Fermilab

Final Report

Director's
Preliminary Review
of
the Super NuMI (SNuMI) Plan

November 14-16, 2006

This page intentionally left blank

Table of Contents

Executive Summary 4
1.0 Introduction 6
2.0 Phase I 7
2.1 Technical 7
2.1.1 Booster Upgrades 7
2.1.2 Recycler Upgrades 9
2.1.3 Main Injector Upgrades 12
2.1.4 NuMI Upgrades 15
2.2 Civil Construction 19
2.3 Project Management 21
2.3.1 Cost 21
2.3.2 Schedule 22
2.3.3 Management 24
2.4. Charge Questions 26
3.0 Phase II 28
3.1 Technical 28
3.2 Civil Construction 30
3.3 Project Management (Cost Schedule and Management) 32
3.4. Charge Questions 33
Appendices 34
Project Cost Estimate 35
Charge 36
Agenda 38
Report Outline and Reviewer Writing Assignments 40
Reviewer Assignments for Breakout Sessions 42
Reviewers' Contact Information 43
Participant List 44
Table of Recommendations 46

Executive Summary

Technical
The NOvA (an off-axis electron neutrino appearance experiment using the NuMI beam) project is near the CD-1 level approval. The project will be approved assuming increased neutrino fluxes resulting from upgrading the Fermilab accelerators and the NuMI beamline. A Super NuMI (SNuMI) plan to upgrade the proton intensity on target, the NuMI beamline, and target hall components following the shutdown of p – pbar collider operations at Fermilab was presented. This plan utilizes parts of the accelerator complex that will be available in that time frame and envisions upgrading the proton on target power levels in two phases. The SNuMI Phase I goal is 700 KW and the Phase II goal is 1.2 MW. A Conceptual Design Report has been prepared for Phase I describing the steps to be taken to operate the Booster at high rep rates, re-fit the Recycler as a proton pre-injector to the Main Injector, and modify the Main Injector and NuMI beamline for more intense beams. A conceptual strategy for incorporating the Accumulator for momentum stacking was discussed as a key component of achieving the Phase II power goal. The success of SNuMI depends critically on the success of the Proton Plan. Both Phases I & II have some technical risk for which accelerator physics simulations are recommended to address before the systems are built.

Cost
The base costs (without G&A, Contingency, or escalation) in FY06$ were presented for Phases I & II as $33.4M and $53.6M. A contingency analysis for Phase I by the SNuMI team suggests 41% on the total base cost at this stage of development. Phase II is at such an early stage that no contingency analysis has been prepared. The kickers, NuMI upgrades, and Management comprise nearly three-fourths of the cost of Phase I and are felt to have a good basis of estimate in selected engineering files from similar work although this information has not yet been documented in the Microsoft Project (MSP) schedule file. The project M&S to labor ratio is ~1.5. This ratio means SNuMI will need to track the economy and regularly update estimates to reflect experience with procurement costs.

Schedule
The schedule for Phase I 700 kW operations is following the Spring 2011 shutdown. This matches the NOvA 5 kton detector startup. Operation at ~400 kW for MINERvA will begin in spring 2010 following the 2009 shutdown. The Phase II plan for operations at 1.2 MW begins late in 2012. The full NOvA detector completion is planned for late in 2012 as well.

An approximately 800 line resource loaded schedule has been prepared based on a detailed work breakdown structure (WBS) for Phase I. The critical path is kickers for much of the project and then the horn and target hall. Early funding needs are the ceramic beam tube (for the kickers) purchase and A/E design of the penetrations and footings of the surface buildings. An early R&D item for Phase II is the operation of an MI cavity with two power amplifiers.

Management

A SNuMI organization has been established in the Fermilab Accelerator Division to design and construct these upgrades. Commendably, twenty five key personnel have already been named at the second and third levels of SNuMI management. Phase I will be treated as a campaign of operations, maintenance, upgrades, R&D, and studies in the style of the Run II and Proton Plan campaigns. A draft Project Management Plan has been prepared that describes the tailored project management tools and procedures that will be applied on this campaign including the technical, cost, and schedule baselines and the anticipated change control procedures. The Project ES&H Coordinator gave a comprehensive talk on the safety documentation and ES&H/QA procedures planned for SNuMI. Plenary and breakout talks were given on accelerator and target hall radiation safety considerations. Finally, there is concern about staffing Phase I to maintain the proposed schedule and simultaneously staffing a small team (6-8 persons) now to focus on Phase II development.

1.0 Introduction

A Director's Preliminary Review of the Super NuMI (SNuMI) Plan was held on November 14-16, 2006. The primary purpose of this Director's Review is to establish a preliminary baseline for Phase I of the plan (aimed at 700 kW), and to establish a viable strategy for Phase II (aimed beyond 1 MW). The assessment of the Review Committee is documented in the body of this report.

Each section in this closeout report is generally organized by Findings, Comments and Recommendations. Findings are statements of fact that summarize noteworthy information presented during the review. The Comments are judgment statements about the facts presented during the review and are based on reviewers' experience and expertise. The comments are to be evaluated by the SNuMI Management team and actions taken as deemed appropriate. Recommendations are statements of actions that should be addressed by the SNuMI team. A response to the recommendations is expected and the actions taken will begin to be reported by SNuMI's Project Management within two months from the review closeout. Progress on the recommendations is to be reported during Working Group Meetings (WGM) or Project Management Group Meetings (PMG) with a complete set of responses to be provided at the next Director's Review.

Reference materials for this review are contained in the Appendices. Appendix A is SNuMI Plan cost estimate with contingency spreadsheet. The Charge for this review is shown in Appendix B. The review was conducted per the agenda shown in Appendix C. The Reviewer's assignments are noted in Appendix D and E, and their contact information is listed in Appendix F. The Review Participants are listed in Appendix G. Appendix H is a table that contains all the recommendations included in the body of this report.

2.0 Phase I

2.1 Technical

2.1.1 Booster Upgrades

Findings

- The majority of foreseen Booster upgrades are contained within the proton plan.

- Impressive improvements have been realized in the last several years in both Booster throughput and loss reduction which have succeeded in keeping residual activation levels nearly constant throughout this period.

- The success of the SNuMI Phase I project relies on the successful completion of the Proton Plan and the successful demonstration of anticipated increase in Booster throughput to 4.3E12 at 9 Hz, providing 14E16 p/hr vs. 7E16 p/hr now.

- All pulsed magnet elements in the Booster are capable of 15 Hz operation. Only the RF systems are limited to an average repetition rate less than 15 Hz. Tests will be performed to establish needs for increasing the RF system repetition rate to 10.5 Hz. If it is determined that hardware modifications are required to reach 10.5 Hz, those upgrades will target 15 Hz capability. Therefore, the SNuMI booster upgrade plan includes the most likely of those upgrades: i) increased cooling to RF tuner endcones, ii) refurbishment of anode power supply systems for 15 Hz operation, and iii) reworking ferrite tuner bias supplies for 15 Hz repetition rate.

- Milestones are in the plan for verifying booster beam quality and efficiency following the proton plan.

- Three main loss contributors are noted in the Booster. The first relates to the creation of the beam gap required for subsequent extraction. The second arises from losses at low-energy, presumably from space-charge dynamics. The third arises from losses during acceleration. It is assumed that the acceleration-related losses can be controlled with the use of the new corrector system to be installed in the Proton Plan.

- Beam power requirements for the booster, in the context of additional demands from the 8 GeV BNB program, awaits a formal decision, and is an important component of the 10.5 Hz vs. 15 Hz decision making process.

- Linac scope is not included in the SNuMI project. Rather, it is assumed that the linac improvements required for long-term operation and viability are included in the Proton Plan.

Comments

- The success of SNuMI relies on the successful completion of the Proton Plan. While tremendous progress is evident, continued dedication to booster performance, loss minimization, and a substantial effort to commission and make use of the booster corrector system will be required.

- The committee suggests considering fallback scenarios in the event that the full performance improvement of the Proton Plan is not realized.

- The committee feels that the losses during acceleration need to be better understood. It was explained that these losses were due to poor control of the orbit during acceleration, and in fact, phase II projections make this assumption, from which closed-orbit-distortion limits are derived. The committee suggests considering other loss mechanisms, such as transition crossing, and in any case recommends further study to clearly identify the source of these losses. The committee encourages development of the gamma-t jump system which is included in the Proton Plan, but which is not yet defined.

