JLab teams are working effectively to execute the EIC Project. The risk reduction associated with the approval of the CD-3A LLP package needs to be more clearly presented (see Comments and Recommendations in this report for more details). The ES&H risks need some work prior to CD-3A OPA review. The EIC project team is experienced and adequately staffed to deliver the CD-3A scope.**

5. *Is the project appropriately addressing the recommendations from the prior DOE SC reviews?* **A conditional Yes (see comments and recommendations).**

6. *Is the project ready for CD-3A approval?* **Yes, after addressing the applicable recommendations in this Director's Review report.**

Subcommittee Reports

SC1 - Accelerator Design and Beam Dynamics

Findings

- Technical design maturity assessment guide includes cost-weighted design maturity. Accel systems performance is 34% done. CD-3A scope is 97% done. FDR completed for all, except first article ESR 591MHz cryomodule requirements, which is 93% done. The CD-3A scope relevant to SC-1 includes:
    - Material for the HSR beam screens.
    - HSR BPM buttons at cryogenic temperatures.
    - 591 MHz single cell cryomodule first article.
    - Superconducting strands for superconducting IR magnets.
    - Cryogenic 2K Satellite plant for IR10.
- Accelerator design status was presented for the RCS, ESR, HSR. Accelerator physics studies covered RF dynamics, beam polarization preservation, beam-beam effects, crab cavity direct RF feedback, stability, noise, and multipoles, bunch merging in the RCS, TMCI at low energy in ESR, and low field and eddy currents in RCS. No open physics questions are associated with CD-3A.
- The plan to re-use APS quadrupoles and sextupoles for the ESR and RHIC dipoles for HSR aims at cost savings. Recent progress includes receiving the first APS magnets from ANL and using realistic multipole errors in dynamic aperture studies for ESR achieving the goal after optimizing the sextupole strengths. The HSR dynamic aperture was optimized with first- and second-harmonic crab cavities and the studies produced tolerances for the HSR IR magnets allowing to move forward the CD-3A LLP of the conductor. The design of the RCS is progressing, the dynamic aperture optimization reached the performance specification.
- The impedance and collective effects physics team incorporated lessons learned at several facilities, including PSI, KEK-B, APS-U. Notably, for the bellows design and the effect of chromaticity on TMCI.
- Impedance budget status for the HSR, ESR, and RCS was presented; geometric wake using a variety of known codes, and resistive wake analytical. Relating to CD-3A components:
    - Simulated temperature rise in cryo-cooled HSR BPM buttons is 43K (resistive-wall and cable), whereas the goal for housing is 30K to avoid gas desorption. Considered satisfactory.
    - HSR beam screen is Cu-clad SS for higher conductivity and has an amorphous carbon coating to mitigate electron cloud. Wakes include beam energy-dependent radial offset.
    - HSR detector-related diagnostics – polarimeter, hydrogen jet, and roman pot – are analyzed from impedance point of
- Using impedances computed so far, the design bunch currents are below the longitudinal microwave threshold predictions. However, the TMCI thresholds may be a concern and require mitigation for the RCS and ESR at low energy. The impedance for the vertical and horizontal collimators in the ESR still needs to be calculated and could be significant.

- Strong Hadron Cooling is NOT required for demonstration of threshold KPPs and early operations. However, much work is ongoing to decide on the optimum choice.
- Physics designs for the electron gun and the 400-MeV linac RCS injector are mature.
    - The HVDC 300-kV electron gun was designed, developed, and successfully tested, meeting all the project requirements. Superlattice GaAs photocathode developed under ODU/JLab/BNL collaboration delivered high QE 2.35%, and 92% polarization.
    - The physics reference design for the 400-MeV linac is completed and ready for procurement process.
- Polarization control and manipulation for the RCS, ESR, and HSR have been well studied and mitigations for various depolarization effects have been identified.
- The machine detector interface (MDI) now has a geometrical footprint that accommodates all the accelerator requirements as well as those of the detector. The magnet lengths and strengths have been determined. The vacuum chamber shapes and dimensions have validated impedances and three-dimensional shapes. The various small detectors downstream have the optimum locations. Background studies are well underway. Masking and shielding requirements are being finalized.
- Many beam-beam calculations have been performed. Augmentations have been made to the code to enable simulating the collisions of two very different beams. Codes from other colliders have been used to verify the results.

Comments

- There were eleven EIC accelerator science talks given during this Director's EIC CD-3A review. The depth of the accelerator science covering the entire project was very impressive not only showing the expertise involved but also the personal dedication to this scientific endeavor.
- The committee feels that the Director's review presentations should be reorganized for the upcoming OPA review. In particular, the focus of presentations should shift from a conference-style discussion to DOE project report style, including detailed descriptions of the accomplished scope of work to date relative to those planned ahead, milestones achieved versus work remaining towards CD-2.
- For the upcoming OPA review, the Plenary presentation should explain which risks in the Project Risk Registry have been retired due to the accomplished design and R&D efforts and which risks are still remaining. The Plenary presentation should provide the review committee with a forecast of risks discussed in detail in the breakout presentations.
- Connections between CD-3A LLP list and accelerator design maturity were not presented clearly. For each of the five CD-3A accelerator long lead procurements, the EIC accelerator design team should write a technical justification to demonstrate the schedule need and whether the scope of the purchase is consistent with accelerator design maturity and is adequate to meet the accelerator science end goals.
- RCS design is maturing, however there appears to be several challenges of concern, including low field in the magnets at injection, injection kickers, bunch merging dynamics at 1 GeV, high current effects.

- The present designed footprint of the second interaction region area appears adequate to allow that area to be constructed in the future without major changes to the remainder of the EIC three rings.
- The team is to be commended for their excellent results with the 300-kV HVDC superlattice GaAs photocathode gun: bunch charge and polarization performance well exceed the RCS injector requirements.
- Analysis of collective effects in ESR should pay attention to the instabilities that may arise during transient dynamics of the injected beam.
- The suite of linac / transport line diagnostics seems too generous and should be scrutinized for potential cost savings.
- The design of the beam screens for the HSR dipoles looks very good. A question can be asked whether other HSR components also need screens, e.g. straight section chambers.
- The impedance of many of the EIC accelerator components have been calculated. One component that has not been calculated is the vertical collimators which should be done soon, since the similar collimators in SuperKEKB dominate the impedance of that ring. There is still a risk that the design bunch current may exceed the lowered instability threshold, which requires further mitigations.
- The beam-beam calculations have made great progress. These calculations should systematically continue adding more physics effects.
- Magnetic shielding will likely be needed for the RCS to help with orbit control. The committee suggests that the mitigation of any remnant magnetic field should receive adequate attention.
- The rapid injection kicker between the electron injection linac and the RCS needs additional effort to advance the design and reduce the technical risk.
- The RCS magnets at the 400 MeV injection point have very low fields (e.g. ~60 gauss in the dipoles). Several methods to increase these fields have been studied. Additional work is needed to converge on a more feasible solution so that the technical risk can be reduced.
- EIC accelerator design is ready to proceed with CD-3A.

