To:

From: William Pellico, PIP Leader

Bob Zwaska: PIP Deputy Leader, Fernanda Garcia: PIP Linac Manager, Keith Gollwitzer: PIP Booster manager, Elmie Peoples: PIP Planning Controls

Subject: Proton Improvement Plan

Project Quarterly Summary FY12 Q1 and Q2

Report #1 May 30, 2012

Project Description

Every proton for the domestic United States High Energy Physics experimental program will be accelerated by the existing, now 40-year-old, Fermilab Linac and Booster until new machines are operational to replace them. Completion of the proposed Fermilab Project X accelerator is anticipated no sooner than 2020 for beams up to 3 GeV and well into that decade for beams at higher energy. The domestic High Energy Physics program for the next 15 years relies on the viability and vitality of the Fermilab Linac and Booster.

The Proton Source Improvement Plan (PIP) is an effort to address the call by the Associate Director for Accelerators for "*delivering 1.8E17 (8 GeV) protons/hour (at 12 Hz) by May 1, 2013*" and "*delivering 2.25E17 protons/hour (at 15 Hz) by January 1, 2016*" while "*ensuring a useful operating life of the proton source through 2025*."

Plan elements are categorized into three major focus areas:
Maintaining viable and reliable operation of the Linac and Booster through 2025;
Increasing the Booster RF pulse repetition rate;
Doubling the proton flux while maintaining 2010 residual activation levels;

The PIP Design Handbook (Beams-Doc-3781-v2) and the master schedule provide a description of the plan elements. These documents are updated regularly to reflect progress along with changes in scope and schedule. The PIP Project Management Plan (Beams-Doc-4052-v2) describes the management procedures that the Fermilab Directorate expects the Accelerator Division (AD) and PIP organization to use in defining the scope and goals, developing plans, monitoring, coordinating, and capturing these activities in a WBS structure and a long range plan.

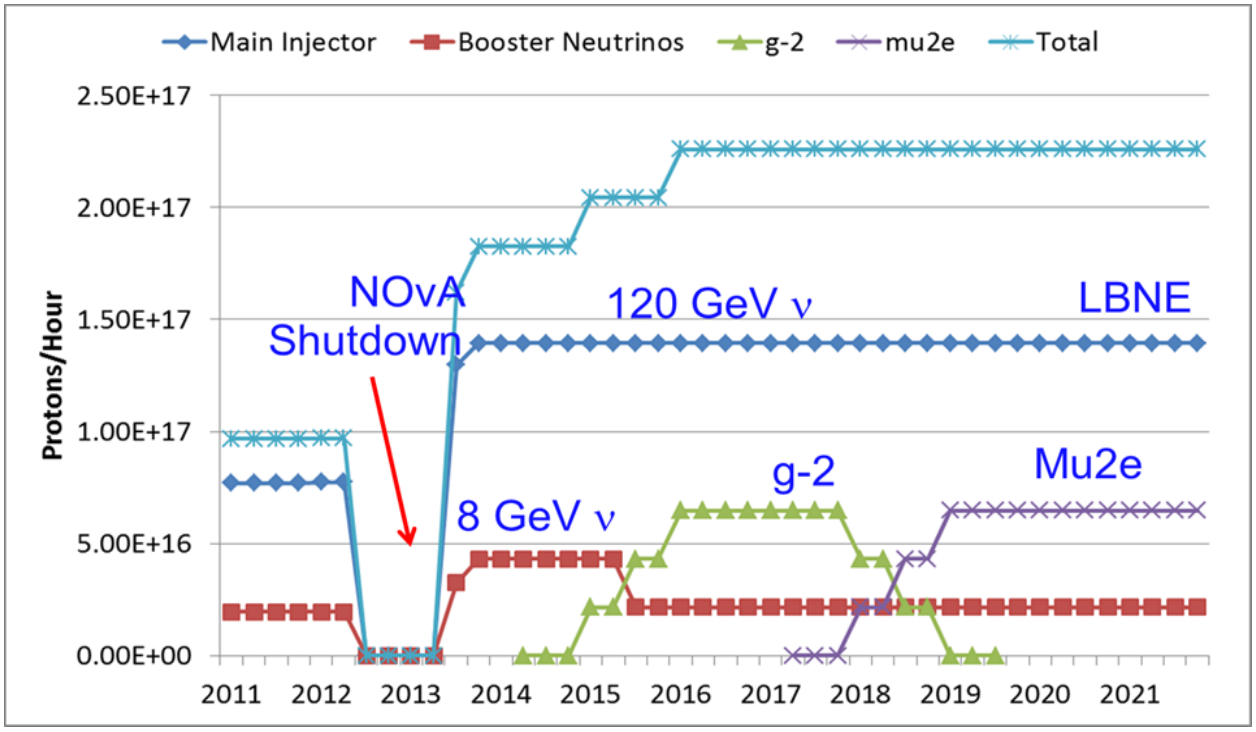
The current and planned proton flux delivery schedule is shown in figure 1. The additional flux is achieved by increasing the Booster beam cycle rate while maintaining current activation and reliability levels.

