Fermilab

Closeout Presentations

from

Director's Review

of the

Proton Plan

August 23-25, 2005

2.0 Linac Upgrades

S. Henderson, SNS/ORNL
A. Nassiri, APS/ANL

Findings

Fermilab staff are actively managing and engaged in mitigating the vulnerability of the accelerator complex to the Burle Industries 7835 power amplifier tube failures. Twelve additional PA tubes are on order. The staff are actively engaged with the manufacturer in both production and schedule as well as technical performance issues.

The low-level RF controls (LLRF) for the Drift Tube Linac are part of the "original equipment" of FNAL. Due to beam loading and finite bandwidth of the LLRF system, the first 10 microseconds of the ~40 microsecond beam pulse is not properly accelerated, and is lost in the linac, resulting in high residual activation levels. Further, the pulse-to-pulse (and perhaps within-a-pulse) energy and position centroid jitter leads to Booster losses. Plans are forming to develop a modern LLRF control system for the DTL. A goal of a settling time of 2 microseconds, amplitude stability of 0.2% and phase stability of 0.4 degrees was presented. The scope is limited to 7 systems.

The linac quadrupole power supply control cards are also part of the "original equipment," and are responsible for 5% of the linac downtime. An upgrade project to replace the control cards with new cards having duplicate functionality is well underway.

Comments

In order to ensure timely production and adequate Quality Control of the ordered Burle 7835 PA tubes, it may be prudent to station an RF engineer at, or at least have heavy presence at, the manufacturing facility.

Priority should be given to testing these tubes at FNAL as they are delivered from the manufacturer. If the yield and tube lifetime look promising, it may be worthwhile to place an additional order to further build-up the tube inventory. Of the various options, building up a large inventory of working tubes is by far the most cost effective.

In parallel, discussions with LANL regarding the Thales option should be pursed right now, rather than waiting to see the performance of the new Burle tubes.

Performance expectations for the Linac, within the context of the Proton Plan, have not been defined. The expectations, based on injected beam requirements from the Booster, need to be defined and communicated. Only with this "target" is it possible to fully define the elements of the Linac Upgrade portion of the plan.

The present linac beam performance parameters (beam size, pulse to pulse and within a pulse energy and position jitter, emittance, energy spread, etc.) are not well quantified. The working instrumentation to perform such measurements is limited.

The LLRF system upgrade is not yet ready for baselining within the Proton Plan. A physics-based specification for the LLRF system was not presented. These specifications should flow from output beam requirements such as energy jitter. In defining the scope of the LLRF project, the short and long-term phase variation of the existing (uncompensated) reference line should be measured. As mentioned, feedforward capability is necessary to achieve the necessary performance.

The design of a new LLRF system will require substantial resources from the RF group. Management should assign the necessary priority to ensure that this project is executed within the timescale of the Plan.

Performance expectations for the linac may also drive further development or refinement of beam instrumentation. Not all BPMs in the linac have working electronics. An extremely useful diagnostic system, the Bunch Length Monitor, is not regularly used and now requires re-commissioning.

The Linac group is encouraged to further develop software-based control of the linac output beam parameters to minimize drifts in energy and position.

Recommendations

1. Consider stationing an RF engineer remotely at Burle to help ensure successful and timely production of 7835 tubes.
2. Aggressively pursue testing of new Burle tubes as they arrive at FNAL.
3. Pursue in parallel the LANL/Thales option right now.
4. Define clear performance expectations for the Linac output beam based on Booster requirements. In addition to intensity parameters, specify parameters such as pulse-to-pulse output energy jitter, within-a-pulse energy/phase slew, horizontal and vertical beam jitter, and so on.
5. Establish, through measurement, the present Linac performance parameters, particularly output beam pulse to pulse jitter and within a pulse slewing.
6. Based on performance requirements, establish LLRF system requirements as well as linac instrumentation upgrade requirements.
7. Incorporate a design review into the Linac quadrupole power supply control card upgrade project schedule.

1.2 Booster Upgrades (Phil Martin, Stuart Henderson, Ed Temple)

Before addressing individual WBS elements, the reviewers would like to point out that in most of the Booster upgrades, and in fact almost every aspect of the entire Proton Plan, there is a decided lack of analysis from both the accelerator physics standpoint and the cost/benefit standpoint to justify each particular upgrade. These analyses may have been done for each WBS element, but they have not been included in the Technical Design Handbook or in the presentations. The Design Handbook should include a substantial level of documentation of the present characteristics of each machine, including beam parameters and available tools (dampers, rf feedback systems, etc.)

1.2.2. Orbump System

Findings

The Orbump system upgrade is being funded in part through the Run II Upgrade. An additional $415K is proposed under the Proton Plan. The present system is limited to 7.5 Hz operation due to heating, and therefore must be replaced to go to higher rep rates. The solution, which will be implemented during the 2005 shutdown, replaces the existing four-magnet bump system with a three magnet system, running at a reduced current. A new power supply is also being fabricated. The replacement eliminates the dc septum magnet, which has been an aperture restriction and loss point; elimination of the dc septum will increase the aperture just ahead of the injection point from 1.5" to 3.25". The upgraded injection system will be capable of 15 Hz operation.

The downstream end of the 400 MeV injection line will also be reconfigured as part of the Orbump replacement, eliminating one bend magnet and rearranging four quadrupoles.

