Department of Energy
Review Committee Report

on the
review of

TEVATRON OPERATIONS AT FERMI NATIONAL ACCELERATOR LABORATORY

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Executive Summary

The reliable and efficient operation of the Tevatron Collider and the NuMI neutrino beam at Fermi National Accelerator Laboratory are a vital component to the U.S. high energy physics program. Improvements to the Tevatron Collider have just been completed, and improvements to the proton accelerators that feed the NuMI facility and to the facility itself are underway.

Dr. Robin Staffin, Associate Director for High Energy Physics, charged a committee of experts to review the operations of the major facilities at Fermilab in order to determine that the improvements to the facilities have been successfully carried out, that they will run efficiently, reliably, and safely until the end of the run of Tevatron, and that the scientific manpower needed to operate the detectors and analyze the recorded data will be available. This review was held on March 27-28, 2007 at Fermilab.

Performance of the Tevatron has improved significantly in the last year due to the completion of the Run II upgrades. The peak luminosity has increased with record peak luminosities going from $180\times10^{30}\text{cm}^{-2}\text{s}^{-1}$ in FY 2006 to $292\times10^{30}\text{cm}^{-2}\text{s}^{-1}$ in FY 2007. With just six months of running in FY 2007, the integrated luminosity of 700 pb^{-1} has exceeded the total integrated luminosity of the previous year. All this has resulted in a total Run II luminosity greater than 2.5 fb^{-1} already delivered to the experiments. Based upon this review, the committee expects that a Run II integrated luminosity of 6.5 fb^{-1} or higher can be achieved.

The proton plan appears to be on track to reach the goal of 320 kW on target while the antiproton program is running, and 400 kW once the Tevatron running is completed. The committee found no serious obstacles to the successful operation of the Main Injector at beam intensities up to 4.0×10^{13} protons per pulse, which is consistent with 400 kW operations, and this intensity has already been demonstrated. It is critical that plans to reduce the uncontrolled beam loss are successfully implemented. The schedule to complete fabrication of the Booster corrector magnets and install them during the August 2007 shutdown is aggressive.

CDF and D-Zero are successfully coping with the higher data rates that accompany the larger luminosity delivered by the Tevatron by modifying the trigger menu as a function of the average instantaneous luminosity. Further increases in instantaneous luminosity will be challenging to handle, so the Accelerator Division is searching for ways to raise the total luminosity without raising the instantaneous luminosity.

The laboratory working with CDF and D-Zero management has studied the manpower that will be available in the next two to three years. These estimates are documented in Memoranda of Understanding with collaborating institutions. The manpower available for operations, computing, and calibration tasks seems to be just adequate.

The number of the injuries that occurred during shutdown activities has gone down significantly over the last several years, and the injury rates for users are very low. However, the overall lab injury rates have now plateaued, and the FY 2007 goals will be challenging to reach.

1 INTRODUCTION

1.1 Background

Fermi National Accelerator Laboratory (Fermilab) operates two major scientific user facilities for the Department of Energy's (DOE) High Energy Physics program. These are the Tevatron Collider, currently the world highest energy hadron collider, and the Neutrinos at the Main Injector (NuMI) neutrino beam, the world's most intense source of neutrinos. The DOE has supported improvements to both of these facilities to maintain them as forefront scientific facilities. Improvements to the Tevatron Collider have just been completed, and improvements to the proton accelerators that feed the NuMI facility and to the facility itself are underway.

Based on recommendations of the Particle Physics Project Prioritization Panel (P5), a subpanel of the High Energy Physics Advisory Panel, the DOE plans to support operations of the Tevatron Collider through FY 2009. The NuMI facility will run for the MINOS experiment through at least 2010 and then will run for the planned NOvA experiment. The reliable and efficient operation of these facilities is vital to the nation's program in High Energy Physics.

1.2 Charge to the Review Committee

The charge can be found in Appendix A.

1.3 Membership of the Committee

The committee consisted of experts in accelerator operations, detector operations, environment, safety, & health, and the management of scientific programs. They were drawn from DOE and DOE national laboratories. The review was chaired by Dr. Michael Procario of the Office of High Energy Physics. The complete list of members is given in Appendix B.

1.4 The Assessment Process

The review was conducted on March 27–28, 2007 at Fermilab. It was based on written material from the laboratory, presentations by the laboratory staff, and discussions between the committee and laboratory management.

1.5 Answers to the Questions in the Charge

In addition to the general request for an evaluation of the performance of the laboratory, there were some specific questions that the committee was asked to address. The answers to these questions are given below.

1. Do the laboratory's operating procedures, maintenance programs, and management practices ensure the reliable operation of the Tevatron complex where maximizing the integrated data delivered to the experiments in the next three years is the most relevant metric?

