Closeout Report on the DOE/SC Status Review of the

Proton Improvement Plan (PIP-II)

Fermi National Accelerator Laboratory

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

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Charge Questions

1. Technical Design: Is the conceptual design for the PIP-II linac sound and likely to meet the specified technical performance requirements? Are R&D efforts being effectively managed to maximize benefits and minimize technical risks to the project?

2. Scope: Is the project's scope sufficiently well-defined to support the preliminary cost and schedule estimates?

3. Cost and Schedule: Are the cost and schedule estimates sufficiently well-defined and of adequate maturity to support the forecasted critical decision milestones and cost range?

4. Management: Is the project being properly managed at this stage? Does the management team possess the skills, expertise, and experience necessary to successfully execute the project? Are plans to identify and allocate staffing and resources consistent with current funding guidance?

5. Environment, Safety, and Health: Is environment, safety, and health being properly addressed given the project's current stage of development?

6. India Institutions and Fermilab Collaboration (IIFC): Is the collaboration proceeding satisfactorily towards meeting the goals outlined in the Joint R&D document? Will the deliverables outlined in the Joint R&D document position India for a successful contribution to the PIP-II construction phase?

WG1: Charge element 1 response

Is the conceptual design for the PIP-II linac sound and likely to meet the specified technical performance requirements? Are R&D efforts being effectively managed to maximize benefits and minimize technical risks to the project?

Yes, the design of the SC linac is well advanced including functional specs, detailed drawings and fabrication plans - this is a continuation of a 7+ year effort to design and demonstrate components for a high intensity proton driver. However, at this stage, the design documentation may be too detailed in some cases if cost and risk reduction strategies will be implemented.

Tests so far of cavity performance are very encouraging. Given the small cavity bandwidth, pulse operation is likely to be problematic. Thus the facility may need to run CW so criteria should be established on how and when such a decision would be made (which will have implications for how the cryoplant is optimized for initial operation). Even CW operation may present problems with the JT valves in the CMs: the LCLS-II experience should shed light on this. The details of cryogenic operation were not presented.

WG1: Charge element 1 response

The R&D program is well organized for the linac effort – The Project has tests planned of critical subsystems to ensure they work in PIP-II. We note however that the test of HB650 CM comes fairly late in the program.

While each of the ring upgrades are reasonable, increasing power while keeping losses manageable is a difficult task. Subtle collective effects can lead to losses that can be very difficult to control. Adding to the difficulty is the change in the timing system due to the change in booster rep rate.

The effort to validate critical aspects of the three-ring transport with low losses is not as well organized as the linac efforts. The Project needs a plan not just to test new hardware, but to use the existing beam operation to learn as much as possible, in particular to check models of injection, transitions, impedance effects and slip stacking. This should also summarize lessons learned from 700 kW PIP-I program.

WG1: Charge element 1 - comments

The feedback systems for the linac RF and the piezo electric tuning systems are under development. The 20 Hz spec for Lorentz force detuning increases the required cavity power by about 50% and looks very reasonable given the 17 kW beam power. The feed-forward for Lorentz force detuning is based on well developed. The RF is based on proportional and integral gain with a well developed digital platform. Both systems have made a considerable amount of progress. The Committee suggests that the Project consider integrating the piezo and RF feedback systems as early as possible.

WG1: Charge element 1 comments

Soon there will be a need to organize design and R&D along project lines, not just proof of principle demonstrations by:

- Start creating Physics Requirements Documents, Functional Requirement Documents and Engineering Specification Documents
- Decide which of the components built during the R&D program will be used in PIP-II and if the satisfy specs.
- Do an overall availability analysis to set/estimate the mean-time-to-failure and mean-time-to-repair values for the major subsystems in the linac.
- Establish general guidelines that the components have to meet in terms of radiation hardness, non-ionizing radiation emissions, pressure vessel safety, electrical safety, magnetization, stay clear, etc.
- List major risks and do a failure modes and effects analysis.

WG1: Charge element 1 recommendations

- Increase the emphasis on the Ring Transport studies
- The technical program needs to systematically address the CD-1 requirements

WG1: Charge element 2 response

Is the project's scope sufficiently well-defined to support the preliminary cost and schedule estimates?

Yes, the project scope is sufficiently defined to support preliminary cost and schedule estimates. They are very far advanced with respect to CD-1 in many cases. The R&D phase is mitigating both technical and cost and schedule risk. However, many of the presentations were much more focused on the R&D phase as opposed to the production phase. This is commensurate with this stage of the project but it will need to change soon. The division of responsibilities are defined for the R&D phase but have not been completely defined for the production phase. This presents some risk to cost and schedule and the division of responsibilities needs to continue to advance as the project continues.

