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Fermilab

Final Report

Director's Preliminary Cost and Schedule Review of Project X

Based on the Initial Configuration Document

March 16-17, 2009

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Executive Summary

Technical

An Initial Configuration Document (ICD) V1.1 (15-Mar-09) for a 2 MW proton source has been prepared based on a concept of a superconducting 8 GeV linac. A companion document the Project X Research, Development and Design Plan has also been prepared which sets forth the R&D and design activities planned for the period FY2009 through FY2012. The scope of work envisioned includes this pre-conceptual effort to support CD-0, all the way through a CD-4 where the hardware is in place, tested, and ready for beam.

The ICD describes the specifications for a “linac solution” to the P5 (Particle Physics Project Prioritization Panel) consensus need for a 2 MW proton source. These specifications and the linac concept provide the basis for a rather complete point cost estimate of meeting the P5 need.

Although this was not a technical review, the committee was asked to assess the adequacy of the RD&D program for meeting the needs of a construction project based on the ICD. Generally, it’s felt that the RD&D program does a good job of meeting these needs. An identified exception is the need for significant additional focus in the RD&D program or elsewhere on the low energy linac cavities and cryomodules.

Improvements to the ICD concept that could result in reduced costs are already underway. Also, an Alternate Configuration Document (ACD) involving a lower energy linac as the first stage and a rapid cycling synchrotron is being developed and a cost estimate for the ACD will be developed by the same team that developed the estimate for this ICD.

Cost

A base cost (without overhead, contingency, or escalation) for the entire Project X activity from FY2009 through construction completion is $744M. A technically driven (assuming no annual funding ceiling) scenario including these adders (current laboratory overheads, a 40% contingency, and escalation from the DOE guidelines) yields a Total Project Cost of $1.49B.

Given that the scope description is felt to be complete, the point cost estimate is felt to be complete as well. The basis of estimate for the “base cost $744M” of this point estimate seems generally conservative. It is thus felt to represent something near the high end of a cost range by most committee members. In particular, the cost estimate for the high energy linac cavities and cryomodules is conservative given the close tracking of the European XFEL and FLASH status and experience.

Assuming the DOE escalation rates are correct, the construction / funding schedule holds, and the scope definition remains stable as described above, the committee as a whole believes the $1.49B TPC represents a conservative estimate for Project X. Several members of the committee felt this number is near the high end of the cost range.

Schedule
The critical decision milestones for technically driven schedule are:

CD-0 - July 2009

CD-1 - December 2010

CD-2 - July 2012

CD-3 - August 2013

CD-4 - March 2018

The critical path was described by the Project X team to be beneficial occupancy of buildings, installation of high energy linac cryomodules, and system tests. HE linac cryomodule production assumed at one per month is not far off the critical path.

Management
A small management team has led the pre-conceptual effort to develop the ICD and RD&D Plan with key input from persons in the Accelerator and Technical Divisions.

Up to nine partner / collaborating institutions are anticipated for Project X. A memorandum of understanding (MOU) for the RD&D phase is circulating among collaborators for review and approval.

A combined R&D and PED funding request profile for years FY2011 through FY2013 was presented which totaled to $74M base cost (unburdened, no escalation, no contingency). Project X should coordinate the request with OHEP to determine if for example the R&D should be broken out as a separate request in those years.

The planned Project Office staff builds from 4 FTEs in FY2009 to 25 in FY2013 at CD-3 and remains flat throughout Project X construction. The Project Office structure assumes several project intensive support functions such as procurement, human resources, and business services will be provided by the laboratory. Examining the desirability of acquiring some of these capabilities (particularly procurement) within the project may be appropriate as the project negotiates overhead and G&A rates with laboratory management.

1.0 Introduction

A Director's Preliminary Cost and Schedule Review of the Project X was held on March 16-17, 2009. The Committee reviewed the cost range estimate that has been prepared based on the initial configuration set forth in the Project X Initial Configuration Document (ICD). The charge included a list of topics and questions to be addressed as part of the review. The assessment of the Review Committee is documented in the body of this report.

Each section in this report is generally organized by Findings, Comments and Recommendations. Findings are statements of fact that summarize noteworthy information presented during the review. The Comments are judgment statements about the facts presented during the review and are based on reviewers' experience and expertise. The comments are to be evaluated by the project team and actions taken as deemed appropriate. Recommendations are statements of actions that should be addressed by the project team. A response to the recommendation(s) is expected and the status of actions taken are to be reported on during future Project X Working Group Meetings (WGMs) and during future reviews.

Reference materials for this review are contained in the Appendices. Appendix A is Project X's cost estimate spreadsheet. The Charge for this review is shown in Appendix B. The review was conducted per the agenda shown in Appendix C. The Reviewer's assignments are noted in Appendix D and their contact information is listed in Appendix E. The Review Participants are listed in Appendix F. Appendix G is a table that contains all the recommendations included in the body of this report.

2.0 Transfer Lines & Injection

Findings

- The 1200-m 8-GeV linac-to-recycler transfer line (TL) is based on the 2005 Proton Driver design. The main change is injection into the recycler ring (RR) rather than the main injector (MI), requiring the addition of a vertical bend.

- The TL is designed for a **maximum beam power of 1 MW** (Pulse length=1.25 ms, rep rate=5 Hz, and 1.6E14 PPP).

- Permanent dipole and quadrupole magnets were used in the TL except for switching, correcting, and matching dipole and quadrupole magnets. FNAL has experience with the existing permanent magnet 8 GeV H- transfer line to the Booster.

- A cryogenic beam shield is used to reduce H- stripping due to Blackbody radiation. The design is similar to the beam screen for the LHC magnets built by FNAL. A distributed cryogenic system is assumed and is not costed as part of TL.

- H- injection uses a foil stripper and includes phase space painting. Pulsed magnets are used for transverse painting and a warm 1.3-GHz rf cavity is used for longitudinal painting as well as for energy correction, if needed.

- RD&D program is designed to reduce technical and cost risk. Potential revisions were identified in the following areas: TL magnets (electro vs. permanent magnets), TL footprint optimization, location of injection absorber (shielding vs. civil construction costs).

- No issued were identified as “High Risk”

- Four potential “Medium to High Risk” issues were identified for 8 GeV transfer line and recycler injection:

    - Losses due to single particle loss mechanism in the transport line

    - Uncontrolled loss in the injection region due to the injected and circulating ions interaction with stripping foil

    - Stripping efficiencies and life time of the injection foil

    - Collection of the stripped electrons and neutrals from the injection process and safely disposing of them in the injection absorber

Comments

- Beam loss due to single particle mechanisms in an H- 8-GeV transport line is uncharted territory.

- For the transverse painting, one power supply is used for 4 horizontal injection kicker magnets and one power supply for two steering magnet in the TL. This posses some additional risk for losses.

- The RR-10 injection region is very busy, and various facility upgrades occurring prior to PX involve building new extraction lines nearby. The committee did not hear sufficient details to determine potential schedule or cost impacts.

- A commissioning plan was not discussed, but may impact cost (e.g. instrumentation).

- *Is the cost range estimate complete?* Total cost estimate of $M 25.5 covers all the subsystems for the transfer line and injection system except beam diagnostics.

- *Has the cost range estimate been prepared using a sound estimate methodology?* Most of the costs derive from scaling previous project cost.

- *Is the schedule set forth reasonable?* Yes, schedule seem to be reasonable

- *Are the labor estimates reasonable?* Yes, total of $ M 8.8

- *Are the materials and services estimated those needed to deliver the facility?* Yes, except for a few detail

- A*re the estimates for the M&S reasonable at this early stage of the project?* Seems low, total of $M 16.7 (labor est. 52% of M&S)

- *Is the estimated contingency appropriate / adequate?* At this stage with various options still open, seems low.

- *Are there ways the cost could be reduced?* NO

Recommendations

1. Determine what is the beam loss budget based on maximum acceptable uncontrolled losses, and develop requirements for space charge tune shift based on beam dynamics modeling.