- The beam losses at low-energy ("collimation losses") are presumably due to space-charge dynamics. These losses could be improved with a dual-harmonic RF system, something which is not in any plan for the booster.

Recommendations

1. Consider the potential benefit of a dual-harmonic RF system in the Booster.

2.1.2 Recycler Upgrades

Findings

- Presently used to store p-bars, the recycler ring (RR) has a large momentum aperture of 1.5 % and a transverse acceptance of 60 π μm. It has shown to store up to 1.3E13 protons. For SNuMI phase I, it will be used to accumulate 5.2E13 protons. This will be done by slip-stacking 6 on 6 booster batches of 4.3E12 protons each.

- The RR will need two new transfer lines, one to inject directly from the booster, one for extraction into MI. The extraction line will have to have enough momentum acceptance for the slip-stacked beam.

- Four new kickers will have to be installed in the RR: 2 similar kickers (consisting of 9 modules each) for injection and gap clearing with very challenging demands on rise-time, fall-time (38 ns each) and flat top stability of ±1 % over 1.552 μs; 2 similar kickers for ejection and full turn abort, challenging in terms of flat top stability of ±1 % over 9.5 μs. The kicker systems are on the critical path for the project.

- The RR will have 2 new 53 MHz RF systems, which are conceptually different from existing ones and require design. In view of phase II, it is planned to purchase material for 4 RF systems. The quarter-wave coaxial cavities have a low R/Q of 20 Ω. Mechanical deformations, stresses and vibration modes of the 1.4 m long, 500 kg inner conductor were analyzed and found to be tolerable.

- Slip-stacking cannot be tested in the RR. Relevant tests of multi-batch slip-stacking in the MI indicate losses of below 5 % at 25 % of the goal intensity, losses of 8 % at 50 % of the goal intensity, and 16 % at 75 % of the goal intensity.

- The cables of the BPM's have to be changed to become compatible with the 53 MHz.

- The DCCT's and toroids do not present a serious issue, but a decision on in-house fabrication or ordering is due 10/2008.

Comments

- The kickers will present non-negligible impedance to the beam. This, along with its impact on the beam stability, is an issue that needs further clarification. The planned coating on the inside of the ceramics is of high resistivity to prevent surface charges, which may not be sufficient to reduce beam impedance.

- Another issue in the RR, the build-up of electron clouds, may also be not sufficiently addressed.

- It is not clear where the 1 % flat top tolerance specification for the kickers comes from. It would be useful to derive a real specification from the simulated effect of flat-top imperfection on the beam dynamics.

- A test is planned of one module of the injection kicker: Since it will test only one "normal" module, and not the fast 5 kV module, it is not clear whether this test can answer the question whether the whole kicker will meet the specification?

- Slip-stacking to the full required intensity cannot be tested in the RR. The demonstrated loss in the MI being above 15 % is not compatible with the requirement of losses below 5 %.; no plan was presented how this stringent requirement will be met. This represents a significant technical risk for phase I.

- There may be an issue with multipactor in the long coaxial cavities.

- There may be a potential conflict in resources if the cavities are designed and built in house, since this may coincide with the tests of the power upgrade of the MI RF system for phase II.

- It is planned to change the BPM cables in the 2009 shut-down. This requires careful coordination with many other activities; maybe it could be considered to perform this task earlier.

- It is of concern to the committee that the RR will be used for a purpose very different from its present use, while it will not be available for any tests until the end of the Tevatron run.

Recommendations

2. Concerning the kicker modules, their impedance and the danger of electron cloud, the committee recommends reconsidering the inside coating of the ceramics in terms of resistivity and SEY (Ti, TiN, …).

3. There seems to be a trade-off between the number of bunches "notched" out in the booster and the stringent requirements on rise- and fall-time of the injection and gap clearing kickers – the specified 38 ns are based on 2 missing bunches. The committee recommends evaluating this trade-off and to prepare for a different number of "notched" bunches as a fall-back solution.

4. In view of SNuMI phase II, the committee recommends to consider purchasing material also for a spare cavity, bringing the total number to 5.

5. Since slip-stacking to full intensity cannot be tested early in the RR, the committee recommends continuation of tests in the MI.

6. Due to the envisaged completely new type of operation of the RR without the possibility of relevant tests before the end of the Tevatron run, the committee

recommends to consider at least fully simulating this new operation, including longitudinal and transverse beam dynamics.

7. Concerning the change of BPM cables, the committee recommends: Assign a coordinator now who will manage the 2009 shutdown activities. Develop the installation plan, and examine what activities could be done in earlier shutdowns to ease conflicts due to multiple personnel working in the same areas and tunnel blockages. (Cables pulls and LCW pipe relocation are two obvious candidates for doing early.)

2.1.3 Main Injector Upgrades

Findings

- The Main Injector will receive bunched beam from the Recycler in bunch-to-bucket transfer mode. Slip stacking will no longer be done in the MI. The injection flatbottom will be minimized and the acceleration rate increased to 240 GeV/sec, yielding a reduction of the repetition period from 2.2 seconds to 1.33 seconds. The vertical quad bus will be upgraded to provide the higher voltage needed for 240 GeV/s.

- Transition is a potential bottleneck for high intensity in the MI. The momentum aperture dictates that the longitudinal emittance should not be much more than 0.3 eVs per bunch. This requirement will be easier to fulfill in Phase II when momentum stacking in the Accumulator replaces slip stacking in the Recycler.

- The Proton Plan will install a two-stage collimation scheme to catch un-captured beam. The design is currently being finalized and will be installed during the 07 shutdown.

- The power required per RF cavity for Phase II with 8.3e13 protons and 240 GeV/s will reach 215 kW, which exceeds the capability of the existing Power Amplifiers by about 25%. A significant upgrade to the MI RF system will address this problem at a cost of 7 M$.

- The original designers of the 53 MHz cavities foresaw the option of installing a second power tube and included a port that is a mirror image of the existing PA connection. The new power tube will act in push-pull fashion with the original tube to drive the cavity. Significant RF engineering is required to implement this option and a full-power prototype will be constructed by 9/2007 and will eventually be installed, and commissioned for operations in the MI.

- For Phase II the MI beam intensity increases to 8.3e13 protons in longitudinal emittance of 0.3 eVs.

- The obsolete 2.5 MHz RF system will be removed from the MI.

- In general, the mode of operation for the MI will be simplified for the SNuMI operating mode.

Comments

- Analysis and simulations of the slip stacking gymnastic indicated that the losses that now challenge the 11 batch mode in MI will still occur when slip stacking is done in the Recycler. It appears that the major determinate of un-captured beam is the Booster longitudinal emittance, not beam loading on the high impedance cavities of the MI. The losses from the un-captured beam will be split between the Recycler and the MI, with the larger portion going to the MI. This implies that it is crucial that the new collimation system is successful in controlling these losses, and puts the collimation system on the project critical path.

- Almost all high intensity proton synchrotrons have a transition jump system (the SPS does not, but it has a 15 second repetition period). It seems like the "burden of proof" for the MI is to show why a jump is NOT needed. The present position appears to be that the jump can be pulled out of the pocket if all else fails. The understanding now is that 0.3 eVs is a practical maximum for the longitudinal emittance at transition. With twice the beam intensity will that value still be practical? Or will emittance blow up at transition lead to high energy beam losses or unacceptable momentum tails in the NuMI beam. This issue can be addressed with simulation, and perhaps machine studies can be designed to explore this brightness regime with especially prepared bunches.

- The power upgrade for the MI 53 MHz cavities seems to be well prepared and ready to hit the ground running. The earliest possible start on this is strongly encouraged, especially in light of the schedule to have a full power test running by 9/2007. The question of verifying the step-up ratio in the push-pull configuration should be addressed early, and the implication of possible new out-of-band resonances in the transfer function for the RF feedback loop must be considered.

- In addition to the losses arising from un-captured beam, there are loss mechanisms that arise from transverse dynamics as well. While perhaps a smaller contributor to total losses, these may become more important in future operation at higher intensity. We encourage the study in both simulation and experiment of all potential loss mechanisms, those related to both longitudinal and transverse dynamics.

- Electron cloud effects may arise as the bunch intensity increases and the longitudinal emittance decreases (bunch length). Examining vacuum behavior and detecting electrons in the MI now may shed light on this effect.

- It seems odd that the manpower for the 8 kW solid state drivers, which are purchased items, exceeds that for the 120kW power amplifiers, which are constructed in house.