We do not think there is any significant cost risk at the component level.

WG1: Charge element 2 comments

More work is required to define the partner deliverables in the production phase of the project and fully integrate all the pieces of the machine.

The path to CD-1 is well defined, however, the amount of work will require significant resources. This may be challenging given the competing priorities within the laboratory. The project is well advanced of CD-1 in certain areas and advancing rapidly. However, certain items required for CD-1 as defined in the Path to CD-1 presentation have not yet been started. It will be important for the project to prioritize and focus efforts to ensure that the CD-1 requirements are fulfilled.

The R&D efforts that are ongoing will reduce the technical risk and provide additional basis of estimate in cost and schedule estimating.

Summary slides of high level decisions and division of responsibilities will be helpful in conveying message to reviewers.

WG1: Charge element 2 recommendation

Finalize the agreements with the partner institutes to fully define the division of responsibilities by CD-2. The Acquisition Strategy needed for CD-1 may require some of this information.

WG1: Charge element 6 response

Is the collaboration proceeding satisfactorily towards meeting the goals outlined in the Joint R&D document? Will the deliverables outlined in the Joint R&D document position India for a successful contribution to the PIP-II construction phase?

We believe that the collaboration is indeed meeting the goals as outlined in the joint R&D document with some qualifications.
There are many examples of intellectual property and hardware flowing back and forth under the aegis of the IIFC collaboration as envisaged in the R&D plan. It is encouraging that the first phase of prototype hardware components have largely met the design specifications when tested. Examples of this are the 650 MHz SRF cavities, power amplifiers and controls.
That said there are issues with US export controls impacting the flow of technical components. The Collaboration is well aware of these problems and is attempting to devise both a blanket solution and individual as-required ones. Obviously this should be a high priority for the US management team as it will act as a drag on the program until resolved.

WG1: Charge element 6 response

The deliverables as described in the joint R&D agreement represent a comprehensive sample of SRF linac hardware and associated systems. Whether this constitutes a successful contribution to the the PIP II Project is to some extent in the eye of the beholder. It certainly provides the basis of success in that a win-win scenario for both India and the US is likely. The US IP provides strong support for major component development for the DAE and the ISNS and IADS concepts. The Indian deliverables for the PIP II construction phase are not completely defined at this point but hardware development in the R&D phase is such that many options are available for a major role in PIP II.

2. Scope: Is the project's scope sufficiently well-defined to support the preliminary cost and schedule estimates? No. The project has identified the major components of project scope and critical project interfaces, particularly for the R&D phase, but cost estimates need to be updated and preliminary project schedule needs to be completed to integrate the entire scope prior to CD-1. However, the project appears to be on track to sufficiently define this in support of CD-1.

3. Cost and Schedule: Are the cost and schedule estimates sufficiently well-defined and of adequate maturity to support the forecasted critical decision milestones and cost range? No. The cost estimate and cost range should be updated. The schedule development needs to be completed to confirm milestones dates against the preliminary funding profile. Again, the project does appear to be on track to sufficiently define this in support of CD-1.

- **Findings**
  - The project's current TPC range is estimated as $465M to $650M, representing only the DOE/HEP funded scope. There is a planned International in-kind contribution in the amount of $108M which is not included in the TPC total nor in the contingency assessments represented within this report.
  - The project cost is currently based on a point estimated of $516M for the DOE/HEP scope and $108M for International in-kind scope. Of the $516M, $95M is indicated as OPC and $421M as TEC. This has not been changed nor updated since the CD-0 review in June of last year.
  - The overall project cost contingency is 35% on to go—the DOE scope of work has $134 million contingency and International in-kind has none.
  - The project established a schedule contingency of 30 months between the planned CD-4 and the CD-4 Level 1 DOE Milestone.
  - The project presented a proposed funding profile but was unable to present an obligation and budget profile by fiscal year and quarter as they are still developing the Resource Loaded Schedule (RLS).
  - The project is budgeting to the top end of the cost range but the funding profile has not been finalized or formally accepted.

- **Findings**
  - Four alternative delivery models to meet the Mission Need were evaluated within the Alternatives Analysis compared across ten different evaluation criteria. No extensive attempt was made to optimize the alternatives outside of Alternative 1 (Reference Design). A full life cycle cost analysis was not performed and the status quo alternative was not analyzed.
  - The Key Performance Parameters (KPPs) for the project are presented as shown below. The point estimate of $516 million is representative of the Threshold and Objective KPPs where applicable.