Answer: Because the Tevatron and NuMI serve large collaborations, CDF, D-Zero, and MINOS that are in the midst of multi-year runs, the user community prefers minimizing all downtime rather than unscheduled downtime, since this results in the largest recorded data samples. The maintenance policy for the Tevatron is designed to optimize the integrated data sample between now and the end of FY 2009. Tracking and analysis of potential system faults appears to be rigorous and effective. System failures are discussed at a daily 9:00 a.m. meeting. Many of the routine maintenance activities are managed opportunistically, so that they can be carried out whenever the complex is down and thus minimize the need for scheduled downtime.

Tevatron magnet failures can result in unscheduled downtime, but these are rare events (1–3 per year) with a variety of root causes. The machine group is particularly proactive in investigating potential signs of system failures due in an aging complex. Operating procedures, maintenance programs and management practices are all designed to optimize the delivered luminosity over the next three years. In particular, we strongly endorse the present policy for maintenance as the most effective for delivered integrated luminosity and science output.

2. What is your evaluation of the progress made in increasing the number of protons available to the neutrino program?

Answer: The proton plan appears to be on track to reach the goal of 320 kW on target while the antiproton program is running, and 400 kW once the Tevatron running is completed. The proton source team has made good use of scheduled beam development time and also time that becomes available when the antiproton source and/or the Tevatron are offline. The upgrades to be installed during the upcoming shutdown from August 6 to the end of September are aggressively scheduled, especially for the Booster corrector system and the Main Injector collimator system.

The committee found no serious obstacles to the successful implementation of the proton plan. Operation of the Main Injector at beam intensities up to 4.0×10^{13} protons per pulse (consistent with 400 kW operations) has already been demonstrated, but it is critical to reduce the uncontrolled beam loss. A collimator system is planned in the Main Injector to accomplish this. Investigations into the electron cloud instability have shown that it is unlikely that this or any other instability will interfere with operations at beam intensities up to 4.5×10^{13} protons per pulse.

3. Do CDF, D-Zero, and MINOS make optimal use of the data provided by the accelerators by minimizing their downtime, recording events efficiently, and processing the data for physics use quickly?

Answer: CDF, D-Zero, and MINOS have focused successfully on minimizing their downtime and streamlining their operations. The efficiency for recording data is high (~85%) for both Tevatron experiments, quite an achievement for hadron collider experiments. The triggering strategy adopted by CDF and D-Zero adjusts the trigger mix with luminosity to maximize the data sample for critical

analyses. For MINOS the efficiency is close to 100%, as expected for a neutrino experiment. For both collider experiments, data is rapidly calibrated, reconstructed, and made available for analysis.

4. Have credible estimates been made of the scientific manpower needed to run the experiments, and will the planned participation of the collaborators meet these needs?

   Answer: CDF and D-Zero have evaluated their manpower needs through the completion of Tevatron operations. They have established a Memorandum of Understanding (MOU) process with the collaborating institutions that extends through FY 2009. The manpower needed for operations, computing, and calibration tasks appear to be just adequately covered by the manpower promised in the MOUs. If manpower promised is not forthcoming and if continued streamlining efforts are not successful, then the remaining collaborators may find the fraction of their time devoted to service activities rather than analysis of physics becoming unusually high.

5. What is your evaluation of the safety performance of the accelerator and detector operations in the last year? Are safety considerations properly integrated into both accelerator and detector operations?

   Answer: Injuries during shutdown activities have consistently declined since 2003; however, overall injury rates for the Accelerator Division have not significantly declined since 2004. Fermilab safety metrics (i.e., Total Recordable Cases and Days Away, Restricted or Transferred rates) are not meeting DOE expectations for FY 2007, and so further improvement across the lab is needed. Laboratory management seems focused on improving these safety metrics.

6. What is your assessment of the laboratory's response to the comments and recommendations from the March 2006 Tevatron Operations review?

   Answer: The laboratory has responded to the recommendations and significant comments from the March 2006 Tevatron Operations review. The 2005 scorecard was closed out and the 2006 scorecard was closed out on schedule.

2 TEVATRON & ANTIPROTON SOURCE OPERATIONS

2.1 Findings

The performance of the Tevatron since the previous operations review has been impressive. The operation in FY 2006 resulted in the integrated luminosity 656 pb^{-1} for the entire year, exceeding the baseline goals. Further performance gains have been made in FY 2007. The peak luminosity has increased with record peak luminosities going from $180\times10^{30}cm^{-2}s^{-1}$ in FY 2006 to $292\times10^{30}cm^{-2}s^{-1}$ in FY 2007. With just 6 months of running in FY 2007, the integrated luminosity of 700 pb^{-1} has exceeded the total integrated luminosity of the previous year. All this has resulted in a total Run II luminosity greater than 2.5 fb^{-1} delivered to the experiments.

