Department of Energy

Assessment

of the

RUN II
LUMINOSITY PLAN
at the
FERMILAB TEVATRON

July 2003

EXECUTIVE SUMMARY

The Department of Energy (DOE) review of Fermi National Accelerator Laboratory's (Fermilab) Tevatron Run II Luminosity Upgrade Program (Run II) was conducted on July 21-23, 2003 at the request of Robin Staffin, Acting Director of the Division of High Energy Physics in the Office of Science. The purpose of this review was to perform a general assessment of the status of ongoing activities and the newly developed Run II Plan and Resource Loaded Schedule and identify potential issues. The Committee was specifically tasked to determine if the Run II Plan is reasonable, identified resources are credible and appropriate, cost and technical risks are assessed, Tevatron reliability and infrastructure concerns are addressed and the project management structure is adequate to successfully implement the proposed plan.

Overall, the Committee finds that Fermilab has a high quality staff working extremely hard on the commissioning, maintenance, and upgrading of the Tevatron complex. The Laboratory's present Run II Plan establishes two new luminosity projections through FY 2009—a base projection of 4.4 fb^{-1} and a design projection of 8.6 fb^{-1}. Based on the information available at the time of the review, the Committee views a luminosity projection of approximately 4 fb^{-1} by the end of FY 2009, as having a reasonable chance of being met. However, meeting the design projection of 8.6 fb^{-1} by the end of FY 2009 is very challenging.

The Run II Plan still needs more work. The Recycler's commissioning and operations plan will not be incorporated into the overall Run II Plan until later this calendar year. Both base and design luminosity projections assume successful integration of electron cooling in the Recycler—a significant uncertainty. It is too early for the Committee to judge whether this ambitious plan is realistic. However, by the time of the February 2004 review, it should be possible to assess whether the plan is on track and whether Fermilab is making changes necessary to successfully execute the plan.

Fermilab's plan incorporates the following four major efforts to improve the Tevatron complex performance by increasing the number of antiprotons that are brought to collision.

- Increase the number of protons that can be used to produce antiprotons.
- Accept a larger number of antiprotons from the target.
- Modify the Antiproton Storage System so that antiprotons can be collected faster and a larger number of antiprotons can be stored.
- Modify the Tevatron so that the more intense antiproton beams do not disrupt the operation of the Tevatron.

The Committee found the plan to increase the number of protons used to produce antiprotons to be credible. The Main Injector is able to capture and accelerate the beam intensities required at present and as anticipated in the Run II plan. The required upgrades for slip-stacking, beam-loading compensation, and feedback systems are ready to be installed. Recommendations were made to further improve emittances throughout the complex and to reduce losses in the Booster.

The Committee found technical challenges in increasing the acceptance for antiprotons from the production target. The redesigned lithium lens looks promising. The goal of improving the aperture of the AP-2 Beam Line from 20x12 mm-mrad to 35x35 mm-mrad is challenging. Previous attempts have not been successful. The experimental procedures needed to identify the aperture restrictions have not yet been developed.

The Committee was unable to fully evaluate the Antiproton Storage System that presently consists of the Antiproton Accumulator. The plan calls for the addition of the Recycler. Due to a vacuum accident in January 2003, the Recycler has not been commissioned, so the planning for its use has been delayed. This planning must be completed and integrated into the overall plan by the time of the February 2004 review. The Committee expressed concern on the available scientific manpower for Recycler commissioning. The Recycler depends on electron cooling to hold large stacks of antiprotons. Progress has been good on the electron cooling R&D and the deployment of electron cooling in the Recycler is well planned. However, the Committee noted that an electron cooling system at such high energies has never been built before and surprises should be expected.

The Committee reviewed efforts to modify the Tevatron for high intensity operations. The Committee found plans to realign the Tevatron appropriate. The Tevatron Electron Lens has been significantly improved, but the Committee requested that experiments be performed before the next review to quantify the luminosity improvements that can be achieved with active beam-beam compensation.