Recommendations

- For the November OPA review, connect the accelerator design studies more clearly to the scope of the five CD-3A accelerator component procurements.
- In the November OPA review presentations: 1) identify recent results of accelerator design studies that reduce or retire project risks, 2) give detailed descriptions of the scope of work accomplished to date, relative to those planned, milestones achieved, and work remaining towards CD-2.
- Respond to the two open January 2023 OPA review recommendations (621-startup scenarios, 622-needed accelerator demonstrations), and close by the end of October 2023.
- Call a topical review focused on the RCS design by the summer of 2024.

SC2 - Accelerator Systems

Findings

- (General) The CD3-A Accelerator Systems scope includes the following items:
  - Actively Cooled Beam Screen Material
  - Cryo Beam Position Monitor (BPM) Buttons and Silicon Dioxide (SiO2)
  - Cables Interaction Region (IR) Super Conducting (SC) Strand for IR SC Magnets
  - Electron Storage Ring (ESR) 591 MHz 1-Cell Cryomodule First Article
  - Design and Fabrication of One 2K Satellite Refrigerator Plant
- (RF) High level RF System requirements are combined in one document: the specifications are 42% complete.
- (RF) There are 15 open recommendations that the project team hopes to address by the FDR.
- (RF) A prototype 591-MHz single cell cavity is being built at JLab. The plan is to test the cavity before the FDR in Jan. 2004, and to have a vendor to build the remaining 16 cavities, either w/ or w/o chemistry and either w/ or w/o cavity dressing.
- (RF) As part of the R&D WBS (6.08.02), prototype BLAs and FPCs are being built that will nominally be used for the first article single cell cavity cryomodule (CM).
- (RF) An LLP under the SRF First Article Cryomodules WBS (6.08.03) is proposed to assemble and test the first article single cell CM. The budget is 3.7 M$, which includes ~ 1.5 FTEs of labor for four years. Completion of the LLP is dependent on deliverables from other WBS elements:
  - Uses a BLA prototype (fabricated and tested at BNL)
  - Uses two FPC prototypes (being fabricated at BNL/JLAB, will be tested at BNL)
  - Requires the high-power test facility at JLAB to be completed (3.5 M$ rough cost, likely located in the LERF test area). But it is not confirmed yet.
  - For the CM high power test, BNL would provide two 200 kW SSAs, two isolators and loads that will be acquired from vendors (nothing has been ordered yet).
  - To regulate the cavity fields, a LLRF system from BNL may be used
- (SC Magnets) The CD3A scope for superconductor procurement for the IR magnets resides in WBS "Cables" and has a budget of $4.13M and is based on vendor quotes.
- (SC Magnets) The IR magnet scope consists of 33 separate magnets, including 7 collared magnets, 18 direct-wind magnets, and 8 spin-rotator solenoids.
- (Cryoplant) The Cryogenic System comprises the following elements: 3 Satellite Cryoplants, The Cryogenic distribution system, and The Cryogenic Control System.
- (Cryoplant) The cryo-team is effectively integrated with sufficient staffing and seamless coordination between BNL and JLab.
- (Cryoplant) The cryo-team has an average of ~15 FTE from 2024 to 2030 with a peak at 23 in 2025.
- (Cryoplant) The CRYO BUDGET is 24% Labor, 76% Procurement, with a total of ~145 M$ and a max at ~40 M$/year in 2028.
- (Cryoplant) In the schedule, design continues until 2028, fabrication commences in 2024, and commissioning activities progress from 2028 to 2030.

- (Cryoplant) In general, this project falls under the category of a brownfield project, presenting challenges associated with the utilization or integration of existing equipment into the new design.
- (Cryoplant) The Satellite Cryoplant Design is based on User Loads, that have consolidated by a workshop, a 25% margin was added.
- (Cryoplant) The Satellite Cryoplants are supported by the Central Cryoplant; margin at the Central Cryoplant is kept at 15% on turbines.
- (Cryoplant) The FDR for the Satellite Cryoplants has been successfully completed, and the Cryoplants Technical Specification is currently at 90%.
- (Cryoplant) The design of the Cryoplant IR-02 and IR-06 could be subject to changes related to users and these are not yet ready for procurement.
- (Cryoplant) However, the maturity of the Satellite Cryoplant IR-10 is deemed sufficient to proceed with CD-3A; The Interface documents with the Infrastructure (Building, Utilities) and Cryo Users (Cavities, Magnets) are at 90%.
- (Cryoplant) The cost and schedule of the Cryoplants are derived from confidential information provided by a reputable vendor.
- (Cryoplant) The estimated cost for the satellite cryoplant IR-10 is ~14 M$ (estimation based at 90% on vendor quotes).
- (Cryoplant) The Review Committee conducted a detailed validation drill-down of the WBS related to Cryoplant IR-10.
- (Cryoplant) The primary risks in the registry are associated with potential delays in Vendor delivery, installation, or commissioning. The Cryoplant IR-10 is in the CD-3A long lead procurement list to mitigate the associated risks.
- (Cryoplant) The Infrastructure (Building and Utilities) contracts for Cryoplant IR-10 are not covered by CD-3A. Consequently, the Infrastructures construction could be started 12~18 months after Cryoplant IR-10 order, and the risk of delay related to Infrastructure availability is relatively high.
- (Cryoplant) The Cryo Team has foreseen adding storage as an option in the Cryoplant IR-10 Contract in case the infrastructures were not ready on time to accept the Cryoplant components, which is not covered in the risk registry.
- (Cryoplant) The Cryogenic Distribution design progresses, however integration at BNL and in the RHIC Tunnel proves challenging.
- (Cryoplant) The Integration Challenges are identified in the risk registry and actively managed by the JLAB Design Team.
- (Cryoplant) The Cryogenic Controls are designed and owned by BNL using hardware already used at BNL. This approach will allow better integration of the new Cryo Scope with the existing BNL Cryo Infrastructure, and to better prepare BNL for commissioning and operation.
- (Instrumentation) Overall instrumentation systems were presented for the linac, RCS, ESR, and HSR along with cost and schedule information.
- (Conv. magnets) Design works are progressing for various magnets.
- (Conv. magnets) Both BNL and JLab are receiving APS magnets to repurpose them for EIC ESR.
- (Conv. magnets) A few challenges are identified related to the RCS magnetic field quality at low field and potential issues with repurposing of APS magnets.