Recommendations

8. We recommend that emittance growth at transition as a function of beam brightness be re-examined in light of the Phase II requirements. If machine studies can be done with relevant bunch parameters then they should be given high priority.

9. It is unlikely that the losses of un-captured beam in the MI will be significantly reduced when 12 Booster batches are slipped stacked in the Recycler compared to now when 11 batches are slip stacked in the MI. The collimation system for MI

must be demonstrated to be effective for Phase I to be a viable design for producing 700 kW.

10. The work on the upgraded power amplifier for the MI should begin a soon as possible.

2.1.4 NuMI Upgrades

Primary Proton Beamline

Findings

- Improvements are planned for the instrumentation and other features such as the regulation of power supplies in order to be able to abort the 1st "bad pulse" under some conditions, not the 2nd bad pulse as is done now.

- It also appears that the need for 3Q120 quadrupoles having improved water cooling is fully appreciated because of the anticipated decrease in the cycle time. This need may be met at reduced cost by reusing "better" magnets freed up by the decommissioning of the Tevatron Collider program.

- Analysis of Mechanical Adequacy of the Decay Pipe Water Cooling System, Decay Pipe Vacuum Window, and Hadron Absorber Water Cooling System

Comments

- The adequacy of these systems has been examined and, as needed, confirmed using FEA calculations.

Recommendations

11. It is commendable that these particular items have already been examined and to reference these to the worst case, condition of a pulse, or pulses of an uninteracted proton beam reaching these components (e.g., the target is missing or the beam is missing the target).

12. The plans outlined in the CDR to add an input to the beam permit system to check for "beam present without muons downstream of the hadron absorber" (indicative of the presence of untargeted beam) is a worthwhile addition given the anticipated increased beam power.

Water Systems

Findings

- The water system components have been analyzed for efficacy at the upgraded beam power. A clear picture is emerging of the systems that can be paraphrased as being classified as "marginal", "barely adequate", and "clearly adequate". This picture changes significantly between Phases I and II.

Recommendations

13. It would be prudent to plan any Phase I work in a manner that does not necessitate undoing and/or repeating it for Phase II. This is particularly true for RAW (Radioactive Water) systems.

Target Design

Findings

- IHEP Protvino prepared a target design for 700 kW beam power using the same Carbon material as the present target. The new target design is based on vertical fins removing the water cooling channels from the beam axis. This is made possible by the fact that for the medium energy configuration needed for NOvA the target does not need to extend to inside the first horn.

- The new target may be OK up to 1.4 MW. IHEP has also produced a conceptual design for a 2 MW target. There are no final designs for the horn and target chase cooling for Phase II 1.2 MW operation.

- No major technical issues exist between the targets for the SNuMI Phase I and NuMI. Experience obtained through the design, construction, and the operation of the NuMI, the analysis using, for example, FEA technique has been made for its upgrade.

- While the installation of these components in an environment with high levels of activation is not trivial, the plans being made seem to address these and the design of the striplines appear to be robust, based upon available operational experience.

Comments

- The upgrade of the target and horns to accommodate 700 kW beam power are mainly incremental improvements further helped by medium energy configuration.

- The target failure early in the NuMI running was due to beam induced water hammer that then lead to excessive motion and metal fatigue. With a clamp over the bellows in the cooling lines that prevents movement the failure has not reoccurred. The new target will not have bellows and also the cooling lines are further removed from the beam.

Recommendations

14. The temperature distribution of the fin structure should be carefully analyzed due to the longer distance between the beam impact and the water cooling.

15. Conceptual and final designs need to be developed for the Phase II NuMI upgrade.

Work Cell Upgrades

Findings

- The present work cell was designed for simple one-for-one component replacements. It is now recognized that minor repairs can be done on horns, based on experience with NuMI without recognizing the feasibility of some simple repair actions. The Work Cell has been used to perform 4 component repairs in the last 18 months.

- Predicted dose rates for SNuMI are expected to reach up to 300-400 R/hr at 1 foot.

Comments

- The reviewers concur with the observation that the horn repairs effected to date using temporary shielding schemes are not all likely to be feasible, with reasonable personnel radiation exposures, at envisioned levels of beam power.

Recommendations

16. The conceptual plans to procure a new off-the-shelf remote manipulator with special tools designed for this application and considerable associated efforts are good ones.

17. It would be advisable to not acquire "used" manipulators that might become available from other facilities due to the potential for contamination, not readily removable.

Radioactive Component Removal Plan (RCRP)

Findings

- The need for such a plan has been recognized and actions to address this need initiated at this early stage. This plan addresses short term and long term storage of radioactive components.

- The constraints on the storage of large, highly-activated components such as the horns in the present "morgue" are understood. Early conceptual design of the required systems exists; there are large contingency associated with theses estimates.

Comments

- Several serious logistic problems have already been identified both at NuMI and at the Target Storage Building (TSB).

Recommendations

18. Measures to address this problem should be continued. As needed, elements of this may be implemented prior to the 2009 down time.

19. Plans for actions to be taken in event of "crane failure" should be made in advance.

Radiological Safety -Phases I and II NUMI Upgrade

Findings

- Extensive analysis of radiological issues for NUMI already exists; much experience from operation of the facility is being gained.

Comments

- Radiological issues for phase I&II are likely to manageable through revised radiological posting and moving radiologically controlled boundaries. Phase II operation may require some additional shielding to reduce dose rate from activated components.

Recommendations

20. The radiation safety analysis will need to be refined as the design proceeds.

SNUMI Radiation Levels Under Phase II Conditions

Findings

- Assessment of prompt radiation conditions has been completed at a preliminary level. While the Booster, Recycler, and Main Injector may present minor problems, the reconfiguration of the Accumulator for use in SNUMI present a more significant issue, mostly attributable to the factor of 7800 increase in proton intensity present.

Comments

- The plans for mitigating the external doses under conditions of accidental beam loss to meet the requirements of the FRCM presented in this review rely largely on active devices (interlocked detectors) and beam monitoring devices along with fences with locked gates that ensure reduced beam intensity when people have to access the Accumulator/Debuncher service buildings and the above ground areas in the vicinity

Recommendations

21. More detailed calculations will be needed to better understand the beam losses in advance of the full development of the Phase II design.

22. The project should consider a study of the possible use of collimation and local shielding inside the Accumulator beam enclosure to better control the prompt radiation hazard passively. A complication may be presented by the fact that the debuncher ring is likely to be retained for a potential physics experiment.

Radiological Safety

Comments

- At several points, considerably quantities of radioactive, and perhaps other regulated wastes, may be generated as part of SNUMI implementation or subsequently. The costs for waste disposal may be considerable and should perhaps be budgeted separately.

- The nature of the work to be done in implementing either phase of SNUMI will likely lead to significant total effective dose equivalent (TEDE). Estimates of this should be made as part of project document in order to understand the profile of TEDE at Fermilab in the affected years.

2.2 Civil Construction

Findings

- The Phase 1 civil construction includes two new service buildings, MI-14 (2250 sq ft) and MI-39 (1500 sq ft), a fourth Anode Power Supply building (250 sq ft) at MI-60, and cooling pond enhancements. The specification requirements and the required methodology for the construction of these buildings are well understood by the project team.

- The estimated cost is $2065K, without contingency or G&A, with contingency of 29% as the proposed allocation.

- DOE space management policy necessitates the demolition of 4,000 sq ft of building space on the Fermilab site to offset new construction planned for this campaign. The estimated cost of this demolition has been incorporated into the plan.

- A categorical exclusion from the NEPA is anticipated for the Phase I civil work. Phase I includes the mitigation of some floodplain acreage in connection with the construction of MI-14 Service Building.

- The proposed schedule installs the tunnel penetrations and service building footings during the summer 2007 shutdown, with the actual building construction following in FY08, resulting in completion in the summer of 2008.

Comments

- Recent bidding experience on other FNAL projects has resulted in bids substantially (~25%) above the estimates, consistent with the general construction industry trends in this region.

- The 2008 availability of the two service buildings is highly desirable so that the space may be utilized for kicker fabrication and testing. Doing the proposed 2007 work appears to be crucial to achieving that, given the certainty of the 2007 shutdown and the greater uncertainty of the timing of the 2008 shutdown. Proceeding with the 2007 shutdown civil work requires both funding and agreement on the locations of penetrations.

- While the requirement for space demolition has been established, the space to be demolished has not been identified at this point. This information would be useful to more precisely identify the funds needed for demolition.

