To:

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Subject: Proton Improvement Plan

Project Quarterly Summary FY15 Q4

Report #12 October 22, 2015

Project Milestones

There were 5 Linac scheduled milestones level 3. Four of them were related with the Linac WBS Linac Notch System: *Linac Notcher (FA) Certify all three stages ready for installation, OPG Module ready for installation, FSLA Operational on Bench Ready to Install into OP and Linac Notcher Beam Shaping/Launch, Diagnostics, Dump Ready for Installation.* The first 3 milestones have been met, which system operational in the lab and tunnel ready for installation was complete 4 months earlier than the project baseline schedule. In contrast, the later was pushed forward by six months. One milestone related with Linac WBS Linac HLRF*, Final Cost Estimate for Linac Gallery Civil Construction* has been delayed for 12 months compared to the project baseline schedule. More information on the status of these tasks are presented on section WBS 1.1.2.3 Linac Laser Notch and WBS 1.1.1.1 High Leve RF. The Booster had 4 milestones; three level 3 and one level 2. Three were completed, one fell into FY16 Q1 and one delayed till FY16 Q2. Both delays were due to shutdown labor issues. Labor has picked back up and work on delayed tasks has made up some lost time.

L	WBS	Description	Baseline	Q3 Date	Q4 Date
3	1.02.03.01.02.05	Booster BPM System, Hdw. & Firmware Prot. Design complete	12/22/14	7/1/15	7/25/15
2	1.02.03.02.01.14	Booster Long. Dampers Complete - boards installed & in Ops	10/30/14	7/2/15	9/30/15
3	1.01.02.03.03.20	Linac Notcher (FA) Certify all three stages ready for installation	12/2/14	9/25/15	9/25/15
3	1.01.02.03.06.23	Linac Notch Beam shaping technology chosen	10/8/14	10/8/14	10/8/14
3	1.02.01.01.03	Specifications for Anode Power Supply Documented	10/15/14	11/26/14	11/26/14
4	1.01.05.02.01.10	Linac LCW System Complete	11/24/14	12/30/14	12/30/14
3	1.01.05.02.02.16	Complete 55 LCW Spare Syst	12/9/14	12/18/14	12/18/14
3	1.02.03.01.01.03	Booster BPM Specification Complete	12/8/14	7/2/15	7/2/15
3	1.01.01.01.02.02	Prototype Klystron Final Assembly Drawings Complete	12/17/14	3/2/15	3/2/15
3	1.02.03.02.01.09	Specifications document for Booster longitudinal dampers done	12/1/14	3/18/15	3/18/15
4	1.01.05.02.01.09	Complete Installation of New Dual Temp System	3/24/15	12/30/14	12/30/14
3	1.01.02.03.05.33	Linac Notch Final Optical Cavity Certified	2/2/15	10/22/14	10/22/14
3	1.01.02.03.02.26	OPG module ready for installation	2/6/15	7/15/15	7/15/15
2	1.02.02.04.07	Commissioning & Beam Studies - Booster Cogging Complete	4/14/15	4/15/15	4/15/15
4	1.01.01.01.02.01	Final Cost Estimate for Linac Gallery Civil Construction	4/21/15	12/21/15	4/21/16
3	1.01.02.03.04.14	Linac Notch FSLA Operational on Bench - ready to install	4/23/15	9/28/15	9/28/15
3	1.02.01.02.03.16	Finish program of gutting & assembling Bias Supply enclosures	4/15/15	6/22/15	11/11/16
3	1.02.03.01.05.02	Booster BPM Production Procure/Assembly Complete	5/15/15	7/21/15	3/1/16
4	1.01.02.03.06.33	Linac Notch Beam Shaping, Diag., Dump ready for installation	9/21/15	2/3/16	3/16/16

Highlight note:
In the FY15 Q4 a significant achievement was accomplished for both PIP and the laboratory. The Booster was for the first time able to operate at 15Hz. This was one of PIP's three goals and a major reason for implementation of PIP. In addition, shortly after achieving 15 HZ, the Booster set an hourly flux record. Over 20% above previous the hourly rate of 1.2E17 pph the new 1.5 pph hourly rate shows we are well on our way to achieving the next goal of 2.3E17 pph.

