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IN-KIND CONTRIBUTIONS: THE PIP-II PROJECT AT FERMILAB

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Abstract

The Proton Improvement Plan II (PIP-II) Project is the first U.S. accelerator project with significant contributions from International Partners. A project management framework was created to fully integrate and make consistent across all partners the design, development, and delivery of In-Kind Contributions (IKC) to PIP-II. This framework consists of planning documentation, procedures, and communication and assessment processes to control schedule, risk, quality, and technical integration over the lifetime of the project. The purpose of this paper is to present the PIP-II IKC model put in place to properly integrate the IKC deliverables into the PIP-II Linac and share experience and lessons learned from its early implementation.

INTRODUCTION

The PIP-II Project [1,2] is an essential upgrade of the Fermilab accelerator complex. An all-new, leading-edge superconducting linear accelerator located in new buildings, combined with a comprehensive overhaul of the laboratory's existing circular accelerators, will deliver multimegawatt proton beam power and, in turn, enable the world's most intense beam of neutrinos for the international Long Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE) [3]. The PIP-II Project is also designed with scalability in mind to enable future upgrades with a broad spectrum of scientific opportunities.

A unique aspect of the PIP-II Project is that it is the first U.S. Department of Energy (DOE) funded particle accelerator to be built with significant international participation. Figure 1 shows a schematic overview of the PIP-II Linac IKC from partner countries indicated by flag. PIP-II will be the highest-energy and highest-power continuous-wave (CW) proton Linac ever built, capable of delivering both pulsed and continuous particle beams.

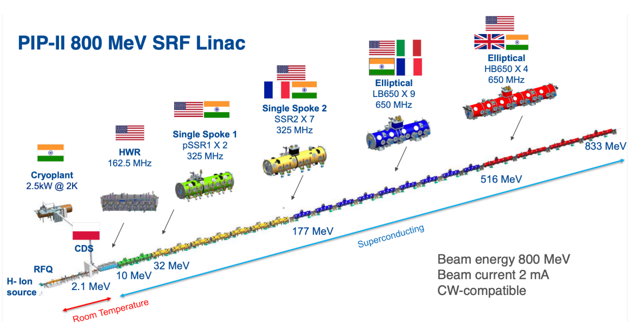

Figure 1: Overview of the significant IKC for PIP-II. Flags highlight which country plans to contribute to PIP-II Project. The flags are in the areas of the specific contribution.

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With major IKC from institutions in India [1], Italy [1,4], UK [1], France [1,5] and Poland [1], the project's international partners bring wide-ranging expertise and know-how in core particle accelerator technologies along with an established track-records in big-physics initiatives.

PIP-II IKC MODEL

The PIP-II Project was baselined in December 2020 and in April 2022 received the approval from DOE to start construction. The DOE portion of the PIP-II Project cost is approximately one billion dollars (i.e., $978M). The IKC cost is estimated to be approximately one third of the DOE approved project cost. The PIP-II Project is planned to be completed at the end of 2028. This date represents the early completion target date.

The IKC size and the international nature of the PIP-II Project required the development of a special planning framework to properly integrate the Partner deliverables into the PIP-II Project scope and schedule. Figure 2 shows a schematic of the IKC life cycle implemented in the PIP-II Project.

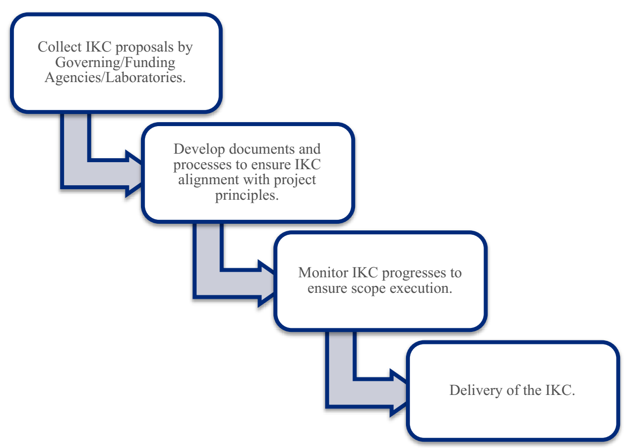

Figure 2: PIP-II Life cycle of IKC.