- The Main Injector cooling ponds were designed for substantially higher power levels than are now being run, and yet during each of the last four summers, they have provided insufficient cooling capacity. It would seem prudent, in the course of doing the pond enhancements as part of the SNuMI campaign, to provide additional pond water area above what is needed to handle the increased load at MI-60.

- The issue of power factor and reactive power under the post-Tevatron operating conditions have not been studied in detail. Additional harmonic filtering may be required, such as relocating the Tevatron harmonic filter to the Kautz Road Substation. Some analysis would be appropriate, and budgeting for the costs as determined necessary.

Recommendations

23. Allocate funds in a timely manner to allow installation of the penetration and building footings during the summer 2007 shutdown. Approval by December 1, 2006, is needed.

24. Specify the location of penetrations both inside the service buildings and to the tunnel.

25. Evaluate the MI cooling pond performance, and determine the incremental pond area required to both support the expected increase in heat load and to provide additional operating margin. Design and construct new pond area accordingly.

26. Assign additional contingency based on recent bid experience.

27. Identify the area(s) to be demolished, so that the associated costs can be better validated.

2.3 Project Management

2.3.1 Cost

Findings

- SNuMI presented a Phase I base cost estimate of $33.443M in FY06 dollars.
- An overall contingency for Phase I was estimated at 41%.

Comments

- The SNuMI Team has come a long way in a couple of months to assemble the cost estimate presented at this review. The SNuMI Team is to be commended for their efforts.
- Some Risk Assessment has been performed and reflected in the contingency assigned to different activities.
- Some Basis of Estimate (BOE) documentation exists but not for all the activities in the schedule. The BOEs need to be completed, retrievable and controlled.

Recommendations

28. Maintain the level of effort that was committed to preparing for this review to continue to refine the scope of Phase I and the cost estimate.

29. Complete the Basis of Estimate (BOE) documentation to support the resources assigned in the Phase I Schedule and store the information in a controlled repository.

30. Continue to refine the bottom-up risk assessment and the top-down risk assessment and assure that the contingency assigned is appropriate for the identified risks.

31. Increase the contingency on the Civil Construction work to reflect the cost increases experienced on recent Request for Proposals (RFPs).

2.3.2 Schedule

Findings

- A Microsoft Project (MSP) Resource Loaded Schedule (RLS) consisting of 570 activities with 828 lines was available at the review.
- The SNuMI Phase I RLS contains 111 milestones that are broken into 3 levels (A-19, B-38 and C-54).
- The SNuMI Phase I RLS contains 28 review activities with resources assigned.
- The RLS has SNuMI Phase I starting on October 2, 2006 and completing on October 19, 2011.
- SNuMI has developed a Work Breakdown Structure (WBS) down through level 6 for Phase I.
- A critical path was shown.

Comments

- The schedule for Phase I is well developed for the short time frame it was assembled in. To get to a baseline schedule some addition cleanup is required:
    - Complete WBS Dictionary including Milestone Descriptions to assure that is well understood what is to be accomplished to mark the task/milestone as complete.
    - Analyze the long duration tasks (>2 months) to determine if the activities can be further broken down or if interim deliverable milestones are needed. This helps to monitor progress.
    - A few activities do not have resources assigned, but it appears that they should (i.e. UID 1103, 1124, 709 and 1408).
    - Review the relationships (predecessors/successors) to assure they are appropriate. When reviewing the activities on the critical path there are some activities that appear to be unrelated to the majority of the other critical activities (kickers).
- Risk analysis needs to be further developed and incorporated into the schedule. Mitigation activities should be included in the base schedule and the remaining risk is addressed with assigning appropriate schedule contingency to the higher level milestones. The schedule needs to be aggressive, but realistic and achievable.
- Resource leveling has not been performed yet. The schedule needs to be resource leveled to assure the accuracy of the projected schedule completion date. This is

critical since the required resources have multiple priorities (Operations, ILC and SNuMI Phase II). Working with TD during this process is crucial since many of their activities fall on the critical path.

Recommendations

32. The SNuMI Team needs to continue to scrub the schedule by addressing the items noted in the above comments. This is needed to achieve a baseline schedule.

2.3.3 Management

Findings

- There is a team in place, consisting of about two dozen people now up from perhaps just a few this summer. Recruitment of key personnel came from the AD primarily, but also throughout the lab. Many of these people have operational responsibilities and responsibilities on other activities. ES&H staffing is in place.

- Project Management is carried in WBS 1.6 and includes costs associated with the L1 and L2 managers, project office staff, and an allowance for some contract labor.

- Documents made available to the committee include a CDR, a parameter list, a draft PMP, NEPA form.

- ESH/QA is being integrated early in the teams planning, especially radiation safety planning.

- There is no funding profile yet.

- Phase I is estimated to cost $ 33M, exclusive of contingency and adders. An additional 41% is estimated for contingency.

Comments

- There is a very good team in place. Progress is very good, rapid, and substantial.

- Phase I is a larger effort than the technical components for the NuMI project which took over six years to complete.

- Currently spare horns are part of the project. Whatever happens during project definition, appropriate spares inventory is essential.

- Labor estimates in some areas look low. Staffing is not yet assured, although the recent signs are positive.

- The team did a very good job of preparing and presenting talks, web sites, documentation, and overall review coordination

- A resource profile was presented, but had not yet been leveled. Schedule contingency has not yet been analyzed.

- Concerns about staffing availability are common at this stage of a project and exist here. The growth in the team is an encouraging sign, but effort will have to be sustained and increased to succeed. Many key members of the team have substantial operational and administrative responsibilities elsewhere.

Recommendations

33. Start regular PMG meetings as described in the PMP.
34. Work with the laboratory to get the FY07 funding guidance soon, along with a funding profile for the outyears for planning the rest of the project.
35. Assure that the SNuMI labor needs are part of AD's, and other organizations', integrated manpower planning.
36. Keep up the impressive rate of progress that you have been achieving recently.

2.4. Charge Questions

2.4.1 Are the physics requirements that SNuMI addresses appropriately stated?

Yes, the physics requirements for SNuMI are well-defined in terms of achieving 700 kW of beam power on the SNuMI target.

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

Yes, as far as we can tell. The parameter list is a high-level table containing some of the main physics parameters. The specifications for many of the required hardware components were derived from beam-physics requirements. It would be useful to expand this parameter list to capture specifications and requirements that fold into the hardware design. Such a parameter list is a useful tool to use in managing changes to requirements and specifications.

2.4.3 Are the design features of the defined elements of SNuMI documented in a Conceptual Design Report, Design Handbook, or other appropriate manner?

Yes, a Conceptual Design Report has been prepared. It captures the main features of the technical plan, the high-level requirements, as well as the cost and schedule.

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

A prototype plan exists for one of the types of required recycler kicker systems, which is one of the highest risk components of the plan. There are other, different, kickers which are part of the same system that are not planned for prototyping. Given the complexity of those kickers, prototyping each type of kicker is warranted. Milestones are included in the plan for making key decisions that drive the designs.

2.4.5 Do the elements of SNuMI address the performance requirements / specifications? Are the designs of these elements reasonable?

Yes, in most cases. The recycler kicker magnet system pushes the state-of-the-art. A fallback plan should be considered in the event that the kicker rise/fall times cannot be achieved.

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

Yes, SNuMI has developed a WBS down through level 6 for Phase I.

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

Yes and No, some of the costs are better defined and documented than others. The SNuMI team needs maintain the level of effort given over the last couple of months to continue refining their scope and cost estimates.

2.4.8 Is there a schedule for the project?

Yes, SNuMI has developed a Microsoft Project (MSP) consisting of 570 activities with 828 lines.

2.4.9 Are the activity durations reasonable for the assumed resources?

Yes, the activity durations appear to be reasonable for the assumed resources. Since the resources have not been leveled based on availability, the current activity durations may change.

2.4.10 Has the schedule been "resource loaded?"

Yes, SNuMI's Phase I schedule has been resource loaded, but the resources have not been leveled to assure the accuracy of the schedule completion date.

2.4.11 Has the schedule been developed with contingency or slack included?

No, schedule contingency has not been incorporated into the Phase I SNuMI schedule.

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

Yes, there are decision milestones contained in SNuMI's Phase I schedule.

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

Yes. In fact for this stage of a project there is a quite-well developed organization chart with L1, 2, 3 managers and in some cases deputies. There is an experienced project manager and deputy in place. Project engineering and ES&H staff positions are also filled.

2.4.14 Have responsibilities been assigned or have they been proposed?

The responsibilities are assigned and are described in the PMP.