This PIP effort has a target M&S fully-burdened cost of $44.4 million which does not include staff cost. These funds assume a flat Proton Source operations budget over the same time period. Table 1 shows the PIP FY M&S profile laboratory management has given as guidance for PIP planning along with labor estimates from task managers. This funding allocation profile was a critical control in development of the RLS.

	FY12	FY13	FY14	FY15	FY16	FY17
Funding $	$6,295,979	$6,726,380	$11,979,420	$12,836,066	$6,789,400	$0
Labor (FTE)	47.79	34.83	32.25	30.43	31.99	4.81

Table 1 Burdened M&S and Labor estimates for PIP **(Base lined Schedule February 2012)**

Figure 1 Proton Source proton flux ramp up expectations for Intensity Frontier.



Overview of PIP Status

This quarter was the official start of the PIP effort with laboratory management signing off on the PIP design handbook in February. Along with the PIP design handbook, the initial resource loaded schedule (RLS) and PIP Management Plan were submitted and approved in February 2012 by laboratory management. These documents describe the PIP task structure, management organization and WBS. This quarter was also the start of the PIP documentation website which can be found at http://www-ad.fnal.gov/proton/PIP/PIP_index.html.

The PIP effort had actually begun over a year prior to this first reporting quarter. In December 2010, following the Proton Task Force report (Beams-doc-3660-v4), a Proton Source workshop was the unofficial beginning of the PIP effort. Early effort was primarily focused on investigating and documentation of the current Proton Source and the requirements of the laboratory program planning. This initial effort included reviews and discussions by both internal and external groups and helped define the current course of action. In FY11, a PIP management structure was formed and approved. Several tasks underway in the Proton Source and RF department critical to PIP were incorporated into the PIP effort. These tasks will show significant progress in this first report period due to their early start dates. Regular PIP management and planning meetings were also started in the first quarter FY12.

Project Milestones

Shown in table 2 below is a list all the level 0 through 2 milestones for PIP through to end of March 2012. This is the first quarter summary also had 37 level 3 milestones. Thirteen level 3 milestones from the base lined RLS were not completed but are not expected to impact the higher level milestones. The main reasons these were not met are the postponement of the start of the FY12 shutdown and the identified personnel were not fully available.

Table 2: PIP Level 0,1,2 Milestones - Summary for 1st and 2nd FY12 Quarter

WBS	Task	Level	Date	Milestone	Status
1.1.1.1	High Level RF	2	Feb-12	Analysis of situation; investigate possible solutions	Completed
1.1.1.1	High Level RF	2	Mar-12	Develop list of viable options to study in detail	Completed
1.2.7.4	Solid State Installation	2	May-11	Upgrade first two RF stations	Completed

PIP Highlights by WBS Section

WBS 1.1 Linac

The vulnerabilities associated with the LINAC are the 200 MHz accelerating system, including power amplifier tubes and other associated systems such as the modulator; utilities for power distribution and vacuum systems; better need for reliable instrumentation along the Linac to improve beam transport and realistic machine model supported by real beam measurements. There are four largest elements of WBS Level 2 in Linac which are further subdivided at Level 3.