3.0 Main Injector Recycler Ring

Findings

- The scope of the Main Injector and the Recycler Ring upgrade is to allow for 2 MW beam operation at 60 – 120 GeV from the Main Injector and about 150 kW beam power from the Recycler ring at 8 GeV. The required peak beam intensity is about 3 times the present peak intensity in the Main Injector and about 10 times the present proton throughput.

- To achieve the somewhat faster acceleration rate and the higher beam intensity the Main Ring 53 MHz rf system needs to be replaced and a second harmonic, 106 MHz rf system needs to be added. Also, new 53 and 106 MHz rf systems are required in the Recycler Ring.

- The majority of the cost is for the new rf systems. The cost estimate is based on past experience with very similar systems and therefore quite reliable. The additional cost for the Recycler Ring modifications and the Main Injector transition energy jump system is much smaller and the estimate is based on existing magnets. The total for 'Engineering, Design, Inspection, and Administration' (EDIA) is about $7.0M or about 11% of total cost ($62M). The total for installation is $3.5M or 6 % of total cost ($62M).

- To prevent electron cloud build-up, 3.3 km of vacuum pipes of the Main Injector will be coated in-situ. The cost estimate also includes replacing the vacuum pipes of the Recycler Ring although this may not be required.

- The RD&D program includes the construction of prototype rf cavities and associated power amplifiers, studies of how vacuum pipe coatings affect electron cloud build-up in the Main Injector and full beam loss simulations including space charge.

- The cost estimate for the transfer line and injection into the Recycler Ring and subsequent transfer to the Main Ring is based on a total of about 350 kW beam power at the 8 GeV beam energy. The injection absorber is designed for about 10% loss. An uncontrolled loss of up to about 1% can be handled in the Main Injector. No collimator is presently costed for the Recycler Ring.

Comments

- Scope of the various beam power options for the Recycler Ring and the associated costs need to be specified more clearly.

- The costed facility is designed to support 1 MW beam power through the linac but there is not place to put this amount of beam power. Commissioning of this level of beam power can only be done for very short time periods.

- The MI/RR tunnel will accept beams that correspond to more than 2 MW beam power. This tunnel looks very different than existing tunnels at SNS and JPARC that were designed for similar or lower beam power levels, which have large access and overhead cranes for rapid component replacement at minimum dose to personnel. This difference should be justified by the project.

- For 2 MW at 60 GeV beam energy the beam power at the 8 GeV injection is 320kW. To keep the uncontrolled loss under 1 W/m the total lost power has to be less than about 3.3 kW or 1%. This includes charge-exchange injection in the recycler, rf capture in the recycler, transfer to the MI, rf capture in the MI and early acceleration in the MI. Beam losses from transition energy crossing are in addition to these losses. A full loss budget for the anticipated beam operation of both the Recycler Ring and the Main Injector should be developed and appropriate collimators and shielding should be designed and costed.

- The EDIA and installation estimates seem low at 11% and 6%, respectively, especially for the rather complex rf systems. About 20 % and 10 % would be more appropriate. The MI/RR RF estimate was compared to updated information from recent requisitions and current quotes from vendors and found to be within 2% of the estimate submitted. A collimator in the Recycler Ring should be added to the cost estimate.

- The schedule for this task as presented seems reasonable.

- There are no high level risks for either the main injector or the recycler ring. There are low and medium level risks for the main injector. The risks are appropriately addressed by the RD&D plan.

- Answer to charge questions for this task:

  - *Is the cost range estimate complete?* The cost range estimate is missing an estimate for the collimator. Otherwise, it is complete and covers all foreseen cost components.

  - *Has the cost range estimate been prepared using a sound estimate methodology?* Yes.

  - *Is the schedule set forth reasonable?* Yes.

  - *Are the labor estimates reasonable?* The labor estimates seem low as a percentage of subsystem cost.

  - *Are the materials and services estimated those needed to deliver the facility?* Yes, except for the uncosted collimator in the Recycler Ring.

  - *Are the estimates for the M&S reasonable at this early stage of the project?* Yes. In fact, some are quite advanced for this early stage.

  - *Is the estimated contingency appropriate / adequate?* Yes, except the contingency for the rf system M&S could be lower than 40%.

- *Are there ways the cost could be reduced?* No

Recommendations

2. Develop a complete beam loss budget for the Recycler Ring and Main Injector and design and cost the appropriate mitigation schemes such as additional tunnel shielding, shielded collimators and/or quick replacement of beam components.

4.0 Instrument & Controls

Findings

- The estimates given were point estimates not range estimates. The estimates were based on experience and comparison to other Facilities such as SNS.

- The estimates for Instrumentation components are done without knowing the final requirements.

- The Instrumentation estimate did not include a separate line item for cable terminators.

- The estimates for Controls in comparison to SNS come out lower in terms of percentage of total project cost. This reduction is explained through the re-use of existing infrastructure, such as the server room and existing accelerator ring, and by the fact that RF and PPS costs are in different cost budgets.

- The Controls Basis of Estimate covers 5 years of labor and one year is stretched to two years.

- The Controls estimate did not include vacuum labor.

- The Instrumentation Basis of Estimate covers 4 years of labor with at least one year stretched and is not profiled over time.

- Instrumentation has budgeted wire scanners and laser wires in the same accelerator segments.

- The Instrumentation R&D budget only included $30k for the laser instrumentation in the first year of R&D.

- Project X development for Controls and Instrumentation depends on R&D for other projects such as Nova.

- The Controls plan is to integrate new control systems, such as EPICS, with the existing ACNET based control system.

- Controls and Instrumentation share responsibilities for systems.

Comments

- We found that an earnest effort was made to come up with the budgets for both the Controls and the Instrumentation costs. The risks were well assessed.

- The final requirements for the Instrumentation should be determined as soon as possible to face the possibility of having difficult and expensive to implement requirements.

- The Control component cost estimate seemed on the low side of sufficient. This should be kept in mind during further budget revisions. The total FTE seems sufficient. Consideration should be given to move some FTE from the Timing system (repeaters) to the Software development, especially Beam Physics Applications.

- The integration of EPICS and/or other control systems in the existing control system should be well planned to avoid delays.

- Consider a separate line item for the cable terminators for Instrumentation.

- The vacuum labor must be accounted.

- The stretching of one budget year into two calendar years leads to a temporary dip in funding. Is this desirable?

- Further detail per year is needed for Instrumentation Labor.

- Depending on the physics requirements, money can be potentially saved by getting rid of either a wire scanner or a laser wire.

- To buy a laser in the first year of R&D, most likely more money is needed in the first year. Money should be added or moved from later years to the first year.

- The Controls and Instrumentation Groups will need clear communication and interface documentation in order to plan and develop those systems for which they share responsibilities.

Recommendations

3. The vacuum labor needs to be included in the Controls labor.

4. The Instrumentation Labor needs to be profiled to account for items such as installation ramp-up and stretched to 5 years or one year added.

5.0 LE Linac Cavities & Cryomodules

Findings

- The basis of the cost estimate for the LE linac is derived largely from:

  1. R&D from HINS and extrapolation of those costs and;

  2. The program at FNAL in support of the ILC

- The primary sections of the LE linac are 1) Ion source, 2) RFQ 3) RT linac 4) low beta spoke linac 5) medium and high-beta spoke linac

  - HINS is addressing 1-4. Technical progress is being made.

  - The intent is that the Project-X RD&D program will address 5

- Project-X costing does not assume that any of the hardware developed under HINS will, in fact, be used in Project-X

- The overall project contingency of 40% is consistent with the substantial remaining technical development required for the LE linacs.

  More detailed findings:

- It is planned that HINS will develop and test at least one ore two low-beta single-spoke cryomodule meeting Project-X requirements

- Beta=0.4 single-spoke cavities and triple-spoke cavities and ancillary systems will be designed built and tested under the Project-X RD&D program; cryomodules for these cavities will be designed but *not* built before the proposed CD-3 from the ICD; the reviewers point out that for the HE linacs a complete beta=0.8 module is planned as part of the RD&D program.