2.4.15 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?

There is a draft Project Management Plan that is complete and approvable.

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

Staffing has ramped up rather remarkably in the last several weeks. There is a good team in place now. It will need to be maintained in light of other responsibilities and will also need to grow as the project evolves. SNUMI II needs more effort now.

2.4.17 Is there a funding plan available or proposed to meet the resource requirements to realize SNuMI?

There is a need-based funding analysis that arises from the project schedule. This will be used as input to the laboratory budget process. There is no funding guidance yet.

3.0 Phase II

3.1 Technical

Findings

- The phase II of SNuMI aims at increasing the beam power on target from 700 kW to 1.2 MW. This is mainly done by using more Booster cycles at an effective 13.5 Hz repetition rate instead of the 9 Hz rate used in Phase I. During the MI cycle time of 1.33 seconds 18 Booster batches are accumulated in the RR. The project proposes to accomplish this by changing the stacking scheme from slip stacking in the RR to momentum stacking three Booster batches in a converted 'Anti-proton Accumulator' and then box-car stack six AA batches in the RR.

- The Accumulator will require a new 7.5 MHz and a new 53 MHz RF system. The Recycler also needs a new 7.5 MHz RF system and two more 53 MHz cavities.

- The increased beam intensity in the MI also requires an upgraded MI RF system using two tubes per cavity. This was part of the original design of the cavities but was never implemented. It is planned to build a prototype with two power tubes.

- A 10% increase of the beam intensity in the Booster is accomplished by putting a notch, which is required for the extraction kicker and is presently done in the Booster ring, in the beam from the Linac This will reduce losses in the Booster and allow for higher throughput. No design for a Linac chopper was presented and it was also not included in the cost estimate.

Comments

- During debunching and rebunching of the high intensity beam in both the Accumulator and Recycler the beam will be potentially unstable depending on the impedance of the rings. Attempts at other machines to debunch and rebunch high intensity beams have been abandoned in the past because of unavoidable instabilities. This represents a potentially fundamental limit to the proposed scheme. The beam dynamics of this process should be studied by calculating instability thresholds in the debunched state. Analytical results should be verified by simulations and/or with beam experiments.

- More RF power needs to be applied to the beam in the MI to cope with the increased beam intensity. The proposed solution of using the second existing ports of the cavities is very appropriate and a prototype with two tubes should be tested as soon as possible.

- The higher bunch intensity and lower longitudinal emittance resulting from the proposed stacking scheme will make crossing the transition energy in the MI more difficult. A transition energy jump system may be needed to avoid beam loss or emittance growth.

- Putting the extraction kicker notch in the Linac beam is clearly beneficial. This could also be done for the slip-stacking scheme by implementing phase resolved Booster RF throughout the cycle, which then can be pre-cogged reliably to the Recycler. A Linac chopper should be developed for this purpose.

- The high beam intensities in the Accumulator, Recycler and Main Injector could generate electron clouds that can cause pressure rise and beam instabilities. This should be investigated.

- Finally, the committee notes that SNuMI phase I and II use two quite different stacking schemes requiring different new hardware to achieve the same goal of increasing beam power delivered to the NuMI target using pbar equipment. Pursuing both schemes in sequence necessarily leads to inefficiencies. It might be better to pick the best scheme and focus all efforts only on this scheme. It would also be useful to study alternative stacking schemes that are less sensitive to beam instabilities and have better efficiency.

Recommendations

37. Estimate the beam loss instability thresholds during the beam stacking processes, in particular during debunching and rebunching of the high intensity beam in the Accumulator and the Recycler, with simulations and/or beam studies.

38. Study alternative stacking schemes that are less sensitive to beam instabilities and have better efficiency.

39. Test a spare 53 MHz cavity with two power tubes as soon as possible.

40. Design a Linac chopper to put a notch in the Linac beam for the Booster extraction kickers.

3.2 Civil Construction

Findings

The Phase 2 civil construction is estimated at $9300K, without contingency or G&A, with contingency of 40% as the proposed allocation. This includes the necessary Space Management demolition costs.

- The above estimate is for approximately 1000 feet of beamline enclosure of standard size, with connections to existing enclosures. The AP-4 line connects from the Booster end of the MI-8 line to the Accumulator, and the AP-5 line connects from the Accumulator back into the MI-8 line, headed towards the MI and Recycler.

Comments

- No determination has been made or assumed regarding the need for an Environmental Assessment for the Phase II Civil Construction work.

- The location where Phase II Civil construction will take place is extremely congested, which will pose significant challenges to both cost and schedule during construction.

- The cost estimates are appropriately based on the unit costs from previous similar activities. The larger contingency reflects the lack of beamline lattice designs.

- The work done to date on the AP-4 line is based on the location of two bend centers in the beamline. The work on the AP-5 line, which has about 90 degrees of bend, is based simply on drawing an arc. For civil design to proceed, beamline designs must be generated. While some back-and-forth iteration may be necessary, the design should be finalized rapidly to minimize civil design effort. Since the AP-5 line also incorporates a large (~20 foot) elevation change, the beamline design could strongly impact the enclosure geometry. For example, there may need to be areas, similar to the MI-8 to Booster connection, with tall ceilings. These will be much more expensive than standard enclosures.

- Without the beamline design, including identification of magnets and their excitations, it cannot be determined what power supplies are required, and in turn, whether a new service building is required.

- The simple arc that was shown results in the AP-5 line crossing the MI-8 line aisle, blocking access. In the course of the beamline design, they should examine the possibility of trajectories that avoid blocking the aisle.

- The AP-4 line demolishes an emergency exit at the upstream end of the MI-8 line. Its replacement has not been conceptualized. Additional ingress/egress will be required from the AP-4 and/or –5 enclosures.

- The cost estimates includes a radiation fence around the existing Antiproton Source. Other remediation may be required, as discussed elsewhere in this report.

Recommendations

41. Assign beam physics manpower with the responsibility to design the AP-4 and AP-5 beamlines.

42. Minimize Phase 2 civil construction design effort until the beamline lattices have been finalized.

3.3 Project Management (Cost Schedule and Management)

Comments

- Attention so far has clearly focused on Phase I. Phase II is a larger effort than Phase I. It is not going to happen without a significant increase in effort. The project suggested that much could be learned with even a month or two of focused study.

- Cost and schedule drivers have been identified, but no beam design work has begun. The makeup of a group to pursue phase II study and design was described, but has not yet been established.

Recommendations

43. Work with lab management to pursue '1.2MW' that does not jeopardize the work on SNuMI I.

3.4. Charge Questions

3.4.1 Does the design concept for Phase II support the objective of delivering at least 1 MW beam power onto the neutrino production target?

With the proposed improvements that are part of the Proton Plan and SNuMI Phase II the proton throughput at the Booster will support 1MW beam power at 120 GeV. However, the proposed stacking schemes of the high intensity proton beam in the Accumulator and Recycler may suffer from instabilities that would prevent 1 MW operation. So the answer is no.

3.4.2 Is the strategy for Phase II viable and does it support the implementation of Phase II in the timeframe presented?

Not yet. While the approach to 1.2MW that was outlined might succeed, there has not been enough study and planning yet to know for sure. The project is not currently staffed to handle both phase I and phase II. The makeup of a phase II team has been specified, but no one has been assigned.

Appendices

Project Cost Estimate

Charge

Agenda

Report Outline and Reviewer Writing Assignments

Reviewer Assignments for Breakout Sessions

Reviewers' Contact Information

Participant List

Table of Recommendations

Appendix A

Project Cost Estimate

for the Director's Preliminary Review of the Super NuMI Plan
November 14 – 16, 2006

PHASE I: Base Costs, no G&A (indirects) or contingency, FY06$k

WBS	Name	Cont %	Labor	M&S	Total
1	SNuMI Phase I	41%	$13,136	$20,307	$33,443
1.1	Booster Upgrades	30%	$139	$518	$657
1.2	Recycler Upgrades	36%	$4,540	$11,697	$16,236
1.3	Main Injector Upgrades	31%	$571	$1,091	$1,662
1.4	NuMI Upgrades	62%	$2,665	$6,101	$8,766
1.5	Beam Physics	37%	$463	$35	$498
1.6	Project Management	30%	$4,759	$865	$5,624

PHASE II: Base Costs, no G&A (indirects) or contingency, FY06$k

WBS	Task Name	M&S Cost	Labor	Total
1	SNuMI Phase II	$31,428	$22,240	$53,668
1.1	Booster	$0	$0	$0
1.2	Recycler	$1,500	$1,500	$3,000
1.3	Main Injector	$6,979	$2,200	$9,179
1.4	NuMI	$4,800	$4,800	$9,600
1.5	Beam Physics	$100	$500	$600
1.6	Accumlulator	$5,835	$5,840	$11,675
1.7	Civil (includes 20% overhead)	$11,214	$0	$11,214
1.8	Radiation Safety	$0	$500	$500
1.9	Project Management	$1,000	$6,900	$7,900

Appendix B

Charge

Director's Preliminary Review of the Super NuMI Plan
November 14 - 16, 2006

Fermilab has prepared a "Super NuMI" (SNuMI) Plan for upgrading the proton accelerator complex in support of our neutrino-based research program following the cessation of Tevatron operations at the end of this decade. The goal for the SNuMI era is the delivery of at least 1 MW beam power onto the neutrino production target, based on effective utilization of accelerator facilities that will become available after the end of collider Run II.

