Closeout Report on the DOE/SC CD-1/3a Review of the

Super Pioneering High Energy Nuclear Interaction Experiment (sPHENIX) Project

Brookhaven National Laboratory

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Committee Chair

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http://www.science.doe.gov/opa/

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Review Committee

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Subcommittee 2—Data Acquisition, Triggers, and Electronics
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Charge Questions

1. Is the sPHENIX conceptual design technically sound and does it address the program's scientific goals? Are the preliminary Key Performance Parameters (KPPs) and Ultimate Performance Parameters (UPPs) appropriately defined and achievable?

2. Are project risks properly identified and are appropriate mitigation strategies in place for this stage of the project? Are the proposed CD-3a long-lead procurements appropriate?

3. Are the cost and schedule estimates credible? Do they include adequate scope, cost, and schedule contingency? Is the estimate for the proposed long-lead procurements appropriate?

4. Is environment, safety, and health (ES&H) and quality being properly addressed given the project's current stage of development?

5. Is the project being properly managed for this stage of the project? Are risks being effectively managed? Is the management team in place to successfully execute the CD-3a scope?

6. Is the project ready for CD-1 and CD-3a approval?

1. Is the sPHENIX conceptual design technically sound and does it address the program's scientific goals? Are the preliminary Key Performance Parameters (KPPs) and Ultimate Performance Parameters (UPPs) appropriately defined and achievable?
   Yes for EMCal, HCal, and TPC

2. Are project risks properly identified and are appropriate mitigation strategies in place for this stage of the project? Are the proposed CD-3a long-lead procurements appropriate?
   Yes for EMCal, HCal, and TPC

6. Is the project ready for CD-1 and CD-3a approval?
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EMCal (WBS 1.3) Findings:

- sPHENIX will have a central tracking aperture with complete azimuthal coverage extending from eta = -1.1 to +1.1. The conceptual design for an electromagnetic calorimeter was presented. The project scope allows complete azimuthal coverage with reduce longitudinal acceptance, compared to the full tracking aperture, extending from eta = -.85 to +.85. Negotiations are underway with external collaborators to extend the range to eta=-1.1 to +1.1.

- The smallest structural component of the EMCal is designated the “Block”. Each block contains four calorimeter towers that are the independent readout elements of the detector.

EMCal (WBS 1.3) Findings:

- The EMCal Blocks are fabricated from a tungsten powder-epoxy matrix with an embedded square array of 0.47mm diameter scintillating fibers on a 1mm x 1mm pitch. The tungsten-epoxy matrix provides both the basic mechanical unit of the EMCal and functions as the shower absorber material. With this geometry, the sampling fraction is ~2%.

- Fibers are held in place during epoxy injection by 6 brass mesh screens to create a final fiber matrix (after epoxy injection) sufficiently uniform to guarantee the required energy and spatial resolution.

EMCal (WBS 1.3) Findings:

- A detector specific QA plan has been prepared for block production at UIUC.
- The towers are approximately projective back to the interaction vertex in both eta and phi. To accomplish this blocks are manufactured in up to 22 unique 2D tapered shapes. Light from each tower is collected by light guides into 4 silicon photo multipliers for a total of >73k sensors in the EMCal.
- The basis of estimate for block fabrication relies on previous purchase experience and actual labor for the prototypes. A learning curve for student labor to be used in mass production is assumed.
- Overall EMCal BOE relies on Quotes and Catalog for ~62% of the cost and analogous design experience for 33%.

EMCal (WBS 1.3) Findings:

- The sPHENIX EMCal has been through 4 generations of prototypes. Eta=0 and Eta =1 variant prototypes have been tested in beam. A final design prototype is being tested in a 2018 test beam. Energy resolution consistent with requirements has been achieved: DE/E < 16%/sqrt(E) + 5%

- The KPP for the initial precision of the pre-calibration is 35% with >90% of all channels live.

EMCal (WBS 1.3) Findings:

- Module and sector assembly will be carried out onsite at BNL. All work at BNL is conducted under the authority of an Experimental Safety Review (ESR) with oversight provide by BNL ES&H personnel and the sPHENIX group Safety Coordinator.