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 200MHz 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

The klystron prototype development continues to make progress.

Klystron design -- The final assembly drawing has been updated to correctly represent the interface panel and all lead shielding. The outline drawing is now being updated and it will be sent to Fermilab once complete.

Klystron manufacturer -- The 1st cavity assembly frequency and loop geometry were finalized. It is waiting to be brazed before the final cold test and weld. The 2nd cavity and 3rd cavity have been finalized and welded. The braze of the wall that joins the 4th and 5th cavities, which was previously reported they had failed, has been completed and passed the vacuum leak check successfully. With that cold testing of the 4th and 5th cavities was complete. The output loop needed more adjustment than expected. CPI had originally purchased 3 different sized loops, but the final dimensions were beyond any of the three loops purchased. A method of separating the solid loop and then re-brazing it as one piece was developed and worked out well. The output cavity wall has been assembled and is currently going through the braze furnace. This output wall is similar to the other wall which required additional rib supports and a new heat shield to be used during the braze. This braze went very smoothly with the added experience of the previous wall as well as the fact that this wall is significantly thicker and more robust. At the time of this report, the team was getting ready to start the bake out. Figure 1 shows the klystron fully assembled.

At Fermilab the main focus on this past quarter was to finalize the layout of the Linac Gallery with a 3D model. Drafting effort was limited due to limited drafter staffing and competition with other on-site projects. In addition for this quarter, resources were re-focus to assist necessary shutdown activities. Furthermore, the final klystron mechanical layout drawing was released by the end of this quarter by CPI's lead engineer. The assigned mechanical drafter is current incorporating the final klystron model to the gallery layout. With a positive result on the acceptance test scheduled for the first quarter of FY16, this will allow the L2 manager to complete the final cost and documentation by the FY16Q2.

Figure 1. Klystron fully assembled getting ready for bake-out.

WBS 1.1.1.2 Linac Modulator

Work is progressing well on developing a prototype modulator capable of replacing the present tube based design.

A total of 35 cells were fully assembled, tested and 28 of them were selected and installed in the fully assembled modulator cabinet this quarter.

The charging supply chosen by the group is Lumina Power/ 6kV. In the last quarter report was told that additional 6 power supplies were ordered, which is required for the 28 cells modulator, and the expected delivery time was expected to happen this quarter. They were delivered approximately 5 weeks late. Furthermore, the supplies, originally specified to be capable of running at 480 VAC, did not pass the in-house test. The first unit tested failed after 5 minutes of running. The team immediately brought this issue to the attention of the vendor lead engineer and a meeting with the chief engineer of the Lumina power supply company was conducted. The team learned that the supply was designed to run two inverters in series when the supply is set at 480 VAC mode since they can't hold enough voltage on their own. They run in parallel when the power supply is set at 208 VAC since this is below the rating of the devices and the system does not require a good balance between the inverters in this mode. They have to balance the resonant frequency of these inverters so that they are capable of sharing the loading equally. This step was not performed on the last order of 6 power supplies since they were not tested at 480 VAC initially, which explains the failure of the first supply. A decision was made to send all 6 units back to the vendor. At the vendor site, 480 VAC tests were performed on the supplies and was reported that another supply failed, even after the resonant frequency of the inverters was balanced by the manufacturer. This too was likely another inverter failure which was confirmed by the vendor after few days. The manufacturer did admit that their system will more reliable if is operated at 208 VAC instead of 480 VAC. Since the resonant frequency can drift as the system ages mean it was decided to modify the control relay rack to run at 208 VAC. This job was carried out this quarter which involved a complete rewiring of the power lines, replacement of all breakers and contactors. This also meant to add a 480/208 transformer to converter the voltage levels. This change on the design represents 10% additional cost on the charging power supply. After performing all the necessary changes the supplies, individually underwent another set of tests at 208 VAC to the dummy load to determine if they run as designed. All supplies performed satisfactory. With this additional problem and a conflict on manpower during the shutdown 2015, the schedule was impacted by a month delay at this point.