- Collect IKC proposals by Governing/Funding Agencies/Laboratories is the initial phase for starting the evaluation of any possible IKC to the PIP-II Project. If IKC are selected on the basis on expertise/know-how in a specific technical field, Agency-Level Agreements or other legally binding agreements are typically established between DOE and the Partner funding agency. These legally binding documents outline the high-level management structure for activities to be undertaken under the agreement and/or its subsidiary agreements. At this stage, it is imperative to clearly define the IKC high-level deliverables.

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- Develop project documents and processes to ensure a proper alignment of the IKC with the management and technical integration principles after the legally binding agreement are in place. For the PIP-II Project, a special set of legally non-binding agreements called Project Planning Documents (PPDs) were created to fulfill this purpose. PPD Part 1 describes the PIP-II project management principles applicable to the IKC Partners. PPD Part 2 describes IKC deliverables, including detailed scope of work, schedule milestones and the description of supporting documentation and activities required to enable PIP-II to meet the DOE O 413.3b [6] requirements, to abide by Fermilab policies and procedures, and to conform to the principals established in the PIP-II System Engineering Management Plan (SEMP). The PPDs define the expected responsibilities of the Partners and the PIP-II Project integrated baseline schedule.
- Monitor IKC progress to ensure scope execution starts after binding and non-binding agreements with the Partners have been agreed upon. This phase begins the execution of the plans and processes developed during the planning stage. The monitoring process includes quality control, interface, and performance verification. A set of Milestones (MS) were developed to baseline the PIP-II Project which enable step-by-step monitoring of IKC progress. MSs were defined for design reviews, procurement, and acceptance phases, in addition to intermediate technical achievement MSs for each sub-system. Documentation deliverables were identified for each MS to ensure complete alignment with deliverables expectations between parties at each stage of the execution phase. Each month, PIP-II IKC Partners report progress, achievements, and status of the agreed IKC MS versus the baseline schedule agreed in the PPD Part 2. Moreover, Partners provide monthly assessment of possible impacts to near term MSs and to final delivery date/s. If delivery delays are indicated, potential mitigation actions are evaluated and reported.
- Delivery of IKC is the final phase of the IKC life cycle. System Acceptance Reviews (SAR) are used to ensure the IKC deliverables can be accepted. They are identified in the PPD Part 2 as MSs that enable the transfer of ownership and technical risk associated with IKC deliverables from Partners to DOE. For the PIP-II Project, the SARs occur in two steps called SAR1 and SAR2 with both identified as MS in the project integrated schedule. SAR1 generally occurs at the IKC Partner location following completion of a Partner driven procurement, fabrication or integration of a system or sub-system, and prior to shipment. SAR2 generally occurs at Fermilab or another Partner location before final integration. SAR2 confirms that the deliverable meets all technical specifications, requirements, and acceptance criteria. At the completion of the SAR2, the ownership of the deliverable is transferred to the DOE. To absorb potential schedule delays, two MS called respectively “SAR2 early” and “SAR2 late” were created. The PIP-II IKC Partners are committed to delivering on the SAR2 early MS date. The difference between the SAR2 early and late dates define the IKC schedule margin with subsequent activities planned after SAR2 late dates. The duration of the IKC schedule margin ranges with respect to the technical complexity of the item to be delivered.

In each step of the IKC life cycle, continuous centralized schedule risk assessment and possible mitigation strategies are planned. In this model, the IKC Partner is solely responsible for the financial management of an IKC until its delivery.

PIP-II IKC: EARLY LESSONS LEARNED AND CHALLENGES

The PIP-II Project implements lessons learned from the IKC working models used by European laboratories like CERN, the European X-ray Free Electron Laser (XFEL) and the European Spallation Source (ESS) but within the DOE O 413.3b project framework. Lessons learned on the early implementation of the PIP-II IKC model are reported as well as the major challenges that the PIP-II Project faces.

Early Lessons Learned

The integration of IKC Partner activities into management and technical principles is a complex exercise that needs to start as soon as an IKC Partner is identified and should be completed and validated before baselining the project. It requires developing several project and technical management processes to ensure successful execution. Due to the complexity of the PIP-II Project, not all the processes were in place and benchmarked before baselining the project. However, a stage-based approach was implemented to provide support in the areas of immediate need to avoid delays to the baseline near term goals.