- (400-MeV linac) The scope of work consists of design, procurement and assembly of the electron source and 400 MeV linac to generate up to 7nC of 85% polarized electron bunches with a 1 – 2 ns bunch length at a repetition rate of 1 Hz.
- (400-MeV linac) The choice of linac output energy, 400 MeV is determined by the existing tunnel, beam bending area and cost constraint.
- (400-MeV linac) The e-source demonstrated the project requirement. The polarized electron gun has produced a beam exceeding EIC required intensity (11 nC vs 7nC) with 92% polarization.
- (400-MeV linac) The 400-MeV linac is planned to be 'Turn-key' procurement based on other project experiences and the scope of work is well within the industrial capability.
- (400-MeV linac) Reference design for the 400 MeV linac and related document (SOW and technical specification) is ready.
- (400-MeV linac) Facility requirements for pre-injector building are identified.
- (400-MeV linac) The 400-MeV linac construction was a scope of CD-3A but now is a scope of CD-3B or CD-⅔. The 400-MeV linac design is a vendor contract covered by PED funds.
- (400-MeV linac) Cost is estimated based on cost proposal from a vendor, recent procurement/labor history for EIC R&D, engineering estimated, and independent cost estimates.

Comments

- (General) There have been notable developments on the overall progress of the accelerator systems and their integration into CD-3A scopes since the last DOE CD-1 review. The EIC team is commended for great technical progress.
- (General) Committee noticed that some of the challenges related with ongoing/planned R&D activities should be captured appropriately in the risk registry, e.g. BLA thermal loads, potential cavity performance degradations due to contamination from the carbon coating or BLA, 400-kW power coupler, cavity mechanical tuner, eddy current effect during ramp-up in RCS, main power supply ripple, etc.
- (General) Committee suggests that the presentations show a slide on the current labor breakdown by lab (people and FTEs) and a slide showing the current organization chart at the WBS 3 level.
- (SC magnet) The conductor LLP has been subjected to a final design review and is considered ready for procurement. Recent analysis shows that significant persistent currents are generated at low field that may impact the beam optics. The optics and magnet team must rapidly converge on acceptable persistent current levels so that the conductor procurement can proceed.
- (RF) For DOE CD-3A review, the dependencies of the single-cell first-article cryomodule scope on the successful completion of other WBS deliverables should be made much clearer.
- (RF) Committee feels it is prudent to have results from all related R&D tests (FPC, BLA, cavity) before they hold the single cell CM FDR.
- (Cryoplant) With the FDR completed, a Technical Specification at 90%, and a budgetary estimate from a reputable vendor, the Team is well positioned for the CD-3A procurement of the IR-10 Cryoplant.

- (Cryoplant) The Cryo team should consider consolidating the numerous process calculations that have been an integral part of the FDR, into a technical note under version control.
- (Vacuum) CD-3A beam screen material LLP is straightforward but interfaces to other systems should be finalized prior to bid (see recommendation).
- (Instrumentation) The inclusion of the HSR cryo-BPMs and SiO2 cables for the CD3-A LLP is justified by the technical and schedule risk since they must be incorporated with the HSR beam screens.
- (Instrumentation) The ESR is planned to operate at a maximum average current of 2.5A. There is a strong likelihood of significant resistive beam heating for much of the beamline instrumentation. Analysis from EM codes indicate that there will not be excessive heating. This should be checked by bench impedance measurements for a few sample components (BPMs, stripline kickers, etc.) to make sure that mechanical variations haven't created unexpected resonances that could generate unwanted heating.
- (Conv. magnet) The RCS magnets must yield excellent field quality at very low field, where steel magnetization may be heavily impacted by stray fields in the tunnel, the history of magnet energization, and variations in the steel properties. In addition, eddy current during field ramp-up may induce large multipoles. Developing and demonstrating that the requirements can be adequately met must be a high priority for the project at this stage, as the decision on injection energy into RCS depends on this.
- (General) The CD-3A scope procurement finalizes a subset of design parameters, which impacts/limits the design space for associated accelerator systems scopes that are currently less advanced in their design. The project should recognize this fact and have a clear communication path to avoid the possibility of inconsistency in specifications/requirements as the broader Accelerator Systems scope proceeds towards final design.
- (General) The project has made significant advances in developing version-controlled interface, parameter, and requirements documentation. It is critical that the project transition to full implementation of version controlled documentation. Furthermore, the project should formalize the mechanism for communication of changes in any of these to impacted WBS elements.
- (General) The project should show the plan to advance design maturity prior to CD2, and be prepared to evaluate actual performance vs expected performance on a regular basis. Furthermore, the process for evaluating design status should be clearly defined and consistently applied across the WBS elements.
- (General) Controls and machine protection were not adequately discussed in any of the presentations in the Accelerator Systems breakout session. The project should clarify the protection strategy for each ring, and identify risks to accelerator subsystems associated with beam loss scenarios.
- (General) There are important ES&H aspects associated with Accelerator Systems. The project presentations would be strengthened if they integrated ES&H concerns into their discussions on status and risk. ES&H must not be viewed by the project as a stand-alone element.

- The detector magnet procurement is currently an element on the LLP list, but the project has also noted that it is a potential candidate for in-kind contribution; the latter would be an excellent development for the project.
- (Magnets) The L3 CAM is spread over many subsystems, including both superconducting and normal conducting magnets. Given the fact that the superconducting IR magnets are on the project critical path and have complex requirements, the project may consider focusing the strong expertise of the current L3 CAM on the most challenging magnets, and add at least one more L3 CAM to help cover the overall magnet scope.
- (RF) For the $370M RF systems scope (WBS 8.6), it is difficult to give a quantitative progress assessment based on just the one talk given on the subject, especially as a progress vs expectations analysis was not presented nor was a summary of technical progress vs milestones. However, the group seems to be on track with design and R&D efforts compared with their expectations at this stage (19 months before CD 2/3).
- (RF) Committee has a concern that there is no float between CM test completion of the first article in April 2024 and start of single-cell CM production. There should be a discussion on RF system critical path and schedule issues where actual production appears to start before CD-2/3.
- (RF) With only 16 single cell cavities required, it seems like production could be done at JLAB vs having a vendor do it. This could be a back-up plan if there's a cost or a schedule benefit.
- (RF/Vacuum) Vacuum and cryomodule systems interface is crucial to cryomodule performance and it appears there may be tradeoffs that need to be discussed and formalized in an interface control document.
- (RF) Tuner for the 591-MHz SRF cavity may be a challenge due to the large tuning range and forces involved. Consider risk reduction through further design, analysis, and possibly a separate review of this system.
- (RF) A transport readiness review was briefly mentioned as part of the design and build process, and this is a great first step. Considering possible transportation of an item early on in requirements and design will allow for easier mitigations if needed.
- (Cryoplant) The integration of the three EIC Satellite Cryoplants with the central cryoplant introduces technical risks.
- (Cryoplant) Building and Infrastructure procurement for the Cryoplant IR-10 (CD-3A) will not be covered by CD-3A. There is a risk that the building and infrastructure will not be ready for this Cryoplant. The project team shall consider adding this risk to the registry for adequate tracking and mitigation.
- (Instrumentation) Costs and schedule for the linac, RCS, ESR, and HSR instrumentation systems are reasonable at this stage of the project.
- (Instrumentation) Transient beam loading in the RF cavities may generate variation of synchronous phases along the bunch trains in the ESR, and the HSR to a lesser extent. There may be a second-order effect for BPM synchronous detection. This should be considered and resolved.