During the preliminary test of the 28 cell testing it was discovered that the built-in voltage regulation loops on each of the charging power supplies was not adequate for accurate running. An in-house design for this circuit to replace the present loop with a learning system was being conducted at the end of the quarter. Finally but not least, the 28 cell system was tested at maximum pulse rate of 4 Hz without problem. At the end of the quarter, the team was getting ready to test the 28 cell at 15 Hz bursts, occurring once every few seconds, to limit the average power dissipated in the dummy load.

Figure 2: Linac Marx-Modulator Cabinet showing cell shelving units and all rows populate with 28 cells.

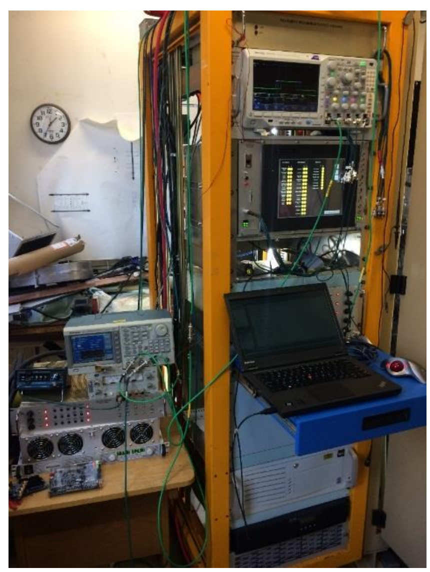

Figure 3: Linac Marx-Modulator controls relay rack.

WBS 1.1.1.3 7835 Procurement

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.2 Accelerator Physics

WBS 1.1.2.1 Simulations and Studies

Linac Level-4 WBS completed (FY15-Q1).

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

Work continues with the development of the laser notch system.

The Critical Device Control module and the Laser Notcher Safety Interface Chassis (LNSIC) for the Laser Notcher was designed, built, and installed. LNSIC has been integrated into the Laser Lab Safety system and is currently in use.

The optical box and its alignment fixtures and safety switches have been installed on the Laser Notcher electronics rack.

The design for the transport and dump enclosure as well as their support structure on the RFQ has been completed and some of the components for these have been fabricated.

The chiller and manifold were designed, installed and implemented for the operation of the Grumman free space amplifiers.

Both Grumman amplifier modules have been tested in the small signal regime.
The water tubing between the chiller and manifold along with all the timing, safety, and network cables are in place in the Medium Beam Transport (MEBT) line.

A new support floor in the MEBT has been installed to cover up the large gap between the RFQ and sliding doors.

The optical BPM's (OBPM) were designed, manufactured and tested in conjunction with the piezo mirror mounts through the LabView program. The horizontal and vertical position response of the OBPM's were found to be pretty linear in the region of ± 4 mm.

Although the development of the LabView software for the operation of the Laser Notcher continues, all of the major devices are now controlled through the program. In addition setting logs have been implemented.

The PriTel 2W amplifier gain medium was modified to reduce the potential of generating a harmful SBS nonlinearity.

The major issue for the 4th quarter has been the fiber connection between the CW PriTel power fiber amp with an average power of 2W and the pulsed Optical Engines fiber amplifier. This interface is through a fiber-to-fiber interface which is required due to the design and geometry of the two amplifiers. The average power at this interface is significant and has been the subject of two failures. It is the team believe that the last failure was due to heating caused by contamination of the fiber tip. To make this robust and less prone to failures, the team needs to get better at inspection and cleaning of the fiber tips AND the laser size at the interface must be increased to reduce the power density. Two techniques have been identified to reduce the power density at this interface by 1 or 2 orders of magnitude. The group is in the process of perusing both techniques. This is the critical path as of now. In the meantime work continues to develop all other systems required for installation.