- SRF infrastructure costs are not part of the cost estimate and assumed to either exist or be provided elsewhere.

- The costing includes a spare module for each of the three spoke cavity types even for the low beta spoke where only 2-3 units each are required

- The basis of estimate for the beta=0.2 single-spoke materials and fabrication is two existing R&D cavities.

- Costs for beta=0.4 single spoke and triple spoke cavities are scaled from the beta=0.2 R&D single-spokes.

- Costs for LE linac cryomodules are scaled in a “high-level” manner from the ILC R&D program. Eliminating of the 5 Kelvin shield is proposed as a possible modest cost reduction for all SRF linacs.

- The approximate cost of the RD&D for LE linac is $5M over three years. Of this approximately $2.3M is allotted for development of two types of cavities and modules where there has been almost no development to date. The RD&D budget for the HE linacs of $12M is in addition to the huge FNAL and worldwide R&D program in support of the ILC.

Comments

- The reviewers agree that the overall cost for the LE linac components is conservative. All important M&S items have been costed and manpower is ample. Significant cost savings are possible.

    - A proposed $8M cost savings due to possible increased performance in LE linacs appears reasonable. It is noted that R&D supporting this is still in its early stages.

    - Some additional cost savings are very likely since unit cavity costs are based on single prototypes. A 20% unit cavity cost reduction for the LE linac, for example, would lead to a savings of order $1M.

- However, both M&S and manpower for LE linac development needed in time to meet the ICD schedule are insufficient. Specifically, development of the triple-spoke modules is unlikely to be sufficiently well advanced at the end of the RD&D and in time for the proposed CD-3 in 2013.

- The cavity/cryomodule RD&D plan must include an evaluation of expected limitations to performance, especially those limits which may impact upgrade strategies. The upgrade path should not include large-scale replacement of cold linac components.

Recommendations

5. Re-evaluate the priorities and scale for LE and HE linac development. Proposed R&D resources should be aligned with a comprehensive and consistent assessment of the cost/schedule risks for all of the linac systems.

6. Based of the assertion that the overall planned LE linac RD&D program is insufficient, the reviewers recommend that RD&D for the LE linac be increased to achieve a comparable level of development as proposed for the HE linac.

6.0 HE Linac Cavities & Cryomodules

Findings

- No cost estimate range was provided. A conservative estimate was presented, 2.4 M$ material and services (M&S) and 0.4 M$ labor per HE Linac Cryomodule, along with cost basis and risks. This conservative estimate seems reasonable for this stage of the project.

- The cost estimate has been developed using actual costs for small quantity procurements resulting in a conservative estimate. The estimate is sound and continued refinement of the estimate may reduce the overall number particularly when quantity discounts are considered.

- The cost estimates for the major Project X systems were prepared in itemized excel spreadsheets and distributed to the committee for convenient examination, as well as summarized in various presentation slides.

- The RD&D schedule for the project is tight. There are several important development activities that are required to be completed in prior to CD2 and a clear plan for RD&D as well as PED plans will be required. The Beta 0.81 cryomodule and the higher power Fundamental Power Couplers need focused efforts.

- The labor estimates seem reasonable at the high level although the detailed supporting documentation is not as clear.

- It appears the materials and services, M&S, estimated are appropriate for the project. The present state of the project organization, specifically the lack of a WBS, makes it difficult to be sure all required items are included. An example is the labor effort for processing FPC.

- An exception to the conservative budgeting for the HE linac may be the RD&D estimate but without understanding the details of how the RD&D and the PED plans dovetail it is difficult to know if the RD&D estimate is sufficient.

- The design gradients in the ICD are 23MV/m and 25MV/m for the HE linac.

- Contingency of 40% is applied to all elements in the project role up. This is reasonable at this stage of the project.

- Cost reduction is possible in several areas. Refinements of the estimate as well as optimization of the Fermi Type-4 cryomodule design are examples of opportunities.

Comments

- The HE Linac cavity and cryomodules are largely based on existing ILC cryomodule designs. Continued effort on the cryomodule optimization should be focused on improvements in operational robustness i.e. performance and reliability. The existing Project X cryomodule designs are relatively mature at this time. Significant RD&D effort would be required to have a substantial impact on the cryomodule cost.

- Significant cost data is available from previous and ongoing work on the ILC project. The XFEL and ILC programs will provide valuable experience in procurement, fabrication, and assembly of cryomodules adding to the basis for cost and schedule estimate.

- A reasonable and straightforward cost reduction path for the HE linac is to use expected component cost savings for larger volume component orders.

- The spreadsheet for the High Energy linac cryomodules (Beta=0.81 and Beta=1) was incomplete as compared to other submitted systems in regard to itemizing M&S and labor. The itemized cost for coupler processing was not found in the supplied documentation. Also, there were small discrepancies between quoted costs in the spreadsheet and various slides. This inconsistency made comprehension of the sources of costs and high level organization difficult. This should be a very easy editorial remedy.

- Development work on the Beta 0.81 cryomodule was halted last year and needs to resume. This is a critical component for the Linac.

- The Fundamental Power Coupler average power operating point is a factor of 2 higher than the ILC cryomodule and needs work. This needs to proceed as early as possible.

- The Project X program is dependent on several other projects (HINS, ILC, SRF Infrastructure) for success. It is important to maintain a high level of contact between these.

- The cryomodule RD&D plan must include an evaluation of expected limitations to performance, especially those limits which may impact upgrade strategies. The upgrade path should not include wholesale - replacement of cold linac components.

- There were comments and suggestions from various committee members to reduce the linac length by operating at a higher cavity gradient given SRF cavity gradient progress in recent years.

- The decision to integrate HINS is strongly coupled to whether it is expected to serve as the Project X front end. The move toward integration could occur just following CD0. The RD&D plan must identify which technical milestones from the HINS program are needed, and when they are needed, in order to facilitate the decision to integrate

- The project is aware that the HOM issue is important and requires further analysis. The committee agrees that this is an important technical issue to follow.

Recommendations

7. Restart the Beta 0.81 cavity and cryomodule development.

8. Develop a plan for the development of the higher power FPC.

9. Develop a cost estimate that considers volume procurement savings as well as an accounting for cavity yield. A reasonable estimate for cost reduction assuming a 25% component M&S savings for higher volume orders translates to a module savings of 21%, or $2.13M total. However, if the 80% cavity yield was not accounted for in the $2.7M estimate, the module saving is then only 14% less than estimated, or $2.32M total.

10. The spreadsheet for the high energy linac cost should be filled out in greater completion and be consistent with costs quoted in other slides and screenshots of the MS Project schedule/budget. The various configurations of HE cryomodules, the cryomodule cost, and cryomodule quantity should be detailed in the spreadsheet.

11. It would be most prudent at this time to leave the budgeted cavity gradients as the ICD design target. This is especially true in light of the recent performance of the FLASH cryomodule #8 that performed at an average gradient of about 25MV/m despite using the best and latest module preparation practices. Progress on SRF gradients should be monitored throughout the RD&D phase for impact on HE linac length. At a minimum, any excess in Project X cavity performance will effectively serve as "installed" spare capacity.

12. Implementing of the presented speculation of omitting the HOM coupler could entail considerable risk to the budget and schedule. An experimental test of the need for an HOM coupler for the Project X beam may not occur until machine commissioning. If the coupler were removed and subsequently prove to be needed, a significant tear-down of the HE linac would be required. The HOM coupler should not be omitted unless there is compelling developmental work with a high degree of confidence that demonstrates that the HOM coupler is not required.

7.0 LE Linac Power Supplies & RF Distribution Balance

We would like to thank the RF team for providing excellent presentations. The RF team did a good job assembling and presenting a reasonable initial cost estimate for LE linac power supplies and RF distribution balance.

We find the overall M&S cost estimates for the LE power supplies and RF distribution and balance to be reasonable and appropriate for a pre-CD0 stage.