- (Instrumentation) It would be useful to specify the lowest beam intensities at which the instrumentation can be used and possibly the instrument resolution at the low intensity. This is particularly useful for commissioning and troubleshooting.
- (Power supply) The requirement of very low ripple for power supplies seems challenging, and could be a technical and cost risk. Committee encourages the continued efforts on interfaces and requirements towards a final plan for CD-2.
- (400 MeV linac) SOW and Technical specifications for the 400-MeV linac are well prepared. Nevertheless, the Committee suggests the project team consider adding the items below in the SOW;
    - Hold points – This will provide the project reviews associated with hold points, determination of best path forward, and written report signed by the project team and communication to the vendor.
    - Separate subsections for interface, responsibility and deliverables – clear articulation of contractor/project responsibilities, contractor provided items/project provided items, etc.
    - Clear descriptions of Intellectual Property – design ownership, the company's reservation of the right to reuse or alter information gained from the project. This will help for future repair/spares/maintenance.

Recommendations

- Prior to solicitation for bid, all requirements and interfaces for CD-3A items must be complete;
    - Converge on acceptable persistent current levels (i.e. superconductor filament size) to enable timely specification for wire procurement.
    - Close vacuum beam screen material FDR recommendation and address related comments before CD-3A review.
    - Create a technical note on the various process calculations developed for the Cryoplants IR-02, 06 and 10 FDR.
- By the DOE CD-3A review, establish a final plan for a testing facility that supports high power RF testing of the ESR 591-MHz 1-cell cryomodule first article.
- Proceed to CD-3A.

SC3 - Detector Systems

Findings

- The detector group has made progress since CD-1 and a full project management is in place. Scientific international (40% US) collaboration ePIC has been organized.
- Integration and coordination between subcomponents including infrastructure envelope, including services (cooling, power, signal), are being taken into account within project organization.
- EIC detector R&D program is being redefined in view of the recent changes to the design of the detector.
- Tracking detector systems still have many key elements that are not finalized: ITS3 not being available in time, may have significant implications. ITS2 is being considered as back up. Conflict between beampipe baking needs and the tracker system thermal sensitivity is an open issue to be addressed.
- Design of the PID detectors are advancing (TDR stage). In principle, plausible solutions to issues have been identified.
- Solenoid reference design is complete. (LLP item).
- Backward EM calorimeter (PbWO4-part of LLP) design is in reasonable state; PbWO4 is a single supplier item. Barrel EM calorimeter is in two sections; Pb Fiber readout with SiPM and Astropix-based imaging layers which is novel. Forward EM Calorimeter is W/Sci where the fibers are a part of LLP.
- Hadronic calorimeters are sampling scintillator calorimeters. Barrel HCAL is a reused sPHENIX barrel calorimeter. Backward calorimeter repurposes STAR scintillators. The Forward HCAL is a W/Fe-Sc with SiPM readout.. The latter is an LLP item.
- There are six far-forward and ancillary detectors planned that will be close to the beamline. The luminosity monitor is planned to be deployed on day 1. The other detectors will be ready but will wait until the beam/background conditions become appropriate for deployment.
- Basic polarimetry methods and detector technologies are established and design is progressing towards CD-2/3.
- EIC is developing a streaming readout architecture. Readout and technology solutions have converged. There is an active hardware and software effort in collaboration with ePIC progressing towards CD-2/3.

Comments

- The detector group has made impressive progress since CD-1. A rather mature project management for this stage exists. International detector collaboration ePIC has been established and the project and the collaboration have good coordination.

- The detector integration both within the detector and also with the accelerator is, as usual, a challenge. At this stage of the project, the detector team is addressing these issues in impressive detail.
- Appropriateness of proposed CD-3A LLP items is central to these reviews. While we got the information from separate talks and questions, a sufficiently detailed summary of these items should be up front in the plenary presentation.
- Presenting a summary of policies regarding ESH and Q for detectors (particularly for outside vendors, universities, and foreign entities) upfront in the plenary session would alleviate concerns from reviewers in a timely manner.
- There are several possible in-kind contributions that could significantly and positively impact the project, if successful. One is the NSF proposal which, if approved, will cover the costs of the backwards EM calorimeter including the PbWO4 purchase. There is also a possibility of in-kind contribution for the detector solenoid.
- Upfront discussion of risks of R&D not coming to a favorable conclusion, and mitigation plans in this case, should be more clearly documented and presented. Where appropriate, for example for the tracking detector, more detailed plans should be developed.
- Since Astropix production for the EM calorimeter is probably the largest silicon detector production for EIC, and one of the largest in the field, there should be more detail about its organization, planning and production in the subdetector presentation.
- An overarching concern is the oversight of production yield and the distribution of key parameters for certain components over a large-scale production. These factors will need to be adequately accounted for in the project planning and management before CD-2.
- Based on the presentations made during this review, it remains unclear whether the process of selecting components and transitioning from the research and development phase to production includes the validation of a substantial system prototype for all components. Full chain tests for subdetectors should encompass all final components, enabling an assessment of whether these components meet the requirements not only in isolation but also in terms of their integration and overall system performance.
- The magnet LLP is ready to go forward. After CD-3A approval, before the solicitation, the recommendations of the Solenoid Magnet Final Design Review should be implemented.
- The LLP items for the detectors are ready to go forward. Presentation can be improved as described elsewhere in these comments.

Recommendations

- Quantify (time, cost, performance) and document, before CD-2, mitigation plans for the possibility that some R&D components will not meet expectations.
- Proceed to CD-3A.