#	Description of Scope	Threshold KPP	Objective KPP
1	SRF linac	Beam delivered through the linac, to the Booster Injection Region	800 MeV beam delivered to Booster Injection Region
2	Booster/RR/MI upgrades	Components capable of delivering 1.2 MW to external beamline installed and beam accelerated in the Booster	
3	Cryogenic Infrastructure	Cryogenic plant and distribution ready to support beam operation, and cooled to operating temperature	
4	Civil Construction	Tunnel enclosures and service buildings ready to support 700 MeV SRF linac and transfer line to the Booster	Tunnel enclosures and service buildings to support 1 GeV SRF linac and transfer line to the Booster

- **Findings**
  - The project's acquisition strategy has not been completed to date.
  - The project's Basis of Estimate (BOE) has not been updated since the CD-0 review and approval. The project identified missing scope elements such as commissioning and various design updates.
  - The vast majority of the estimate is based on a P5 FY13 estimate with minor modification for scope differences since that time. The BOEs do not contain contingency (estimate uncertainty/maturity) which is typically applied by the Level 3 subsystem manager. Instead contingency is applied in a top down manner at this stage.
  - The project assessed the point estimate class as between a Class 3 and 4 – per DOE G 413.3-21. This was based upon the project definition related to design, fabrication, and testing of the R&D phase. Based on this assessment, the project has determined the range as -10% and +26% for the low and high percentages applied to the point estimate.
  - The project presented a plan for completion of CD-1 requirements such as the Alternatives Analysis, PPEP, and Resource Loaded Schedule (RLS) but did not have information related to missing information for this review such as the WBS dictionary, risk register, interface documentation, or scope requirements mapping.

- **Findings**
  - Primavera P6 is being used for establishing and updating the base units and schedule going forward. At this time Cobra is not used for rating the base units from P6. A separate series of excel tabs in a large spreadsheet is being used at this time. The project stated that Cobra will be used as they approach CD-2 but not likely for the CD-1 review.
  - The project states and the review team confirmed that the critical path cannot be displayed at this time.
  - The partially developed Primavera P6 schedule with time-phased project scope was presented along with the methodology for fully planning the remaining scope in the schedule. The resource loaded schedule is expected to be funding profile constrained but the project team is building a technically driven schedule first, then applying constraints as needed for funding.
  - The project is considering a tailored approach of a CD-2/3a for Long Lead Procurement (LLP) of conventional facilities, site preparation, and Niobium procurements for SRF cavity fabrication, in order to mitigate risks. The project is working toward a goal of 70% design maturity for CD-2, however, R&D is not expected to be fully complete until FY2020.

- **Findings**
  - The project presented an organization structure with To Be Determined (TBD) for some staffing areas that will need to be filled prior to CD-1. Some of those roles include Project Controls, ESHQ, Procurement Manager, and Superconducting Linac Lead Engineer.
  - A project risk registry is not in place. There are five high level risks discussed within the PPEP but no formal risk register nor risk management plan has been created. The project does not plan to have a standalone Risk Management Plan (RMP), rather use the Fermi Risk Management Procedure for projects and tailor as needed.
  - The CD-0 recommendations have been assessed by the project and they have marked those items as closed.

- **Comments**
  - The estimate is unchanged from the June 2015 CD-0 review, a detailed assessment by the review team on the appropriateness of the estimate based on the state of design maturity could not be determined fully. Based on information that was reviewed and presented by the project team, there are elements (scope and costs) missing from the estimates presented. Other improvements such as the application of escalation and assessment of uncertainty and risk within the project need to be incorporated into the estimate, as well.
  - After the incorporation of missing scope elements, updating costs for FY16, and assessing risk/uncertainty, it is probable that the point estimate and TPC range will grow outside of what was established at CD-0.
  - The project needs to be prepared for the level of detailed information required for an ICR. Thought should be given to the presentation of this material and dynamic capabilities of data provided to not only the review teams but the project team for quality reviews prior. A dynamic ability to review and communicate the cost estimates is recommended.

