PIP-II Linac Installation and Commissioning External Review: Scope/BOE/VE Review Report

Document number: PIP-II-Doc#

Document Approval

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Revision History

Revision	Date Release	Originator: Role:	Description of Change
	2/22/2019	F.G.Garcia L2 Manager	Initial release

Revision control is managed via Fermilab Teamcenter Workflows.

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1. Introduction

Review committee members are expected to review the PIP-II Linac Installation and Commissioning's technical scope, conduct activity drill down and provide assessment of effort level and cost effectiveness of material and service charges. Reviewers are also expected to help thinking about the potential value engineering venues during the BOE drill down.

2. Review Agenda

PIP-II Linac Installation and Commissioning External Review: Scope/BOE/VE

Date: March 4-5, 2019

Time: Day 1: 08:00 - 17:00 Day 2: 08:00 – 13:00

Location: Fermilab / Accelerator Division Building (behind Wilson Hall)

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Indico Site: https://indico.fnal.gov/event/19887/

Participants:

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3. Review Charge Statement

The committee is requested to review the technical scope of the Linac Commissioning and Accelerator WBS elements. Furthermore, the committee is expected to go in depth on the Basis of Estimate (BOE) documentation and estimates being presented and evaluate for accuracy, completeness. We also would like the committee to provide any ideas on how to improve the strategy by providing feedback in the context of Value Engineering.

More specifically, we would like the committee to consider the following questions:

1. Is the technical scope of the Linac Installation and Commissioning adequate to meet PIP-II key performance parameters?
2. Is the cost estimate adequate to carry out the technical scope of work with reasonable technical risks?
3. Is the cost estimate sound for each activity, service and material procurement?
4. Is the support document of cost estimate complete and on-track to support DOE Independent Cost Review?
5. Is there any opportunity for Value Engineering for each system?
6. Are there any other issues that have been identified and need to be addressed?

From this review, we seek from the Review Committee comments, suggestions on how to improve, if applicable, our cost estimate strategy and whether the scope is comprehensive to reach PIP-II goals.

The Review Committee is kindly asked to submit a Review Report no later than 2 weeks after the conclusion of the review. A Review Report template will be provided.

4. Reference Documents

List any relevant documents reviewed by the Committee.

1	1950	Inst - Project Management and Coordination (PM)
2	1953	Inst - WFE - Project Management and Coordination (PM)
3	1956	Inst - WFE - PIP2IT
4	1959	Inst - WFE - PIP-II
5	1962	Inst - TI - Project Management and Coordination (PM)
6	1965	Inst - TI - Spoke Test Cryostat (STC)
7	1968	Inst - TI - PIP2IT Infrastructure Services for HWR SSR1
8	1971	Inst - TI - PIP2IT - 650 MHz CryoModule Test Stand
9	1974	Inst - TI - PIP2IT - SSR1-CM2 and SSR2 Test Stand
10	1977	Inst - TI - Horizontal Test Stand No. 2 (HTS-2)
11	1980	Inst - BldgI - Project Management and Coordination (PM)
12	1983	Inst - BldgI - Cable Database and Layout for PIP-II (CableDB)
13	1986	Inst - BldgI - Mechanical Systems for PIP-II (Mech)
14	1989	Inst - BldgI - Electrical Systems for PIP-II (Elec)
15	1992	Inst - LI - Project Management and Coordination (PM)
16	1995	Inst - LI - Installation Planning (IP)
17	1998	Inst - LI - Support Equipment

18	2001	Inst - LI - PIP2IT Disassembly and Storage (PIP2IT)
19	2004	Inst - LI - Linac Installation
20	2007	Inst - Comm - Project Management and Coordination (PM)
21	2010	Inst - Comm - PIP2IT
22	2013	Inst - Comm - PIP-II
23	2016	Inst - AP - Project Management and Coordination (PM)
24	2019	Inst - AP - Accelerator Physics Studies
25	2022	Inst - AP - Shielding Assessment (Shld)

Review Report

Introduction

A two-day review of the PIP-II project was held on March 4th and 5th, 2019. The review committee was chaired by Joseph DeLong (SLAC), John Schmerge (SLAC), Thomas Russo (FRIB) and Farshid Feyzi (FNAL).