WBS 1.1.1 200 MHz RF Power System

The 200 MHz RF Power System represents approximately 40% of the total scope of the PIP project. There are 3 level 4 elements which will be described below.

WBS 1.1.1.1 High Level RF

During the first quarter of FY12 a L4 manager was appointed to this task. The manager gathered background information of the Linac 200 MHz HLRF system to develop a path forward. Meetings were held during this period in order to define the task goals, objective, scope, timetable to the new manager. Options have been explored and evaluated. A special meeting was held in February with PIP management to assess the progress made in the first quarter and set strategic directions for the write up.

WBS 1.1.1.2 Linac Modulator

The work performed during the first quarter was related with the development of a new 200 MHz Modulator Specifications. The Working Group was formed during second half of FY11. It constitutes of

member of the Linac Group, AD/EE support engineers and a former 200 MHz technical expert as a consultant. During the first quarter of FY12 a new chair was appointed to this WG.

The waveform description that was developed and studied is shown in Figure 2.

Studies and simulations were performed in order to confirm or refute each parameter.

A technical document was written which discuss all the parameters specifications in detail (beamsdoc-3979). A formal presentation was also given to the PIP management team during the regular PIP Status Report Meetings in November 2011.

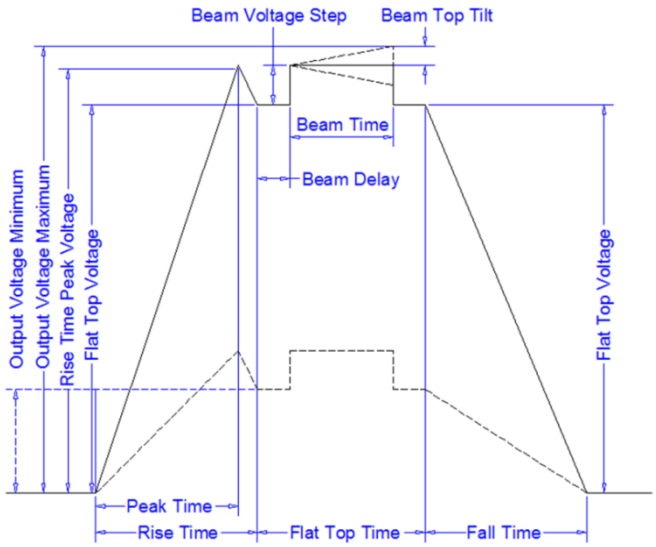


Figure 2: Linac 200 MHz Modulator Wave Form description.

Late in November letters were sent to five different companies to explore the interest level in pursuing this project. Among the five companies, two of them decided to no-bid our request. The proposals being explored at this point in time are:

1. Fermilab EE Support Department
    - Basic modulator design appears to meet all the performance specifications
    - The present technical challenge lies on the protection scheme during a tube spark while ensuring the modulator switching devices to survive.
2. Diversity Technologies Inc.
    - Meeting held at Fermilab in December 2011 with DTI CEO and Engineer.
    - DTI has not proposed a modulator that meets our specifications. Instead, DTI proposes to change the way we modulate the 7835 triode using hard switches and tube biasing circuits. This technique has never been achieved and long term stability would have to be carefully studied.
    - Currently working on a study plan to test their tube modulation to determine feasibility.
3. SLAC National Accelerator Laboratory
    - Proposed a modulator design using P2 Marx cells under development for klystron modulator for the ILC.
    - A Statement of Work (SOW) was completed in April 2012 that allows SLAC to cost out a design using P2 Marx cells to create a modulator capable of meeting our specifications. The work should be completed by August 2012 with a deliverable of a detailed design and cost estimate.
4. Continental Electronics Corporation

- Linac Engineer visited Continental Headquarters, in Dallas, March 2012 to discuss their plans to upgrade the Linac modulator.
- Continental is proposing a multi cell solid state modulator design capable of meeting many of our modulator specifications.
- Continental Staff visited Fermilab late April 2012 for a second meeting. Currently working on costing an engineering study to address many of the challenging specifications parameters needed for their solid state design.