- The production steps for modules are well understood but must be scaled up for mass production. A full pre-production sector is planned to understand mass production fixtures and procedures and to anchor the labor part of the basis of estimate.

- The EMCal schedule is on or near the critical path throughout the entire project. W-powder and scintillating fibers must be procured under CD-3A to allow work to start on fiber filling and block casting when the labor force becomes available at UIUC.

EMCal (WBS 1.3) Findings:

- Principal project risks have been identified in a risk registry and mitigation strategies have been suggested.

- The EMCal block will have a light-injecting fiber to calibrate the SiPMs. No other beam-off detector calibration mechanism (cosmic muons, radioactive source) is considered at this time.

EMCal (WBS 1.3) Comments

- The EMCal is a very solid design demonstrated in multiple test beam measurements. While the variation of sampling fraction as a function of depth and other contribution might introduce a constant term in the energy resolution, the KPP value appears to be overly conservative for such a uniform design. The value used for HCal appears more in line with this kind of calorimeter and we recommend the group reconsider the EMCal KPP goals.

- In the present plan, the sensitivity to ionizing radiation of each EMCal block is not fully proven until beam collisions in sPHENIX. Although the basic elements (W powder, epoxy and Sci-fibers) are simple and should leave very little space for surprises, we suggest the use of radioactive sources or injection of UV light along the fibers to simulate ionizing radiation in the EMCal blocks during the production or assembly phases.

- The assembly effort for the EMCal towers based on student labor might result in "student burn out" during fiber filling. The project recognizes the risk. Other projects have found the necessity to revert to technicians effort and such a possibility, albeit more expensive, should be entertained in the risk registry or in the contingency.

- Due to the limited EMCal eta coverage after de-scoping, the jet acceptance/ fiducial region will be restricted. For one of the premier detector in Ion Physics in the next decade this does not appear a wise choice. We invite the collaboration to pursue every means to extend EMCal to the full HCal eta coverage to insure full depth for jets studies. This decision must be made in a timely fashion because it becomes irreversible once full commitment to sector assembly is made.

- Advanced Procurement Plan for the Scintillating Fibers and the W powder were provided upon request. These appear to be "Procurement Office" documents. Plans for QA at vendors, acceptance criteria and vendor visits exist and were presented, albeit in a somewhat scattered form.

- The Risk Registry for EMCal is sound and well thought through. We suggest however to consider the possibility to include a risk pertaining to the Epoxy used in the EMcal construction, especially for the structural function in the modules assembly.

- There is a small inconsistency between the attenuation length in the recent purchase order specifications (>=1.6m) and the one specified in Table 4.1 of the Conceptual Design Report. The difference will not influence the performance, but the documents should be brought into agreement. Also, the fiber specifications document should be fully signed prior to the execution of the order.

EMCal (WBS 1.3) Recommendations

- Prior to CD-2, Add a risk to the "block production" fiber filling activity to reflect the possibility of "student burn out". Develop a credible mitigation strategy

- Prior to CD-2, add an additional step to section 9 of the "Detector-Specific Quality Assurance Plan for EMCalorimeter Block Production for the sPHENIX Project". Add the use of UV light in addition to the use of white light when evaluating light transmission via the fibers through the block. Scintillation light should be visible emerging from each fiber.

- Prior to CD-2, aggressively pursue options (possibly with in-kind contributions from new Collaborators) to restore the pseudorapidity coverage of the EMCal.

- Prior to CD-1, revise EMCal KPP to better reflect actual experience with the uniformity SiPMs and Blocks
- Finalize and sign the specifications for the scintillating fibers and proceed to the execution of the Purchase Order.
- Proceed to the execution of the W-powder Purchase Order.

HCal (WBS 1.4) Findings:

- sPHENIX will have a central tracking fiducial acceptance with full azimuthal coverage extending from eta = -1.1 to +1.1. The conceptual design for a hadronic calorimeter was presented. The project scope allows complete azimuthal coverage with longitudinal acceptance extending from eta = -1.1 to +1.1.