The committee was requested to review the technical scope of the Linac Commissioning and Accelerator WBS elements (121.04.01 to 121.04.07 inclusive). Furthermore, the committee was expected to have an in-depth evaluation of each sub-system Basis of Estimate (BOE) documentation and estimates and provide feedback on accuracy and completeness. The committee was also tasked providing ideas on how to improve the strategy by providing feedback in the context of Value Engineering.

Charge questions:

1. Is the technical scope of the LINAC Installation and Commissioning adequate to meet PIP-II key performance parameters?
   Yes, the scope is fully identified but, in some cases, not fully covered. See details below.
   The committee did not see any missing scope.

2. Is the cost estimate adequate to carry out the technical scope of work with reasonable technical risks?
   Yes, for this level of design maturity the cost estimates are adequate. Technical scope will be clarified over the course of the next few months and the base of estimate should be refined as the design matures.

3. Is the cost estimate sound for each activity, service and material procurement?
   Yes, however some systems lacked the depth required for a full analysis of the cost.

4. Is the support document of cost estimate complete and on-track to support project baseline?
   No, the documentation was inconsistent and different methods were used to fill them out across each WBS element at level 3. BOE templates were used differently by each CAM. Anomalies and errors in the BOE forms need to be addressed.

5. In your opinion, is there any opportunity for Value Engineering for each system?
   Yes. There are always opportunities for value engineering. Some suggestions are listed below.

6. Are there any other issues that have been identified and need to be addressed?
   Yes. See recommendations below.

This report is organized by talk, there is a section for each talk given and each section has the traditional findings, comments and recommendations. That is followed by our summary.

Introduction and Overview of LINAC Installation and Commissioning

Fernanda Gallinucci Garcia (Fermilab)

Findings:

An overview of the PIP-II site shows the accelerator is located within the circumference of the TEV accelerator. This allows for leveraging the existing infrastructure of the accelerator.

Extensive testing has been and continues to be conducted on the warm front end of the accelerator.

The cryogenic plant is an in-kind contribution. For this report all in-kind contributions will be considered complete and correct and will not be included in the review.

FNAL has a cryomodule test facility currently being used to test modules for the LCLS-II project at SLAC. FNAL has extensive experience in testing cryomodules and in particle free construction. The test facility will be expanded as part of this project to include an area for testing the warm front end with cryomodules. This gives the project an opportunity to test modules with beam.

Comments:

A clear description of the technical scope at the level 2 WBS was not presented in this talk. In the future this presentation should clearly define the scope to be reviewed.

Roles and responsibilities are mapped in a very complicated manner and requires a clear definition in the form of ICDs and R2A2s to facilitate communications and to clarify interfaces.

Interfaces are crucial due to the organizational structure and stakeholders for the ICDs need to be identified.

With the extensive testing of the warm front end and the capabilities of the cryomodule test facility. The project is on a good foundation to succeed.

Recommendations:

Ensure that the Interface Control Documents are fully developed and approved by all stakeholders.

Ensure Roles, Responsibilities, Authorities and Accountabilities are clearly defined for all members of the project team.

Warm Front-End Scope

Lionel Prost (Fermilab)

Findings:

The Warm Front-End scope of work covers design, procurement and fabrication of the warm front end and High Energy Beam Transport. This effort is well advanced, and the design is quite mature. These systems will be built and tested in the CMTF as part of PIP2IT. Much of the equipment that has already been commissioned with beam will be reused in the test facility. Components have been received as in-kind contributions from India. The ion source will require work to bring it from the prototype state to production ready.

Comments:

This scope of work is straightforward and introduces little risk to the project. The source was describes as needing work to make it production ready.