Findings

- Low-Energy (LE) linac power system for the 8-GeV PX is comprised of eight 2.5-MW klystrons operating at 325-MHz., four modulators/charging supplies and over 107 low- and high-power vector modulators.

- For the purpose of the cost estimate, the LE system is configured to provide 20 mA beam current at a final beam energy of 420 MeV with a beam pulse length of 1.25 mSec at a 5 Hz repetition rate.

- The LE linac pulsed modulator is based on an in-house "Bouncer" type design. FNAL has built five of these modulators in the past ten years.

- The cost estimate for the modulator system and the charging power supply is based on the internal experience, engineering estimate and recent procurement history.

- PX team is considering taking advantage of the technical advances in HV solid-state switching devices and is following the development of a Marx-type modulator at SLAC.

- PX team plans to evaluate 325-MHz IOT's to drive each cavity in place of 8x2.5 MW klystrons and 107 vector modulators as a part of the technical risks mitigation.

- For the current linac front-end configuration, 32 low- and 75 high-power vector modulators are required.

- PX team provided the scope of the estimated work of the system protection includes slow and fast RF interlocks. The RF protection system will interface with the modulator controls. The RF interlocks will control fast RF switch connecting the LLRF output to the klystron RF amplifier. The goal is to inhibit RF power in less than 1 microsecond to limit energy depositions below 1 Joule to prevent damages to the equipments.

- Several technical risks associated with the LLRF system were identified including field regulation of multiple cavities from a single RF power amplifier, resonance control of the spoke resonator cavities, regulation with low klystron power overhead and phase reference line distribution will be addressed in the RD&D plan.

- PX LLRF team is currently collaborating with various laboratories to address key technological challenges.

Comments

- Labor costs were generally a rough estimate based on past experience. The committee did not find it to be as accurate as the M&S costs. In most cases, the labor costs the LE RF power distribution systems are underestimated. The committee ask the project team to review its initial labor cost estimates and make proper adjustment, if necessary, to be consistent with the scope of the work and the M&S costs.

- The design choice of using fewer RF sources driving multiple cavities may provide a cost saving. However, the required vector modulators may represent a possible risk to the cost, performance and complexity.

- We encourage the PX team to fast track the test and characterization of vector modulators in HINS.

- We encourage the PX team to do a technical and cost feasibility study of using an IOT as an alternative RF source.

- We encourage the PX team to also consider solid-state RF drivers when possible. This option may have less technical and cost risks without compromising performance.

Recommendations

13. Review and provide better reliability specifications for the LE power supplies and RF distribution system for a more complete cost determination and impact.

14. Better define the upgrade path to minimize unforeseen and unexpected cost and technical impacts on the rf systems.

15. Do a technical and cost benefit analysis of using one RF source per RF load to determine and provide a quantitative basis to judge the potential gains or risks of the vector modulators.

16. Provide a refined labor estimates that realistically projects the upper cost range.

17. Develop a comprehensive and an integrated schedule that clearly identifies responsibilities, interfaces and interferences among various tasks. Make appropriate cost and schedule adjustments to mitigate risks.

8.0 HE Linac Power Supplies & RF Distribution Balance

Findings and Comments

- Overall, the costing group headed by John Reid did a good job of assembling an estimate for the HE Linac RF Systems based on the current machine description, which in some cases is not complete.

- *Is the cost range estimate complete?* The estimates of the rf system cost drivers are fairly thorough with the exception of the installation and commissioning costs, which will require the development of a more integrated schedule for the machine construction. The rf system estimates assume no provisions would be made to accommodate upgrades in repetition rate and pulse length, which is not case in some of the other areas, so better guidelines on future upgrades should be provided.

- *Has the cost range estimate been prepared using a sound estimate methodology?* The estimate is more of a 'most-likely' cost than an upper limit on the possible cost. While it is true that volume discounts were not included for most items, which should lower the costs, generally there was not an attempt to capture the high-end of the cost range for items, especially for the labor portion.

- *Is the schedule set forth reasonable?* Only a rough schedule was given that included four years of RD&D and four years of construction. While the production rate assumptions seem reasonable in most cases, the interferences among the various tasks has not been worked out in detail. For example, it was assumed the rf systems would be assembled in place in the klystron gallery although the gallery would be only available toward the end of the construction period, so some work may need to be staged elsewhere.

- *Are the labor estimates reasonable?* The labor requirements are generally a rough estimate based on past experience and are not as accurate as the M&S estimates. As people noted, labor is usually underestimated, and it would have been better to pad the costs with whatever historical factor is usually associated with the work. In my experience, this can easily be a factor of two, for example, due to unforeseen logistics problems and multiple demands on people's time. In a more factory-like production mode, this factor will hopefully be smaller.

- *Are the materials and services estimated those needed to deliver the facility?* In general, the group did a good job at identifying all the components needed to complete the rf systems. A few items seem to have gotten lost between the boundary definitions, but the associated costs are small and the boundaries in general were well defined among the six or more people doing the estimates.

- *Are the estimates for the M&S reasonable at this early stage of the project?* The M&S estimates were obtained in most cases by using actual costs of items recently purchased or by asking for quotes, which is a sound approach. In some cases, the project adjusted the estimates from foreign vendors to better reflect what US vendors would likely charge.

- *Is the estimated technical contingency appropriate / adequate?* The cost of spares are included in the various subsystems although without much justification for the quantities. In general, people did not have reliability specs (e.g., subsystem availability requirements), which would have helped the project determine the number of spares and whether added redundancy is needed so repair efforts could be deferred.

  Although Steve Holmes' guidelines to the reviewers noted that 'to first order you should accept that the configuration described will meet the technical goals,' people did well to identify the areas where problems may arise. Of particular concern are the reliability of the L-band vector modulators, which are under development and have not been high power tested, and the ability of the LLRF system to regulate the beam energy during the pulse using the vector modulators, which have inherent delay times.

- *Are there ways the cost could be reduced?* Everyone providing estimates also noted areas in which the costs could be reduced, but the savings would not be large (at least relative to the project cost), and in many cases, the project would entail incurring more risk. For example, the modulator group is considering a distributed charging system and is willing to adopt the Marx approach if it proved to be as reliable as the Bouncer design and had a lower cost.

Recommendations

18. Work to better define the reliability specs for each rf subsystem to allow a better assessment of their cost implications. In particular, this should be done for the modulators which have historically been a major cause of downtime. Also, the upgrade path needs to be defined so everyone is working with the same assumptions. For the rf systems, these choices could have a major impact on both the RD&D and construction costs.

19. Do a second pass of the cost estimate, this time using more historically justified labor estimates to capture the high end of the cost range. Also work to produce an integrated schedule so any interferences among the competing tasks are identified and adjustments to the schedule and costs can be made. Finally, estimate the possible cost impacts of the technical risk items noted above. In particular, it is recommended that a design with one rf source per rf load be costed to provide a quantitative basis to judge the potential gains or risks of the vector modulators.

9.0 Cryogenics

Findings

- Multiple valid costing methods were used for the cryogenics system that is complete and reasonable for a system at this stage of the project. The assumptions (which are supportive interfaces from other projects groups such as civil), appear to be complete and integrated into the work plan and schedule. The work plan schedule durations and sequencing include all anticipated major cryogenic tasks which supported by reasonable and appropriate FTE labor estimates according to general labor categories. Material and services in support of the work plan are included in the estimate and are reasonable. Appropriate cost saving reuse of existing supportive cryogenic equipment is included within the work plan. Based on the presentations, the cryogenic system should be able to built at the cost stated with only small draws on project contingency

- The technical content is reasonable with anticipated risks for the cryogenic system are low to medium.

- A key issue for success in the cryogenic system is the clear understanding between the cryogenics group and other Project X groups on what components and systems are being provided by whom along with a clear, fixed understanding of the technical requirements that the cryogenic system must meet

Comments

- Further cost saving should be realized should a systemic process cycle optimization study be conducted during CD-0 or the early stages of CD-1. When incorporated into other projects this has proven to be very effective in reducing the size or number of components which would normally be supplied. The information generated by the study would then be incorporated into the equipment specifications which are generated during CD-1.