The Run II accelerator upgrades are effectively complete and are largely responsible for the increase in integrated luminosity. In the 2006 shutdown, improvements were made to the beam separators (collision helix) and a second transverse electrons lens (TEL2) was installed. The separators have reduced the long range beam-beam interaction, and the new TEL has raised the tunes of individual bunches. Both of these contributed to longer beam lifetimes and thus larger integrated luminosities. In particular, the implementation of the new collision helix with the increased separations resulted in the predicted improvement in luminosity lifetime of 16%.

In FY 2006, prior to the March 2006 review, the major cause of downtime was due to the failure of three magnets. Two of the three magnet failures were a result of a failure of the LHe Kautszky values. Significant repairs and preventive maintenance tasks were performed during the 2006 shutdown including the replacement of all 1200 LHe Kautszky valves. The reliability since the March 2006 review has been good. There have been two failures that have resulted in a total of approximately three weeks of down time—the first was a magnet failure during a QPS induced quench and the second was due to a damaged O-ring causing loss of cryogenic insulating vacuum.

The Tevatron team has addressed the recommendation of the 2006 review to continue to investigate beam-beam effects in the Tevatron in order to ensure that the Tevatron is not limited by the antiproton intensity at the ultimate Run II parameters. In this regard impressive progress has been made in understanding the beam lifetime and the effect of beam-beam interactions through both experiments and modeling. Experiments show that with the present parameters, the long range beam-beam interaction is no longer an issue. With the smaller antiproton beam sizes most antiprotons are burned in luminosity, which is good. However, now the proton beam lifetime is becoming limited by the head-on beam-beam effect.

Weak-strong simulations indicate that increased beam intensities may be difficult to achieve at the present working point. To make further gains in the beam intensities, a plan has been developed to move the tune closer to the half integer. Correction of the linear optics has helped to reduce the width of the half integer resonance. However the beam-beam simulations show that in order to take advantage of the new working point it is necessary to also correct the energy dependent β-functions. In the 2006 shutdown,

cables were pulled for the new sextupole circuits and initial testing of the new circuits with protons should be possible in the next few months. To improve the understanding of the beam-beam effect, a strong-strong simulation has been developed and the multi-bunch mode is being studied.

Since March 2006, the antiproton production rate is up by 15% from 20 to 23 mA/h, which is primarily due to the implementation of a test version of the stacktail equalizer. Other improvements include newly designed Li lens and target modules, increasing the target yield and reliability. Also the new target module is more robust than the previous target module. Each target disk saw approximately 6×10^{18} protons which is roughly 30% more than the older modules saw. These together with improvements in operational efficiency have led to further improvements in the average performance.

The known aperture limits of the Debuncher and Accumulator rings are being addressed. The tighter orbit control employed by feedbacks in the transfer lines ("Autotune") has helped increase the acceptance in the AP-2 beamline and the Accumulator ring. Further improvements (e.g., refined stacktail equalizer, Accumulator lattice with higher slip factor, notch filters, and shorter cycle time) are planned, and can be expected to further improve the antiproton production rate. Antiproton (non-stacking) time has been reduced to about 15 minutes by judiciously performing only those checks in setup that have a relatively high probability of revealing a fatal flaw and accepting some losses.

The recycler is routinely "stashing" about one-half of the goal, 600×10^{10} antiprotons. Improvements include an optimized working point, allowing higher space-charge tune shift. New adaptive RF correction, which equalizes the charge in individual bunches in the Tevatron, is beneficial to and much appreciated by the experiments.

2.2 Comments

As stacking rates and intensities increase, new challenges are appearing on the horizon: the Debuncher may need more attention (aperture and cooling), and there is an instability in the Recycler above 500×10^{10} antiprotons. The team is aware of these issues and is considering mitigating measures. We believe stacking rates of 25–28 mA/hour should eventually be reached, which is an increase of 20% over current performance.

It would be useful to have the expected gains from each of the remaining outstanding improvements quantified in order to assist in setting priorities and evaluating trade-offs.

Based upon this review, the committee expects that a Run II integrated luminosity of 6.5 fb^{-1} or higher can be achieved.

2.3 Recommendations

1. Develop a plan for the Debuncher to support stack rates in excess of 35 mA/hour to ensure that the Debuncher does not become a bottleneck.

2. Experiments are becoming occupancy limited at the higher peak luminosities. Investigate operational options to maximize integrated luminosity for a given peak luminosity.

3 PROTON SOURCE OPERATIONS

3.1 Findings

The overall goal of the proton plan is the delivery of 320 kW on target while the antiproton production is running, and 400 kW once Tevatron operations end. This is to be achieved with operational improvements and scheduled system upgrades.

A major component of the improvements is implementation of slip-stacking for neutrino production in the Main Injector. Currently, two Booster batches are slip-stacked into one Main Injector RF bucket for antiproton production, and five individual Booster batches are placed in the remaining RF buckets for neutrino production. This results in a mode of operation called 2+5, where 2 batches go to antiproton production and 5 batches to neutrino production. Part of the proton plan is to implement a 2+9 mode, where two Booster batches are slip-stacked for antiproton production, eight Booster batches are slip-stacked into four Main Injector RF buckets and one Booster batch is placed into the remaining RF bucket resulting in nine Booster batches going to neutrino production.

