WBS 1.1 – Linac Upgrades

The performance of the Linac is not a significant bottleneck to proton delivery. Linac projects focus on improving reliability, addressing vulnerabilities where equipment failure would curtail operations for a significant period of time, and improving instrumentation to allow better characterization of the machine.

WBS 1.1.1 – Linac PA Vulnerability

The first stage of the Linac uses five power amplifier tubes. These tubes fail at a rate of 6-8 tubes per year. Typically about 2/3 of the failed tubes can be rebuilt by the vendor; the others must be replaced with new tubes. The availability of replacement tubes has remained critical since the start of Run II. This lack of spares is a serious vulnerability, both in the immediate future and for the long term viability of the experimental program. It is essential that Fermilab work with the vendor to increase tube production and testing, and build up an inventory of spare tubes. It is also important that the lab have a backup plan in the event that the PA vendor goes out of business entirely.

To this end, a working group was formed. The initial part charge was to determine the best way to build up the spare supply of PA's. After visiting the company, it was decided that the best way was to place a single large order for 12 PA's and to provide some money to repair an exhaust station, which constituted a bottleneck to production.

The second part of the committee's charge was to investigate various options for Linac upgrades in the event that the supply of PA's is terminated. At the time of this writing, the investigation is complete and the details can be found elsewhere [cite-7835Team]. To summarize, the team identified two viable options:

- Replacing the 200 MHz power system with one based on the Thales 628 diachrode tube. Note that because this tube has a lower peak power than the Burle 7835, we would need two tubes per tank on four of the five tanks in the Low Energy Linac.
- Replacing the entire Low Energy Linac with one incorporating a RFQ ion source and a 400 MHz, klystron driven, drift tube Linac. For costing purposes, the design considered was based on linacs available from Accsys Technology [cite-http://www.accsys.com/]

The cost of these two options was estimated to be $35M and $55M respectively. It should be noted that the 200 MHz upgrade could be done incrementally, which might be easier in terms of funding and scheduling, whereas the replacement would have to be done all at once and would require at least 6 months of down time.

The $1.5M M&S estimate for this WBS element is for procurement of the 12 PA's. These tubes were requisitioned and delivered on schedule during the year since the last review. Originally, this task contained a provision for a test station to pursue develop the Thales tube option; however, based on the success of spares requisition, this was not seen

as a wise investment, so this part of the task was descoped, and the task is now considered complete.

WBS 1.1.2 – Linac Quad Power Supplies

The five tanks in the first stage of the Linac, the 200 MHz Drift Tube Linac (DTL), contain 120 drift tubes, each with an internal quadrupole magnet. Because of the high current required by these magnets, they are pulsed at 15 Hz to avoid excessive heat. The pulsed supplies are original to the Linac. While they have operated fairly reliably for the last 35 years, it is believed that we risk significant downtime in the next ten years.

We have investigated the option of replacing the power supplies entirely; however, it was decided that the high cost, manpower requirements, and system disruption that this project would require were not warranted. Instead, it has been decided to upgrade the timing and controls hardware to improve reliability.

This will involve designing and replacing seven individual cards in each of the 130 power supplies. Although it modern electronics would make it possible to replace all of the control electronics with something much more compact, it is felt that it will be less disruptive to replace the cards individually with functional equivalents.

At this time, the first of the seven cards has been designed and the production run requisitioned. The remaining cards are being designed.

WBS 1.1.3 – Linac Instrumentation Upgrade-DESCOPED

Initially, the Proton Plan contained an explicit line item to cover instrumentation upgrades in the Linac. Ultimately, however, we determined that the scale of this upgrade was small enough that it could be handled under the standard department operating budget, so it has been removed from the project.

WBS 1.1.4 – Linac Low Level RF Upgrade

Currently, there are a number of issues with the Low Level RF for the Low Energy Linac. In particular, there is a settling time of some 10 μsec due to beam loading effects. By upgrading the Low Level RF system, this time can be reduced to 2 μsec. This would lower Linac Beam loss by at least 20% at the current maximum booster intensities. It will also result in improved beam energy stability, which should significantly lower injection losses in the Booster.

At present, the RF modulators monitor the cavity voltage and use that to feedback on their output; however, they have insufficient bandwidth to hold the RF amplitude constant during the beam pulse. The goal of the new LLRF system would be to run the modulator open loop and have the LLRF system accomplish the fine amplitude control using a driver amplifier at the PA driver. The result will be more constant acceleration during the beam pulse, which will allow the Booster to more easily capture the beam.

The specifications for the system are shown in Table 1.1

Category	Specification
RF Phase Control	.5º
Cavity Amplitude	.2%
Settle time	< 2 μsec
Ouput Power	100 mW
Control	Local and Remote

TABLE 1.1: WQB Specifications for Booster LLRF Upgrade

The LLRF system has been under study for some time, particularly during the 2006 shutdown. Modeling of the system is roughly 90% complete, and the design of a new control system is proceeding under the direction of the Accelerator Division RF Department.

The cost estimate is being refined, but at this time it is largely based on the cost of the High Energy Linac LLRF system. The benefit of this improvement will be an increased average to peak ratio for the Booster.