In addition to the four main luminosity improvement thrusts, significant progress in instrumentation and simulation was observed. Two major simulation achievements were discovering an acceptance limitation in the Booster, and understanding the linear coupling in the Tevatron due to coil movements in the dipole magnets. The Committee expects modeling to provide significant benefits and it is crucial to the overall success of the plan.

The Committee noted an increased emphasis on instrumentation since the October 2002 review. The plan has adequate resources listed to implement the instrumentation upgrades, but the Committee noted that specific individuals were not always listed and was concerned about shortages of people with specific skill sets.

Updated cost estimates for the luminosity upgrades and maintenance and reliability projects were provided during the review. The total cost of these activities over a four-year period is approximately $59 million. The Committee views the cost estimates to be complete in that the majority of cost elements and major cost drivers have been identified. However, the quality of the cost estimate is preliminary—it is not a project baseline-quality control estimate. Approximately 50 milestones (between July 2003 and September 2007) have been developed that represent physical progress evaluation points, major scope decisions, and planned internal technical reviews. The timing, nature, number, and sequence of milestones seem appropriate.

Overall the resources assigned to the various Run II subprojects appear reasonable. However, there is a critical need for additional accelerator physics and engineering resources to assist with the Recycler, modeling, and applications software.

The Committee concluded that management has been a limiting factor. The whole Laboratory faces a great challenge to effectively apply the considerable human and technical resources available within and outside of Fermilab in achieving the scientific potential of the Tevatron complex. Fermilab management has addressed this issue by making significant management changes within the Beams Division and Run II organizations. These changes may apply the mix of knowledge and experience to succeed, but there is as yet no significant track record. The Committee believes that it is essential to add more accelerator expertise to the management team in order to bring the technical strength of the team to the required level. Fermilab management must establish appropriate management milestones in the next few months and carefully monitor them over the next year to judge the performance of the new management teams.

In summary, Fermilab is being responsive to its stakeholders by taking steps to improve the reliability of the Tevatron complex; by developing a preliminary Plan that lays out the technical scope of work and associated resources; and by making management changes to effectively execute their plan. The Committee recommends that DOE closely monitor Fermilab's efforts and look for performance that shows the ambitious Run II Plan is achievable.

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1. INTRODUCTION

1.1 Background

The Fermilab Tevatron was operated as a 900 GeV on 900 GeV proton-antiproton collider in Run Ib from December 1993 until February 1996. The typical peak luminosity at the beginning of stores in Run Ib eventually reached 1.6×10^{31} $cm^{-2}s^{-1}$ and the total luminosity integral was approximately 140 pb^{-1}. Fermilab has carried out a major upgrade of the accelerator complex to increase the luminosity for Run II. The centerpiece was the construction (1992-1999) of a new 150 GeV synchrotron, the Main Injector (MI). The MI was designed to replace and improve on the performance of the Main Ring for delivering a proton beam to the Antiproton Source and injecting protons and antiprotons into the Tevatron. A new 8 GeV antiproton storage ring, the Recycler, was also constructed and installed in the MI enclosure to increase the antiproton storage capacity of the complex. The upgrade also included additional stochastic cooling in the Antiproton Source, various beam-mode dampers, and a six-fold increase in the number of both proton and antiproton bunches in the Tevatron (from 6 to 36) to limit the number of interactions per crossing at increased intensity.

Before Run Ib began, it was envisioned that the typical peak luminosity for that run would reach 1×10^{31} $cm^{-2}s^{-1}$ and that the upgrade program would subsequently provide a five-fold increase to 5×10^{31} $cm^{-2}s^{-1}$ for Run II. The projection for Run II peak luminosity was moved to 8×10^{31} $cm^{-2}s^{-1}$ after 1.6×10^{31} $cm^{-2}s^{-1}$ was reached in Run Ib, and then to 2×10^{32} $cm^{-2}s^{-1}$ when the Recycler was added to the MI project in 1997.