WBS 1.1.3 Instrumentation

WBS 1.1.3.1 Beam Position Monitors

First Linac Level-3 WBS completed (FY13-Q2).

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, water and vacuum systems are composed of mostly 40 year-old equipment beyond its practical service life. There are three Level 4 elements in this WBS.

WBS 1.1.5.1 Power Distribution

Linac Level-4 WBS completed (FY14-Q4).

WBS 1.1.5.2 LCW distribution

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.5.3 Vacuum System

Linac Level-4 WBS completed (FY14-Q4).

WBS 1.2 Booster

Part of the PIP effort for the Booster Accelerator is to address the increase proton beam flux that will be demanded by the Fermilab program in the upcoming years. The increased flux will be achieved by providing beam on more/all of the Booster cycles; certain equipment will increase from an average 7.5 Hz to 15Hz. Overheating of old components is a major concern; several Booster PIP tasks are to upgrade/refurbish equipment to run at 15 Hz. During the FY15Q3, we were able to test the Booster at 15 Hz.

The aging original equipment and infrastructure of the Booster are vulnerable due to obsolescence and increase wear due to the increase of flux. Some of the PIP effort is to replace these possible reliability problems.

WBS 1.2.1 RF

WBS 1.2.1.1 Anode Supply

Both anode supplies are in the process of being installed during the 2015 accelerator shutdown. The first supply has been used to shake out the process of installation and testing. The lessons learned from the first installation has made the second anode supply installation go smoother. At the end of FY15Q4, the first installed anode supply was in the process of testing/commissioning. The completion of the installation and testing of both anode supplies will be done early in FY16Q1. This task needs to be completed for the accelerator complex to meet the beam demand for FY16.

WBS 1.2.1.2 Bias Supply

Nine retrofit bias supplies have been tested and installed. The last bias supply is undergoing was late; man power to do the conversion has been diverted to accelerator shutdown activities. However, this task was recently completed after the shutdown and supply has been tested.

WBS 1.2.1.3 *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

The cavity test stand task will not be done since there will be no benefit to PIP.

WBS 1.2.1.5 Cavity and Tuners Refurbishment

During this last quarter, the 18^{th} cavity-tuner set refurbishment and testing was completed. This cavity was installed during the shutdown. When the shutdown ends early in FY16Q1, the booster will be capable of providing beam at 15 Hz.

The 19^{th} cavity-tuner set refurbishment was also completed as FY15 ended. The cavity awaits to be tested. RF experts that perform the test are involved with shutdown activities and then with commissioning. This cavity is expected to be installed in November 2015.

WBS 1.2.1.6 New Tuners

Previously, a high power test stand for ferrite cores showed that one of four different core sets (two different permeabilities from two vendors) was acceptable. The acceptable core samples have been implemented into a tuner and been certified. The tuner was installed on a re-furbished cavity; the cavity has been operation since FY14Q4. A purchase order for enough ferrite cores to build twenty tuners was placed. During FY15Q4, the vendor has delivered, and we have accepted, the balance of one set of ferrites. The vendor has encountered a problem making the second set of ferrites (low value of permeability); the vendor has corrected the problem and we should receive the balance of ferrites during FY16Q1.

Fermilab Technical Division is using the ferrite cores with other sub-assemblies to build new tuners. The assembly group has gained experience building the new tuners. Now, assembly is about three weeks to complete a tuner. Eight tuners have been built and passed acceptance tests.

WBS 1.2.1.7 Replacement Cavities

Comparison of a model developed for the current Booster RF cavities and the temperature measurements taken as part of the refurbishment task continues. Further tests of cooling rates will be done to be compared with the simulation. A preliminary look into making small improvements to the cavity-tuner design is being done. Detailed temperature measurements were done during cavity and tuner set refurbishment certification (WBS 1.2.1.5); further measurements were done during the next cavity tuner set certification. Simulation model verification continues and requires another set of temperature measurements which will be done on the next cavity-tuner set.