- HCal design should permit absorption of >95% of the energy of a 30 GeV and result in a Gaussian-like energy resolution of ~ 150%/sqrt(E).

- The outer HCal sector structure is built up from tapered 1020 low carbon steel absorber plates oriented in a slightly off axis radial direction (a tilted plate calorimeter).

- Scintillator tiles are placed interdigitally between the steel plates and are divided into 48 towers per sector. The scintillator tiles have gone through 4 rounds of prototyping with the anticipated Russian provider (Uniplast).

- Each HCal scintillator tile is readout by a single wavelength shifting fiber coupled to a single SiPM**.**

- The inner HCal is interior to the superconducting magnet and thus uses non-magnetic material as the absorber material. At the present time, scintillators and readout instrumentation for the inner HCal is not included in the project scope.

- Mechanical prototypes of both the inner and outer HCal sectors have been completed.

- Scintillator/fiber tile assemblies for HCal are a requested long lead time procurement via CD-3A approval. This is proposed to control the risk inherent with the Russian vendor.

2.1 Calorimeters and TPC

T. Cormier, ORNL / G. Apollinari, FNAL

Subcommittee 1

- Scintillator-tile assemblies will be dimensionally tested and light output will be measured in Russia before shipment.
- Overall BOE for HCal relies on Professional Judgment for ~50% of the cost and analogous design experience for 48%.
- Four prototypes have been tested with test beams. Results are achieved which are in good agreement with simulations and meet sPHENIX requirements

HCal Comments

- The HCal is based on proven technologies. The design appears robust and appropriate for the sPHENIX goals and the performance in energy resolution appropriate for this kind of detector. The KPP are appropriate for this kind of detector.

- The solution to procure assembled tiles from Uniplast is cost effective and appropriate to achieve the goals of sPHENIX.

- Risk Registry for HCal is sound and well thought of.

- Advanced Procurement Plan for the tiles were provided upon request. These appear to be “Procurement Office” documents. Plans for QA at vendors, acceptance criteria and vendor visits exist and were presented, albeit in a somewhat scattered form.

HCal Recommendations

- (CD-3a) Proceed to the execution of the HCal Tiles Purchase Order.

TPC Findings

- sPHENIX is proposing CD-1 for a second generation TPC central-tracker following many of the developments of the ongoing ALICE TPC upgrade design.

- In sPHENIX, the TPC provides the precision tracking needed for upsilon physics and essential elements of jet physics measurements.

- GEM, micro-pattern detectors, will be used as the primary electron gain elements providing the required signal gain (e.g. x 2000 in ALICE) while lowering the associated positive ion feedback into the TPC drift volume and large electrostatic track distortions.

2.1 Calorimeters and TPC

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Subcommittee 1

- The TPC will use the SAMPA ASIC developed for ALICE on their readout cards allowing both continuous and triggered readout. A readout card prototype was shown.
- Prototype field cages have been built.
- The sPHENIX TPC design utilizes 3 radial sectors and 12 azimuthal sectors allowing rather small GEM foils to be used.
- Temple University, Vanderbilt University, Wayne State University and Weizmann Institute together constitute GEM handling and preparation factories
- Stony Brook University is the principal TPC fabrication/assembly site
- The Gem production rate at CERN drives the overall sPHENIX TPC schedule

- sPHENIX will support a technical staff person in the CERN GEM fabrication shop to control their own GEM foil production.
- The required TPC support subsystems including gas, cooling and laser calibration are all well understood.
- The project team suggests that undergraduate students will form a substantial fraction of the TPC fabrication and testing workforce.
- TPC tracking will employ space charge corrections linked to collider luminosity in the manner of STAR rather than the ALICE approach linked to instantaneous event rate.

TPC Comments

- The TPC group is very strong with a number of people that have substantial experience in gas detector projects including those with GEM elements.
- It is a very smart approach to take advantage of the many years of GEM TPC R&D by the large ALICE TPC group.
- The TPC readout card is much denser that the corresponding ALICE card but cross talk appears reasonable.
- There are a number of QA/QC steps needed in chamber production including qualification of GEM foils and various sub assemblies. The team leaders understands this but details were not presented as part of the sPHENIX CD-1 project plan.