Run II of the Tevatron (without the Recycler) began in March 2001 with the beam energy increased to 980 GeV. Commissioning of the accelerator did not proceed smoothly. By the end of 2001, the seriousness of the problem was widely recognized, progress continued to be slow, and in 2002 the Division of High Energy Physics asked Fermilab for a written plan to improve the luminosity and conducted a review of that plan in October 2002, chaired by Dr. David Sutter.

The primary goals for the integrated luminosity in the plan presented at the October 2002 review are expressed in terms of “base” goals that have a high degree of certainty of being achieved and “stretch” goals that represent the practical limit of performance. The most likely outcome is expected by Fermilab to be somewhere in between the base and stretch goals. The luminosity goals for FY 2003 presented at the October 2002 review are shown in Table 1-1.

Table 1-1. FY 2003 Luminosity Goals presented at the October 2002 Review

	Integrated Luminosity pb^{-1}	Best Peak Luminosity $\times 10^{31}$ $cm^{-2}s^{-1}$	Best Weekly Integrated Luminosity pb^{-1}
Base	200	5.0	10
Stretch	320	8.0	15

At the October 2002 review, planning for the years beyond FY 2003 was less developed. The technical changes needed to continue to improve the luminosity have been identified:

- Slip stacking in the Main Injector,
- Antiproton yield improvements,
- Improved transfer into the Tevatron,
- Lithium lens gradient upgrade,
- AP2-Debuncher aperture upgrade,
- Antiproton stochastic cooling improvements,
- Electron cooling in the Recycler,
- Rapid antiproton transfers between the Accumulator and the Recycler, and
- Tevatron beam-beam compensation.

In October 2002, Fermilab presented to DOE two goals for their projected integrated luminosity through FY 2008. A base goal of 6.5 fb^{-1} and a stretch goal of 11 fb^{-1}. At this review, the projections were revised to be a base projected integrated luminosity through FY 2009 of 4.4 fb^{-1} and a design projection of 8.6 fb^{-1}.

By July 2003, the Tevatron was close to its "base" goals with a maximum initial peak luminosity of 4.5 $\times 10^{31}$ $cm^{-2}s^{-1}$. The highest weekly integrated luminosity to date is 9.2 pb^{-1}, and by July 14, 2003 the total integrated luminosity for FY 2003 had reached 188 pb^{-1}.

1.2 The Luminosity Improvement Plan

A plan including a resource-loaded schedule from FY 2004 through FY2009 was delivered to DOE on June 15, 2003 and was the subject of this review. It contains the technical elements listed in Section 1.1. Two elements, not listed above, were still being considered in the plans presented in October 2002, but have since been dropped. These were: 1) decreased bunch spacing from 396 nsec to 132 nsec, and 2) returning antiprotons from the Tevatron after stores to the Recyler. Instead, the Recyler now is planned to be used to store antiprotons from the Accumulator.

The plan replaces the "base" and "stretch" goals, with "base" and "design" projections. These revised projections assume the same technical scope of work but use different assumptions to estimate the projected increase in the luminosity.

The "base" projection is a conservative projection that includes schedule contingency. Project management believes it is highly likely that the "base" projection can be achieved. It uses historical data on the number of hours the Tevatron can run per week and models the increase of luminosity from very low to normal values after shutdowns. It has explicit schedule contingency added to the bottoms-up derived schedule.

The "design" projection assumes that operational parameters will reach values closer to the maximum achievable. It has no explicit schedule contingency. It assumes that the operational hours will improve with time, and its model of return to normal luminosity after shutdowns has a faster rate of increase. The Fermilab management team believes there is a reasonable probability of achieving the "design" projection and it may even be exceeded. A comparison of initial and revised projections, from the plan submitted in June 2003, is shown in Table 1-2.