SC4 - Infrastructure

Findings

- The EIC Infrastructure scope consists of ~152 ksf of buildings, electrical distribution and mechanical cooling infrastructure for over 50MW of thermal load to house, power and cool the EIC systems.
- The Infrastructure team completed the award of the A/E design contract and preliminary design is underway.
- A comprehensive requirements management system has been developed by the Infrastructure team and EIC systems engineering group to capture and document technical requirements of the various technical divisions. The system is configuration managed and once requirements are vetted, enables communication of requirements to the A/E.
- The Infrastructure CD-3A LLP scope consists of 15 unit substations that will provide for building loads for all EIC buildings to enable beneficial occupancy upon building completion. Experimental loads are not included.
- The 15 unit substations cost estimate is based on the average of 3 vendor quotes provided in 2023 plus an allowance for project team travel to the vendors site for inspection and testing. No installation costs are included other than vendor field personnel costs for start-up.
- The design and specifications for the 15 unit substations are complete, the Statement of Work (SOW) is complete and the Advance Procurement Plan is complete. An Acquisition Plan (AP) is being prepared in parallel with a request for waiver of the need for an AP due to the nature of this procurement as a commodity.
- The justification for early procurement presented includes:
    - Procurement cycle times quoted by vendors and experienced by other DOE Projects in the 2.5 - 3 year range
    - The need to have this equipment installed prior to building completion to enable beneficial occupancy and follow-on installation of programmatic equipment
    - The procurements are at various times near the critical path (30 days)
    - If procurements are delayed, temporary power could be implemented but at a ~$9M cost penalty to the Project
    - Getting onto vendor's manufacturing schedules for this equipment is critical as demand remains high and number of manufacturers is limited
- An additional ~60 MW of power will eventually need to be brought to the EIC site to meet the EIC and BNL's overall power needs as an off-project activity. A study to provide this power by the supplying utility was recently completed and is being evaluated by BNL however was not covered under this review.
- The existing RHIC tunnel has been structurally evaluated to be adequate for additional 25-year useful life. Some electrical and life-safety code modifications may be required going forward but will be covered under off-project maintenance initiatives.

- The ERL design has not been finalized and may impact the Infrastructure design schedule if a decision is not made before the end of 2Q24.
- Infrastructure has worked with the technical divisions on potential scope changes that include:
  - Beam position monitor structures
  - Strong Hadron precooler at IR2
  - RF Amplifier at IR6
- The Infrastructure team has addressed all prior recommendations, none are open.

Comments

- The Infrastructure team is making excellent progress in developing requirements and initiating the preliminary design process with the A/E. Substantial progress has also been made in developing electrical utility requirements, mechanical cooling system requirements, assessing sustainability opportunities and developing readiness for CD-3A.
- The need for early procurement of the unit substations is compelling but is not emphasized in the presentations. Consider increased emphasis on CD-3A LLP justification, early in the presentations and details should follow in the breakouts.
- Consider adding additional discussion in the OPA-CD3A Review presentation to address potential ES&H concerns with the receiving and handling of major equipment purchases. Take credit for work planning already in-place at BNL to support the early procurements and initiate preparation of the Project Construction Safety Plan to assure early readiness for any "construction like" activities.
- The cost estimates (vendor proposals) for the 15 Unit Substations are appropriate and reasonable. It is of a quality (Class 2 per DOE Cost Estimating Guide 413.3-21A) to support CD-3A approval. Appropriate contingency has been applied at the overall project level. They are ready for CD-3A.
- The Infrastructure team in concert with the systems engineering group is utilizing a robust configuration management process to obtain and integrate equipment utility requirements (power, cooling, heat loads, and other utilities). This formal process is in place and functioning well. Use of the system has resulted in a high level of traceability, transparency, and consistency and will be a valuable operational tool going forward if properly maintained.
- Key off-project activities such as site power upgrades and facility maintenance activities should have their decision by date and need by date identified to drive timely decisions and financial commitments in MOU's between EIC, BNL and other stakeholders.
- Conventional Facilities Scope is well defined for this stage of the project. Power and cooling requirements are well understood. Approximately 152,000 GSF of new construction is currently identified but space optimization studies are also underway. It is understood and assumed that some scope additions will be required in advance of CD-2. Infrastructure is working closely with the technical teams to mitigate impacts.
- Consider review of LLP activity as presented in the schedule for an opportunity to identify sub-activities as presented on the procurement slides to monitor schedule and facilitate EVMS implementation. Review schedule assumptions for "negotiation" phase which may be optimistic.

- The Preliminary project schedule is well prepared. Schedule logic and activity durations are reasonable for this point in the project
- Conventional Construction Risk assumptions, particularly cost escalation, are appropriate for this stage of the project, however risk for off-project activities such as site power should be updated to assure visibility and the most current understanding.
- The team should work with procurement and BHSO to highly prioritize CMGC procurement to realize the many benefits of early participation, i.e. value engineering, constructability reviews, cost estimating activities, and partnering activity.
- DOE High Performance Sustainable Building (HPSB) requirements will be followed as required and will not require LEED certification for the buildings. Consider adding some discussion on a few specific HPSB examples in the presentations for the OPA CD-3A Review.
- The Infrastructure team has recently filled the key position of Lead engineer for Design. The Team should consider filling the key Construction Manager position prior to award of the CM/GC contract.
- Due to continued uncertainty over the ERL design, the Infrastructure team has appropriately paused A/E design of that element. The team should assure that all measures to rapidly incorporate the needed design effort can be made once decisions about the ERL approach are finalized.
- Consider continued evaluation of opportunities for additional LLPs as the project plans for CD-3B. Similar cost savings and risk reduction may be realized if the opportunity exists to procure long lead equipment such as pad mounted switches, generators and transformers.

Recommendations

- Elaborate on the benefits of the proposed unit substation LLP, and impacts if not implemented, in the plenary and breakout presentations for the OPA-CD-3A Review.
- Identify the Decision by Date and/or Need by Date for key off-project Infrastructure dependencies by 2QFY24.
- Proceed to CD-3A.

SC5 - Environment, Safety, and Health & Quality

Findings

- The project has identified and dedicated ESH&Q staff. These ESH&Q personnel are identified on the Project's organization chart.
- There is a MOU in place between BNL and JLAB that addresses ES&H and QA/QC considerations.
- A HAR is in place and approved.
- There has been a security vulnerability assessment completed, per the project.
- The ES&H staff are somewhat involved in the design reviews for equipment.
- A quality plan for the project, at both BNL and JLAB has been developed and is approved.
- There is an ISM plan in place for the overall project, and ISM is practiced at both BNL and JLAB with the interface between the two labs identified in the MOU.
- The ES&H leads for both Laboratories communicate on an ad-hoc basis.