Consider building two new sources and using the prototype source as a spare.

For the source consider a design build contract. The prototype source can easily be used as a reference design.

Recommendations:

Clearly identify each PIP2IT component that will be moved to PIP-II and re-used in the accelerator and clarify the changes that are required to other components to make them production ready. Include the safety critical devices including barriers that protect people near the ion source.

Basis of Estimate drill down:

Findings:

While reviewing the slides it was noted that the speaker is committed for 30% of his time as LOE for this scope. The labor estimate slides did not show his effort. Drilled down into the BOE for HEBT. Where good factual basis could be found they were entered in the spreadsheet. However there are a number of items without a foundational reference. Reviewing the narrative there is excellent reference information to support the estimate both with respect to resources and M&S.

Comments:

The Estimated uncertainty was reported as incorrect.

The documentation is in two forms, a narrative and a cost spreadsheet. These documents should somehow be consolidated, it is difficult to see the whole picture and drill down to the actual BOE. There is a note in the HEBT tab of the spreadsheet that describes a 32% difference between the sum of the known (well founded) costs and the estimate: The difference relates to the design level and the cost of similar work/beamline at PIP2IT. This was not explained well and may be a design maturity judgment factor.

Recommendations:

Add a column to the spreadsheet that describes the basis of estimate for example: Estimate based on previous procurement of the same device and link to the PO. Estimate based on similar experience, and link to a document describing the experience. This would help “drill down” into the cost estimate. Other CAMs provided this information in their spreadsheet.

Work with the project office to ensure the data provided in the BOE documents is complete and correct (such as estimated uncertainty).

When finding items in your scope that you cannot clearly define a cost for, use as much detail as possible and work with the project office to improve the cost estimate.

Test Infrastructure Scope

Jerry Leibfritz (Fermilab)

Findings:

This scope of work covers the required infrastructure to facilitate cryomodule testing in the CMTS facility. Cave extension, electrical, LCW… as well as the cryogenic transfer lines. The scope also covers conversion of a cavity test cryostat.

Comments:

This work is a core competency of FNAL, there is a well-established team in the CMTF and their experience will be leveraged to expand the facility to accommodate the PIP2IT program. The level of maturity for the HWR/SSR1 test stand is advanced and the SSR2 and 650MHZ test stands are at the preliminary level. The latter are currently planning packages currently.

Recommendations:

None

Basis of Estimate drill down:

Findings:

Cost of 4 SRF pump carts in vacuum scope.

Cryogenic transfer line CLT for test standes is already bought and is not on project.

U-tube cost estimate based on in-house fabrication.

Cable installation labor estimated by T&M contractor.

Comments:

Test stand labor for SSR and 650 are estimated by adding up actuals for CMTS1 and then applying a 10% factor. This seems arbitrary. M&S for SSR and 650 test stands are estimated from actuals of CMTS1 then items that are not needed are removed. But again, a factor of 10% or 30% is applied. In both above cases, a better method would be estimate based on CMSTS1 and engineering judgment.

Time for management, (0.5 FTE) appears low.

Recommendations:

If 10% or 30% factor is used on cost, then you need a better justification. Alternatively, do a bottom-up estimate based on experience which already exists in the group.

Building Infrastructure Scope

Jonathan Hunt (Fermilab)

Findings:

The scope of work covers the following systems:
Utilities: Low Conductivity Water (LCW) system, Compressed air distribution for valves and cooling, Radioactive Water (RAW) system, AC power distribution from Conventional Facilities terminations to machine infrastructure interfaces, Utility Nitrogen.

Planning and developing layouts of utilities, racks, cables, and cable trays for the LINAC Complex, PUB, and BTL, Purchase of all standard cables, connectors, and racks.

Comments:

This is a large scope of work and there are many interfaces. Managing this will be difficult and there will likely be multiple subcontractors working with FNAL staff simultaneously.

A significant support staff will be required for these activities to manage transfer of materials to contractors as well as field support to quickly answer questions when they arise.