Recommendations

20. The cryogenic group should confirm with their supportive groups (civil, software, controls, personnel safety systems, etc.) that the requirements and costs of their support has been included within their project estimates and that their schedule planning aligns and is integrated with the needs of the cryogenic system project plan. At this stage of the project this could be in the form of simple confirming memos until more formal project management documentation is in place.

21. Project X should clearly identify which components of the system are ready for the upgrade and which will need to be changed. Those components that are ready for the upgrade should have their capabilities protected during any subsequent value engineering process so that they are still ready for the upgrade.

10.0 Conventional Facilities

Findings

- Cost estimate data for Conventional Facilities is based on the December 2008 ICD. Pricing is based on 2009 dollars, no escalation or contingency are included. CF team utilized Means Cost Data and prior Fermi experience to develop the estimate. The estimate utilizes a 15% additive factor to R.S. Means based construction estimates to account for added DOE/FNAL requirements. A combination of Fermi labor and A/E contracts will be utilized to complete engineering and design for conventional facilities.

- Extensive development has been completed on prior project concepts (since 2000). This provides substantial information basis for current plans.

- At least two other significant projects (Mu2e, DUSEL) are being planned for concurrent design and construction in this area of the Fermi Site.

- There are technically challenging construction activities that require crossing under the existing Main Ring and Anti-proton tunnel and intersecting with the Main Ring at the injection point.

- The construction will require dewatering of areas with activated groundwater and excavation of activated soils.

- The project will impact over 65 acres of wetlands. Mitigation of these wetlands will be required however the project team is experienced in this process. It is assumed that an Environmental Assessment will result in a Finding of No Significant Impact with regard to this project.

- The Conventional Facilities estimate includes an allowance of $18M to provide demolition to meet the DOE space offset requirements.

- The Conventional Facilities estimate includes an allowance of $20M to provide upgrade, replacement and repair of miscellaneous infrastructure required to support the project.

- A schedule indicating the relation of CF design & construction activities and interdependence with design & construction of accelerator facilities has not been completed.

- A preliminary radiation shielding analysis has not been prepared yet to determine shielding requirements for CF construction or other measures to minimize/prevent soil and groundwater activation.

- The project indicated the currently proposed size of the cryo service building may be larger than necessary

- There are currently no plans to pursue LEED certification for the CF construction however LEED principles are being incorporated in the design where feasible.

- There are no current plans to utilize an independent commissioning contractor for testing and start-up of building equipment and systems. Commissioning will be completed by FNAL staff.

- The conventional facilities are intended to incorporate features to accommodate several planned upgrade paths for the accelerator facilities including increases in energy.

- The schedule allows 13 months from CD-2 to CD-3 – the period to advance preliminary design to detailed construction documents.

- The schedule allows 4 years and seven months from CD-3 to CD-4 – the period available for construction of conventional facilities.

Comments

- The cost estimate level of detail is sufficient for this early stage of development and benefits from development of earlier project concepts however there are a number of substantial allowances included in the estimate. Additional estimate confidence would be gained by further development of the basis for the allowances for the RF area, Infrastructure support and Space offset and there may be opportunities for cost reduction in these allowances.

- The staffing levels required for specific scope are not clearly detailed. Additional work is needed defining the staffing resources and responsibilities needed for PED and RD&D funding. The funding types seem to merge together.

- Construction scope and estimates seem appropriate, however, some of the square foot costs for buildings which form the basis of the estimate are assumed to include supporting systems such as fire protection, electric distribution and lighting and plumbing. When these added systems are included, the square foot costs are likely to be higher.

- The 40% contingency is appropriate for this early level of estimate development given the uncertainty in facility requirements definition at this time.

- The project has an allowance of $20M to provide upgrade, replacement and repair of miscellaneous infrastructure required to support the project. The details of this allowance include a variety of on-site utilities and facilities that are not broken out in the estimate. Leaving this as a lump-sum allowance increases the likelihood that it may be deleted as a cost saving measure when it includes elements that are important to the project.

- The other significant projects (Mu2e, DUSEL) being planned for concurrent design and construction in this area of the Fermi Site may impact Project X schedule if performed simultaneously. Funding for all of these proposed projects is uncertain. Coordination and staffing requirements for multiple concurrent projects may overwhelm current laboratory resources. Dedicated resources will be needed to meet stringent project requirements. The Laboratory should develop plans for staffing and support of multiple projects.

- The most technically demanding construction activity is likely to be passing under existing tunnels and rejoining the tunnel in the intersection region. FNAL is experienced in this type of construction yet there is currently limited understanding of how this will be accomplished.

- A significant portion of the construction will require dewatering of areas with activated groundwater and excavation of activated soils. The current shielding basis in the estimate is also likely to enable continued formation of activated soils and groundwater. If this is no longer acceptable to regulatory authorities there is significant cost and schedule risk associated with activated materials during construction or additional shielding and/or impervious capping to prevent activation.

- DOE Order 430.2B includes the following requirement: Achieve a LEED Gold certification for all new construction, and major building renovations in excess of $5 million. Current project plans do not comply with this order. The project should review this Order for compliance requirements and commit or gain a waiver for environmental and sustainability issues.

- Solutions to the wetland mitigation include creation of alternate on-site wetlands or purchase of of-site wetland credits. It may be feasible to create on-site wetlands that address the wetlands requirements and provide LEED credit for designation of a nature preserve.

- The project has an allowance of $18M to provide demolition to meet the DOE space offset requirements. It may be possible to pursue waiver of the on-site demolition requirement at significant cost savings to the project.

- The validity of the design and construction schedule can not be verified without a high level schedule that indicates key dependencies between accelerator design and construction and conventional facility design and construction. The 13 month period from CD-2 to CD-3 will be difficult to complete detailed construction packages unless all accelerator facility requirements are well defined and relatively fixed at CD-2. The 4 year 7 month construction period may offer opportunities for acceleration of conventional facilities and cost reduction but cannot be determined with current information.

- The absence of a preliminary radiation shielding analysis to determine shielding requirements for CF construction increases the risk for cost increase. This is exacerbated by the need to allow for future higher energy upgrades to the accelerator and potential regulatory drivers to reduce activation products in groundwater and soils.

- A more definitive sizing basis for the Cryo service building may provide opportunities for cost savings.

Recommendations

22. Review items delineated as allowances in the cost estimate. Incorporate into specific areas of the cost estimate or provide scope assumption basis for the allowance.

23. Clarify what costs are operating funded RD&D versus PED.

24. Provide a design basis for shielding requirements at the desired energy level.

25. Develop the schedule to a level that reflects interdependencies between conventional facilities and the other technical elements to confirm schedule capabilities.

11.0 Project Cost and Schedule

11.1 Project Management (Office) Cost & Schedule

Findings

- The proposed Project Management Office and organizational structure appears, in first approximation, reasonable and appropriate overall, in terms of covering the respective management responsibilities.

- An overall schedule is only available at a very rudimentary stage (basically CD milestones, and estimates for overall R&D, LE- and HE-linac and conventional facility construction periods necessary). The one exception is the PED schedule (containing a significant fraction of the R&D) which has been worked out in detail and with resource loading, along the methods for cost estimate mentioned.

Comments

- Staffing of the Project Management Office is considered by the Committee on the lean side, possibly too lean. This depends, however, on the detailed arrangements to be made for matrixing in existing Laboratory services, which has not been worked out yet in any quantitative detail.

- A robust Project Management Office will be necessary on a project of this scope and size, particularly given the proposed collaborating structure. Sufficient staffing at the interfaces is needed to effectively and coherently carry out the tasks (e.g. procurement, ES&H and QA, reporting etc.). In particular the monitoring and reporting requirements need full understanding of budget/cost/schedule software to carry out effectively project specific reporting, including EVMS, risk management, system integration, change process activities, contingency budgeting etc. must be considered. This effort should not be minimized.

- It seems desirable to define a first outline of a WBS beyond level 2.