The overall plan to achieve the proton plan goals has been presented. The main ingredients are:

- continuation of machine studies in Main Injector between now and the shutdown later this year to commission the 2+9 mode,
- installation during the shutdown of half of the new Booster corrector system at the long straight sections that should improve orbit, tunes, coupling and chromaticity control in the vertical direction, and
- installation of the Main Injector collimator system.

The plan after the shutdown is to bring the Main Injector into operation with the 2+9 slip-stacking scheme and progressively increase intensity, until the proton plan goals are met with no penalty on antiproton production operations.

The 2+9 mode has already been demonstrated in development studies with 4×10^{13} protons delivered to the NuMI target, which is a significant milestone towards the goal of achieving the ultimate proton plan goal of 4.5×10^{13} on target.

The 2+9 mode of operation is limited by RF stability and beam losses in the Main Injector. The overall present losses are about 10% and arise from kicker losses and beam spilling out of the RF buckets. In order to make the scheme operational it is necessary to limit the uncontrolled losses to less than 5%. This loss level is believed to be tolerable due to the novel collimator system in the Main Injector that will be installed during the planned shutdown in August 2007.

The performance, test results and the delivery and installation plan for the Booster corrector packages have been presented. The new system will considerably improve the existing one. The present plan is to install 24 vertical corrector packages during the 2007 shutdown and the 24 horizontal ones next year. This should improve beam losses in the

Booster, which is a fundamental limitation. An upgrade of the Booster to allow 15 Hz operations is not part of the proton plan, but may be proposed for a future upgrade project.

The Booster corrector magnet construction schedule is success oriented. The last correctors are expected to be ready for installation at the end of August. The power supplies are scheduled to be installed prior to the start of the shutdown.

Status and plans of recent and future upgrades to Main Injector systems were presented and discussed.

The new beam loss monitor system installed last December in the Main Injector has worked well and is necessary to allow slip-stacking operation for neutrino operations, in particular for the capability of aborting on losses.

For the Main Injector RF system, the plan is to replace one of three power transformers to improve RF tube power dissipation, to replace some tube-based amplifiers with solid state amplifiers, and to improve the RF beam loading compensation system by adding a double-peaked comb filter with one turn delay in order to further stabilize the coupled bunch modes.

Collimation capabilities were added to the Booster to Main Injector transfer lines to reduce halo in the Booster beam that generated losses in the Main Injector. The collimators in MI8—two five-ton marble collimators—were commissioned and initial results are promising.

A consistent effort in simulating the losses during slip stacking in Main Injector has been pursued with the STRUCT code together with simulation of radiation and energy deposition with MARS. A purely linear model predicted losses at high dispersion regions. Adding magnet non-linearity and apertures to the simulation reproduced the observed data much better. At present the model treats non-linearities statistically as opposed to assigning individual measured data to individual components.

The new Main Injector collimation system is a two-stage collimation system with 20-ton secondary collimators. Stepping motors allow movement of the overall collimator, but there are no moving jaws inside. The assumption here is that orbit control in Main Injector is good enough to control beam in the collimators. The system is designed to deal with approximately 5% losses in the Main Injector.

The overall availability and uptime of the proton source operations is dominated by the reliability of the neutrino targets and horns. Downtime due to the Linac, Booster, Main Injector and transfer lines is a small fraction (i.e., <10%) of the overall downtime of proton operations.

An effort is in place to provide spares for the neutrino target and the horns. Barring further failures before the shutdown, one spare for each horn type and one spare for the target (other than the old target that is presently limited to production of high energy neutrinos) should be available after the shutdown this year. An engineer has been hired specifically for horn welding. The present target is designed for 400 kW, so there is no

need to further upgrade the target design for the proton plan.

In order to minimize the additional stress on the target from the higher intensity anticipated after the shutdown, the NuMI team has demonstrated the feasibility of increasing the spot size on the target from the present 1 to 1.2 mm.

Simulations have predicted a potential for electron cloud instabilities in the Main Injector as the intensity is increased. Fermilab has initiated an e-cloud simulation effort to validate the original predictions, which although in the early stages has provided preliminary results.

Electron clouds related measurements have also been done. The secondary emission yield (SEY) parameter in the Main Injector has been determined to be approximately 1.8, which exceeds the SEY of 1.3 used in the original simulations. Electrons have been detected at transition, and a pressure rise has also been observed. More measurements with improved instrumentation are planned. However, the Main Injector has already been run at 4×10^{13} protons per pulse, and the observed pressure rise is far away from operational limits. The goal is 4.5×10^{13} protons per pulse, so the probability of the e-p instability becoming a serious problem is low.