The primary purpose of this Director's Review is to establish a preliminary baseline for Phase I of the plan (aimed at 700 kW), and to establish a viable strategy for Phase II (aimed beyond 1 MW). Within this context the committee will be asked to assess all aspects of the SNuMI Plan: technical performance goals and implementation strategy, cost estimate, schedule, and management structure.

The Phase 1 of the SNuMI effort is considered a "campaign" in the sense of the Run II Luminosity Upgrade and Proton Plan campaigns. That is the Phase 1 of SNuMI is not a "project" in the formal sense of a DOE project. However, selected project management techniques will be used in managing the campaign.

Phase II maybe considered a "project" in the formal sense of a DOE project. It is recognized that this review is being conducted at a very early stage of Phase II of the SNuMI project, thus it is a "preliminary" review and material presented will not be developed to the level of sophistication or detail of a more mature project.

As part of this assessment the questions listed in Attachment 1 of this charge should be addressed. The Director's Review Committee is asked to present findings, comments, and recommendations in a closeout session with the SNuMI team, AD Management, and Fermilab Management at the end of the review and in a written report soon thereafter.

Charge for the Director's Preliminary Review of the SNuMI Plan
Attachment 1

Phase I Questions:

Technical

- Are the physics requirements that SNuMI addresses appropriately stated?
- Have these physics requirements been translated into accelerator technical performance requirements / specifications?
- Are the design features of the defined elements of SNuMI documented in a Conceptual Design Report, Design Handbook, or other appropriate manner?
- Are the prototype plans and decision paths appropriate for the less well-developed elements?
- Do the elements of SNuMI address the performance requirements / specifications? Are the designs of these elements reasonable?

Cost

- Has a Work Breakdown Structure (WBS) been developed?
- Do the cost estimates for each WBS element have a sound basis and are they reasonable?

Schedule

- Is there a schedule for the project?
- Are the activity durations reasonable for the assumed resources?
- Has the schedule been "resource loaded?"
- Has the schedule been developed with contingency or slack included?
- For the less well-developed technical elements have decision milestones been included in the schedule?

Management

- Is there an appropriate management organizational structure in place or proposed to accomplish the design and construction?
- Have responsibilities been assigned or have they been proposed?
- 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?
- Are there adequate staffing resources available or planned for this effort?
- Is there a funding plan available or proposed to meet the resource requirements to realize SNuMI?

Phase II Questions:

- Does the design concept for Phase II support the objective of delivering at least 1 MW beam power onto the neutrino production target?
- Is the strategy for Phase II viable and does it support the implementation of Phase II in the timeframe presented?

Appendix C

Agenda

for the Director's Preliminary Review of the Super NuMI Plan
November 14 – 16, 2006

Tuesday, November 14 – Comitium (WH2SE)

8:00 - 8:45 AM	45'	Executive Session (Comitium - WH2SE)	Ed Temple
8:45 - 8:55 AM	10'	Introduction	Steve Holmes
8:55 - 9:10 AM	15'	NOvA Beam Requirements	Mark Messier
9:10 - 9:35 AM	25'	SNuMI Plan Overview	Alberto Marchionni
9:35 - 9:55 AM	20'	SNuMI Beam Physics	Robert Zwaska
9:55 - 10:10 AM	15'	**BREAK**	
10:10 - 10:30 AM	20'	Booster present performance and upgrades	Eric Prebys
10:30 - 11:05 AM	35'	Recycler Upgrades	Paul Derwent
11:05 - 11:25 AM	20'	Main Injector present performance and upgrades	Ioanis Kourbanis
11:25 - 12:00PM	35'	NuMI Upgrades	Mike Martens
12:00 - 1:00 PM	60'	**Lunch (2nd Floor Crossover)**	
1:00 - 1:40 PM	40'	Overview of Phase II	Nancy Grossman
1:40 - 2:00 PM	20'	Civil Construction (Phase I & II)	Dixon Bogert
2:00 - 2:20 PM	20'	Accelerator Complex Radiation Safety	Anthony Leveling
2:20 - 2:40 PM	20'	NuMI Beamline Radiation Safety	Kamran Vaziri
2:40 - 3:05 PM	25'	Strategy, Cost and Schedule (Phase I & II)	Nancy Grossman
3:05 - 3:15 PM	10'	Proton projections	Robert Zwaska
3:15 - 3:30 PM	15'	**BREAK**	
3:30 - 4:30 PM	60'	Breakouts Sessions 1-4 (See Breakout Details for Room Assignments)	
4:30 - 6:30 PM		Executive Session (Comitium WH2SE)	Ed Temple

Wednesday, November 15, 2006

8:00 - 8:30 AM	Cost and Schedule Executive Session (Comitium WH2SE)	Ed Temple
8:30 - 10:30 AM	Breakouts Sessions 5-7 (See Breakout Details for Room Assignments)	
10:30 - 10:45 AM	**BREAK** (Outside of Comitium)	
10:45 - 12:45 AM	Breakouts Sessions 8-10 (See Breakout Details for Room Assignments)	
12:45 - 1:45 PM	**LUNCH** (2nd Floor Crossover)	
1:45 - 2:45 PM	SNuMI's Respond to Committee Questions	Nancy Grossman

	(Comitium, WH2SE)	Alberto Marchionni
2:45 PM - 6:30+ (Break at 3:45)	Executive Session and Report Writing (Comitium, WH2SE)	Ed Temple

Thursday November 16, 2006

8:30 - 2:00 PM	Closeout Dry Run with working lunch (Comitium - WH2SE) Breaks taken as necessary.
2:00 PM	Closeout (Curia II - WH2SW)

<u>Breakout Session Details</u>

Tuesday, November 14

3:30 - 4:30 PM	1) **Booster and Main Injector** (One North – WH1W)	Ioanis Kourbanis
	2) **Recycler: injection line, extraction line** (Black Hole – WH2NW)	Paul Derwent
	3) **NuMI: primary proton line, decay pipe & hadron absorber** (Snake Pit – WH2NE)	Mike Martens
	4) Management/Cost/Schedule/Strategy (Phase I & II) (Comitium - WH2SE)	Nancy Grossman

Wednesday, November 15

8:30 - 10:30 AM	5) **Recycler: Kickers, Slip-Stacking Scheme, RF Systems** (Black Hole – WH2NW)	Paul Derwent
	6) **NuMI: target chase cooling, target and horns** (Snake Pit – WH2NE)	Mike Martens
	7) **Management/Cost/Schedule/Strategy (Phase I & II)** (Comitium - WH2SE)	Nancy Grossman
10:45 - 12:45 AM	8) **Overview of Phase II** (Black Hole – WH2NW)	Ioanis Kourbanis
	9) **Civil Construction** (Phase I & II) (One North – WH1W)	Dixon Bogert
	10) **Radiation safety/shielding** (Phase I & II) (Snake Pit – WH2NE)	Anthony Leveling Kamran Vaziri

* Indicates attending via video conference.