- The cost for supporting regular advisory committee activities does not appear in the Project Management Office.

Recommendations

26. Establish a clear overall management and organizational diagram, delineating responsibilities, interfacing and matrixing with Laboratory services, with collaborating institutions, and project reporting within Fermilab and with DOE.

27. Check the list of responsibilities and deliverables with DOE O 413.3A for completeness.

28. Define the Project Management tools to be implemented.

29. Carry out the next iteration on PM cost (and schedule) using the structure established under recommendation 25.

30. Develop an approximate WBS to a lower level, such as level 4.

11.2 Overall Project Cost, Scheduling and Funding

Findings

- Project X scope presented an 8-GeV H- superconducting linac, which included a Low Energy Linac from 325 MHz to 420 MeV, a High Energy Linac from 1.3 GHz to 8 GeV, conventional facilities which include a beam transport line and assorted modifications to existing Fermilab infrastructure. The project scope is consistent with the HEPAP/P5 recommendation and supported by an Initial Configuration Document (V1.0, 31 October 2008)

- The Project X Total Project Cost (TPC) was estimated at of $1.49B then-year dollars, which included fully burdened costs, escalation, and a top-down estimate of 40% contingency.

- The project presented a high-level schedule with the major project phases logically linked. CD-4 was projected as March 2018. No optimization of schedule or resource-leveling was performed at this time. The primary critical path drivers were identified as cryomodule production and civil construction.

- The cost estimate assumed the normal Fermilab labor rates and institutional indirect rates for labor and M&S.

Comments

- The Project X TPC, with the assumed out-year escalation, construction / funding schedule and commodity pricing, can be considered an upper bound for the TPC. Opportunities for cost reductions appear to be possible. Some areas that might prove fruitful are:
  - Lower causal beneficial rate that accurately reflects the projects indirect costs.
  - Optimize the overall schedule by evaluating the critical path activities.
  - Optimize the conventional facilities 'soft costs'.
  - Develop an acquisition strategy that optimizes 'make versus buy' decisions.
  - Optimization of the project capabilities and technical systems

- At this stage, the project should evaluate scope contingency strategies, one of which may be to evaluate the science case behind a 6GeV SC linac with an option (or upgrade path) to an 8 Gev linac. Other contingencies in scope should be carefully evaluated as well.

- The top-down cost contingency of 40% is appropriate for this stage of the project and should be maintained through CD-1.

- The schedule presented for PED seems reasonable. But the mix of R&D activities with PED makes a clear identification of cost and schedule for these different project phases difficult. Project management should as soon as possible obtain clear guidance from its DOE program office on the constraints (or lack thereof) for different project phases (and thus 'colors' of funding).

- A high-level, broadly-based risk management plan should be developed in the next iteration. Some risks that should be evaluated:
  - Programmatic - such as impacts to existing science programs during the construction/installation phase
  - Technical - related to cryomodules, SC cavities, power tradeoffs, etc.
  - Business - such as currency and large commodity procurements
  - Environmental - such as wetland mitigation, site access

Recommendations

31. For the next cost roll-up, reevaluate the TPC in light of some of the suggested options for cost reductions.

32. In preparation for CD-1, perform a high-level risk analysis to identify the major risks to the project and prepare appropriate mitigation strategies.

33. Prepare a preliminary acquisition strategy which includes a discussion of collaboration management, organizational structure, and a comprehensive procurement plan.

12.0 Charge Questions

12.1 Is the cost range estimate complete?

Based on the methodology used for the estimates performed for version 1.1 (15-Mar-09) of the Initial Configuration Document (ICD), an appropriate contingency, and credible arguments provided by the project team of future additional optimization and cost reduction, the upper bound of the cost range ($1.49B) estimate appears reasonable, appropriate and reliable assuming the DOE escalation rates are correct, and the construction/funding schedule holds. Several members of the committee felt this number is near the high end of the cost range.

12.2 Has the cost range estimate been prepared using a sound estimate methodology?

The overall approach to establishing cost estimates for the project seems adequate. It is heavily based on, and scaled from existing or prototyped technology and/or facilities (ILC, JLab, SNS, ANL…) and has a clear understanding of present Fermilab infrastructures and facilities. It utilizes DOE escalation rates and a contingency considered appropriate and adequate for this stage of the project.

12.3 Is the schedule set forth reasonable?

The technical schedule has been developed for the current ICD and appears reasonable. It will provide the backbone for the fully resource-loaded complete project schedule. However, with the exception of PED, the latter has not been developed yet.

12.4 Are the labor estimates reasonable?

Much of the labor estimates are scaled from R&D and prototyping (in particular within the ILC context), from recent facility projects (SNS, FLASH), and from instrumentation and civil construction activities at Fermilab and collaborating laboratories. This provides for a reasonable FTE estimate of personnel, with efficiencies appropriately taken into account. The labor cost rates at this point are taken as the Fermilab rates which, the Committee feels is an appropriate median value.

12.5 Are the materials and services estimated those needed to deliver the facility?

The reviewers find that all of the major materials and services needed to deliver the facility have been included in the cost estimate.

12.6 Are the estimates for the M&S reasonable at this early stage of the project?

Similarly, cost estimates on M&S for the construction of the facility are reasonable for this stage of the project, and in the case of many components represent an upper bound on cost. One exception is M&S for the RD&D program which is insufficient to meet the proposed ICD schedule.

12.7 Is the estimated contingency appropriate / adequate?

The contingency appears appropriate to cover technical performance risk, as well as cost and schedule risk from technical performance issues. The Committee feels though that adopting the suggested DOE escalation rates over such an extended time period poses some additional risk which the project team needs to consider.

12.8 Are there ways the cost could be reduced?

Dana Arenius: The cryogenic system should realize further cost reductions should a system process cycle optimization study be conducted during the CD-0 project phase. The study should result in further or smaller equipment components which can be folded into the equipment specification development during CD-1. This method has proven very successful in other programs.

Walter Henning: Overhead structure (75% "Divisional Overhead" seems too high, but depends on how Fermilab wants to handle a new large project vs. their programmatic funding etc... As a single-purpose lab it will be different from the way it is - or can be - done in multi-purpose lab structure...)

Karen Hellman: On the Conventional Facilities cost estimate, there is an $18M item for space offset costs. This requirement could be removed if a waiver is approved by DOE. The submittal for the waiver should be made by the Federal Project Director prior to CD-1 approval.

Thomas Roser: The biggest cost savings could be obtained from reducing the linac energy to 6 GeV or as low as is possible and still be able to inject into the MI. The Recycler can still be filled by injecting into the MI at 6 GeV and then accelerating to 8 GeV before transfer to the Recycler. Very little time would be lost in the MI cycle for this. At 6 GeV there would be no need for the cold beam screen and the transfer line could be shorter with higher magnetic fields. For the upgrade stay at 6 GeV to save civil construction cost and just increase intensity and repetition rate of the linac and explore how well one can produce pions/muons for a neutrino factory or muon collider.

Chris Adolphsen: Run the linac at a lower repetition rate since only 2 of every 7 pulses are currently being used – this change will apparently be incorporated in the next design iteration. As much as possible, arrange to buy the HE linac components from the vendors who will nominally be ramping down production for XFEL in 2013. The should also accelerate the construction schedule. Assume a higher gradient in the beta = 1 cavities, perhaps 30 MV/m based on recent progress and a reasonable extrapolation over the next four years when 800 cavities will be produced for XFEL.

12.9 Is the PED funding profile adequately defined to support a request for PED funds later this year?

The Project presented a FY11 – FY13 base cost profile for R&D and PED activities combined, which summed to $72.9M. Adding in burdens (at the Fermilab G&A rate) and 20% contingency, the Project X R&D-PED total is ~$135M.

Comparing the R&D and PED fractions to LCLS and NSLS-II projects, an appropriate R&D budget for Project X is $45M, and PED budget is $90M. The profile below is compatible with other projects, however the project team should vet this against the Project X projections.