Comments

The new Orbump system looks good. However, it would be useful to see some further analysis of the injection process. There are no plans to do any phase-space painting of the H^- injection. Painting could be used to provide additional control of the injection process, limiting the growth of the transverse emittances in a more controlled fashion than blow up due to space charge. The 400 MeV line has room for installing additional elements for that purpose, although it is almost certainly too late to incorporate any additional elements during the upcoming shutdown. It should not be too late, however, to plan for their installation by adding flanges where appropriate and pulling cables if calculations show it to be desirable.

As noted above, part of this project is being funded under the Run II upgrade. This includes the magnets themselves (three for installation plus three spares) and the girder on which they will be installed. The project manager was not able to provide a breakdown of what costs were being charged to the Proton Plan, which total $415K of which $122K is the power supply. The power supply has been fabricated.

The first-article Orbump magnet has a noticeable gradient, and several others are already far along in fabrication. Fixing the gradient could jeopardize the schedule. It is not clear how serious the magnetic variation is from the standpoint of beam performance. The field variation is not too different from the present Orbump magnets in magnitude, although the present magnets have a sextupole component rather than a quadrupole error. This review committee concurs with the opinion of the internal review that the magnitude of the gradient is sufficiently small that the project should proceed to install the first three magnets and if necessary, develop a fix for the subsequent three magnets.

In response to one recommendation from the internal review, the Level 3 Manager has developed a commissioning plan. The response to the second recommendation, to perform a sensitivity analysis to errors in injected beam position and angle, power supply jitter, etc. is underway. The variation of the injected beam energy, both during the Linac beam pulse and pulse-to-pulse, was also presented. Some of this variation may be reduced with the proposed improvements to the Linac LLRF.

Recommendations

1. Model the H^- injection process over a range of intensities and evaluate the benefits of phase-space painting. If it appears useful, determine what beamline elements need to be installed. Determine if any modifications to the new 400 MeV line vacuum system should be made to facilitate future installation of these elements.
2. Continue evaluating the sensitivity to beam and power supply errors requested by the internal review. Evaluate the effect of the observed energy variations on the Booster capture process to establish the importance of the implementation of the Linac LLRF improvements, and their relative priority.

1.2.3. Booster Correctors

Findings

The present corrector system is capable of providing limited orbit, tune and resonance control. The Proton Plan project is proposing fabricating new magnets and power supplies. At a cost of $6,262K, this is one of the most expensive upgrades proposed. The installation of the magnets would occur in the 2007 shutdown.

Comments

The justification for this upgrade is not well presented. Intuitively the Booster should perform better with full-field orbit correction, with better tune and chromaticity control, and with much better resonance correction capability. Were the cost much less, one would certainly proceed with this task. But the cost does give one pause. However, it is clear to the committee that the majority of the effort and cost is well justified, and if one is going to pursue a substantial change, it seems sensible to do the best one can.

In response to the internal review, the specification for the tuning range of the quadrupoles has been increased. The beam motion during acceleration, relative to the injection orbit, was shown, which indirectly addresses another of the recommendations. Perhaps much of this motion could be corrected with magnet alignment, but that iterative procedure requires tunnel access and study time, both of which are in short supply.

The power supplies could be built in-house, but suitable supplies are also available at a higher cost, which has been built into the estimate. It is planned to power every element independently, in large part because placing the higher-order elements in series circuits increases the power supply voltage requirements beyond what is reasonably achievable. The committee recognizes the importance of having the full complement of dipole and normal quadrupole and normal sextupole correctors, all of which need to be independently powered for proper orbit control, and for fast tune and chromaticity manipulation at transition. However, the need for independently powered skew quadrupoles and skew sextupoles is much less obvious. The skew quadrupoles are not limited by the voltage constraints that the other elements are. Arranging them in four families would save over $50K in power supply costs. The supplies for powering every skew sextupole magnet will cost about $180K.

The labor estimates shown during the 2007 shutdown, which includes the corrector installation, indicate a total of only eight people. This seems low by a factor of three or four.

Recommendations

1. Determine the path to the decision as to whether the power supplies are built in-house or procured from the outside. Make the decision a project milestone.
2. Continue to address the concerns of the internal review regarding tune working points, corrector control software, etc.
3. Evaluate the beam physics requirement for the skew quadrupole and skew sextupole elements, and determine if all need to be powered, and if so, whether they can be grouped into families within ramp rate requirements and power supply voltage limitations.
4. Review the labor estimates for corrector installation and update the Resource Loaded Schedule and Cost Estimate accordingly.
5. (To lab management) Approve the corrector upgrade so that the Booster will have a robust system of correctors to help it achieve the demands of the coming decade.

1.2.4. Booster 30 Hz Harmonic

Findings

Adding a 30-Hz component to the Booster magnet excitation reduces the energy gain per turn. This then requires less rf voltage, or, for the same rf voltage, provides more bucket area during acceleration. The cost is estimated at $2,361K.

Comments

The decision whether or not to pursue this subproject is expected in early 2006.

The internal review committee recommended dropping this project, so that the resources could be used elsewhere. The project has carried out simulations and beam studies (ramping the Booster to an energy of 6 GeV, which emulates some aspects of the 30 Hz harmonic.) Further studies are required at the end of the 2005 shutdown to help decide whether this subproject is to be pursued.

The beam simulations that have been done suggest that, as suspected, if the 30-Hz harmonic is implemented, the gamma-t jump system will also be required. These simulations show the capability of delivering beams of 6.5E12.