The task has been renamed from new to replacement. Fermilab has recognized that any new/replacement cavities should work with PIP II and a possible future rapid cycling synchrotron. Requirements satisfying now and for the future have been determined. A review of the technical specifications was held. The review panel agreed that the specifications meet the needs of PIP and PIP II; it was noted that the specifications could work with a possible future rapid cycling synchrotron.

WBS 1.2.1.8 Cavity 1013

The cavity was put into operation in FY14Q4 and was operational during FY15Q1. There have been no problems with this reworked cavity. This task is considered complete.

WBS 1.2.1.9 Second Harmonic Cavity

The investigation of possible benefits of using a higher order harmonic cavity continues; in particular, for beam capture and transition crossing. The investigation is focused upon a perpendicular biased cavity. Work previously done at SSC and TRUIMF was our starting point. Modelling and simulations progress has led to improvement over the old designs. Garnet sample testing show that it is suitable for a perpendicular biased cavity. Parts are being orders and manufacture to build a partial mock-up which will be used for further testing for design and simulation validation.

WBS 1.2.1.10 Rework of Two Cavities

Although not new cavities, PIP has decided to reclaim two other cavities and rework them to be the 21st and 22nd Booster cavities (similar to the rework done for cavity 1013; WBS 1.2.1.8). Long lead time items are being procured. This work will commence after the refurbishment task (1.2.1.5) is complete. Tuners will be provided by work done by the New Tuner task (1.2.1.6).

WBS 1.2.1.11 Three New RF Stations

In addition, PIP will implement three additional RF stations to bring the total number of Booster RF stations to 22. This requires electrical work, water cooling work, assembly of power equipment and cable pulling.

The 20th RF station was completed during the 2015 shutdown. This new station will be part of the commissioning of the accelerator complex early in FY16Q1.

The remaining two RF stations will be completed in the 2016 summer shutdown. An initial conceptual layout has been done for these two stations. Clearing of space and preparing these areas has begun.

WBS 1.2.2 Accelerator Physics

WBS 1.2.2.1 Simulations and Studies

The people assign to the task of organizing, performing and analyzing beam studies has been consistent for the last few quarters. The main work is being done by an accelerator scientist in the Proton Source Department. There are several physicists from the Accelerator Physics Center also involved. The control programs for adjusting the lattice and tunes have been combined. The resulting application can adjust either the lattice or tune without affecting the other. Testing of this application is on-going and has to not affect operations.

The Booster was shut down for most of this quarter. Work was done to further develop the simulation models.

WBS 1.2.2.2 Alignment and Aperture

Currently, no further magnets are scheduled to be moved. There are a few candidate magnets, but current simulation and beam studies (WBS 1.2.2.1) do not suggest that there will be noticeable improvement. The centers of the apertures have been designated as the ideal orbit (see WBS 1.2.2.1). We may return to this task in the future.

WBS 1.2.2.3 Booster Notcher

This task would be considered complete with the exception of some modified components are more activated than expected. Part of the upstream absorber mask was removed. By removal, of the activated mask, the area upstream of the absorber will hopefully not be susceptible to as much gamma ray shine from activated components. The part of the mask that remained, is further into the absorber shielding and hence workers in the area will have less exposure. During FY16, activation measurements of components of the absorber and the near the absorber will be done to see if the activation caused by the notch beam is contained within the absorber. We will continue studies to understand.

WBS 1.2.2.4 Booster Cogging

Studies of the new cogging board and code were concluded in FY15Q3. The cogging board was put into operation. This task is finished with the exception for interfacing with Linac laser notching system in FY16.

WBS 1.2.2.5 Booster Collimation

The collimation task is to control Booster beam loss after implementing the above notcher and cogging systems. A group has started studies of using existing collimation components. These studies include simulations, beam loss observations and exercising collimators movements.