Appendix D

Report Outline and Reviewer Writing Assignments

for the Director's Preliminary Review of the Super NuMI Plan
November 14 – 16, 2006

Executive Summary	Ed Temple
1.0 Introduction	Dean Hoffer
2.0 Phase I	
2.1 Technical	
2.1.1 Booster Upgrades	Stuart Henderson Erk Jensen
2.1.2 Recycler Upgrades	Erk Jensen Mike Brennan Phil Martin
2.1.3 Main Injector Upgrades	Mike Brennan Stuart Henderson Erk Jensen
2.1.4 NuMI Upgrades	Sayed Rokni Don Cossairt Thomas Roser Yoshi Yamazaki
2.2 Civil Construction	Karen Hellman Phil Martin
2.3 Project Management	
2.3.1 Cost	Dean Hoffer All
2.3.2 Schedule	Dean Hoffer All
2.3.3 Management	Greg Bock Karen Hellman
2.4 Charge Questions	
2.4.1 Are the physics requirements that SNuMI addresses appropriately stated?	Stuart Henderson Thomas Roser
2.4.2 Have these physics requirements been translated into accelerator technical performance requirements / specifications?	
2.4.3 Are the design features of the defined elements of SNuMI documented in a Conceptual Design Report, Design Handbook, or other appropriate manner?	
2.4.4 Are the prototype plans and decision paths appropriate for the less well-developed elements?	
2.4.5 Do the elements of SNuMI address the performance requirements / specifications? Are the designs of these elements reasonable?	

2.4.6 Has a Work Breakdown Structure (WBS) been developed?	Dean Hoffer
2.4.7 Do the cost estimates for each WBS element have a sound basis and are they reasonable?	
2.4.8 Is there a schedule for the project?	
2.4.9 Are the activity durations reasonable for the assumed resources?	
2.4.10 Has the schedule been "resource loaded?"	
2.4.11 Has the schedule been developed with contingency or slack included?	
2.4.12 For the less well-developed technical elements have decision milestones been included in the schedule?	
2.4.13 Is there an appropriate management organizational structure in place or proposed to accomplish the design and construction?	Greg Bock
2.4.14 Have responsibilities been assigned or have they been proposed?	
2.4.15 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?	
2.4.16 Are there adequate staffing resources available or planned for this effort?	
2.4.17 Is there a funding plan available or proposed to meet the resource requirements to realize SNuMI?	
3.0 Phase II	
3.1 Technical	Thomas Roser All
3.2 Civil Construction	Karen Hellman Phil Martin
3.3 Project Management (Cost, Schedule and Management)	Greg Bock All
3.4 Charge Questions	
3.4.1 Does the design concept for Phase II support the objective of delivering at least 1 MW beam power onto the neutrino production target?	Thomas Roser Stuart Henderson
3.4.2 Is the strategy for Phase II viable and does it support the implementation of Phase II in the timeframe presented?	Greg Bock Karen Hellman

* Note underlined names are the primary writer.

Appendix E

Reviewer Assignments for Breakout Sessions

for the Director's Preliminary Review of the Super NuMI Plan
November 14 – 16, 2006

November 14, (3:30 – 4:30 PM)	
1) Booster and Main (One North – WH1W)	Mike Brennan Stuart Henderson Erk Jensen
2) Recycler: injection line, extraction line (Black Hole – WH2NW)	Phil Martin Thomas Roser
3) NuMI: primary proton line, decay pipe & hadron absorber (phase I + II) (Snake Pit – WH2NE)	Don Cossairt Sayed Rokni Yoshi Yamazaki
4) Management/Cost/Schedule/Strategy (Phase I & II) (Comitium - WH2SE)	Greg Bock Karen Hellman Dean Hoffer Ed Temple
November 15, (8:30 – 10:30 AM)	
5) Recycler: kickers, slip-stacking scheme, RF systems (Black Hole – WH2NW)	Mike Brennan Stuart Henderson Erk Jensen Phil Martin
6) NuMI: target chase cooling, target and horns (Snake Pit – WH2NE)	Don Cossairt Sayed Rokni Thomas Roser Yoshi Yamazaki
7) Management/Cost/Schedule/Strategy (Phase I & II) (Comitium - WH2SE)	Greg Bock Karen Hellman Dean Hoffer Ed Temple
November 15, (10:45 – 12:45 PM)	
8) Overview of Phase II (Black Hole – WH2NW)	Mike Brennan Stuart Henderson Erk Jensen Thomas Roser Yoshi Yamazaki
9) Civil Construction (Phase I & II) (One North – WH1W)	Karen Hellman Dean Hoffer Phil Martin
10) Radiation safety/shielding (Phase I & II) (Snake Pit – WH2NE)	Greg Bock Don Cossairt Sayed Rokni Ed Temple

Appendix F

Reviewers' Contact Information

for the Director's Preliminary Review of the Super NuMI Plan
November 14 – 16, 2006

Greg Bock
Fermi National Accelerator Laboratory
M.S. 208
P.O. Box 500
Batavia, IL. 60510
630-840-4302
bock@fnal.gov

Mike Brennan
Brookhaven National Laboratory
M.S. 0911B
Upton, NY 11973-5000
(631) 344-3755
brennan@bnl.gov

Don Cossairt
Fermi National Accelerator Laboratory
M.S. 119
P.O. Box 500
Batavia, IL. 60510
630-840-3465

Karen Hellman
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL. 60439
630-252-7808
khellman@anl.gov

Stuart Henderson
Oak Ridge National Laboratory
MS 6462
PO Box 2008
Oak Ridge, TN 37831-6462
865-241-6794
shenderson@ornl.gov

Dean Hoffer
Fermi National Accelerator Laboratory
M.S. 200
P.O. Box 500
Batavia, IL. 60510
630-840-8898
dhoffer@fnal.gov

Erk Jensen
CERN AB-RF L19510
CH-1211 Geneva 23
Switzerland
+41 22 76 74298
Erk.Jensen@cern.ch

Philip Martin
Consultant
623 Antler Ridge Rd
Sequim WA 98382
360-582-9445
ptmartin@olypen.com

Sayed Rokni
Stanford Linear Accelerator Center
Mail Stop 48
2725 Sand Hill Road
Menlo Park, CA, 94025
rokni@slac.stanford.edu

Thomas Roser
Brookhaven National Laboratory
Building 911B
Upton, NY 11973-5000
631-344-7084
roser1@bnl.gov

Ed Temple (Chair)
Fermi National Accelerator Laboratory
M.S. 200
P.O. Box 500
Batavia, IL. 60510
630-840-5242
etemple@fnal.gov

Yoshi Yamazaki
Deputy Director, J-PARC Center
Shirakata-Shirane 2-4, Tokai-mura,
Naka-gun, Ibaraki-ken
319-1195, Japan
+81-292-84-3717
yoshishige.yamazaki@j-parc.jp

Appendix G

Participant List

for the Director's Preliminary Review of the Super NuMI Plan
November 14 – 16, 2006

Last Name	First Name	Affiliation	Role
Adamson	Phil	Fermilab/AD	Attendee
Ader	Christine	Fermilab/AD	Presenter
Anderson	Terry	Fermilab/AD	Attendee
Anderson	John	Fermilab/AD	Attendee
Andrews	Michael	Fermilab/AD	Presenter
Appel	Jeff	Fermilab	Directorate
Arnold	Sally	DOE SO	DOE SO
Ball	Maurice	Fermilab/AD	Presenter
Baller	Bruce	Fermilab/AD	Fermilab/AD
Bock	Greg	Fermilab/PPD	Reviewer
Bogert	Dixon	Fermilab/AD	Presenter
Brennan	Mike	BNL	Reviewer
Broemmelsiek	Daniel	Fermilab/AD	Presenter
Capista	David	Fermilab/AD	Attendee
Childress	Sam	Fermilab/AD	Presenter
Cibic	Robert	Fermilab/BSS	Attendee
Collins	Joe	Fermilab/BSS	Attendee
Cooper	John	Fermilab/PPD	Attendee
Cossairt	Don	Fermilab/ESH	Reviewer
Derwent	Paul	Fermilab/AD	Presenter
Dey	Joseph	Fermilab/AD	Presenter
Dixon	Roger	Fermilab/AD	Fermilab/AD
Ducar	Robert	Fermilab/AD	Attendee
Gerardi	Michael	Fermilab/AD	Attendee
Grossman	Nancy	Fermilab	Presenter
Hammond	Lee	Fermilab/FESS	Attendee
Harding	Dave	Fermilab/TD	Attendee
Hellman	Karen	Argonne	Reviewer
Henderson	Stuart	Oak Ridge	Reviewer
Hoffer	Dean	Fermilab	Reviewer
Holmes	Steve	Fermilab	Directorate
Hu	Martin	Fermilab/AD	Presenter
Hurh	Patrick	Fermilab/AD	Presenter
Hylen	Jim	Fermilab/AD	Presenter
Jensen	Erk	CERN	Reviewer
Jensen	Chris	Fermilab/AD	Presenter
Johnson	David	Fermilab/AD	Presenter
Kobilarcik	Thomas	Fermilab/AD	Attendee
Kourbannis	Ioanis	Fermilab	Presenter
Leveling	Anthony	Fermilab	Presenter
Livengood	Joanna	DOE SO	DOE SO
Lutha	Ron	DOE SO	DOE SO
Marchionni	Alberto	Fermilab	Presenter
Martens	Mike	Fermilab	Presenter
Martin	Phil	Consultant	Reviewer