Refine the requirements for Low Conductivity Water, the current estimate is 11MW but may be as low as 7MW. The SSAs, which require the bulk of the heat dissipation may not require LCW investigate this possibility. Consider using PCW.

Verify gallery and LINAC tunnel water are not mixed or you risk radioactive water leaks in the gallery.

Recommendations:

Develop and maintain an ICDs and clearly establish roles and responsibilities.

A close relationship with Conventional Facilities and the technical teams will be required. Ensure documentation packages between organizations are consistent if not consolidated.

Power, water, air conditioning… requirements, if distributed among many may be inflated if each subsystem builds in their own margin. Centralizing this may save significant cost by better managing the margin.

There should be a facility wide grounding plan. FRIB hired a consultant who recommended ground mesh size (for protection against RF) and construction techniques (like ground pads for VFDs).

Consider identifying electrical and mechanical lead project engineers.

Basis of Estimate drill down:

Findings:
Development of cable database is included in the scope (CAPTAR).
Good basis of estimate on mechanical systems.
Looking through the BOE for racks and cables there were references to ways and means standards.

Manager 0.3to 0.4 FTE, seems low
Cable M&S in this scope, $11.03M
Cable plant design admin 0.18 FTE, design itself 2 FTE, is this total or per year, need table
Utility nitrogen for valves and for vacuum
Cable install labor transferred to CF
Inconsistency with Curt's presentation on who installs which cables, FNAL or contractor. Definitions of technical and other cables need to be clearer.
Magnet cables up to 1000ft. Too much voltage drop and heat. Consider moving PSs closer (but this is outside the scope of this review)
There will be guardrails for protecting CM RF coupler
PIPII mechanical systems estimate have proper backup. Fluids installation labor estimated based on experience and engineering judgment, does it include foreman? M&S has mostly quotes.
Engineering is estimated in M&S, is this double counted?
Do better job labeling sections in spreadsheets.
RF couplers cooled by compressed air, what is the usage? Discharged into tunnel?
Consider interlocks on compressed air pressure so valves don't open or close

Comments:
Cable routing may be difficult if not impossible along the transfer line without buildings along the way. Losses in dipole/quadrupole magnet cables will cause 10s of kW of loss. Diagnostics may not work at all over a km distance. Consider recycling the existing buildings.

4-man years of effort assigned to cable plant design including routing of trays and cables. From the high-level document.

Davis Bacon Determination will dictate cost to some extent.

Look at other installations for lessons learned.

The hours allotted to installation of cables seems reasonable.

Reevaluate the effort required to design the cable plant. This includes the trays and routing of ~18,000 cables. The effort estimated is 2.7 FTEs and is more likely to be 5 FTEs. If the location of field devices and racks are fixed, consider using a design firm to execute the routing of tray and cables. Consider discussing the lessons learned from the FRIB installation.

Recommendations:

Consider developing a cable criteria document

- U/L listed. Tray rated. Fire ratings
- Voltage rating – cables commensurate with the application
- Same with connectors
- Develop a standardized list so that various group's pick from the approved list
- Approvers of cable types may need to be expanded to include safety and technical. Look to others for best choices.

Engineering effort and estimate for crew foreman may not be properly accounted for. Review and correct as necessary.

Linac Installation Scope

Curtis Baffes (Fermilab)

Findings:
This scope of work includes planning and execution of the installation of the PIP-II LINAC, from the Warm Front End through the HB650 upgrade section. This includes planning, design of support structures for cryomodules and warm units, disassembly of PIP2IT, logistics and transportation support for PIP2IT and installation-ready cryomodules, subsystem integration of warm units, installation of all LINAC systems (in the high-bay, tunnel and gallery), and checkout of the LINAC to bring installed systems to a state of readiness for beam commissioning.
Additionally, the CAD model for the accelerator falls under this WBS.

Comments:
Safety by design is a commendable approach, engineering safety into the systems from the start will significantly reduce the risk of injury during construction and into operations.