WBS 1.2.2.6 Radiation Shielding

Beam studies concerning the beam loss profile and measurements of beam loss radiation through penetrations have been done. Simulation studies involve the effectiveness of the passive shielding, active detectors and radioactive source terms for penetrations are nearly complete.

A Total Loss Monitor (TLM) system of eight long detectors has been installed; each detector covers three Booster periods. The assembly, testing and installation of the needed electronics was completed during FY15Q2. Beam loss tests and measurements have continued. The analyses and write-up investigating beam loss as well as TLM responses continue. The TLM and radiation shielding assessment need to be concluded before much more proton flux can be attempted.

WBS 1.2.3 Instrumentation

WBS 1.2.3.1 Beam Position Monitors

The design work for the beam position monitor system is complete and procurement has started.

WBS 1.2.3.2 Dampers

Studies were conducted which showed that the damper board and code work and will perform the needed function. During FY15Q4, the final programming was done. Once the accelerator complex is commissioned, the damper board will be part of operations.

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

The task is done.

WBS 1.2.5.2 Power Distribution

The last power transformer has been manufactured. The transformer is identical to the two transformers previously purchased by PIP. The installation was completed during the 2015 shutdown.

WBS 1.2.5.3 Vacuum System

The aged components will be replaced as opportunities present themselves with downtime of the Booster. Previously purchased vacuum equipment awaits opportunities for installation. During the shutdown, some vacuum work was done. The last procurement was started at the end of FY15. The end of the PIP vacuum work will be done during the 2016 summer shutdown.

WBS 1.2.7 Solid State Upgrade

The task is done.

Booster Budget – Costs and Obligations Updates (FY15 Q4)

The FY15 fourth quarter had no significant budget changes. PIP to PIP II alignment discussions are still ongoing with plans to complete a document describing the necessary work to be released soon. PIP tasks as aligned to PIP II are understood and RLS adjustments are nearly complete. The biggest task that required alignment and offers significant impact to PIP schedule is the replacement Booster cavities. The laboratory management requirement that any replacement cavity be used as part of PIP II Booster operations and also it use in the yet undetermined Booster replacement required significant effort.

PIP budget and labor through the end FY15 are provided below. The delay in modulator work due to labor shortages pushed M&S into FY16. The desire was to test and verify the operation of the 28 cell modulator before purchasing hardware for the remaining units. A positive test would reduce risk and could provide additional information on the chosen hardware. Since that test is now on-going the M&S was had significant carryover into FY16. However, due to recent funding issues, lab management has requested that 3 M of the carryover be removed from PIP FY16 budget to cover shortfalls in other areas. In addition to the removal of the PIP carryover, a request to remove an additional 1.5 M from FY16 PIP budget has been made. PIP managers have therefor gone through all tasks and removed any M&S that would not have a significant impact to the labor and immediate PIP plans. This was a difficult task and we provided our best effort to lab management. A final decision is pending and should be ready for release in FY16 Q1.

Table 1 PIP FY15 Q4 (End of Year) budget table

FY15 PIP OBL BUDGET K$ **	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	5,105.6	1,178.8	479.2	3.447.6
Labor	5,465.5	6,276.4		-810.9
FY15 Sums	10,571.1	7,455.2	479.2	3,115.9

The labor for this past fiscal year, provided in figure 4 below, is very similar to the previous quarter and shows that PIP has been close on most of the requested labor. Also like last quarter, the bump in mechanical from TD is due to the increased effort in building new Booster tuners. This will improve the refurbishment process and help improve uptime. Consistent labor has resulted in efficient and consistent PIP progress. It can be seen that PIP consumed more labor than planned. Activities, like the Booster anodes, took longer and ended up requiring more labor. Completion of these tasks were tied to the shutdown/startup plans and the necessary labor was provided to accomplish the task.