The 30-Hz harmonic is the proposed path to trying to achieve intense beams out of the Booster. In that sense, it is somewhat orthogonal to the baseline path of slip-stacking lower intensity beam in the Main Injector. In one way, it could be viewed as a fallback in the event slip-stacking doesn't perform as well as planned. Higher intensities would of course also benefit the Booster Neutrino Beam.

Recommendation

1. Determine how the decision will be made whether to include the 30-Hz harmonic subproject.
2. Focus the simulations and beam studies to provide the answers necessary to make that decision.

1.2.5. Gamma-t System

Findings

A system of pulsed quadrupoles was installed in the late 1980s to increase the speed at which the beam passes through the transition energy. This system was found to exacerbate coupled-bunch instabilities after transition, and has not been used much since. In the meantime, longitudinal dampers have been implemented to cure the instabilities.

The correction element upgrade will require removing the gamma-t quadrupoles, but space remains for shorter quads. The shorter quads would not give as large a transition jump as the present ones do, but the present ones are overkill. There is some question as to the present quadrupoles are still usable, since they have been exposed to substantial radiation in the past three years.

Comments

The committee believes a gamma-t system should be a valuable tool for preserving the longitudinal emittance, in particular in producing quality, low emittance beam for slip stacking in the Main Injector. It should be determined whether the existing magnets are still usable and if so, studies should be performed to see if using the gamma-t jump can reduce the longitudinal emittance and thereby benefit slip stacking. If the magnets are not useable, it would be prudent to build new ones so that the system can be resurrected.

Recommendations

1. Determine if the present gamma-t quads are still usable, and if so, conduct studies to see if they can reduce the longitudinal emittance of the beam delivered to the Main Injector.
2. Decide, based on the results of these studies, if the gamma-t system should be retained.

1.2.7 Drift Tube Cooling

Findings

This project will be completed during the upcoming shutdown. It has a cost of only $12K.

Comments

It is unclear why this subproject wasn't moved onto operations, given the insignificant cost.

Recommendations

None.

1.2.11. Booster Dump Relocation

Findings

This subproject will be implemented during the 2005 shutdown. It involves installation of an existing dump block into the upstream part of MI-8 line, relocation of three of the Long 12 kickers and a spare MP01style pulsed septum magnet into the MI-8 line. The fourth Long 12 kicker will remain, and can be used to improve the Long 3 extraction.

Modest civil construction is required to provide penetrations for the septum magnet cables. The bid package for this has been prepared, but has not been released. The release of it is awaiting the decision by lab management on the shutdown start date.

The existing Long 13 extraction region will no longer used, allowing the existing septum magnet to be raised away from the beam, eliminating it as a loss point. Presently that magnet is the highest loss point after the collimators. The kickers will be placed where a shield wall presently resides; that wall must be removed, and the critical devices for Booster to Main Injector transfers will be changed. The new design requires a reconfiguration of the Booster and Main Injector radiation safety systems. The Booster and Main Injector Safety Assessment Documents must be revised to reflect the configuration changes.

Comments

Removal of the existing Long 13 extraction ought to improve Booster performance a few percent and should simplify Booster operations and tuning.

The dump block to be used is the one fabricated for MI-8 commissioning, later used by MiniBooNE for the same purpose. It was never intended for long term or high rate use. An internal review was held to evaluate the entire subproject. It identified several calculations (radiation and thermal) that need to be done. Those calculations are in progress, and based on them, limits will be placed on the amount of beam that can be deposited in the dump. Cooling panels on the outside of the dump could raise that limit if necessary.

In order to reduce dose to personnel during accesses, the dump can be augmented with additional shielding, possibly using the blocks removed from the shield wall to make space for the kickers. Details need to be worked out, again based upon the ongoing calculations.

The amount allocated for the civil construction is $100K. When asked, project management was unable to say how much has been spent to date on FESS effort. It is planned to do this work as a change order to a nearby, unrelated project.

Recommendations

1. Complete all necessary calculations to determine the allowed beam deposition on the dump. Reconvene the same internal review committee to review the results.
2. Develop the schedule for the Safety Assessment Document revision and approval process.

1.2.13. Booster RF Modifications

Findings

This subproject involves increasing the reliability and availability of the Booster rf system by installing solid state drivers in place of the present cascode tube configuration. It is estimated to cost approximately $9M. This has not been included in the cost estimates for the Proton Plan.

The committee heard a presentation on Booster downtime. The rf system is responsible for the largest amount of downtime, and has by far the most downtime entries. The reliability has been degraded in the MiniBooNE era, and unless steps are taken, it is expected to continue to worsen with NuMI operation.

Although downtime is the most straightforward way of evaluating Booster reliability and availability, it does not give a complete picture. For the Main Injector to be able to accomplish slip stacking with high efficiency, the Booster needs a minimum rf voltage of 900 kV. During 2005 there have been considerable periods when the Booster was not capable of this, including one stretch of 45 days when they could not make a tunnel access to repair a water leak.

One rf system, station 12, (out of the 18) has had the proposed solid state driver in place for approximately four years. This is to be compared to the other stations which have a typical life of one year.

A 19th station presently has a prototype wide-aperture cavity installed. It is planned to replace this with a spare cavity identical to all the other cavities; it will have the solid state driver configuration. Operations with this second cavity will give additional experience with the solid state driver. The 19th cavity by itself should provide a significant increase in the availability of good quality beam.