3.2 Comments

We wish to congratulate the Fermilab staff working on the Proton Plan for the successful operations of the proton source and the neutrino beam and the successful test of the 2+9 slip-stacking scheme in the Main Injector. The latter is an important milestone in the overall development of the proton plan.

The original projections for intensity and performance of the proton beam have been correctly revisited and adjusted down in light of the initial operational experience. The correction is consistent with the ultimate goals of the neutrino program.

Switching to the operation mode in which all Main Injector batches are delivered to the target has efficiently used the opportunities offered when the antiproton production is off or the Tevatron is down.

Completed upgrades to Booster and Main Injector are still relatively new and further studies are necessary to take full advantage of these upgrades. Main Injector personnel feel that present study schedule and plans are sufficient.

The schedule to install the Main Injector collimators is rather aggressive, and may take longer than the scheduled duration of shutdown. Utility pipes need to be re-routed to provide room for the collimators.

The present strategy for the commissioning of the Main Injector is to decrease slip-stacking losses to a 5% level and use the collimator system in order to achieve the ultimate goal of 4.5×10^{13} proton per pulse in operations.

3.3 Recommendations

1. The losses during slip stacking in the Main Injectors are critical to the development of the proton plan. We recommend continuing to focus the attention on this with high priority, with allocation of machine study time and parallel improvement of the modeling capabilities. The goal should be to limit losses to less than 5% of the total intensity.

2. Ensure that enough machine study time is allocated to the improvement of the 2+9 slip-stacking scheme before the shutdown, so that this can be the default operation scheme after the shutdown.

3. Collimators in the Main Injector and correctors in Booster are major proton plan components to be accomplished during the 2007 summer shutdown. We recommend insuring that the schedule for the Booster correctors production and installation be pursued aggressively, and that full installation of the Main Injector collimation system is consistent with the length of the shutdown.

4. Allocate enough machine study time to commission the new corrector system in Booster.

5. Continue improving performance of the MI8 collimators (0.5% is now collimated in normal operations, but more collimation should lead to further improvements).

6. Continue to improve the modeling of the collimation process and energy deposition in the Main Injector with the goal of having a good agreement between the model and measurement. This is critical for the proton plan and all intensity developments beyond.

7. Expedite and focus efforts on the production of spare targets and horns. Once this is accomplished, focus resources on reducing the access and replace time of targets and horns by revisiting procedures and personnel training.

8. Continue the effort on e-cloud measurements and simulations in the Main Injector.

4. Detector Operations

4. 1 Findings

The experiments had a number of issues related to the machine operation that have been addressed.

- Minimize background in the experimental halls.
- Level the instantaneous luminosity and bucket-to-bucket variations.
- Maximize the integrated luminosity.
- Daily coordination takes place at 9 AM meetings and includes accelerator and experiment personnel.

CDF and D-Zero are running well and are accumulating high quality data. At present the analysis is going well. A large number of publications are coming out and an impressive list of topics is being worked on to produce physics results from Run II data.

CDF and D-Zero use 84–87% of the delivered beam. This is an excellent record compared to other experiments with similar complexity. Both experiments are on track to accumulate 5–6 fb^{-1} on tape out of the expected 6–7 fb^{-1} to be delivered by the machine.

The increased luminosity coupled with the fact that the beam crossing time has been held constant at 390 nsec results in an average of 2-3 interactions per crossing. At peak luminosity that average is over eight interactions. Both collaborations have moved aggressively to optimize data taking by modifying the trigger menu as a function of the average instantaneous luminosity.

The data volume for both CDF and D-Zero will increase significantly in the next two years due to increased bandwidth. The computing models of both experiments rely heavily on extensive use of the GRID and “opportunistic” computing as well as outside resources.

Both CDF and D-Zero have estimated the available and needed manpower in FY 2008 and FY 2009. They have streamlined the running of the experiments, reducing the number of people on shift and automating data production as much as possible. They continue to pursue further reductions in the manpower needed to operate the experiment and process the data. Nevertheless it will be a challenge to run the experiments and analyze the data collected.

The Collider experiments have done a good job in streamlining the running of the experiments and should have the manpower to run the experiment until FY 2009. The manpower needed to analyze the data is difficult to estimate but is clearly a problem. The collaborations need to prioritize the physics analysis they are going to be able to perform with the more limited manpower available.

MINOS is running well and data taking is limited by the number of protons delivered to their target. Increasing the number of protons per pulse might be limited by the target capabilities. The collaboration is aware of the problem and solutions are being developed. MINOS manpower to run the experiment and analyze the data appears to be adequate.

All the experiments have safety as a high priority. It is included in their work planning and approval process. Training commensurate with the hazards encountered is assured (e.g. MINOS underground hazards). The experiments have had only first aid cases since the last review, which is an excellent safety record.