	FY11	FY12	FY13	total
R&D + PED (unloaded)	20	41	12	73
R&D + PED (load + cont)	37	75	23	136
R&D (load + cont)	20	10	10	40
PED (load + cont)	17	65	13	95
check sum	37	75	23	135

Issued March 31, 2009

Appendices

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Reviewers' Contact Information

Participant List

Table of Recommendations

Appendix A

Cost Estimate

Director's Preliminary Cost and Schedule Review of Project X
Based on the Initial Configuration Document
March 16-17, 2009

Project X Cost Estimate by WBS Level 2

		Total	SWF	M&S
1	Project X	$743,545,773	$188,942,289	$554,603,484
1.1	Project Management	$23,486,856	$19,889,856	$3,597,000
1.2	LE Linac	$102,709,193	$22,495,803	$80,213,390
1.3	HE Linac	$222,568,170	$27,096,446	$195,471,724
1.4	MI/RR	$61,680,357	$12,071,807	$49,608,550
1.5	PX Instrumentation	$22,999,772	$15,645,066	$7,354,706
1.6	Controls	$26,426,678	$20,818,858	$5,607,820
1.7	Cryogenics	$47,641,600	$6,679,600	$40,962,000
1.8	Utilities & Interlocks	$7,625,914	$1,962,620	$5,663,294
1.9	Conventional Facilities	$195,359,000	$46,750,000	$148,609,000
1.10	8 GeV	$25,497,919	$8,791,919	$16,706,000
1.11	Integration	$7,550,314	$6,740,314	$810,000

FY 09 $, no burden, no contingency, and no escalation

Appendix B

Charge

Director's Preliminary Cost and Schedule Review of Project X Based on the Initial Configuration Document March 16-17, 2009

The Committee is to conduct a Director's Preliminary Mission Need Review of the proposed Project X at Fermilab. The Committee is to review the cost range estimate that has been prepared based on the initial configuration set forth in the Project X Initial Configuration Document (ICD).

The HEPAP / P5 June 2008 Report supports three particular future initiatives that rely on the development of a very high intensity proton source at Fermilab:

A neutrino beam for long baseline neutrino oscillation experiments: A new 2 megawatt proton source with proton energies between 50 and 120 GeV would produce intense neutrino beams, directed toward a large detector located in a distant underground laboratory

Kaon and muon based precision experiments exploiting 8 GeV protons from Fermilab's Recycler, running simultaneously with the neutrino program: These could include a world leading muon-to-electron conversion experiment and world leading rare kaon decay experiments.

A path toward a muon source for a possible future neutrino factory and, potentially, a muon collider at the Energy Frontier: This path requires that the new 8 GeV proton source have significant upgrade potential.

In light of the need to integrate these opportunities into a coherent program for the future of U.S. HEP the committee "recommends an R&D program in the immediate future to design a multi-megawatt proton source at Fermilab and a neutrino beamline to DUSEL…"

Assuming the ICD describes at the early concept level a facility that will meet the Mission Need (multi-megawatt proton source) set forth by the HEPAP / P5 Subpanel, the committee should address the following questions / topics:

1. Is the cost range estimate complete?
2. Has the cost range estimate been prepared using a sound estimate methodology?
3. Is the schedule set forth reasonable?
4. Are the labor estimates reasonable?
5. Are the materials and services estimated those needed to deliver the facility?
6. Are the estimates for the M&S reasonable at this early stage of the project?
7. Is the estimated technical contingency appropriate / adequate?
8. Are there ways the cost could be reduced?
9. (Is the PED funding profile adequately defined to support a request for PED funds later this year?)

The Committee should conduct the review, share their findings / comments / recommendations with the Project X Team and Fermilab management in a closeout meeting, develop a report and submit it to the Fermilab Directorate soon after the review.

Appendix C

Agenda

Director's Preliminary Cost and Schedule Review of Project X Based on the Initial Configuration Document March 16 - 17, 2009

Start	End	Time	Subject	Presenter
Monday, March 16, 2009				
8:00 AM	8:45 AM	0:45	Executive Session, *One North (WH1NW)*	Ed Temple
8:50 AM	9:00 AM	0:10	Project X Introduction, *One West (WH1W)*	Steve Holmes
9:00 AM	9:30 AM	0:30	Project X Initial Configuration, *One West (WH1W)*	Paul Derwent
9:30 AM	10:15 AM	0:45	Project X Systems and Interfaces, *One West (WH1W)*	Sergei Nagaitsev
10:15 AM	10:30 AM	0:15	**BREAK (outside One West)**	
10:30 AM	11:15 AM	0:45	Cost Estimate Development Process, *One West (WH1W)*	Jim Kerby
11:15 AM	12:30 PM	1:15	Breakout Sessions	
			• Project Management; Cost and Schedule Development; and PM Costs, *Black Hole (WH2NW)*	Steve Holmes*
			• Cavities & Cryomodules for LE Linac and HE Linac, *One North (WH1NW)*	Mark Champion*
			• RF for LE Linac and HE Linac, *Theory 3NW Conf. Room (WH3NW)*	John Reid*
			• Main Injector / Recycler Ring; Transfer Line; and Injection, *Hornets' Nest (WH8XO)*	Dave Johnson*
			• Instrumentation and Controls, *The Req Room (WH4NW)*	Manfred Wendt*
			• Cryogenics, *Snake Pit (WH2NE)*	Arkaidy Klebaner*
			• Conventional Facilities, *ConFESSional (WH5E)*	Russ Alber*
12:30 PM	1:30 PM	1:00	**LUNCH (WH2X)**	
1:30 PM	3:15 PM	1:45	Continue Breakout Sessions as Above	
3:15 PM	3:30 PM	0:15	**BREAK**	
3:30 PM	4:45 PM	1:15	Continue Breakout Sessions as Above	
4:45 PM	6:00 PM	1:15	Executive Session, *One North (WH1NW)*	Ed Temple
7:00 PM			Dinner at Chez Leon	
Tuesday, March 17, 2009				
8:00 AM	9:00 AM	1:00	Executive Session, *One North (WH1NW*)	
9:00 AM	10:00 AM	1:00	Answers to Questions, *One North (WH1NW)*	
10:00 AM	1:20 PM	3:20	Report Writing with Working Lunch, *One North (WH1NW)* Email Report to terickson@fnal.gov at or before 1:20 PM	
2:00 PM	4:30 PM	2:30	Closeout Dry Run, *One North (WH1NW)*	
4:30 PM	5:30 PM	1:00	Closeout Presentations with Fermilab and Project X, *Curia II (WH2SW)*	
5:30 PM			Adjourn	

* Indicates Breakout Chairs

Appendix D

Report Outline and Reviewer Writing Assignments

Director's Preliminary Cost and Schedule Review of Project X Based on the Initial Configuration Document March 16 - 17, 2009

Executive Summary	Ed Temple
1.0 Introduction	Dean Hoffer
2.0 Transfer Lines & Injection	Deepak Raparia Kathy Harkay
3.0 Main Injector Recycler Ring	Thomas Roser Alexis Smith-Baumann
4.0 Instrument & Controls	Willem Blokland Mike Spata
5.0 LE Linac Cavities & Cryomodules	Michael Kelly Eric Chojnacki Joe Preble Marc Ross
6.0 HE Linac Cavities & Cryomodules	Joe Preble Eric Chojnacki Michael Kelly Marc Ross
7.0 LE Linac Power Supplies & RF Distribution Balance	Ali Nassiri Chris Adolphsen Richard York
8.0 HE Linac Power Supplies & RF Distribution Balance	Chris Adolphsen Ali Nassiri Richard York
9.0 Cryogenics	Dana Arenius John Weisend
10.0 Conventional Facilities	Karen Hellman Martin Fallier
11.0 Project Management Cost & Schedule	Walter Henning Mark Reichanadter Dean Hoffer Ed Temple
12.0 Charge Questions	
12.1 Is the cost range estimate complete?	Walter Henning Mark Reichanadter
12.2 Has the cost range estimate been prepared using a sound estimate methodology?	Walter Henning Mark Reichanadter
12.3 Is the schedule set forth reasonable?	Walter Henning Mark Reichanadter
12.4 Are the labor estimates reasonable?	Walter Henning Mark Reichanadter
12.5 Are the materials and services estimated those needed to deliver the facility?	Michael Kelly Dana Arenius

12.6 Are the estimates for the M&S reasonable at this early stage of the project?	Michael Kelly Dana Arenius
12.7 Is the estimated contingency appropriate / adequate?	Walter Henning Mark Reichanadter
12.8 Are there ways the cost could be reduced?	Chris Adolphsen
12.9 Is the PED funding profile adequately defined to support a request for PED funds later this year?	Mark Reichanadter Dean Hoffer

- Note underlined names are the primary writer.