Comments

Replacing the present cascode tube drivers with the solid state drivers would improve the reliability of that one part of the system. Unfortunately, that in itself will not deliver greatly improved system availability. Station 12 has had roughly the same amount of downtime as the other 17 stations thus far in 2005.

In addition to the 19th cavity, there is space in the Booster for a 20th cavity. This would presumably provide even greater availability of beam suitable for slip stacking.

Greater attention to preventive maintenance – as opposed to the "run it till it breaks" philosophy that has been adopted in the collider era – will be pursued. This would include replacing power amplifiers when they begin to show signs of degradation.

Other measures under discussion include modulator refurbishment and cable replacement but the costs for these were not well understood.

During the Main Injector break-out session presentations, there was considerable discussion of the importance of the longitudinal emittance of the beam coming from Booster. Additional feedback and beam loading compensation is highly desirable for producing stable beam.

Recommendations

1. Install the 19th cavity with the solid state driver.
2. Develop cost estimates for a 20th cavity, for modulator refurbishment, and for cable replacement.
3. Defer a decision on the solid state driver issue until experience is gained with the 19th cavity in operation.
4. Consider implementing RF feedback and beam loading compensation in the Booster to improve stability of bunch rotation required for slip stacking as well as reducing the RF power requirements associated with paraphasing. This would probably require the solid state driver amplifier upgrade.

4 Main Injector Upgrade (WBS 1.3) – DRAFT 2

(Greg Bock, Ali Nassiri, Flemming Pedersen)

Findings

- Currently the MI is running in mixed mode with 2 Booster batches slip-stacked for pbar production (intensity currently 6.5E12, RunII objective 8E12) followed by 5 Booster batches using bucket to bucket transfer for NuMI (intensity currently about 2E13) for a total MI intensity of about 2.65E13.

- A number of upgrades aim to increase the total intensity to about 4.4 to 5.5E13 protons per cycle. The main component is a number of studies and modifications which allows for slip stacking of the NuMI beam injecting 9 Booster buckets into the 5 available MI slots for NuMI and is the basis for the beginning of phase III of the proton plan.

- Higher observed and expected losses in the MI associated with these upgrades are being addressed through induced radiation monitoring and collimator projects. While the MI-8 injection line single pass collimator system is currently well defined, this is not yet the case for the proposed MI collimation system.

- The slip stacking efficiency (pbar target toroid/MI injection charge) is currently about 90% and has degraded slightly (by about 5%) since mixed mode operation (NuMI + pbar production) started a couple of months ago. This is due to an abnormal poor lifetime of the slip-stacked pbar production beam during the injection plateau not yet fully understood.

Comments:

- Beam parameter list specifying required intensities, transverse and longitudinal emittances is missing.

- What are the capture efficiencies of the slip stacking scheme as function of intensity and Booster longitudinal emittances? How much of the capture loss and ghost bunches at high intensity are due to transient beam loading effects (imperfect beam loading compensation), possible microwave instabilities or too large Booster longitudinal emittances?

- This issue is important both for future slip stacking of NuMI beam as well as Run II performance. The Run II rapid action task force is currently addressing this issue with the goal of achieving target Run II performance.

- An analysis of expected growth rates of coherent transverse and longitudinal coupled bunch instabilities driven by resistive wall and cavity fundamental and parasitic modes were not presented. Existing transverse and longitudinal multibunch dampers may have sufficient margins to cope with the anticipated higher growth rates.

• We were not shown numbers comparing the microwave instability thresholds of the low $\Delta p/p$ bunches with actual machine impedance in Booster and Main Injector.

Recommendations

• Establish a beam and machine parameter list including transverse and longitudinal acceptances, beam intensities, transfer efficiencies, longitudinal and transverse emittances and required RF matching voltages at ring to ring transfer.

• Determine acceptable RF beam loading transients, Booster longitudinal and transverse emittances to enable efficient slip-stacking in the Main Injector by a combination of machine studies and simulation.

• Determine expected transverse and longitudinal growth rates and study whether existing multibunch damping systems are adequate.

• Study whether electron cloud accumulation might become a problem with the longer high intensity bunch trains.

• Compare microwave instability thresholds of low $\Delta p/p$ bunches required for slip stacking with actual machine impedance in Booster and Main Injector.

• An early test of acceptance of the NuMI beam line with slip-stacked beam strongly recommended

4.1 Large Aperture Quads (WBS 1.3.1)

Findings

• All quadrupoles in the MI injection/extraction area are limiting the physical aperture leading to beam loss and will be replaced

• These quads are being manufactured and 5 out of 7 are expected to be ready for installation in the forthcoming 2005 shutdown and will thus increase the aperture of the MI.

Comments

• Scope, cost and schedule well defined. Should increase MI acceptance as anticipated.

• Some beam commissioning effort is required following installation

4.2 MI Collimation (WBS 1.3.2)

Findings:

• As anticipated Main Injector losses and residual activation of components have grown as the accelerator delivers more protons to the antiproton source and NuMI.

• Plan is being implemented to monitor, record, and automate measurements of losses and residual radiation levels.

• Improved loss monitor electronics available in 2006 will help maintain adequate knowledge of losses

• Program to further measure, simulate and understand Main Injector losses is beginning soon. Expect to design MI collimator system and suitable lattice modifications by end of 2005.