The laboratory and the experiments have addressed the resource issues raised in the last review via the Tevatron Collider Experiment Task Force. The task force included key laboratory managers from the Particle Physics and Computing Divisions as well as the experiments' spokespeople and key operations managers.

4. 2 Comments

The machine and the experiments work well together.

Both CDF and D-Zero have done an impressive job in optimizing data taking and running the detector efficiently.

The computing needs of both experiments will increase significantly. It is not obvious that "opportunistic" computing resources will be available at the expected level. Capturing the needed resources from outside might require additional manpower.

To maximize the physics output the integrated luminosity should be maximized while the instantaneous luminosity is kept as low as possible.

The number of full time post docs and students is going down faster than the FTE count for the experiment. This might put an undue burden on the remaining post docs and graduate students. CDF and D-Zero is collecting high quality data and can be attractive to students and post docs who have the opportunity to do a full, significant analysis in a relatively short time. The collaborations are aware of this and need to work with the Lab management and the funding agencies to ensure that they are kept as an attractive option to postdocs and students.

The active trigger menu is a good way to optimize data taking at high luminosity. The analysis of the data is more complicated due to the multiple interactions. Pattern recognition programs are being revisited and optimized for the presence of multiple interactions. All of this means that expertise and resources will need to be kept on developing these tools.

Creating the right safety atmosphere in a diverse collaboration is not an easy task and CDF, D-Zero, and MINOS have done a good job in creating such an atmosphere.

A commendable result of the task force work has been the increase in support of international collaborators at the lab, as well as an increase in the number of RA

appointments for CDF and D-Zero. This is necessary to the continued success of the program.

4.3 Recommendations

1. Develop a priority list for the computing needs of the collaboration that will be put in place in case all computing resources are not available as expected.

2. CDF and D-Zero need to work with the Lab management and the funding agencies to ensure that they have sufficient manpower to run the experiments through FY 2009 and to analyze the data beyond this date. Particular emphasis should be on retaining postdocs and graduate students through the intense analysis phase that will follow shutdown of the experiment.
3. The collaborations should identify all individuals who will be needed to cover critical service tasks through the running life of the experiment. For this to be useful it should be completed within the next year.
4. Collaborations should start to implement a priority list of the physics topics they will address assuming manpower will not allow them to analyze all physics topics of interest.

5. MANAGEMENT

5.1 Findings

The goals of the short-term and future accelerator based physics program are properly aligned with national priorities and DOE guidance. The highest priority is to run the collider program for CDF and D-Zero. In parallel, there is a neutrino program consisting of MINOS, MiniBoone, and SciBoone. There are in addition test beam users using the 120 GeV fixed target Meson Area. Management continues to effectively set priorities between the present Collider program, Run II luminosity upgrades, the International Linear Collider (ILC), and proton upgrade plans. The major priority is to ensure that the FY 2009 Run II luminosity goal is met and that the transition to the FY 2010 era is planned and properly executed.

The Run II luminosity upgrades are 100% completed. Peak luminosity continues to increase, but there have been two Tevatron magnet failures this fiscal year, which have impacted the integrated luminosity in FY 2007. Reliability of the Tevatron systems continues to be addressed. Tevatron operations in FY 2006 had a 23% unscheduled downtime performance, exceeding slightly the DOE goal of no more than 20%. The FY 2007 beam availability at store is presently at an average of 103 hours per week. This will be required to reach the FY 2007 design goal of 1.5 fb^{-1}. The FY 2006 beam availability average was 101 hours per week. The present expectation is to achieve an integrated luminosity of 6–7 fb^{-1} by the end of FY 2009.

Antiproton production rate is one of the major luminosity performance objectives. Significant performance gain has been achieved. The goal is about a factor of 30% performance increase to be realized by improving the average antiproton-stacking rate. Management formed a dedicated team to address the objective since the March 2006 DOE review. This has been a successful move.

Operations of the proton source can be quickly adapted to send all protons to the neutrino program whenever antiproton production is interrupted.

Management is aware of the primary issue of managing the transition at the end of Tevatron operations in FY 2009. The ILC efforts were integrated into the existing laboratory structure and not isolated as a standalone effort. This minimizes the “us-them” situation and the loss of attention of key personnel to provide quality Tevatron operations. Substantial organizational changes have been made during the past year in the Accelerator Division to optimize Run II and neutrino operations and other accelerator efforts.

The management organization has undergone several significant changes. The Laboratory organization was re-aligned on April 1, 2006. Three new positions of Chief Operating Officer, Chief Financial Officer, and Environment, Safety & Health Director report directly to the Laboratory Director. A new Deputy Director is in place. A re-competition of Fermilab’s M&O contract, that expired December 31, 2006, was awarded to Fermi Research Alliance (FRA).

The recommendations from the FY 2005 scorecard that were not closed by the FY 2006 review have now been completed. The FY2006 scorecard was completed on time.