WBS 1.1.1.3 7835 Procurement

The scope of this task is to develop a four-year inventory of the 7835 power tube. A procurement schedule was planned based on a dynamic statistical analysis of the tube parameters for the past 5 years. Also, a front loading tube purchase was recommended in order to save approximately 4% on total M&S cost. The procurement plan was presented to the PIP upper management team and other members of the project during the PIP Status Report meeting in November. During the first quarter of FY12, two new tubes were purchased. Late January 2012, in order to match budget profile, the number of tubes to be purchased was reduced from 7 to 6 which reduce the goal of developing four-year inventory by 12.5%.

WBS 1.1.2 Accelerator Physics

WBS 1.1.2.1 Simulations and Studies

Early October 2011 a new L4 manager was assigned to this task after the departure of the scientist who was leading this task. The first month of the quarter was devoted to the transition phase, by gathering the project's materials, resources and familiarizing with the task. The rest of the quarter was dedicated to create the first version of a complete Linac Lattice using Parmila as the particle tracking tool. Some initial development of the user-friendly GUI interface using Java code and Phyton programs were accomplished by the end of the quarter. A presentation of the current status was given at a PIP Status Report Meeting to the PIP upper management team and PIP members early January. Lately the efforts have been devoted to compare beam measurements with simulations results. In addition, initiated developing scripts to convert Parmila input file to TraceWin.

WBS 1.1.2.2 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.1.2.3 Linac Notch Creation

The Linac Laser Notching (utilizing a laser to neutralize the H- beam) activity has made significant progress since the initial proposal last fall in the following areas:

1) Location of the laser/H- ion interaction cavity
2) Refined the laser system requirements

3) Identification of components for the optical pulse generation
4) Refinement of requirements for each of the major laser systems
5) Identifying potential vendors for the various components of the laser system
6) Starting on the design of the laser matching and optical cavity design

In the original proposal for the Linac laser notcher the interaction cavity (for the laser and the H- ions) was to be installed at the end of the 400 MeV line. This location required beam tube modifications, quad magnet stand modifications, the construction and installation of a new absorber to dispose of the neutralized H- ions and relocation of the laser profile monitor. In addition, the laser system would be installed outside the booster tunnel and require transporting the laser light into the Booster tunnel. All of this is doable, but at some level of complexity and cost. At the end of Q2, the group revisited possible alternative locations for the interaction cavity to be installed and a suitable location was found in the 750 keV line downstream of the RFQ where the only modifications required are to the vacuum beam tube between RFQ and Buncher. At the end of this report period, a conceptual design for the interaction optical cavity was created.

WBS 1.1.3 Instrumentation

WBS 1.1.3.1 Beam Position Monitors

The Linac BPM system is old and obsolete. The plan is to update the existing RF log amp electronics with digital boards. Furthermore, in the High Energy Linac there are 62 BPM position channels and only 40 channels had been readout since the HE upgrade in early 1990's. The board chosen was a third generation of the Pbar BPM system, also being used by the MuCool Test Area (MTA) beam line. Addition features to the original design involve an implementation of a calibration system to improve long-term stability and phase measurement for time of flight (TOF) and energy measurement.

The board is capable of computing position averages and delivers all the position data to ACNET control at 15 Hz. During this first quarter, the first prototype board was complete and 4 BPMs signals were split to be read by the old and new board simultaneously. Below a picture of the new board and a data comparison between the new and old readout electronics for one split signal. This successful prototype test met the first task milestone (L3) and moved to the production of the remaining boards.