• Losses currently due to tails of injected Booster beam will create non-trivial residual radiation at proposed operating intensities. Collimation in the MI-8 Line to remove beam tails is specified and design/fabrication is underway. An internal review of the system was recently completed. Cost, schedule and manpower needs are manageable but will continue to require commitment to permit installation and commissioning in FY06.

Comments:

• Schedule for MI-8 collimator installation during the upcoming shutdown is tight, but probably manageable.

• Planning for developing collimation systems in the Main Injector requires additional FTE effort. That effort is being assembled.

Recommendations:

• Proceed with the MI-8 injection line collimation system.

• Continue with the program to monitor, record, and automate measurements of losses and residual radiation levels.

• Continue the design effort for the Main Injector ring collimation system.

4.3 NuMI Multibatch studies (WBS 1.3.3)

Findings:

• The conceptual design of a 2+9 pbar and NuMI multibatch slip-stacking scheme was presented. The plan requires a cooling upgrade of the MI injection kicker (MI-10) and profits from an improvement of the after pulse of the MI-52 pbar extraction kicker.

• Simulations of a back-up scheme employing barrier bucket stacking was also shown.

• The plan addresses the feasibility of this scheme by a combination of machine studies and simulations. The low voltage operation required during slip stacking requires efficient transient beam loading compensation of the MI RF system.

• Imperfections in Booster to MI bucket to bucket matching clearly affects percentage of beam not captured.

• The Run II rapid action task force is currently addressing issues affecting the efficiency of the slip stacking scheme and the success of the NuMI multibatch slip stacking depends strongly upon how successful they will be in improving the efficiency of the slip-stacking process.

• ESME simulations have addressed the longitudinal dilution and limited acceptance caused by the two RF frequencies during the slipping process.

Comments:

• Without effective beam loading compensation in the Booster, the bunch rotation RF voltage in the Booster is strongly affected by intensity.

• The efficiency of the slip stacking process depends highly on correct Booster emittances and correct bunch rotation process.

• Voltage reduction in Booster done by para-phasing groups of cavities, which requires very high power levels in one group of cavities. Will this work at the highest Booster design intensity?

• RF feedback in Booster would allow for voltage reduction without paraphasing which would reduce required RF power

• Consider implementing RF feedback and beam loading compensation in the Booster to improve stability of bunch rotation required for slip stacking as well as reducing the RF power requirements associated with paraphasing. Would probably require solid state driver amplifier upgrade.

Recommendations:

• Continue machine studies and simulations in close collaboration with the Run II rapid action task force.

4.4 MI RF Upgrade (WBS 1.3.4)

Findings:

• The current RF system appears to have both adequate power and adequate voltage to enable acceleration at a rate of 205 GeV/c at maximum design intensity. Very little gain in cycle time if higher RF power and/or higher RF voltages were available.

• The RF feedback ensures that the Robinson high current limit will not be a problem inspite of the fact that the power delivered to the beam will exceed the cavity power dissipation. This is expected from theory and has been supported by machine studies at reduced RF voltage.

• Calculations showed that final and modulator plate dissipations are within acceptable limits for required RF power levels at maximum design intensity

• Major and expensive upgrade of MI RF power (second tube and associated drivers) has been removed from the proton plan.

• A realistic Simulink model is available of the RF cavity including its feedback and feedforward systems to study beam loading transients. Coherent beam phase response not currently included in this model, so complete stability analysis (Robinson type instability) not possible with this model. Resulting RF waveshaves used as input to ESME for longitudinal phase plane tracking.

Comments:

• The committee agrees with the decision not to include the RF power upgrade in the proton plan.

Recommendations:

• Consider including the coherent beam response in Simulink model for complete stability analysis.

• Continue the longitudinal ESME tracking with beam loading transients to study the effects on slip-stacking efficiency of imperfections in beam loading compensation system. Determine whether improvements in the beam loading compensation might be needed (e.g. one-turn delay comb filter feedback).

- Consider implementing the longitudinal phase plane tracking in the Simulink/MATLAB environment to facilitate analysis of beam loading transients.

Charge Questions:
S. Henderson, ORNL
A. Nassiri, ANL
F. Pedersen, CERN
P. Martin, FNAL (ret)

7.1 Are the (high-energy) physics requirements that the Proton Plan addresses stated?

Yes. The Proton Plan charge states: "Develop a plan for a set of upgrades and operational improvements to maximize proton delivery to NuMI and BNB….Estimate projected proton delivery (PoT) to both beam lines."

The Proton Plan "Design" scenario projects ultimate rates of 3.3E20 Protons on Target per year for NUMI and 2.8E20 for BNB, based on 5.8E13 protons per 2.2 second MI cycle. The expectations are stated in terms of projections, rather than as "top-down" design requirements. In particular, the BNB intensity lacks a concrete goal. Rather, the Plan projects BNB intensity based on available excess Proton Source capacity.

7.2 Have these physics requirements been translated into accelerator technical performance requirements/specifications?

Not in all cases. Performance requirements and specifications have been stated mostly in terms of final output intensities of the booster and MI. Many of the intermediate performance requirements and specifications that are necessary for achieving the desired intensity, such as parameters related to beam quality at each machine interface, are not stated in the Design Handbook. Further, for many of the systems we were not presented with the accelerator physics justification or benefit that is driving hardware requirements.