- **Comments**
  - Ensure the project cost in the acquisition strategy, PPEP, and Alternative Analysis reflect the same updated point estimate.
  - One of the options assessed within the Alternatives Analysis did not include keeping the status quo, or the "do nothing" alternative. Additionally, the criteria used for assessment of the four options did not appear to fully assess the life cycle costs associated with the options versus an annual operating cost. Ensure that the Alternatives Analysis addresses the GAO best practices guide for Alternatives Analysis or provide justifications for deviations.
  - While the project is funding constrained and operating in an uncertain environment, the team is taking advantage of what resources they have available and attempting to focus those on key scope areas to move the project forward where possible.
  - Progress has been made to further develop the schedule in P6 since the CD-0 Review. The schedule, so far, is developed at 70% of the R&D scope, which is approximately $33M (Direct Cost) of the total project budget. The information that is developed thus far and the plan for taking a high level schedule to detail plan that into P6 is commendable. However, care should be taken to not over plan future activities given the current R&D phase of the project and use of planning packages is encouraged.

- **Comments**
  - The planned FTE profiles within the project office seem to be low at this stage of the project, given the amount of work that remains to be completed prior to CD-1. It should be noted that some of the staffing for the project are fractionally assigned.
  - The use of the Fermi Risk Management Procedure for the primary process related to risk is viewed as an acceptable practice in principle. However, to meet the intent of a Risk Management Plan (RMP) within DOE Order 413.3b, the project needs to document deviations from the Fermi procedure that are related to the project's risk scoring and the frequency of reviewing risks. The project should make the use of the Fermi procedure in lieu of a Risk Management Plan clearer to reviewers as many will be looking for that information at CD-1.
  - The project urgently needs to develop a risk register and assess the threats and opportunities within that register. This needs to be developed well prior to CD-1 to ensure that the expected values for risks are assessed and included in the validation of the contingency needs. The current contingency level presented (35% to go), appears acceptable for this type of the project – generally speaking – but is pending further analysis based on the issues stated above.

- **Comments**
  - A critical and near-critical path schedule and analysis needs to be performed by CD-1. For example, it appears that there is no float for NEPA completion which is needed by CD-2. The NEPA completion work is funding constrained but can be accelerated by reallocating project funds.
  - The plan to CD-1 appears aggressive based on the current level of available resources and items remaining for creation, optimization, and review of the schedule, cost, risk, uncertainty, and scope.
  - The project should continue the process of benchmarking similar projects in terms of cost estimating, schedule development, project risks, and resource requirements.

- **Recommendations**
  1. The project needs to complete the CD-1 planning related to the schedule, risk and uncertainty analysis, cost, and identification of needed scope to validate the ability to meet the planned critical milestones and funding profile.
  2. Prior to the CD-1 ICR, ensure that the Alternatives Analysis addresses the GAO best practices guide for Alternatives Analysis or provide justifications for deviations.
  3. In the next three months, evaluate the remaining work and resource needs to ensure a successful CD-1 and ICR can be accomplished within the project's proposed dates.
  4. Complete all documentation required for the ICR and CD-1 review, such as the Acquisition Strategy, PPEP, and RMP.

PROJECT STATUS as of October 2016		
Project Type	Line Item	
CD-1	Planned: Q4 FY18	Actual: TBD
CD-2	Planned: Q1 FY20	Actual: TBD
CD-3	Planned: Q4 FY21	Actual: TBD
CD-4	Planned: Q1 FY29	Actual: TBD
TPC Percent Complete	Planned: 2.1%	Actual: 2.1%
TPC Cost to Date	$13.8M	
TPC Committed to Date	$15.4M	
TPC	$516M (Range $465M - $650M)	
TEC	$421M (Range $421M - $532M)	
Contingency Cost (w/Mgmt Reserve)	$134M (Range $134M - $168M)	35% on to go
Contingency Schedule on CD-4	30 months	21% on to go
CPI Cumulative	N/A	
SPI Cumulative	N/A	

4. Management: Is the project being properly managed at this stage? Does the management team possess the skills, expertise, and experience necessary to successfully execute the project? Are plans to identify and allocate staffing and resources consistent with current funding guidance? In general, yes, yes, and yes. In more detail the project has focused on technical progress and has a plan to CD-1 which can lead to success. That said PIP-II has plenty of work to do to become more of a project, and the next year can be used constructively to make that change.

5. Environment, Safety, and Health: Is environment, safety, and health being properly addressed given the project's current stage of development? Yes. It is noted that the proposed re-use of PIP2IT components in PIPII means that all safety requirements envisioned for PIPII need to be applied now to these items.

6. India Institutions and Fermilab Collaboration (IIFC): Is the collaboration proceeding satisfactorily towards meeting the goals outlined in the Joint R&D document? Will the deliverables outlined in the Joint R&D document position India for a successful contribution to the PIP-II construction phase? In general yes, however given how critical international collaborations are to the success of PIP II we believe progress on these should be more actively and transparently reported. Issues and proposed solutions should be included in these reports, and the appropriate levels of management informed should their help be required. The deliverables are sensible; creating a system that makes it possible to deliver those items in a timely manner is critical to the success of the partnership.