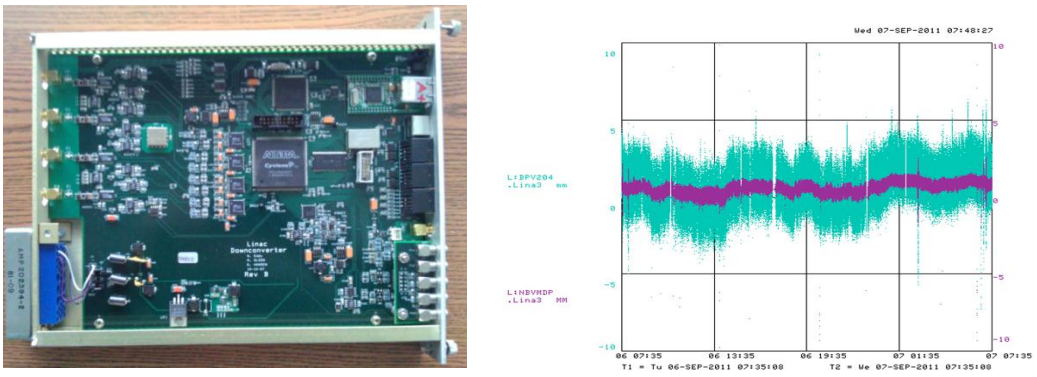


Figure 3 Linac BPM board (left) and performance (right) comparison with original log amp board.

WBS 1.1.4 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.1.5 Utilities

The Linac Utilities, such as power distribution and vacuum systems are composed of mostly 40 year-old equipment beyond its practical service life. There are two Level 4 elements in this WBS.

WBS 1.1.5.1 Power Distribution

The substation specifications were finalized and sent out for bid at the end of 2011. A presentation of the plan was given at a PIP Status Report Meeting to the PIP upper management team and PIP members. The contract was awarded early February 2012 to Federal Pacific at a cost approximately 8% lower than expected. The estimate date for delivery is June 2012.

In addition to the L3 transformer upgrade, the Motor Control Center (hereafter referred as MCC) task, which was originally planned for FY13, was moved to FY12. The rationale for changing the original RLS schedule was based on the scheduling advantages of installing MCC in conjunction with L3 transformer during the long lab wide Shutdown 2012 due to the impact on the level of powering off the whole 200 MHZ system. Therefore, in February the bid process was initiated and a contract awarded with Siemens was completed in the same month at a cost of approximately $50,000.00. Lately, the activities have been concentrated in developing the installation plan for both systems.

WBS 1.1.5.2 *Not Used*

Some numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established.

WBS 1.1.5.3 Vacuum System

A cost estimate was created for upgrading vacuum components in the Linac. Potential vendors have been identified and contact for quotes on the root blower stations. A presentation of the plan was given at a PIP Status Report Meeting to the PIP upper management team and PIP members.

WBS 1.2 Booster

The PIP effort for the Booster Accelerator is similar in some basic ways to the LINAC due to the age of both accelerators being 40+ years in operations. The task structure also mirrors that of the LINAC in many ways. However there are significant differences and concerns for the two accelerators.

The Proton Source Department has been working for years to increase the number of cycles that have beam. To reach beam on every cycle (15Hz operation), the RF systems are being upgraded. Several years ago, development of a modern power system for the RF, solid state, was shown to work. During the last two years a final design was settled upon and two RF stations were upgraded to solid state. With PIP, the remaining 17 stations will be upgraded. However, the RF cavities and tuner systems themselves are the original equipment and cannot run beam on every pulse due to overheating. The cavities and tuners are being refurbished to provide the needed additional cooling. The components are being cleaned-up, tested at 15Hz before re-installation. In addition to the near-term refurbishment, new tuners and cavities will be built.

Besides the vulnerable RF cavities-tuners, PIP addresses the aging infrastructure. The low conductivity water system has developed leaks over the years which will addressed by replacing pumps and valves. The vacuum system has antiquated components and will be replaced with modern equipment. The electrical transformers will be replaced as well.

With the larger proton beam flux, the possibility of more beam loss and activation of Booster equipment is a concern. Systems and procedures for operations are being developed and implemented to reduce beam loss and in certain circumstances contain beam losses. The goal is to not increase the amount of beam loss and activation as the proton flux essentially doubles.

WBS 1.2.1 RF

WBS 1.2.1.1 Anode Supply

Work was done on initial design for the anode supplies which will replace the 40 year old operating system. The work is based upon the Main Injector anode supplies.

WBS 1.2.1.2 Bias Supply

Testing of a spare bias supply to measure the temperatures of heat sinks and silicon-controlled rectifiers (SCRs) was done in preparation for procurement. The specifications for the bias supply transformer are being developed for procurement of a prototype.