The "Design" scenario in the proton projections spells out 5.8E13 protons per MI cycle, whereas the MI projections state 4.4-5.5E13 protons/cycle.

A controlled Parameter List would be an appropriate place to collect the performance requirements and specifications as well as the scope of the project.

7.3 Are the design features of the defined elements of the Proton Plan documented in a Technical Design Report, Design Handbook or other appropriate manner?

Generally, no (at least not that we were shown). The Design Handbook captures some design features of those parts of the plan that are ready to be baselined. The level of detail of technical specifications varies greatly from sub-project to sub-project. The accelerator physics justification in the Handbook for many of the subprojects is completely absent and must be included, together with expected performance improvements. For many of the elements the flow from machine limitation to accelerator physics understanding to hardware specification to expected performance improvement was not presented.

Use of a more formal method for controlling and documenting specifications is appropriate. In addition, it would be very useful to maintain a controlled Parameter List.

7.4 Are the prototype plans and decision paths appropriate for the less well-developed elements?

No. The less-well developed elements are at a stage at which the decision paths are generally not clear. Examples include MI ring collimation system, Multi-batch operation for NUMI and Booster RF modifications.

7.5 Do the elements of the Proton Plan program address the performance requirements/specifications? Are the designs of these elements reasonable?

The elements of the Plan which are ready to be baselined appear to meet the output beam intensity requirements, and their designs are reasonable. It is difficult to assess whether the Plan meets intermediate requirements and specifications, e.g. beam quality at each machine interface.

5.0 Project Management

Reviewers: M. Lindgren, P. McBride,

Findings

The Proton Plan management presented a high level overview talk, and a talk that covered the scope of the project, method of work, an overview of the OBS and WBS. The WBS presented has 5 level 2 subprojects, including one for Project Management. There are Level 2 managers in place for all subprojects. The WBS structure shown was designed to follow the Organizational Breakdown Structure at Level 2 and below.

To summarize:

- The campaign has a WBS and OBS.
- There is a management team in place.
- A resource loaded schedule was shown which included milestones. Some of it was developed bottoms up, and some of it is still top down.
- There is a design handbook, BoE and cost estimate documentation, and a PMP which includes change control, reporting, and risk analysis.
- Project Management Group (PMG) oversight is in place.
- Line management for safety runs through AD and TD departments.
- The project has spent about $1M in FY05.
- Overall cost was projected to be $25.6M, which includes 51% contingency.
- Total cost for project management was given as $1.7M, which includes 30% contingency.
- Scope of the project is not completely defined, which will have a cost impact.

Comments

The project is to be commended for their rapid adoption of some key project management tools. The reviewers feel that having experienced project support people in place early is very good. Especially important to have Sims fully committed. The suite of tools proposed seems appropriate to manage the campaign.

We feel that the project office should work closely with the AIP (Mike Andrews) and Safety officers in other areas of the plan, to ensure good communication about safety throughout the project.

The team needs to continue to work hard on generating requirements documents for the project. This will assist everyone in defining the technical solutions which can in turn help put the costs on a much firmer basis. The design handbook is a good working document to start from.

The cost estimate for Project Management has not been determined bottoms-up. Total cost for project management seems appropriate for a campaign of this size, which will be executed largely at the Fermilab site, but costs are currently running well above projections. Resource types need to be updated, as the scheduler and budget officer are not included in the estimate. The M&S request is low, but the costs of the office are somewhat subsumed into AD headquarters so it is difficult to determine if it is adequate.

R&D funding might be used to advantage for getting early starts on Thales, etc., prototyping.

Recommendations

- Project management should work with AD management and the directorate to ensure that labor requirements are understood at all levels, especially for shutdowns.
- We recommend that the level 2-3 management positions be filled with "non-placeholder" names.
- Project management costs should be revised to include all relevant personnel.
- Fermilab procurement personnel should be brought on board and fully integrated into the planning for executing the large procurements.
- The PMG membership list should include the Head of AD projects.
- A one page master schedule should be developed from a roll-up of the full RLS, with the critical path clearly visible.

- A controlled Parameter Table should be developed and maintained.
- The project office should create a list of fully scoped tasks that may not be done, with a decision tree and cost savings for each, and a list of currently un-scoped tasks that may be done, with a decision tree and cost for each.
- Project management spoke to a schedule which was tied to a completion date of July, 2008. In order to achieve this completion date the SWF cost profile should be adjusted to match the available funding profile.
- The role of the PMP should be better understood. If it is to be a working document for the Proton Plan it should be worked through to eliminate inconsistencies, signed by the relevant people, and given a revision number.
- The PMP should define the role of the deputy PM.
- The change control section of the PMP should be updated and made consistent throughout. The PM should be given authority over cost changes below a certain threshold. How the directorate plans to hold and allocate contingency, and the line authority path should be more clearly defined.
- Effects of shutdown timing and duration on the proton plan schedule should be examined in detail, and contingency plans that include changes in shutdown timing should be made.
- Another director's review of the Proton Plan should be scheduled in approximately 6 months time.

Charge Questions

7.13 Is there an appropriate management organizational structure in place or proposed to accomplish the design and construction?

Yes, we believe an appropriate structure has been proposed, but has yet to be fully staffed. There many places where names are assigned to multiple boxes, which may indicate that some key people are oversubscribed.