Findings

- A project management team is in place managing a staff of over 50 FTE's. The project recently added of Associate Project Manager for Planning and Reporting.
- Staffing requirements have been developed for both R&D and construction phases
- Laboratory safety policies and procedures are governing beam operations at PIP2IT.
- NEPA strategy has been developed and is being implemented. The wetlands delineation is complete. The environmental review form (EENF) has been drafted.
- The collaboration with India/DAE is in the R&D phase. DAE deliverables are defined in Joint R&D document. The scope is aligned with potential DAE contributions to the construction phase.
- There is potential for Italy/INFN and/or UK/STFC contribution in the construction phase.
- PIPII presented a plan for the R&D program leading to CD-1 at the end of FY17; CD2/3a in FY19, and CD-3 at the end of FY20 (Tier 1 milestones).
- The project has modified the R&D program in response to receiving $18.2M in FY17 as compared to the $25M expected at the CD-0 review
- The plan includes all R&D being complete before CD-3

Findings (cont'd)

- The project is heavily matrixed out of FNAL Divisions and is not the highest priority in those discussions
- The project has focused on technical risk reduction since CD-0 and is starting just in the past 7 months to develop a full resource loaded schedule.
- A draft PPEP exists. Initial KPPs, milestone development methodology, and reporting methods are under discussion.
- Monthly reports are being sent to the program since December 2015.
- An alternatives analysis has been submitted to HEP. The program office concurs with PIP II developing alternative 1, the SC linac option.
- The project has strengthened the team with Project Engineer/Electrical, APM/Planning, and two divisional coordinators identified. PIPII has plans to continue to populate the Project office before CD-1.

Comments

- The project team is very experienced and appears adequate to successfully deliver the project. Staffing appears to be appropriate for this phase of the project, however, competition for resources with other projects will require careful coordination at the laboratory level. Project controls may need to be augmented.
- The project team can be ready for CD-1 in a year, however there is considerable work to do not just in completing the requirements but in continuing to formally establish and operate as a project on a daily basis.
- The project does not have a risk registry. A risk registry is a critical item for the development of a project mindset. PIP II should start constructing the risk table immediately, and use it to make decisions on how to best move the project forward. The risk registry will help balance hard technical risks with softer, but very real, project risks and inform choices and use of contingency. The current staffing plan does not include a Risk Manager. Consider identifying a project Risk Manager prior to CD-1.
- The risk table, and the updated BOEs, will need to be used to defend the contingency assumed for the project at CD-1.

Comments (cont'd)

- International collaborations are a critical component leading to the success of PIPII. As implemented the deliverables are in-kind contributions, with small cost risk but real schedule risks. To date the quality of deliverables has been good, and the long term visits of Indian engineers to Fermilab a real positive to working through 'on the ground' issues as they arise. The current agreement is being updated based on the experience of the past 18 months and the revision is expected to be signed in early CY2017. To ensure that the collaboration continues to successfully grow, a method for transparently tracking deliverables on a regular basis should be implemented, such that issues are identified based on facts and can be addressed by the appropriate level of collaboration management.
- An assumptions document has not yet been developed. A PIP II – Fermilab MOU has not yet been developed. (These could be one document). Writing of these documents helps clearly define the scope of the project.
- The IIFC joint R&D document will need to be updated in January 2017 to include R&D through 2020.

Recommendations

1. As soon as possible establish a risk management tool to strengthen the risk management process to ensure that risks are reported consistently (cost slip, in-kinds to be included). Use the tool!
2. Actively address issues that arise in the international collaborations.
3. Use the risk registry to re-evaluate the Project and R&D program such that the Project reaches major milestones (CD milestones) as fast as possible.
4. Agree with the program the appropriate level of risk assumed at each CD step. Present a plan for this at the next review.
5. Develop a key assumptions document prior to CD-1.
6. Develop a MOU with Fermilab Leadership that outlines the projects needs prior to CD-1.
7. Contingency development should be informed and verified by BOE and risk analysis at CD-1.
8. Revise the IIFC joint R&D document prior to January 31, 2017.
9. Consider leading the export licensing and IP-right issues and make it a standard part of your in-kind collaboration strategy to ensure uniformity during execution of contracts. Establish overall coordination support (regulatory issues, logistics) for in-kind contracts by the project.