- ALICE finds it essential for an experiment staff person to participate in GEM foil pre-qualification in the CERN shop. sPHENIX would benefit from adopting this approach.

- ALICE finds it essential to conduct "burn-in" of assembled chambers at full voltage in the presence uniform, high intensity, x-ray illumination that produces total chamber currents comparable to full luminosity operation in the collider.

TPC Recommendations

- Prior to requesting CD-2, the project team should finalize a Detector Specific QA Plan for materials; handling and subassemblies for the scope of work performed in the four GEM factories. The plan should detail all tests to be performed including test objectives and procedures and final acceptance criteria.

- Prior to requesting CD-2, the project team should create a chamber assembly procedures document and a Detector Specific final chamber QA plan for work to be conducted at Stony Brook. The plan should detail all tests to be performed including test objectives and procedures and final acceptance criteria.

1. Is the sPHENIX conceptual design technically sound and does it address the program's scientific goals? Are the preliminary Key Performance Parameters (KPPs) and Ultimate Performance Parameters (UPPs) appropriately defined and achievable?
   Yes

2. Are project risks properly identified and are appropriate mitigation strategies in place for this stage of the project? Are the proposed CD-3a long-lead procurements appropriate?
   Yes

6. Is the project ready for CD-1 and CD-3a approval?
   Yes

Findings

- The proposed DAQ, Trigger and Electronics designs meet the Scientific Objective and Performance goals of the sPHENIX experiment.
- The sPHENIX proposal significantly leverages the investment in PHENIX by reusing the following: DCM2, SEB, ATP, Buffer Boxes, and Event Builder Software.
- The proposal have creatively capitalized on technologies and equipment developed elsewhere, for example by ATLAS, ALICE, and NSLS II.
- The subsystem managers have extensive and relevant experience ranging up to over 30 years, often on PHENIX.

Comments

- The Committee recognizes the experience, competence, and professionalism of the team working on the DAQ, Trigger and Electronics.
- The presentations were very well structured and provided the committee with the information we needed to assess the project.
- The overall design is well matched to meeting the challenge of collecting data from sPHENIX.
- The costs were credibly estimated and appeared appropriate for this stage of the project.
- The schedule of the various subsystems were appropriately integrated.
- The committee recognizes and appreciates the importance of the OSI.
- Careful tracking and oversight will be needed to ensure the SAMPA delivery and performance.
- The planned radiation qualification of all components on the TPC FEE board needs to be performed if not already documented.

Recommendations

1. Proceed to CD-1 and CD-3a.

4. Is environment, safety, and health (ES&H) and quality being properly addressed given the project's current stage of development?
   Yes

6. Is the project ready for CD-1 and CD-3a approval?
   Yes

Findings

- Project documentation (PEP, PHAR, and QAP) is complete and appropriate for the stage of the project.
- NEPA determination documentation is complete.
- The framework of the QAP document is well structured.
- EHS&Q aspects are integrated as evidenced by the presentations and posted documentation.
- The risk matrix for the RMP and PHAR is not consistent.

Comments

- The practice of institutional visits is commendable and will provide benefits in quality, safety and teaming efforts.
- The lab will be migrating from OHSAS 18001 to ISO 45001. The new ISO standard has a greater focus on risk assessment and stakeholder engagement which will need to be factored into the project.
- The risk matrix in the PHAR should be reevaluated so that the likelihood and consequences definitions are realistic and translatable to the project.

Recommendations

1. Recommend CD-1/3A approval

2. Are project risks properly identified and are appropriate mitigation strategies in place for this stage of the project? Are the proposed CD-3a long-lead procurements appropriate?
   Yes, however an additional scrub of the project risks should be conducted before CD-1.