7.14 Have responsibilities been assigned or have they been proposed?

Yes. The boundaries of many responsibilities between the plan and the existing department structures are intertwined somewhat, which makes the project more difficult to track.

7.15 Is there a Project Management Plan outlining the organizational structure, summarizing the technical, cost and schedule (including milestones) baselines, and setting forth the change control procedures and reporting processes that will be used?

Yes, but to be a useful document there is additional work that should be done, and as mentioned above, it should be signed and the revisions controlled.

7.16 Are there adequate staffing resources available or planned for this effort?

Not able to determine this. There seems to be a cumulative $4M difference between the available funding for SWF and the FY06-07 SWF + contingency extracted from the current schedule.

7.17 Is there a funding plan available or proposed to meet the resource requirements to realize the Proton Plan?

The available resources shown by fiscal year do not match the budget authority requested to meet the current schedule.

6.0 Cost and Schedule

Reviewers: Mike Lindgren, Phil Martin, Patty McBride and Dean Hoffer

Findings:

- The cost estimate for the Proton Plan is $25,664K (w/contingency & escalation and w/o indirects) of which $9,134K of the cost estimate is for subprojects that are being developed or are place holders.
- A Microsoft Project schedule for the Proton Plan was presented to the committee with a completion date of July 16, 2008.
- Within the Proton Plan there are 2 AIP projects (Booster Horizontal Corrector – BHC & Booster Vertical Corrector - BVC).
- The Proton Plan cost estimate was escalated using a rate of 4.3% for Labor and 2.8% for M&S per year. The Proton Plan Management will be revising the cost estimate using the updated escalation guidance for the Budget Office.
- The schedule currently contains 12 review activities of different types (i.e. technical, design and project decision reviews). Additional reviews will be added to the schedule as some of the Level 3 subprojects continue to be developed.

Comments:

- A Milestone Dictionary that defines the criteria that has to be met to declare a milestone complete does not currently exist. The Proton Plan Management agree that they need to create the Milestone Dictionary with the input from the Level 2 and 3 Managers. The committee agrees that the Milestone Dictionary is needed and encourages the Proton Plan Management to complete this quickly since there are 14 A&B level milestones that are scheduled to complete by the end of this calendar year.
- Bases of Estimate (BOE) documentation exists within the Proton Plan's MSP file and in a 3 ring binder for those subprojects that have been fully developed. For subprojects that are in development or are currently a place holder the BOE documentation is limited or does not exist. The Proton Plan Management needs to assure that the BOE documentation is completed for the developing subprojects and for the place holder subprojects when they are finalized.

Recommendations:

- A cleanup on the MSP schedule file mechanics is needed on items such as:
    - Assign resources to overseeing work tasks that are performed by contractors. Be consistent throughout the project.
    - Assign resources to perform TD testing activities even though their costs are not effort reported to the Proton Plan, but are costed as part of TD's overhead. These resources are needed to complete the effort on schedule.
    - Change procurement tasks to cover the duration from placing the procurement until material is received, so you can more easily identify Obligations as well as BCWS. Also, treat the way procurements are tracked in the schedule for cost of < $100K the same as for those

procurements > $100K unlike how they were dealt with in the Run II Luminosity schedule. Assign appropriate level of resources for the procurement tasks and be consistent throughout the schedule. This will help in the accuracy in both Obligations and EV reporting.

- As part of an overall Risk Analysis the Proton Plan Management should perform various What-Ifs with their schedule by moving the start dates of the 2006 and 2007 shutdowns to determine the impact on accomplishing the subproject deliverables, key milestones, resource needs and the schedule of the projected protons on target increase.
- Phase 1, 2 and 3 milestones that are tied to complete specific deliverables that relate to a level of protons on target should be added to the schedule and the Project Management Plan (PMP), similar to the phase milestones in the Run II Luminosity for delivering luminosity.

Cost Questions:

7.6 Has a Work Breakdown Structure (WBS) been developed?

Yes, a WBS exists for the Proton Plan down to level 7 in some branches. The WBS has been incorporated into a Microsoft Project (MSP) schedule, which currently contains 560 lines.

7.7 Do the cost estimates for each WBS element have a sound basis and are they reasonable?

Yes & No, some of the subprojects have been fully detailed with a bottoms up cost estimate with a reasonable cost basis (see list in Executive Summary). There are other subprojects that are still being developed or are place holders with a top down cost estimate. The Proton Plan is at the stage that they can be “Baselined” as long as they invoke the Change Control Process to manage changes from the current plan.

Proton Plan – Schedule - P. McBride

Is there a schedule for the project?

Yes, there is an overall schedule for the Proton Plan and its sub-projects. It has been worked out in detail only for some sub-projects.

Are the activity durations reasonable for the assumed resources?

The activity durations are well determined for the next six months.

Has the schedule been "resource loaded?"

Yes, the well-developed sub-projects have a schedule that has been "resource loaded". These sub-projects were developed in bottoms-up detail.

Has the schedule been developed with contingency or slack included?

Float has been evaluated for each item in the bottoms-up estimates. These estimates include some contingency. The schedule risk associated with the uncertainty in scheduling of shutdowns has not yet been evaluated.

For the less well-developed technical elements have decision milestones been included in the schedule?

Yes. We did not review in detail the timing of these decisions, but in many cases we found the path to these decision milestones are not well defined.