WBS 1.2.1.4 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.1.4 Cavity Test Stand

A description of the layout and setup for a test stand was produced. ES&H is reviewing the proposed shielding of the test stand. The shielding is necessary due to the activation of the tuners and cavities as well as for x-rays produced during testing. RF equipment from the Tevatron will not be moved and equipment will not be purchased until final ES&H approval to proceed with the test stand layout.

WBS 1.2.1.5 Cavity and Tuners Refurbishment

The first cavity and tuner set were removed after the termination of the Tevatron collider program. The cavity was known to have vacuum issues and proved to be difficult to repair. A series of tests at several rates and power were performed to measure temperatures at different locations on the cavity, tuners and connections. A team learned to dismantle, repair and re-assemble the tuners. The refurbished cavity-tuners system final test was to run at 15Hz at full power for several days while monitoring the temperatures. The connection between the tuners and cavity were troublesome. The tolerance for these connections is more stringent than had been necessary before for operations as well as what was expected. Every time that the temperature of a connection was too large, it would take several days to disconnect from the test setup, redo the tuner-cavity connection and re-establishing the test. After successfully passing the final test after refurbishment, the cavity-tuners was not re-installed, as well as the removal of a second cavity-tuners, since the laboratory deemed operation was most important; the exchange of cavity-tuners will take place at the beginning of the FY12 shutdown. Table 3 below gives our current timetable.

WBS 1.2.1.6 New Tuners

Two types of ferrites are needed for the tuners. Ferrites provided by potential vendors are being tested. Low power testing showed that no samples met the larger magnetic permeability specification; a vendor has sent a second set of samples. We are also making a high power testing setup for the ferrites. After vendors for ferrites are qualified; we will order the first set of ferrites and procure the remaining materials for making tuners.

WBS 1.2.1.7 New Cavities

A model is being developed of the current Booster RF cavities. The temperature measurements taken as part of the refurbishment task are being used to benchmark the model. We are looking to make improvements of the current design to increate the aperture as well as eliminate potential hot spots (potential failure points).

WBS 1.2.1.8 Cavity 1013

With spare and left over material from the original building of RF Booster cavities, there is enough to build an additional cavity. It has become obvious why certain pieces were not used originally; these pieces are being reworked such that all of the pieces will fit together to form a functional cavity. The original goal was to replace an operational cavity before the FY12 shutdown; with this not being possible, the priority for this task will be lowered.

WBS 1.2.2 Accelerator Physics

WBS 1.2.2.1 Simulations and Studies

Studies have been on-going with the development of data acquisition methods and procedures. Data have been collected throughout the Booster ramp cycle and then been analyzed. These results have been compared to the simulations. In cases of disagreement, studies were done to validate the data and/or check the simulations input.

WBS 1.2.2.2 Alignment and Aperture

As with the studies above, development of data acquisition methods and procedures have been done. Data analysis shows the locations where the aperture is small. Based upon the limiting aperture locations, a proposed first magnet move-alignment has been worked out. The move, re-taking of aperture data and analysis will be done early within the FY12 shutdown.

WBS 1.2.2.3 Booster Notcher

The main person for the original design and work retired at the end of FY11; a new level 4 manager was identified in December. An internal review of the notcher was done in February; adjustment to the design and implementation are being/going to be done according to the reviewers' recommendations. In particular, we are looking to include additional shielding material by performing additional MARS simulations. The basic components of the absorber have been ordered. The basic components of the absorber will be assembled and tested before final installation during the FY12 shutdown. Preparations for moving the notcher kickers and associated power system have done; the movement of these items will occur during the FY12 shutdown.

WBS 1.2.2.4 Booster Cogging

Based upon the current cogging equipment, initial code development for the new magnetic cogging method-system has been done.

WBS 1.2.2.5 Booster Collimation

The collimation task is to control Booster beam loss after implementing the above notcher and cogging systems.

WBS 1.2.2.6 Radiation Shielding

There are on-going discussion and simulations of the material to be put into the Booster penetrations for shielding purposes.