3. Are the cost and schedule estimates credible? Do they include adequate scope, cost, and schedule contingency? Is the estimate for the proposed long-lead procurements appropriate?
   Yes

6. Is the project ready for CD-1 and CD-3a approval?
   Yes

Findings:

- The project presented a Cost Range of $26.5M to $34.5M, an early finish date of first quarter FY22 and a CD-4 date of first quarter FY23.
- Proposed BAC is $20.5M, and the point estimate is $26.6M.
- Contingency is $6.02M and the project has forecast 14 months of schedule contingency (float).
- As of April 2018, the project is 5% complete with actual costs of $898.2K.
- Cost estimate was developed bottom-up by L2 and L3 managers.
- The project estimate includes both costed and uncosted labor in the form of contributed effort.
- The cost estimate is assigned by resource type by units (labor hours and non labor direct dollars) to the activities in the schedule.
- The project schedule is logic driven and resource loaded, and provides input to the procurement and staffing processes. It currently has over 1,600 activities including 213 milestones.

Findings: (2)

- The project critical path runs through the EMCal Prototype Procurement, EMCal Fab/Assembly, Calorimeter Electronics Fabrication Assembly, Calorimeter Electronics Procurement, Calorimeter Electronics Fabrication/ Assembly (SiPMs) Production, EMCal Module/Sector Production Fabrication/ Assembly, EMCal Sector Testing and Early Completion.
- The project schedule contains 160 logic ties from the project to external RHIC activities.
- The project has completed EVMS training and will be implementing the certified BNL EVMS system.
- The project risk register has 32 active risks, with 3 High, 6 Medium and 23 Low, and 1 opportunity. Risks are reviewed monthly.
- Total risk cost impact is $1.98M, and a total schedule impact is 480 days.

Comments

- The project has a very capable project management / controls team. The support provided by the central PM organization should continue through CD-2.
- The Control Account Managers were very knowledgeable about their scope, schedule, cost, and risks and appear prepared to execute beyond CD-1/3a.
- The MIE project scope is clearly defined, and is well integrated with the contiguous RHIC activities. The WBS appears to contain the complete project scope of work.
- The schedule is very mature for CD-1, very nicely organized and supports the schedule range. Based upon a logic analysis, the 14 months of schedule contingency seems reasonable.
- The project may want to include a greater number of milestones to identify all interface points with off-project efforts, and to better facilitate tracking contributed effort.
- Prior to CD-2, evaluate techniques for monitoring and controlling the significant contributed effort that will not be visible with EVMS.

Comments (2)

- Student labor on the project is equivalent to 55 FTEs which may present schedule and cost issues. A detailed review for risks associated with the student labor is encouraged.
- The project may want to consider distributing float within the schedule to buffer areas where specific schedule contingency could be useful (student labor, foreign procurements).
- The planning for the Long Lead Procurements (LLPs) appears complete and sufficient for CD-3a.
- The project estimate is very mature for CD-1 and supports the point-estimate. All vendor quotes should be refreshed before CD-2.
- While the detailed estimate review was cumbersome, the details supported both the estimate and the resource loaded schedule.

Comments (3)

- The approach to both estimate uncertainty and event risks appears to be sound, and the cost contingency appears reasonable. However, inconsistencies in estimate uncertainties were observed and the risk register appears to be incomplete (student labor) and the probabilities (staff turnover) may be optimistic.
- A funding profile which includes the spread of risk based contingency is essential to ensure adequate funds are available for the project in the event of a risk being realized. While a sPHENIX risk based funding profile was presented, it has not been finalized and continues to need some refinement.

Recommendations

- Before CD-1
  - Review and update the risk register.
  - Finalize the risk based contingency and funding profile.