Management has formed the Scientific Program Steering Committee to develop a strategic program of accelerator-based physics. A report is due on August 1, 2007. Three basic steps have been identified: 1) identify and categorize the human resources that are presently available, 2) develop the scientific strategic plan that defines the future human resource needs, and 3) conduct a human resource gap analysis and develop an implementation plan. It is presently estimated that there would be a decreased staff need of approximately 175 FTEs between Tevatron and fixed target neutrino operations.

Management continues to be concerned with an aging workforce and retirements of key personnel. The uncertain future is causing significant anxiety in the staff about their future employment. Flowing the technical workforce between operations and projects helps ameliorate some of the personnel problem. Losing leadership of collider scientists to other projects is a concern.

Substantial effort has been made to develop reliable estimates for the evolution of collaboration manpower on CDF and D-Zero. These studies indicate that there will be a 50-60% reduction in available FTE effort over the next three years. Efforts have been made to identify economies in the need for manpower to operate the detector or process the data.

A vulnerability analysis of critical components continues to be an ongoing effort. Booster components and the linac 7835 power tubes are high cost items that were completed. Upgrades and replacements are in progress for other items.

Since the last operations review, the Accelerator Division has experienced 11 Total Recordable Cases (TRC) and 2 Days Away, Restricted, or Transferred (DART) cases. When injury rates for this division are considered over time, shutdown injury statistics have steadily improved since 2003 but overall injury rates have not significantly declined since 2004. There were no recordable injuries involving users at the CDF, D-Zero, or MINOS facilities since the last operations review. Each laboratory division has developed an ES&H Plan for FY 2007. The Accelerator Division plan includes reasonable actions to improve safety, including activities designed to increase management participation and employee engagement on safety related activities.

The laboratory as a whole met the contract target for DART rate in FY 2006, but exceeded the target for TRC rate. The TRC rate has shown improvement in the first half of FY 2007, but both TRC and DART rates remain in excess of DOE goals for the year. Both the Fermi Site Office and laboratory management are focused on improving these safety metrics. It may prove useful for the laboratory to try to determine the reasons for the successful drop in injury rates during shutdown activities, as well as the excellent safety statistics for users, and try to apply those lessons learned throughout the laboratory including the more routine work within the Accelerator Division.

The laboratory conducted a gap analysis for implementation of 10 CFR 851, which is the new Worker Health and Safety Rule, and did not find significant concerns. FRA submitted its Worker Health and Safety Plan as required, and it is currently under review

by the Fermi Site Office. The laboratory does not anticipate the need to make major changes in processes or requirements to be compliant with the rule.

Since the last operations review, the laboratory has worked to better understand the formation and transport of tritium in the NuMI enclosure in response to last year's violation notice from the Illinois Environmental Protection Agency (IEPA). As a result, the laboratory is now capturing tritium-contaminated condensate from the enclosure. In addition, the affects of increasing beam power (as projected for the NOvA experiment) have been analyzed and will be presented in the NOvA Environmental Assessment (EA), and Fermilab plans to implement additional measures in the NuMI tunnel during the 2007 shutdown period to further mitigate the potential for a future tritium release.

The laboratory has reached agreement with the IEPA on a Compliance Commitment Agreement to respond to the violation notice, which was issued as a result of low levels of tritium released offsite in Indian Creek. One element of that agreement is more frequent sampling of creeks and ponds. This sampling has shown that tritium levels have consistently been below detection limits in not only offsite creeks but also in many of the onsite cooling ponds.

Upon detecting tritium in Indian Creek, Fermilab began an aggressive effort to keep the public informed. These efforts have continued since the last operations review, and have included public meetings and a web site that displays the results of ongoing tritium sampling of offsite creeks. The lab has already begun to engage the public in the NOvA Environmental Assessment process by briefing them on the draft analysis and inviting them to comment on the EA when it is published for review.

Fermilab has worked with the experiments to target additional support for critical areas that are impacted as collaborators shift their efforts to the LHC.

In general, the user community continues to express happiness with the support that Fermilab provides and the communication with management and the operations staff on scheduling and operations issues. They are happy with the machine performance and are excited about the physics discovery potential. There is concern about the dwindling budgetary support for Fermilab and the university groups working on Run II. A concern was expressed that the Tevatron Task Force recommendations have not been fully implemented.

5.2 Comments

The Accelerator Division is to be commended for successfully managing challenging Run II luminosity upgrades to meet cost and schedule targets and achieving an excellent FY 2006 and FY 2007 (to date) delivered luminosity performance.

The Committee agrees with the Fermilab expectation of achieving an integrated luminosity of 6–7 fb^{-1} by the end of FY2009.

The maintenance policy for the Tevatron is designed to optimize the integrated data sample between now and the end FY 2009. We strongly endorse the present policy for maintenance as the most effective for delivered integrated luminosity and science output.