Comments

- The HAR is silent on the hazard of activated equipment and facilities along with any ionizing radiation hazard from the existing facility outside of the operating machine. The reused magnets and equipment from APS have activation sufficient to be DOT regulated for shipment and are thus a real hazard that must be captured for the CD-3A Review.
- The project needs to have a singular document defining the regulations/codes and standards, with the year or edition noted, to which all of its designs and installation will adhere and comply. It is important that this document is in place for procurements and communication of requirements to in-kind partners. Further, any equivalences should be identified and submitted for DOE approval, if required. This should be used for designs going forward in the accelerator, infrastructure, and detector focus areas. Projects spanning more than 3 years will see changes in editions and some requirements if there is not a static set of design codes and standards to be followed for the overall duration of the project. This should also include retrofitting or reuse of equipment and facilities to ensure that they are defined for grandfathering or updating to the decided current codes to be used.
- The ES&H risks and mitigations have not been fully analyzed and developed in the project Risk Registry. For example, risks are not fully analyzed and mitigated for interfaces, transportation, material handling, and legacy conditions. The integrated project team must be vigilant throughout the project lifecycle in continuously evaluating and updating risks and mitigations to avoid complacency on the significant and challenging ES&H and QA risks.
- Prior to CD-2, update the HAR to include the hazards identified for reused facilities and equipment retrofit activities.
- The Project needs to clearly articulate how ESH&Q requirements will be flowed down and implemented by in-kind partners.

- It is concerning that most of the Quality Control Plans necessary for the CD-3A procurements have not been started. These documents are necessary for capturing critical requirements and inspections, and an electronic data collection system for capturing this information has not been identified.
- Several documents important for CD-3A, including the Configuration Management Plan, Procurement Plan, and Systems Engineering Management Plan, were posted as "drafts". Follow-up discussion indicates the Configuration Management Plan has been released. Final, signed documents should be posted for the IPR.
- The Construction Safety Plan is planned for completion by the CD-2. If, however, there are any physical facility modifications or installations as part of the planned CD-3B then this will need to be completed prior to the CD-3B review.
- Handover requirements for end item data packages (travelers, inspection and test reports, non-conformance reports, red-lines/as-builts, etc.) should be defined and turned over to the Project early.
- In lieu of PRR, ensure requisitions and specifications are reviewed and signed-off by ES&H prior to award, including high-dollar, high-consequence commodity items.
- There should be stand-alone ES&H and QA slides in technical presentations that address unique hazards and QA challenges for those topical areas. The presentations should include an awareness by the Project to demonstrate their awareness of recent safety issues in the Office of Science complex.
- Presentations should address how ESH&Q are fully integrated into the Project's design, procurement, and work planning and control processes. A presentation in a breakout session should be considered for future reviews.
- The Project is encouraged to ensure ES&H participation in design reviews.

Recommendations

- Prior to the IPR, update the HAR to include the ionizing radiation hazard for activated equipment.
- Prior to requesting ESAAB CD-3A approval, the project needs to prepare and approve a singular document defining the regulations/codes and standards, with the year or edition noted, to which all of its designs and installation will adhere and comply.
- At the project level, a process must be formally documented how nonconformances will be reported and dispositioned by the project collaborators.
- Prior to the start of inspection, test and acceptance testing of any CD-3A long-lead items, the project must have implemented the BNL system for tracking manufacturing instructions, inspection and test steps and results, and nonconformance reporting.
- Prior to the IPR, update the ISM Plan to include the elements of the posted standalone ISM Plan addendum.

SC6 - Cost and Schedule

Findings

- The project posted most material two weeks in advance of the review.
- Project has a Resource Loaded Schedule (RLS) with a Work Breakdown Structure, identified Control Accounts, and Control Account Managers.
- The project also has Basis of Estimate (BOE) documentation and a WBS dictionary.
- The project is planned in one P6 project for the entire scope, with no sub-projects.
- The project was able to separate the CD-3A scope and CD-3A EVMS practice scope in documentation and reporting through coding.
- A funding profile was presented with a TPC of $2,800M.
- IRA funding of $138M enables the EIC project to support the CD-3A scope, which must be costed by 2027.
- Risk Management has been ongoing since CD-1. Risk Board Meetings and risk workshops have been held. A risk management plan draft was presented.
- The full Risk Register presented has 225 risks; including threats, opportunities and retired risks. There are 19 CD-3A risks which include 17 threats and 2 opportunities.
- The project is leveraging the BNL EVM system by using standardized tools, reports, processes, and structure.
- A list of Long Lead Procurements valued at $66.7M was presented. These are included in the CD-3A scope.
- Significant procurements >$250k are planned and tracked in the BNL Procurement Tracker.
- Started EVMS practice on August 1, 2023.
- The project baseline schedule has 24,986 activities, including 397 activities in the CD-3A Scope and 336 activities in the CD-3A Associated Scope for practicing EVMS.
- The project baseline CD-3A Scope and Associated Scope schedule has 116 long-duration activities (defined as 60 working days) and 90 Milestones.
- The project baseline CD-3A Scope and Associated Scope schedule has 233 non-resource-loaded activities. There are four CD-3A activities with Schedule Visibility Tasks (SVT) in the activity name (as per BNL EVMS standard). The remaining SVTs have various purposes, including procurement processing activities, where resources are captured in project office LOE or off-project burdening.

Comments

- The Project Controls team and CAMs were very responsive to questions.

- Thanks to the CAMs who were interviewed. These interviews went well, as the CAMs understood their schedules, risks, and BOEs. Although some weaknesses were highlighted in the following comments, none were of concern to the review team.
- Great progress was made detailing the schedule since CD-1. The number of activities in the P6 schedule has nearly doubled, and the CD-3A scope is well-developed.
- CAMs have good technically strong BOEs, with some minor cleanup required, e.g., don't make reviewers do the math and some missing backup for labor resources.
- The Project Controls Team was adequately staffed to keep up with the monthly business rhythm, and the BNL and JLAB teams appear to work together seamlessly to develop the project schedule.
- CAMs had a good understanding of the critical path and explained how they would alleviate schedule delays, if necessary.
- Because the CD-3A work was only recently prepared for baseline (to exercise the team/process), we are not able to assess the team's ability to perform EVMS reporting from provided materials (VARs, CPRs, WADs, etc.) per the Earned Value Management System (EVMS). Also, the project could not produce BEI and CEI reports per Project Analysis Standard Operating Procedure (EPASOP) DOE-PM-SOP-05-2020 January 14, 2020, which may be used by the DOE review committee. These reports will be helpful for the project team and may be used by the IPR committee.
- There is a concern that the project available contingency is dropping. The committee was not able to assess if this trend will continue. However, there is no evidence this issue will affect CD-3A. Does the project schedule account for rejected manufactured components? Does the amount of material bought in this early procurement fully mitigate the risk of rejections or meet the rejection assumptions?
- There are minor holes in the schedule compared to the BNL EVMS and Project expectations, e.g., noting lags/constraints in a P6 notebook, activities that do not have resources without designation of SVT or other qualifier, and other coding errors.
- The Risk Register should be scrubbed again to ensure completeness and backs up the justification for CD-3A. For example, Superconducting Strands (WBS 6.06.02.07) has a possible risk opportunity of up to 25% if strand specifications can be relaxed, which is not captured in the Risk Register.
- The project should continue to hold Risk Management Boards on a monthly basis, assessing all project risks, as per the Risk Management Plan. The project should not lose sight of the rest of the overall project risk.
- A few BOEs were updated after documents were posted for the review. Some posted BOEs were not traceable to P6. However, updated BOEs were shown during CAM interviews, which were traceable to P6. The most current BOEs, that support the P6 data, should be posted for reviewers, and any updates, after posting, should be communicated to the review committee.
- The WBS dictionary was reviewed and appeared complete for its intended purpose, i.e., providing scope boundaries. Adding more details to this controlled document may result in time-consuming management to keep the document consistent and up to date.