PROJECT STATUS		
Project Type	MIE	
CD-1/3A	Planned: July 2018	Actual:
CD-2	Planned: July 2019	Actual:
CD-3	Planned: July 2019	Actual:
CD-4	Planned: Dec 2022	Actual:
TPC Percent Complete	Planned: 5 %	Actual: 5 %
TPC Cost to Date through April 30, 2018	$898.2K	
TPC Committed to Date through April 30, 2018	$1,375.5K	
TPC	$26,550 K	
TEC	$20,531 K	
Contingency Cost (w/Mgmt Reserve)	$6,019 K	30.1 % to go
Contingency Schedule on CD-4B	14 months	33 %
CPI Cumulative	NA	
SPI Cumulative	NA	

2. Are project risks properly identified and are appropriate mitigation strategies in place for this stage of the project? Are the proposed CD-3a long-lead procurements appropriate?
Yes, the risks appear adequate for this stage of the project, once a risk for contributed labor is evaluated. More proactive mitigations should be developed prior to CD-2. The long-lead items are appropriate.

5. Is the project being properly managed for this stage of the project? Are risks being effectively managed? Is the management team in place to successfully execute the CD-3a scope?
Yes, the Project is currently being managed appropriately and can handle the CD-3a procurements. However, there are some concerns about the stability of management personnel moving forward.

6. Is the project ready for CD-1 and CD-3a approval?
   Yes. The Project is ready for CD-1 and CD-3a approval once appropriate recommendations have been addressed.

Findings

- The sPHENIX science mission is to perform measurements of Jets and Upsilons produced in heavy ion collisions in RICH.
- CD-0 was received in September 2016
- sPHENIX is a major upgrade to the PHENIX detector. It repurposes > $20M in existing PHENIX equipment, infrastructure and support facilities. The Project is funded as an MIE by redirecting operating funds.
- The PHENIX detector is largely being replaced but the infrastructure is generally being reused.
- sPHENIX interfaces with BNL-funded Infrastructure and Facility Upgrades (~27M). There is a common P6 file that connects the MIE funded Project work with these activities to facilitate integration of the efforts.
- The Project includes 3 new detectors and their support systems: a Time Projection Chamber, Electromagnetic and Hadronic calorimetry.

- sPHENIX is negotiating for extended calorimeter coverage and the addition of a silicon pixel detector. New non-DOE sources of funding are being sought.
- The Project is reusing the BaBar superconducting magnet, delivered from SLAC in 2015. The magnet has been successfully tested at full power at BNL. This was all accomplished off-Project.
- The scheduled early completion date is October 2021, leaving 14 months of schedule contingency to CD-4 (Dec 2022).
- The Project has a preliminary funding profile with a Total Project Cost of $26.55M. An obligation profile was presented and compared to the funding profile.
- BNL has granted the sPHENIX project the Extraordinary Project Rate for overhead charges. This rate is fixed for the duration of the Project.
- The cost range is $26.5M to $34.5M.
- The Project and the Collaboration have together evaluated the potential Project scope contingency. Their conclusion is that little, if any, scope contingency exists.

- The high end of the cost range was based on the DOE Cost Estimating Guide. The Project asserts that their cost estimate falls into the Class 3 estimate class based on the degree of project definition. Based on this, the upper end of their cost range has been set to be 30% higher than the point estimate.
- The Project indicated that a review of the Risk Register, the degree of estimate uncertainty and their alternative analysis also contributed to their evaluation of the cost range.
- The Project presented a labor profile that peaks at 62 FTE in FY20. A significant fraction of the labor is designated as collaborator contributed, including thousands of hours of student labor.
- The MIE split between labor/M&S is 7/93%. This split is a consequence of the large amount of contributed labor.

- About 90% of the BNL labor required by the Project is resident in the BNL Physics Department sPHENIX group. The remaining 10% comes from the Collider Accelerator Department and the Instrumentation Division. MoAs with these organizations have been prepared. MoAs covering off-Project activities are also being developed. It is the Project's intent to develop MoAs with the collaborating institutions as well.
- The Project has developed a Risk Management Plan and a Risk Register that includes cost and schedule risks. The Risk Management Plan and Risk Register were reviewed by members of the NSLS II Project in January 2018.
- Dedicated Risk Management Board meetings are planned to be held one per month beginning after CD-1.
- The Project presented a table of Threshold and Objective KPPs. Installation is not a Project deliverable. Beam collisions are not required to satisfy the KPPs.
- The Project presented an Alternatives Analysis and a Lifecycle Analysis.
- A series of reviews are planned for all construction activities. This includes reviews of design, prototype performance, procurement readiness and safety.