Appendix E

Reviewers' Contact Information

Reviewer Contact Information
Director's Preliminary Cost/Schedule Review of Project X
3/16/2009 - 3/17/2009

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Page 1 Reviewer List 3/11/2009

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Director's Preliminary Cost/Schedule Review of Project X
3/16/2009 - 3/17/2009

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Appendix F

Participant List

Director's Preliminary Cost and Schedule Review of Project X Based on the Initial Configuration Document March 16 - 17, 2009

Role	Last Name	First Name	Affiliation
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Appendix G

Table of Recommendations

Director's Preliminary Cost and Schedule Review of Project X
Based on the Initial Configuration Document
March 16 - 17, 2009

#	Recommendation	Assigned To	Status/ Action	Date
	2.0 Transfer Lines & Injection			
1	Determine what is the beam loss budget based on maximum acceptable uncontrolled losses, and develop requirements for space charge tune shift based on beam dynamics modeling.			
	3.0 Main Injector Recycler Ring			
2	Develop a complete beam loss budget for the Recycler Ring and Main Injector and design and cost the appropriate mitigation schemes such as additional tunnel shielding, shielded collimators and/or quick replacement of beam components.			
	4.0 Instrument & Controls			
3	The vacuum labor needs to be included in the Controls labor.			
4	The Instrumentation Labor needs to be profiled to account for items such as installation ramp-up and stretched to 5 years or one year added.			
	5.0 LE Linac Cavities & Cryomodules			

#	Recommendation	Assigned To	Status/ Action	Date
5	Re-evaluate the priorities and scale for LE and HE linac development. Proposed R&D resources should be aligned with a comprehensive and consistent assessment of the cost/schedule risks for all of the linac systems.			
6	Based of the assertion that the overall planned LE linac RD&D program is insufficient, the reviewers recommend that RD&D for the LE linac be increased to achieve a comparable level of development as proposed for the HE linac.			
	6.0 HE Linac Cavities & Cryomodules			
7	Restart the Beta 0.81 cavity and cryomodule development.			
8	Develop a plan for the development of the higher power FPC.			
9	Develop a cost estimate that considers volume procurement savings as well as an accounting for cavity yield. A reasonable estimate for cost reduction assuming a 25% component M&S savings for higher volume orders translates to a module savings of 21%, or $2.13M total. However, if the 80% cavity yield was not accounted for in the $2.7M estimate, the module saving is then only 14% less than estimated, or $2.32M total.			
10	The spreadsheet for the high energy linac cost should be filled out in greater completion and be consistent with costs quoted in other slides and screenshots of the MS Project schedule/budget. The various configurations of HE cryomodules, the cryomodule cost, and cryomodule quantity should be detailed in the spreadsheet.			

#	Recommendation	Assigned To	Status/ Action	Date
11	It would be most prudent at this time to leave the budgeted cavity gradients as the ICD design target. This is especially true in light of the recent performance of the FLASH cryomodule #8 that performed at an average gradient of about 25MV/m despite using the best and latest module preparation practices. Progress on SRF gradients should be monitored throughout the RD&D phase for impact on HE linac length. At a minimum, any excess in Project X cavity performance will effectively serve as "installed" spare capacity.			
12	Implementing of the presented speculation of omitting the HOM coupler could entail considerable risk to the budget and schedule. An experimental test of the need for an HOM coupler for the Project X beam may not occur until machine commissioning. If the coupler were removed and subsequently prove to be needed, a significant tear-down of the HE linac would be required. The HOM coupler should not be omitted unless there is compelling developmental work with a high degree of confidence that demonstrates that the HOM coupler is not required.			
	7.0 LE Linac Power Supplies & RF Distribution Balance			
13	Review and provide better reliability specifications for the LE power supplies and RF distribution system for a more complete cost determination and impact.			
14	Better define the upgrade path to minimize unforeseen and unexpected cost and technical impacts on the rf systems.			

#	Recommendation	Assigned To	Status/ Action	Date
15	Do a technical and cost benefit analysis of using one RF source per RF load to determine and provide a quantitative basis to judge the potential gains or risks of the vector modulators.			
16	Provide a refined labor estimates that realistically projects the upper cost range.			
17	Develop a comprehensive and an integrated schedule that clearly identifies responsibilities, interfaces and interferences among various tasks. Make appropriate cost and schedule adjustments to mitigate risks.			
	8.0 HE Linac Power Supplies & RF Distribution Balance			
18	Work to better define the reliability specs for each rf subsystem to allow a better assessment of their cost implications. In particular, this should be done for the modulators which have historically been a major cause of downtime. Also, the upgrade path needs to be defined so everyone is working with the same assumptions. For the rf systems, these choices could have a major impact on both the RD&D and construction costs.			

#	Recommendation	Assigned To	Status/ Action	Date
19	Do a second pass of the cost estimate, this time using more historically justified labor estimates to capture the high end of the cost range. Also work to produce an integrated schedule so any interferences among the competing tasks are identified and adjustments to the schedule and costs can be made. Finally, estimate the possible cost impacts of the technical risk items noted above. In particular, it is recommended that a design with one rf source per rf load be costed to provide a quantitative basis to judge the potential gains or risks of the vector modulators			
	9.0 Cryogenics			
20	The cryogenic group should confirm with their supportive groups (civil, software, controls, personnel safety systems, etc.) that the requirements and costs of their support has been included within their project estimates and that their schedule planning aligns and is integrated with the needs of the cryogenic system project plan. At this stage of the project this could be in the form of simple confirming memos until more formal project management documentation is in place.			
21	Project X should clearly identify which components of the system are ready for the upgrade and which will need to be changed. Those components that are ready for the upgrade should have their capabilities protected during any subsequent value engineering process so that they are still ready for the upgrade.			
	10.0 Conventional Facilities			

#	Recommendation	Assigned To	Status/ Action	Date
22	Review items delineated as allowances in the cost estimate. Incorporate into specific areas of the cost estimate or provide scope assumption basis for the allowance.			
23	Clarify what costs are operating funded RD&D versus PED.			
24	Provide a design basis for shielding requirements at the desired energy level.			
25	Develop the schedule to a level that reflects interdependencies between conventional facilities and the other technical elements to confirm schedule capabilities.			
	11.0 Project Cost and Schedule			
	11.1 Project Management (Office)Cost & Schedule			
26	Establish a clear overall management and organizational diagram, delineating responsibilities, interfacing and matrixing with Laboratory services, with collaborating institutions, and project reporting within Fermilab and with DOE.			
27	Check the list of responsibilities and deliverables with DOE O 413.3A for completeness.			
28	Define the Project Management tools to be implemented.			
29	Carry out the next iteration on PM cost (and schedule) using the structure established under recommendation 25.			
30	Develop an approximate WBS to a lower level, such as level 4.			

#	Recommendation	Assigned To	Status/ Action	Date
	11.2 Overall Project Cost, Scheduling and Funding			
31	For the next cost roll-up, reevaluate the TPC in light of some of the suggested options for cost reductions.			
32	In preparation for CD-1, perform a high-level risk analysis to identify the major risks to the project and prepare appropriate mitigation strategies.			
33	Prepare a preliminary acquisition strategy which includes a discussion of collaboration management, organizational structure, and a comprehensive procurement plan.			