WBS 1.2.3 Instrumentation

WBS 1.2.3.1 Beam Position Monitors

Design work for the Booster beam position monitor system will begin after completion of the Linac beam position monitor system.

WBS 1.2.3.2 Dampers

Work defining the hardware requirements for the longitudinal damper system was started.

WBS 1.2.4 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.5 Utilities

WBS 1.2.5.1 Low Conductivity Water System

During the FY12 shutdown, the low conductivity water system will be upgraded. The work has been specified, bid and contracted. Procurements for the part of the upgrade being done by Fermilab personnel have been done.

WBS 1.2.5.2 Power Distribution

Transformer design will be based upon recent new equipment implemented at Fermilab and will start after the Linac transformer is installed during the long shutdown.

WBS 1.2.5.3 Vacuum System

Vendor quotes are being acquired for vacuum equipment needed for the upgrade. Purchasing will occur soon. The goal is to replace some of the aged components during the FY12 shutdown.

WBS 1.2.7 Solid State Upgrade

The Booster RF solid state upgrade has been going on piecemeal for several years with purchasing of enough components to assemble the main elements of the solid state system: power amplifier, driver module and modulator. With the Proton Improvement Plan, we have been able to buy components in quantities. We have procured enough to complete ten power amplifiers, driver modules and modulators. We have started the procurement of the remaining components to complete the upgrade.

With the termination of the Tevatron program, some labor resources were allocated to work on assembly of the three main elements. Five power amplifiers, ten driver modules and four modulators have been assembled. The assembly processes have become more parallelized and time to assemble each main element is decreasing. The increased production rate has been factor into the schedule and completion of the solid state is expected to be finished during FY13.

Table 3 Solid State and Cavity Refurbishment Time Table

BRF	Solid State	Cavity 15Hz	Status	Date Removed	Planned Install	Date Installed
1	X			11/12/2012	1/2/2013	
2	X			10/15/2012	11/29/2012	

3		6/15/2012		9/10/2012	10/29/2012	
4		6/15/2012		8/13/2012	9/24/2012	
5	X			7/16/2012	8/27/2012	
6	X			6/15/2012	7/30/2012	
7	X		cavity refurbishment underway	5/4/2012	6/15/2012	
8	X	X		10/8/2011		5/2/2012
9		8/15/2012		12/17/2012	1/28/2013	
10		8/15/2012		1/14/2013	2/25/2013	
11		2/15/2013		2/11/2013	3/25/2013	
12	X			3/18/2013	4/29/2013	
13		11/15/2012		4/15/2013	5/27/2013	
14		11/15/2012		5/13/2013	7/1/2013	
15		12/15/2012		7/15/2013	8/26/2013	
16		12/15/2012		8/12/2013	9/30/2013	
17		9/15/2012		9/16/2013	10/28/2013	
18		9/15/2012		10/14/2013	11/25/2013	
19	X			11/18/2013	12/30/2012	

X= SS Upgrade Completed, X = Cavity Refurbishment Completed

WBS 1.3 RFQ

The RFQ effort for the first two quarters FY12 has been extensive. The entire line up though the test diagnostic line has been installed and tested.

- Two magnetron plasma sources
- LEBT (Solenoids, Trims, Eiznel Len)
- 201.25 MHz RFQ
- All associated vacuum, power and diagnostics components
- Diagnostic Line (Wires, emittance scanners, toroid, spectrometer magnet)

The beam testing has been very successful up to the RFQ. The current, efficiency and emittances look good. However, a major problem was found when the beam energy was measured. The output beam energy of the RFQ is not the required 750 KeV but approximately 710 KeV. This is currently being worked on and is expected to cause a delay in the planned installation later in FY12. Work on the MEBT planned for the 2nd quarter FY12 was delayed due to labor needed to investigate the RFQ energy issue.

PIP Budget – Costs and Obligations Updates (FY12 Q1 & Q2)

This budget summary section will be inclusive from the start of FY12 before a base lined fully burdened schedule was produced. Since that time, the PIP has ramped up budgeting and effort allocation requirements to meet a RLS. Labor and cost estimates have undergone many changes in an effort to firm up PIP goals and resource requirements. Tables 4 and graph 1 below show the status of PIP budget with RLS estimates from the baseline budget created in February 2012. Variances in the RLS and actual

PIP numbers are due largely to less labor being available compared to PIP RLS requests and some purchases in the second quarter being delayed due to the FY12 shutdown.