- Dates in some of the spreadsheets, i.e., the long lead procurements, didn't match the award dates in P6. Ensure the dates across documents are in alignment.
- Some practice with moving through documentation and screen sharing would help the team demonstrate familiarity with the material.
- We found a 30-day SVT activity in the working schedule that was split into a 25-day and 5-day activities. The 25-day was completed and the 5-day activity is still open. This practice was not done under change control and will interfere with the CEI metric. Guidance should be articulated to the PCS team regarding this practice.
- Consider making specific coding more visible to CAMs, e.g., using standardized layouts with code fields or adding short descriptors to the beginning of the activity description (SVT, PP, Proc) for Schedule Visibility Task, Planning Package, Procurement, and other non-resource loaded activities. This would be helpful for CAMs, who may not have access to the coding fields.
- Consider breaking out near-term (through FY25) LOE activities into quarters. It would give more flexibility for baseline changes instead of being stuck in a freeze period.
- Procurement needs to be informed and involved in the schedule update process for their activities. Consider inviting them to the status meetings and copying them on schedule outputs so they are aware of upcoming procurements and prioritization of each.
- Cost and Schedule drilldowns conflicted with the technical discussion. Consider offsetting the drilldowns or provide time in the technical discussions for the C&S team to do drilldowns.

Recommendations

- Before the CD-3A IPR, ensure the project team can demonstrate an ability to meet management and reporting needs, e.g., vendor follow-up, monthly reporting/change control processing cadence (practice EVMS).
- Before the CD-3A IPR, CAMs should have one-on-one on-job-training sessions with PCA to build EVMS "muscle memory".
- Before the CD-3A IPR scrub documents for consistency and completeness as noted in comments above.

SC7 - Project Management

Findings

- Management of the Project includes an Integrated Project Team with representatives from the Office of Nuclear Physics, BHSO, TJSO, and the Project Team.
- There have been changes to the plan for Critical Decisions since the last DOE review including a possible CD-3B and removal of CD-4A.
- The Project Organization Chart at Level 2 Org is aligned with the project WBS structure.
- A governance model including international partners has been developed and is actively engaged, e.g. EIC Science; EIC Advisory Board; Resource Review Board; Program Advisory Committee.
- The EIC Project plan is coupled to the schedule for the planned shutdown of RHIC in 2025 to leverage the roll-off of highly skilled staff. A detailed staffing plan has been developed which shows staffing requirements by resource type from P6, actual hours charged from the respective labs' payroll systems, and the staff which are available to support the EIC. Those available staff include a forecast of the staff which will ramp down from their work on RHIC operations and TJNAF SRF operations work on other partner projects.
- Ten out of eleven Final Design Reviews have been conducted for the CD-3A scope. The remaining FDR for the 591MHz 1-cell cryomodule is scheduled for Jan. 2024.
- The contingency estimated on CD-3A scope is 35% and is supported by a risk analysis, which concluded that 33% would be sufficient with a 90% confidence level. For the overall project, the contingency on work to go is 31.3%.
- The CD-3A package includes two items that coil become an In-Kind contribution from collaboration partners.
- Systems Engineering is outlined in the Systems Engineering Management Plan (draft), Requirements Management Plan (released) and Interface Management Plan (released).
- Design maturity is determined based on design review completion. The design maturity percentage for the total project is 42%.
- The Project Management Plan (PMP) was updated on September 26, 2023, but does not include a sufficient description of the roles in the Technical Support and Integration box of the organization chart.

Comments

- The committee thanks the project team for a well-organized review, high-quality presentations, and responsiveness to the committee's inquiries and requests.
- The committee found that including a CD-3A is the right approach for the EIC project due to its technical complexity and the current environment of vendor and supply chain issues. The project team has appropriately identified long lead procurements that mitigate overall risk and that have reached the appropriate readiness for the start of construction.

- The risk management system is mature and the project is actively managing risks. The project has made a good first start on the risk analysis of the CD-3A package but more work should occur prior to the OPA review. While risks related to the scope of the CD-3A deliverables were modeled, the risk of a delay in the approval of CD-3A itself was not modeled. Presenting the impact of a delay to CD-3A approval would support its urgency.
- The current tailoring strategy includes a CD-3B approval in Q1FY25 and CD-2-3 in Q3FY25. Including the CD-3B in this strategy will provide valuable flexibility needed as funding conditions evolve and the design continues to mature.
- The level of cost contingency (35%) on CD-3A appears to be sufficient, but the level on the entire project (31.3%) is low for this stage of the project. At the upcoming IPR, the project should be prepared to discuss the plan to define a level of risk-based contingency that will support the project baseline.
- Technical plenary talks (accelerator, detector, infrastructure) should increase their focus on CD-3A project management aspects (scope, cost, and schedule) in order to demonstrate ownership as the team moves into execution. These presentations would also benefit from consistency in format when presenting common topics such as design maturity/reviews, risks, motivations for LLPs, WBS/organization, and responses to previous recommendations. A common template would be helpful in addressing these concerns.
- The charge for the November 2023 IPR includes questions related to R&D status and CD-2 baseline preparations that were not in the charge for this review. The IPR presentations should include a timeline to CD-2 readiness, which will both answer the charge question and support the urgency of CD-3A.
- The review would have benefited from a consolidated presentation on the status of in-kind contributions and the management systems available to accommodate them, especially with respect to the CD-3A package.
- Advance Procurement Plans (APPs) need to be started early so that the technical and procurement teams are ready to execute the CD-3A scope. Sufficient information is already available to draft the CD-3A APPs, which should be made available for the IPR.
- The project organization chart has been updated to include a Technical Support and Integration group. The PMP should be updated to include a description of these functions and any others which the project management team deems appropriate. There was confusion amongst the review team regarding the interface of responsibilities, such as configuration management, between the quality and systems engineering groups.
- Engineering processes for design, technical configuration management/change control and data management should be piloted during CD-3A and fully implemented well in advance of CD-2.
- Good progress has been made on identifying requirements and approving requirements documents. Interface definition has just started and appears on track for CD-2. Interface Requirements documents need to be finalized. For the CD-3A scope, the project should define the set of documents they consider equivalent to the interface requirement documents.