Machine studies appear to be appropriately managed to be supportive of ongoing research and machine operations.

The Committee continues to be concerned that the Run II effort may be significantly impacted by other projects and operations that were not within the scope of this review. We encourage management to be sensitive to this issue.

Collaboration and Fermilab management will need to continue to actively monitor and plan for reductions in available manpower to operate the collider detectors and process the data. The 50–60% reductions in FTEs available appears to still meet operational needs, but suggests high rates of service contribution that may impact physics productivity. The planning for FY 2007–FY 2009 should be extended beyond the end of operations, to better ensure the physics exploitation of the Tevatron data set.

Identifying the required offline computing resources will increasingly become a challenge as the LHC experiments, with their significant computing demands, become operational. This may impact the efficiency of producing physics in future years, along with the foreseen reductions in collaboration manpower.

The resources being applied to the various programs are adequate. There is a concern about the additional funding needed due to increased power rate costs in FY 2007 and beyond and the need for resources for the support of laboratory infrastructure.

The Accelerator Division and Technical Division ES&H Plans include reasonable actions for improving safety within each division. Management is appropriately focused on safety as a priority. Improvements in safety statistics should continue to be sought.

The laboratory should be commended for their proactive approach to resolving and communicating issues related to tritium onsite. These efforts should continue as plans for NOvA move forward.

5.3 Recommendations

1. Continue the open and proactive approach with the regulators and the community to ameliorate the tritium contamination issue.

2. Complete the strategic scientific physics and manpower transition plan by the established August 1, 2007 date.

3. Determine the reasons for the successful drop in injury rates during shutdown activities, as well as the excellent safety statistics for users at the CDF, D-Zero, and MINOS facilities, and try to apply those lessons learned throughout the laboratory.

Appendix A

Piermaria Oddone
Director
Fermi National Accelerator Laboratory
P.O. Box 500
Batavia, Illinois 60510

Dear Dr. Oddone:

The High Energy Physics program of the Department of Energy supports among other world leading efforts in particle and particle astrophysics the Tevatron program at Fermi National Accelerator Laboratory (FNAL). The Tevatron program currently consists of world-class research at the energy frontier and precision measurements of neutrino properties utilizing the Tevatron accelerator complex, the NuMI beam line, the two large collider detectors, CDF and D-Zero, and the MINOS experiment.

Over the last year, a series of key upgrades and improvements have been completed in the Tevatron complex and its associated detectors. The current plan of the Laboratory is to run the Tevatron collider and the detectors through FY 2009. In addition, the NuMI beam line and MINOS have completed more than one year of their planned multi-year run. This makes it an opportune time for the Office of High Energy Physics (OHEP) to examine the operations of the Tevatron complex and the resident detectors to ensure that plans are in place to maintain reliable and efficient operation for the rest of the decade, and that the laboratory has allocated adequate resources to implement the plans.

We plan to conduct a peer review of the accelerator and detector operations of the Tevatron complex on March 27-28, 2007. Michael Procario of OHEP will chair the review. We ask that the lab prepare material including documentation and presentations that will allow our consultants to answer the following questions.

1. Do the laboratory's operating procedures, maintenance programs, and management practices ensure the reliable operation of the Tevatron complex where maximizing the integrated data delivered to the experiments in the next three years is the most relevant metric?
2. What is your evaluation of the progress made in increasing the number of protons available to the neutrino program?
3. Do CDF, D-Zero, and MINOS make optimal use of the data provided by the accelerators by minimizing their downtime, recording events efficiently, and processing the data for physics use quickly?
4. Have credible estimates been made of the scientific manpower needed to run the experiments and will the planned participation of the collaborators meet these needs?
5. What is your evaluation of the safety performance of the accelerator and detector operations in the last year? Are safety considerations properly integrated into both accelerator and detector operations?
6. What is your assessment of the laboratory’s response to the comments and recommendations from the March 2006 Tevatron Operations review?

This review serves an important function in ensuring that the nation’s HEP program is achieving the maximum scientific benefit from the nation's investment. I thank you for your cooperation in this matter and look forward to this important review.

Robin Staffin
Associate Director
Office of High Energy Physics

Appendix B

Tevatron Operations Review **Fermilab** **March 27-28, 2007** Michael Procario, Chair	
SC 1 **Tevatron Operations**	**SC 2** **Proton Source Ops**
David Robin (LBNL)* Uli Wienands (SLAC)	Fulvia Pilat (BNL)* Mike Plum (ORNL)
SC 3 **Detector Operations**	**SC 4** **Management**
David Lissauer (BNL)* William Wisniewski (SLAC)	Derek Lowenstein (BNL)* David MacFarlane (SLAC) Stephanie Short (OHEP)
DOE Observers	
Bruce Strauss, OHEP Joanna Livengood, FSO	