- ES&H and QA experts are assigned to the Project.
- The Project plans to send BNL ESH&Q personnel to collaborating institutions to ensure that project work is being done safely and to appropriate standards of quality.
- ESH and quality managers attend design reviews to ensure that ESH&Q issues are adequately addressed.
- The Project has a liaison from the Procurement Department.
- The Project has developed a master QA plan. All construction activities require targeted QA plans.
- The Project uses the VAULT system to organize and manage engineering drawings and docdb to manage documentation.
- The Project critical path runs through EMCal construction and calorimeter electronics.
- Project documentation for CD-1 has either been completed or submitted.

- Four long-lead procurements have been identified for items on or near the critical path. These are
  - 50% of the scintillating fibers for EMCal
  - 50% of the Tungsten powder for EMCal
  - Silicon Photomultipliers for EMCal
  - Scintillating tiles for the Outer Hadron Calorimeter
- Prototyping has been completed for all four long-lead items. The first three are ready to procure. The fourth item is being reviewed for procurement readiness.
- The procurements for the scintillating fibers and Tungsten powder are phased contracts that require CD-3 approval to purchase the balance of materials.

- The Project presented an integration plan and an Integration Matrix that references specific Integration Control Documents.
- An Office of System Integration will facilitate management of interfaces. This Includes representatives from every group. Representatives attend design reviews and work to mitigate conflicts.
- A recommendation Tracking System exists.

Comments

- The Project Management team possesses significant relevant experience. Many members of the Project team have worked together on PHENIX for many years and they appear to function well as a group.
- The Project has benefited from a favorable base budget this year but is vulnerable to reduced base funding in future budgets. This is identified as a significant project risk.
- The schedule contingency of 14 months is vulnerable to schedule risk, particularly those related to base funding. The Project and the Program Office should re-evaluate the schedule contingency prior to CD-2.
- There is a risk, identified in the Risk register, that key personnel from the Project might depart from the project. Succession planning is advised as a mitigation for this risk. It's critical that there is team continuity between CD-1 and CD-2, building on the successful management of the Project to date.
- The Life Cycle and Alternative Analysis have both been completed in sufficient detail.

- The Project has essentially no scope contingency. The small amount of available scope contingency has already been implemented to bring the cost in line with budget guidance.
- Good attention is being paid to interfaces for a Project at CD-1. This will pay dividends as the project progresses.
- The small amount of contingency in the early years of the Project impacts carryover that makes the Project more sensitive to schedule delays due to Continuing Resolutions.
- There appears to be good interaction between the Procurement Department and the Project. Weekly meetings are held to keep everyone informed about progress and to plan for upcoming procurements.
- The procedure for reviewing designs and procurements should be clearly described in future reviews.
- The Risk Registry is in good shape for this stage of the Project. There are some issues with the evaluation of the individual risk probabilities. These should be refined in future Risk Management Board meetings.

- A risk associated with contributed personnel should be added to the Risk Register because of the Project's heavy reliance on these resources.
- Many of the risk mitigations appear to be reactive rather than proactive. Developing more proactive strategies should be a focus of future Risk Management Board meetings.
- Sending ESH&Q representatives to collaborating institutions is a best practice. The visits are intended to share lessons learned, to form relationships and to make sure that the institution's ESH&Q policies are being followed. It is useful to include a quality representative as well as safety personnel.
- The current plan for early procurement of the fibers and the Tungsten powder involves phased procurements where the second phase requires full CD-3 approval. This introduces a risk should CD-3 not occur as scheduled. Discussions with the Program Office should be held to discuss approval of the full procurement of these two items as part of CD-3a. This does not necessarily impact the funding profile.

Recommendations

1. Ensure a long-term, stable Project Management team through at least CD-2 to ensure project success.
2. Analyze the risk to the Project from the large amount of contributed labor prior to CD-1.
3. The Project and the Program Office should ensure prior to CD-2 that the schedule contingency is updated following a re-evaluation of schedule risks.