- The staff planning was comprehensive and shows the available labor pool, including the transfer of staff from RHIC operations. The end of RHIC operations in 2025 means a large number of staff (~200) become available to support the EIC. This will need to be synchronized appropriately with CD-3 so that their critical skills can be utilized optimally.
- Consider strengthening the Collider-Accelerator Department/EIC relationship with a liaison whose role could be to facilitate off-project dependencies (e.g. accelerator equipment removal and staff transitions).
- The institutional MOU between the EIC Project and BNL contains a number of off-project scopes of work which are required for EIC success. The funding for these dependencies needs to be identified and agreed to and key milestones for these need to be included in the EIC project schedule.
- The Directors of BNL and TJNAF are very engaged with the EIC Project and are working together to address high level issues. Their joint advocacy going forward communicating the value of EIC to stakeholders will be a vital component of the project's success.

Recommendations

- Prior to the November IPR, reorganize the presentations and material to more clearly present the CD-3A package distinct from the overall project status.
- Prior to the November IPR, clearly show the impact if the CD-3A package is not approved and construction start is delayed until CD-3 approval. Also include the results of this analysis in the CD-3A justification form.
- Prior to the November IPR, finalize and prepare for signature all documents required for CD-3A approval consistent with the DOE O413.3B CD-3 Requirements checklist.
- Proceed to the November IPR after addressing the applicable recommendations in this Director's Review report.

Appendix 1 – EIC CD-3A Director's Review Committee Charge

Electron-Ion Collider Directorate

Brookhaven National Laboratory

Building 1005S
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Upton, NY 11973-5000
Phone 608.999.1740
jyeck@bnl.gov

managed by Brookhaven Science Associates
for the U.S. Department of Energy

date: *August 10, 2023*

from: *Jim Yeck, EIC Project Director/Associate Laboratory Director*

Memo

subject: *CD-3A Director's Review of the Electron-Ion Collider (EIC) Project*

I request your assistance in conducting a Critical Decision 3A (CD-3A) Director's Review of the Electron-Ion Collider Project at Brookhaven National Laboratory on October 10-12, 2023. The purpose of this review is to assess the EIC Project's design and readiness to meet CD-3A, Long Lead Procurement (LLP) Approval. The charge to the Director's Review committee is based on the expected charge for the Department of Energy's (DOE) Office of Project Assessment (OPA) CD-3A Review on November 14-16, 2023.

The EIC plans to request approval on a CD-3A LLP package estimated to cost about $100M. DOE CD-3A approval milestone is planned for January 2024. The EIC design continues to mature and the LLP items are completing design reviews. It is anticipated that 80% of final design reviews for the LLP items will be complete prior to the planned CD-3A approval milestone. Robust system engineering processes, a Design Maturity Plan, and Technical Review Plan are in place to ensure sufficient assessment at each phase of design and project implementation.

The Electron-Ion Collider (EIC) is the next generational facility for research in nuclear physics. At the EIC, it will be possible to tackle several key scientific questions in fundamental physics such as determining the 3D structure of protons and nuclei, searching for gluon-saturated matter and solving the mystery of the proton spin. This future facility will be constructed at Brookhaven National Laboratory (BNL), and jointly managed by BNL and Jefferson Lab. The EIC Project secured DOE CD-1, Approve Alternate Selection and Cost Range, approval in June 2021. CD-2 approval is planned for 2025.

The committee is asked to respond to the following CD-3A charge questions:

1. Is the project team effectively executing the work? Are technical issues appropriately and proactively being addressed? Are the proposed CD-3A long-lead procurements appropriate?
2. Are the cost and schedule estimates credible? Do they include adequate scope, cost, and schedule contingency? Are the estimates for the proposed CD-3A long-lead procurements appropriate and can these procurements be properly tracked?
3. Is environment, safety, and health (ES&H) and quality being properly addressed given the project's current stage of development?
4. Is the project being properly managed? Are risks being effectively managed? Is the management team in place to successfully execute the CD-3A scope?
5. Is the project appropriately addressing the recommendations from the prior DOE SC reviews?
6. Is the project ready for CD-3A approval?

* * *

CC: L. Lari
J. Fast

Appendix 2 – EIC CD-3A Director's Review Committee

Sarah Cousineau, Co-Chairperson, ORNL
Mark Reichanadter, Co-Chairperson, Retired SLAC

SC1 Accelerator Design & Beam Dynamics	SC2 Accelerator Systems	SC3 Detector Systems	SC4 Infrastructure
* Timur Shaftan, BNL	* Sang-Ho Kim, ORNL	* Rik Yoshida, ANL	* Martin Fallier, retired BNL
Kathy Harkay, ANL	Chris Adolphsen, SLAC	Gabriella Carini, BNL	Steve Cannella, BNL
John Seeman, SLAC	John Byrd, ANL *Remote*	Luciano Musa, CERN *Remote*	Rikard Larsson, ESS
Sasha Valishev, FNAL	Eric Fauve, SLAC	Tim Whitlatch, JLAB	
	Brian Hartsell, FNAL		
	Sarin Philip, Jlab		
	Soren Prestemon, LBNL		
POC- Ferdinand Willeke	POC- Kevin Smith	POC-Elke Ashenauer/Rolf Ent	POC- Charles Folz

SC5 Environment, Safety and Health & Quality	SC6 Cost and Schedule	SC7 Project Management
* Darren Marsh, SLAC	* Richard Marcum, FNAL	* Marc Kaducak, FNAL
Jeff McGhee, ANL *Remote*	Mandi Harris, FNAL	Diane Hatton, retired BNL
Crystal Schrof, retired ORNL	Lorri Stapelton, FNAL	Allison Lung, JLAB
	Helen Taaffe, ANL-arriving late	Dan Stout, FRIB *Remote*
POC- Charles Schaefer	POC- Cathleen Lavelle	POC- Luisella Lari

Observers	
Robert Cardonna (BHSO)	Bryan Foley (TJSO)
Joe Diehl (BHSO)	Craig Ferguson (TJSO)
Bob Gordon (BHSO)	Wayne Skinner (TJSO)
Caroline Polanish (BHSO)	Ivan Graff (ONP) *Remote*
Lin Shi (BHSO)	Paul Mantica (ONP) *Remote*
	David Dean (JLab)

LEGEND
SC Subcommittee
* Chairperson

Count: 31 (excluding observers and POCs)