Last Name	First Name	Affiliation	Role
McCluskey	Elaine	Fermilab/FESS	Presenter
Messier	Mark	Fermilab	Presenter
Pellico	William	Fermilab/AD	Attendee
Philp	Paul	DOE SO	DOE SO
Prebys	Eric	Fermilab	Presenter
Procario	Mike	DOE	DOE
Rameika	Gina	Fermilab/PPD	Attendee
Reilly	Robert	Fermilab/AD	Presenter
Rokni	Sayed	SLAC	Reviewer
Roser	Thomas	BNL	Reviewer
Seiya	Kiyomi	Fermilab/AD	Presenter
Stefanik	Andy	Fermilab/FESS	Presenter
Strauss	Bruce	DOE	DOE
Tariq	Salman	Fermilab/AD	Presenter
Temple	Ed	Fermilab	Reviewer
Tinsley	Dave	Fermilab/AD	Presenter
Vaziri	Kamran	Fermilab	Presenter
Wands	Bob	Fermilab/AD	Presenter
Wehmann	Alan	Fermilab/AD	Attendee
Wildman	David	Fermilab/AD	Presenter
Xiao	Meiqin	Fermilab/AD	Presenter
Yamazaki	Yoshi	KEK	Reviewer
Zwaska	Robert	Fermilab	Presenter

Appendix H

Table of Recommendations

for the Director's Preliminary Review of the Super NuMI Plan
November 14 – 16, 2006

#	Recommendation	Assigned To	Status/ Action	Date
	2.1.1 Booster Upgrades			
1.	Consider the potential benefit of a dual-harmonic RF system in the Booster.			
	2.1.2 Recycler Upgrades			
2.	Concerning the kicker modules, their impedance and the danger of electron cloud, the committee recommends reconsidering the inside coating of the ceramics in terms of resistivity and SEY (Ti, TiN, …).			
3.	There seems to be a trade-off between the number of bunches "notched" out in the booster and the stringent requirements on rise- and fall-time of the injection and gap clearing kickers – the specified 38 ns are based on 2 missing bunches. The committee recommends evaluating this trade-off and to prepare for a different number of "notched" bunches as a fall-back solution.			
4.	In view of SNuMI phase II, the committee recommends to consider purchasing material also for a spare cavity, bringing the total number to 5.			
5.	Since slip-stacking to full intensity cannot be tested early in the RR, the committee recommends continuation of tests in the MI.			

#	Recommendation	Assigned To	Status/ Action	Date
6.	Due to the envisaged completely new type of operation of the RR without the possibility of relevant tests before the end of the Tevatron run, the committee recommends to consider at least fully simulating this new operation, including longitudinal and transverse beam dynamics.			
7.	Concerning the change of BPM cables, the committee recommends: Assign a coordinator now who will manage the 2009 shutdown activities. Develop the installation plan, and examine what activities could be done in earlier shutdowns to ease conflicts due to multiple personnel working in the same areas and tunnel blockages. (Cables pulls and LCW pipe relocation are two obvious candidates for doing early.)			
	2.1.3 Main Injector Upgrades			
8.	We recommend that emittance growth at transition as a function of beam brightness be re-examined in light of the Phase II requirements. If machine studies can be done with relevant bunch parameters then they should be given high priority.			
9.	It is unlikely that the losses of un-captured beam in the MI will be significantly reduced when 12 Booster batches are slipped stacked in the Recycler compared to now when 11 batches are slip stacked in the MI. The collimation system for MI must be demonstrated to be effective for Phase I to be a viable design for producing 700 kW.			
10.	The work on the upgraded power amplifier for the MI should begin a soon as possible.			
	2.1.4 NuMI Upgrades			

#	Recommendation	Assigned To	Status/ Action	Date
11.	It is commendable that these particular items have already been examined and to reference these to the worst case, condition of a pulse, or pulses of an uninteracted proton beam reaching these components (e.g., the target is missing or the beam is missing the target).			
12.	The plans outlined in the CDR to add an input to the beam permit system to check for "beam present without muons downstream of the hadron absorber" (indicative of the presence of untargeted beam) is a worthwhile addition given the anticipated increased beam power.			
13.	It would be prudent to plan any Phase I work in a manner that does not necessitate undoing and/or repeating it for Phase II. This is particularly true for RAW (Radioactive Water) systems.			
14.	The temperature distribution of the fin structure should be carefully analyzed due to the longer distance between the beam impact and the water cooling.			
15.	Conceptual and final designs need to be developed for the Phase II NuMI upgrade.			
16.	The conceptual plans to procure a new off-the-shelf remote manipulator with special tools designed for this application and considerable associated efforts are good ones.			
17.	It would be advisable to not acquire "used" manipulators that might become available from other facilities due to the potential for contamination, not readily removable.			
18.	Measures to address this problem should be continued. As needed, elements of this may be implemented prior to the 2009 down time.			
19.	Plans for actions to be taken in event of "crane failure" should be made in advance.			

#	Recommendation	Assigned To	Status/ Action	Date
20.	The radiation safety analysis will need to be refined as the design proceeds.			
21.	More detailed calculations will be needed to better understand the beam losses in advance of the full development of the Phase II design.			
22.	The project should consider a study of the possible use of collimation and local shielding inside the Accumulator beam enclosure to better control the prompt radiation hazard passively. A complication may be presented by the fact that the debuncher ring is likely to be retained for a potential physics experiment.			
	2.2 Civil Construction			
23.	Allocate funds in a timely manner to allow installation of the penetration and building footings during the summer 2007 shutdown. Approval by December 1, 2006, is needed.			
24.	Specify the location of penetrations both inside the service buildings and to the tunnel.			
25.	Evaluate the MI cooling pond performance, and determine the incremental pond area required to both support the expected increase in heat load and to provide additional operating margin. Design and construct new pond area accordingly.			
26.	Assign additional contingency based on recent bid experience.			
27.	Identify the area(s) to be demolished, so that the associated costs can be better validated.			
	2.3.1 Cost			
28.	Maintain the level of effort that was committed to preparing for this review to continue to refine the scope of Phase I and the cost estimate.			

#	Recommendation	Assigned To	Status/ Action	Date
29.	Complete the Basis of Estimate (BOE) documentation to support the resources assigned in the Phase I Schedule and store the information in a controlled repository.			
30.	Continue to refine the bottom-up risk assessment and the top-down risk assessment and assure that the contingency assigned is appropriate for the identified risks.			
31.	Increase the contingency on the Civil Construction work to reflect the cost increases experienced on recent Request for Proposals (RFPs).			
	2.3.2 Schedule			
32.	The SNuMI Team needs to continue to scrub the schedule by addressing the items noted in the above comments. This is needed to achieve a baseline schedule.			
	2.3.3 Management			
33.	Start regular PMG meetings as described in the PMP.			
34.	Work with the laboratory to get the FY07 funding guidance soon, along with a funding profile for the outyears for planning the rest of the project.			
35.	Assure that the SNuMI labor needs are part of AD's, and other organizations', integrated manpower planning.			
36.	Keep up the impressive rate of progress that you have been achieving recently.			
	3.1 Technical			
37.	Estimate the beam loss instability thresholds during the beam stacking processes, in particular during debunching and rebunching of the high intensity beam in the Accumulator and the Recycler, with simulations and/or beam studies.			
38.	Study alternative stacking schemes that are less sensitive to beam instabilities and have better efficiency.			

#	Recommendation	Assigned To	Status/ Action	Date
39.	Test a spare 53 MHz cavity with two power tubes as soon as possible.			
40.	Design a Linac chopper to put a notch in the Linac beam for the Booster extraction kickers.			
	3.2 Civil Construction			
41.	Assign beam physics manpower with the responsibility to design the AP-4 and AP-5 beamlines.			
42.	Minimize Phase 2 civil construction design effort until the beamline lattices have been finalized.			
	3.3 Project Management (Cost Schedule and Management)			
43.	Work with lab management to pursue '1.2MW' that does not jeopardize the work on SNuMI I.			