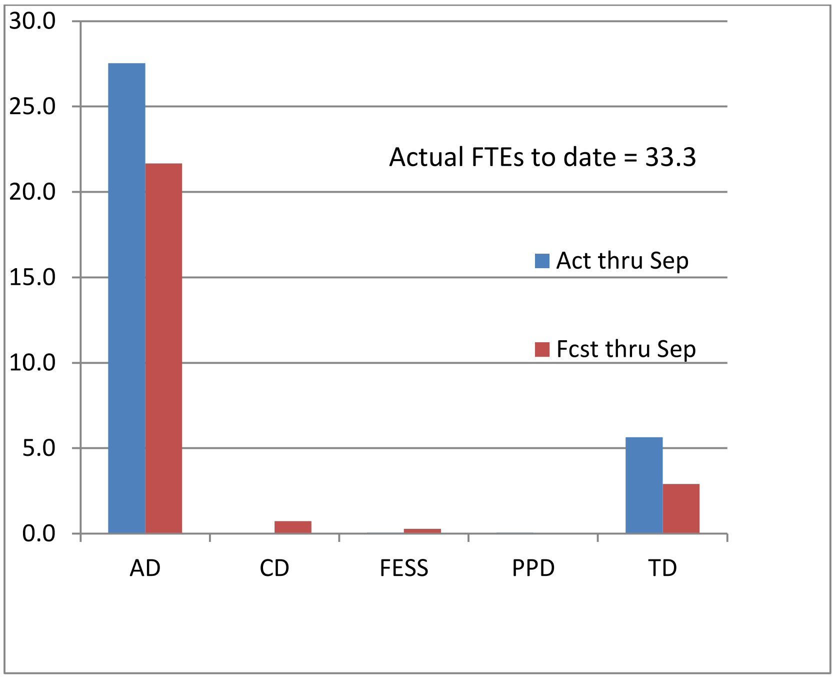

Figure 4 PIP FY16 labor summary

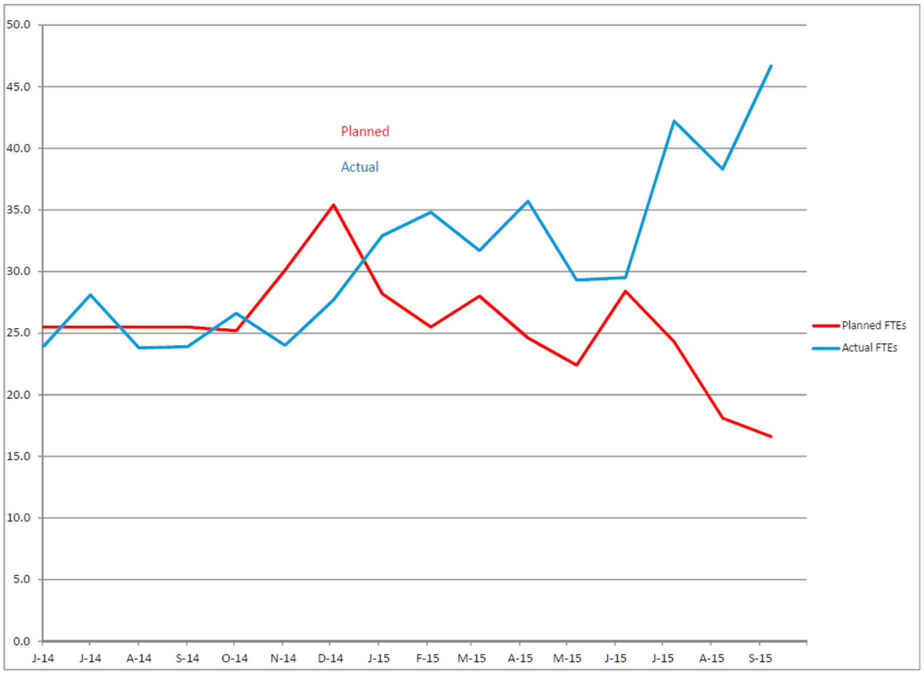

Figure 5 PIP labor usage throughout FY16