Executive Summary for the Proton Plan Director's Baseline Review

A Director's Review of the Proton Plan was held on August 23-25. The Proton Plan Team presented its plans for a phased campaign designed to increase the proton intensity delivered to the NuMI beamline while continuing to operate the Booster Neutrino Beam and Run II. The campaign consists of several modifications and additions to the Linac, Booster, and Main Injector. A management approach has been adopted that is similar to that used for the Run II Luminosity Upgrade . Recently an internal Accelerator Division review was held and the Proton Plan Team is responding to recommendations from that group. To those recommendations we add ours in this report (In some cases we repeat recommendations; in one case we offer a contradictory recommendation.) This committee believes that the 'campaign' approach can work. However, it is essential that the project is soon 'baselined' by the Director's office after due consideration of the recommendations that follow in this report and the AD report. Change control, configuration control, and design review must then follow. Coordination across the sub-elements needs improvement.

TECHNICAL

Members of the Fermilab Proton Plan campaign team presented elements of their plan to increase the proton intensity of the accelerators for the Neutrino Physics program. Improvements will be made to the Linac, Booster, Main Injector, and some transfer, injection, and extraction beamlines. The design goal of the Proton Plan is to provide 3.3E20 protons on target (PoT) per year for the NuMI beamline along with 2.8E20 PoT (per year) for the Booster Neutrino Beam that serve the neutrino program.

The elements of the Proton Plan shown in Table 1 are developed sufficiently for baselining. Column 3 shows the Review Committee recommendation regarding readiness to be baselined.

Table 1

WBS #	Element	Committee Recommendation
1.1.1	Linac PA Vulnerability	Ready
1.1.2	Linac Quad Power Supplies	Ready
1.2.2	ORBUMP System	Ready
1.2.3	Booster Correctors	Ready
1.2.4	Booster 30 Hz Harmonic	Ready, but decision not made
1.2.7	Drift Tube Cooling	Ready
1.2.11	Booster Dump Relocation	Ready
1.3.1	MI Large Aperture Quads	Ready
1.3.2.1 1.3.2.2	MI-8 Collimation System	Ready
1.3.4	MI RF Upgrade (with current reduced scope)	Ready

The elements shown in Table 2 were presented as currently known candidates to be further developed and presented in the future to be baselined under the Proton Plan change control system.

Table 2

WBS #	Element
1.1.4	Linac LLRF
1.2.5	Booster Gamma-t
1.2.13	Booster RF Modifications*
1.3.2.3	MI Collimation System
1.3.3	Multi-batch Operation

*A possible Booster Solid State RF Upgrade, estimated at ~$7M but not currently budgeted, was discussed which will be handled under change control if it is to be pursued.

A Proton Plan Design Handbook that describes the elements of the campaign has been developed. This Design Handbook will be revised as the Proton Plan evolves and constitutes the Technical Baseline. This committee affirms the Church Committee (AD Internal Review Committee) recommendation that the Design Handbook be expanded and used by all participants throughout the project. A table presenting the Parameter List for the Proton Plan would be a desirable addition to the Design Handbook.

An important element of the Proton Plan contributing to PoT for the NuMI beam is multi-batch slip stacking in the Main Injector. An early test of the acceptance of the NuMI beamline for this beam is strongly recommended.

COST

Currently a total cost of $25,664K is foreseen for the Proton Plan campaign. There is a sound basis for the cost estimates (~$19.5M including contingency) for elements proposed to be baselined. Less detailed estimates were available for the other elements. More detailed elements will be included with Change Proposals for new baseline elements as the Plan evolves. A Work Breakdown Structure (WBS) has been prepared with 5 level 2 elements, some of which are expanded to levels 4 and 5. A contingency analysis at level 2 of the Workbreakdown (WBS) has been prepared.

SCHEDULE

A resource loaded schedule (RLS), using Microsoft Project, has been prepared. Schedules for the elements being proposed for baselining are more detailed than those for other elements. In particular, the coming six month resource need has been coordinated with Department Heads and their responses of availability have been incorporated into the RLS. The schedule for activities occurring later will need to be modified to reflect more realistic shutdown assumptions once they are known.

The RLS shows most of the person power resource needs over time for the Proton Plan. The Proton Plan is well underway with some key elements planned for completion and installation in the next accelerator maintenance shutdown tentatively scheduled to begin in November. The presently planned activities extend through 2008.

MANAGEMENT

The Project Manager and Deputy Project Manager for the Proton Plan have been named. The Accelerator Division Project Group provides scheduling, documentation, and budget support. A Proton Plan "organization" mirroring the WBS has responsible individuals named at levels 2 and 3. Staffing for the Proton Plan activities will be provided in a matrix manner from selected AD Departments.

A draft Project Management Plan (PMP) for the Proton Plan was presented. Project Management concepts and tools which are being tailored for application to the Proton Plan campaign include: the PMP, a Design Handbook, WBS, Resource Loaded Schedule, Technical / Cost / Schedule baselines, Basis of Estimate and Cost Estimate documentation, Change Control, Reporting, and Risk Analysis & Mitigation. The Director's office will provide oversight through the Proton Plan Project Management Group (PMG) . This suite of Project Management tools seems reasonable and appropriate.

Two elements the Booster Vertical Correctors (BVC) and Booster Horizontal Correctors (BHC) are proposed as Accelerator Improvement Projects (AIP). They will be subject to the formal AIP procedures. Other elements may be proposed as AIPs as the Proton Plan evolves.