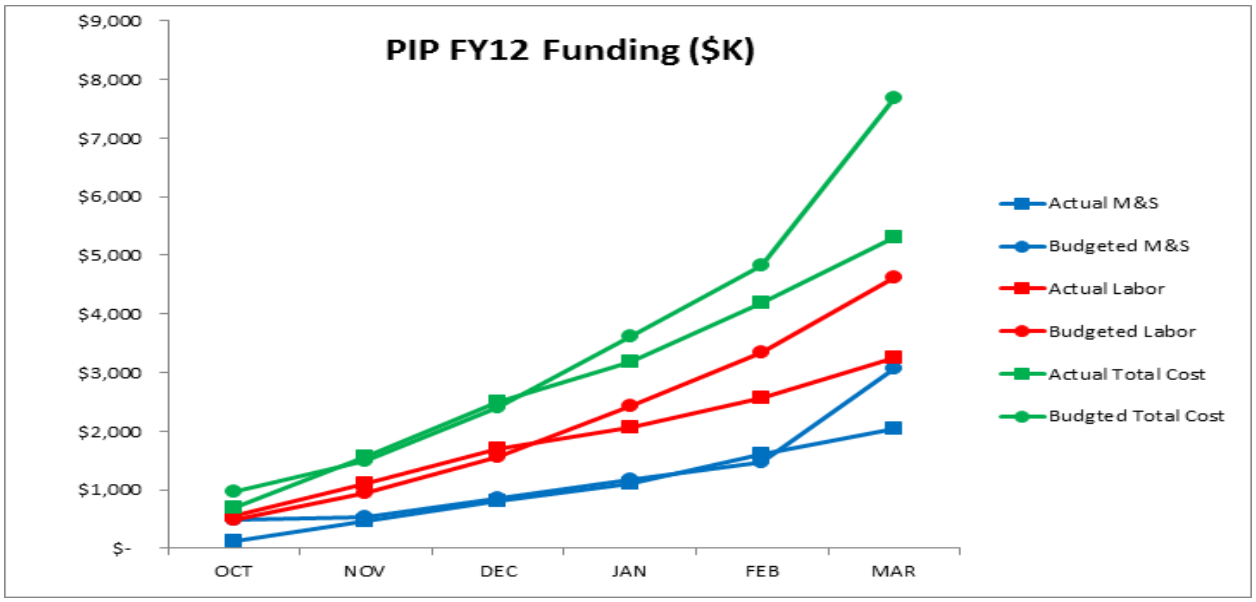
Table 4 PIP Year to Date Budget Summary (including requisitions in process and includes 18% M&S and 88% labor burden)
*** represents 20% additional M&S budget allocation beyond the guidance that developed Table 1**

FY12 PIP OBL BUDGET K$	OBL BUDGET	YTD OBL	3/12 RIP	BUDGET BAL
M&S	7,595 *	2,044	298	5,253
Labor	6,884	3,253		3,631
FY12 Sums	14,478	5,297	298	8,884

Shown below in graph 1 is a monthly breakdown of to date labor and M&S cost for PIP effort for FY12 Q1 and FY12 Q2 compared to RLS projections.

Graph 1 PIP Labor and M&S Cost - April FY12

Graph 1 FY12 Q1 and Q2 Resource Plot



PIP Management and Meetings Summary

These first two quarters of the PIP effort have had the typical issues you would expect for such a large effort and with large budget and labor guidance variability (fluctuation). Weekly PIP summary and management meetings have proved essential in ramping up PIP and in the development of a RLS. The M&S and labor outlined in the current RLS will be sufficient to make significant progress on PIP this FY and give the task managers the needed guidance and resources. However, corrections to both the labor and M&S profile are currently underway and will be reflected in the next report. PIP planning for FY13 and outlying years is also expected to need significant changes and is likely to require a re-baseline of PIP