Working around cryomodules introduces the risk of venting the cavity strings careful planning of this work will be required (if the design is like SLAC cryomodules).

A significant amount of work planning and control will be required to maintain safety and schedule. Developing this process early will save time later.

Recommendations:
Develop and maintain an ICDs and clearly establish roles and responsibilities.

Ensure consistency with drawings provided by other WBS elements and consolidate drawings where possible.

Basis of Estimate drill down:

Findings:
Cool down of CMs in installation scope, is this appropriate and is the estimate adequate?
There will be one cryo transfer line per CM, fabrication in cryo scope, installation in this scope
Installation of utilities in highbay is in 12.04.04, installation of utilities in tunnel and gallery is in 12.04.05. Can both scopes be transferred to CF?

Rack integration is in 12.04.05 except when it is not! e.g. warm magnet supplies are integrated by magnet scope. Need to be clear on this.
Cable termination labor for both ends of cables are estimated in gallery scope, not split between tunnel and gallery
No sprinklers are allowed in the tunnel
Cable termination for technical cables done by FNAL labor, for magnet load cables done by contractor. Is this well-defined?
How is QA during installation done and where is the labor for it?
Linac installation labor detail estimate is very thorough and there is good back up based on installation of PIP2IT installation
Linac installation total labor is about 26,000 hrs, about 7 FTE for 2 years. Seems reasonable.
Support equipment estimates are also well detailed with appropriate backup
CM transporter will be a design and build contract
Particle free glovebox may not be adequate. Add estimate for portable cleanroom
Installation tools estimate seems reasonable, check if it covers cost of CM transporter.
Installation labor for CDS estimated by cryo group but is in install scope, who carries the risk?

Comments:
The particle free requirements in installation and methodology were not specified.
QA during installation was also not covered.

Recommendations:
Develop clear particle free standards and methods for installation.

Beam Commissioning & Accelerator Physics

Eduard Pozdeyev

Findings:
Scope of work includes development of beam commissioning plan of the PIP-II, planning, developing and optimization of the high-level applications to be used during beam commissioning. It also includes costs associated with the setup of a local control room in the PIP-II LINAC Gallery, assembly of the diagnostic carts, installation of temporary shielding within the beamline enclosure and beam commissioning of booster.

This scope also covers the analysis of shielding and the development of shielding requirements.

Comments:
Suggest developing the transition to operations (TTO) plan soon and make the commissioning plan consistent with TTO.

Recommendations:
Consider cooldown, RF testing and integrated system testing be in the commissioning scope.

Drill down on:
Commissioning and Accelerator Physics

Findings:
While the estimate appears sound during discussions of how the estimate was prepared and when compared to the plans for LCLS-II. There was no information presented on the Basis of Estimate.

Comments:
Cost estimates appear about 20% lower than might be expected based on other facilities. However, for this level of maturity this is reasonable.

Recommendations:
Complete the Basis of Estimate documentation using past experience and the experiences at other labs with similar scope and document the methods used.

Summary comments

There are inconsistencies in the documentation we were shown. An overall QA of the BOEs needs to be done prior to future reviews. The reference material and instructions provided to the CAMs may have had some ambiguities. Following the flow from P6 task through estimated cost was difficult.

A tremendous amount of work has gone into this, and the effort put in is commendable. There is room for improvement in the way it was presented. But the underlying information in most areas has been completed with diligence.

Consistent use of language and expanding acronyms in presentations would be helpful.

Overall QA approach and labor for QA/oversight were not covered.

Project office involvement in this review was less than expected. Their presence would have been helpful both to the review team as well as they themselves. Watching the reviewers struggle with the documentation could produce significant lessons learned for the project controls team.

In the cases where we did a drill down, CAM efforts appear to be too low. This needs to be reevaluated and compared to similar facilities.

A recurring theme throughout the recommendations is to clarify roles and responsibilities and document this in the form of Interface Control Documents.