The IKC scope was integrated in the PIP-II systems engineering principles defined in the PIP-II SEMP. Project requirements defined at the highest level in the PIP-II Global Requirements Document flow down to specific sub-systems and devices through physics, functional, and technical requirement specifications as well as interface control documents. When a Partner is a designer of record for their scope, they are expected to concur with the technical requirements for their deliverable and approve the derivative acceptance criteria. In addition, Partners also follow the progression of design reviews from preliminary through final designs. A special effort is applied when components from different IKC Partners contribute to the same sub-system. For example, this is the case for the elliptical low-beta cryomodules that are produced via IKC from Italy (cavity), U.S. (instrumentation, gate valve, pipeline) and France (remaining cryomodule parts & cryo-module assembly), before being shipped at Fermilab and integrated in the PIP-II Linac. Management of these technical integration activities is critical to ensure all IKC deliverables achieve their requirements and can be accepted and integrated into PIP-II.

Changes to baseline designs, requirements, and interfaces in the PIP-II Project are evaluated through the design change control process that includes Partner stakeholders. PIP-II IKC Partners are also integrated the change control board where changes to IKC scope and schedule are evaluated. The integration of IKC Partners in the change control process helps them understand the possible effects of an IKC proposed change to their scope or schedule and to the integrated PIP-II Project. This approach also promotes the evaluation of possible shared mitigation actions, between the PIP-II Project and IKC stakeholders.

Before starting IKC production, to ensure alignment with PIP-II quality principles and procedures (including environment, safety, and health expectations), each IKC Partner developed quality assurance plans. Quality Assurance and Control (QA/QC) workshops aligned the QA/QC expectations between PIP-II and Partners. The establishment of a Quality Control Coordination Group forum with the participation of all IKC Partners is improving the communication on quality management.

Finally, the current focus is to finalize acceptance plans, criteria, and handover rules for IKC deliverables. This ongoing activity is helping solidify project management and technical expectations and requirements.

Challenges

In a multi-national environment like in the PIP-II Project, special effort is needed to understand possible cross-cultural differences, to maintain credibility with all the stakeholders, and to cultivate trust through clear communication. A common governance structure was established with each IKC Partner to facilitate complex coordination among Partners. This structure includes technical interface roles at each sub-system, as well as specific organizational supporting roles in project management, technical integration and quality fields to match the scope and complexity of the in-kind deliverables framework. Frequent meetings between key stakeholders at all levels of the organization assure complete alignment and early identification of possible issues. In addition, a three-tiered governance and communication approach (funding agencies, laboratory, project) is designed to facilitate communication and coordination, allow for escalation of issues and their resolution, and provide multi-layered influence and motivation. This structure has been in place since the planning stage of the PIP-II project and is functioning successfully.

The PIP-II Project is presently entering in the execution phase and it will soon face different IKC procurement strategies with a specific legal framework corresponding to each Partner. Even if the PIP-II Project has already established processes to validate the technical information before and after a contract is awarded (through Procurement and Manufacturing Readiness Reviews respectively), challenges remain to prevent supplier schedule and quality related risks. For these reasons, each IKC Partner developed a risk management plan before starting construction. This best practice was not only implemented to ensure alignment with the PIP-II risk management principles, but also to sensitize the Partners about the need to continue monitoring and managing their risks during the project life cycle. Risk workshops held with each IKC Partner analyze risk exposure and identify risks to include in the Partner risk register. Partners risks that could influence delaying of the integrated PIP-II Project are captured in the integrated PIP-II risk register.

Completion of prototypes, pre-series and pre-production items represent activities with associated schedule risk if they are predecessors to IKC related construction activities. Priority is set to avoid or limit the risks of IKC Partner delivery delays. Currently several high technical risks are already retired. Given the scale and complexity of the Linac development programme, the Fermilab project team has constructed the PIP-II Injector Test facility (also known as PIP2IT) as a system engineering testbed for PIP-II's advanced technologies. Completed last year, PIP2IT is a near-full-scale prototype of the Linac's room-temperature front-end, which accelerates protons up to 2.1 MeV, and the first two PIP-II cryomodules (HWR and SSR1) that then take the beam up to about 20 MeV [7].

CONCLUSION

PIP-II is likely not the last project to benefit from international collaboration – there will be more to come.

With the governance, project planning, and technical integration approach adopted for PIP-II, a successful integrated project model now exists for future projects to use.

ACKNOWLEDGMENTS

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