Table 1-2. Integrated Luminosity (fb^{-1})

	Base		**Stretch**	**Design**
	Oct '02	June '03	Oct '02	June '03
FY03	0.3	0.3	0.4	0.3
FY04	0.7	0.6	1.0	0.7
FY05	1.7	1.0	2.5	1.4
FY06	3.2	1.5	5.0	2.2
FY07	4.7	2.1	8.0	3.8
FY08	6.5	3.3	11.0	6.2
FY09	8.3	4.4	14.0	8.6

1.3 Charge to the Committee

In a memorandum (Appendix A) dated April 23, 2003, Dr. Robin Staffin, Acting Director of the Department of Energy (DOE) Division of High Energy Physics, requested that Mr. Daniel R. Lehman conduct a review of the Tevatron Run II Luminosity Upgrades. The charge asked the Committee to assess the performance of the Tevatron in FY 2003, as well as the plan for FY 2004-2006. It included a series of specific questions to be addressed by the Committee, including:

- Is the Laboratory plan reasonable to achieve the stated luminosity improvements?
- Have adequate resources (i.e. manpower, funding, etc.) been identified and allocated to carry out the plan?
- Is the proposed resource-loaded schedule credible and appropriate in light of the technical tasks required?
- Have the major technical, schedule and cost risks been adequately identified and assessed in the plan?
- Have the issues of reliability of all elements of the Tevatron complex and the site infrastructure been adequately addressed?
- Is the management structure adequate and appropriate for implementing the proposed plan to a successful completion?
- The committee is also asked to assess the laboratory's response to the comments and recommendations from the October 2002 review.

1.4 Membership of the Committee

The DOE Review Committee was chaired by Daniel R. Lehman of the Office of Science, Construction Management Support Division. The Committee was organized into six subcommittees with members drawn from DOE national laboratories; U.S. universities; accelerator laboratories in Canada, Germany, and Switzerland; the DOE Office of Science. The Committee membership and subcommittee assignments are found in Appendix B.

2. TECHNICAL

2.1 Accelerator Physics

2.1.1 Findings

Excellent progress continues to be made by the Beam Physics Department in support of Run II luminosity goals. The Committee applauded their involvement in various machine-specific projects.

All three of the recommendations that were made at the October 2002 review have been and continue to be addressed. A number of temporary Task Forces that cross over multiple departments have been established. The role of the Shot Data Analysis team has been expanded. Realistic modeling and simulation activities have been enhanced.

Remarkable results have already been obtained from the accelerator modeling effort. In particular, the Beam Physics Department has contributed to significant breakthroughs in the understanding of the optical imperfections at the Booster (aperture limitations caused by edge focusing of the dog-leg dipole magnets) and at the Tevatron (linear coupling induced by systematic coil movements in the arc dipoles). This modeling effort has important implications for the performance of the accelerator complex and should be actively pursued.

The Beam Physics Department has recently been renamed the Accelerator Integration Department, and its mission has begun to be re-defined. The department's main task is to operate in a vital "horizontal" role across "vertical" machine groups, taking a global perspective (for example, looking at the broad effects of changing machine-specific parameters).

There continues to be a climate where shorter-term production goals are given high priority at the expense of longer-term performance. For example, the pressure to achieve 225 pb^{-1} in FY 2003 has resulted in reduced beam study time.

2.1.2 Comments

The Committee encouraged continued modeling work in particular areas, such as space charge and transition crossing in the Booster, and beam-beam effects in the Tevatron. The former could result in finding cost-effective methods of improving proton source brightness.

The Committee also anticipates the development of a comprehensive model of the collider complex, from source to collisions. The Committee found that the upgrade plan too heavily emphasizes machine-specific goals. A global model would make transparent any benefits to be gained from perturbing particular machine parameters from their nominal goals. This would allow cost-benefit optimizations to be made, and would aid in efficient allocation of resources. One example of an issue that would benefit from a more comprehensive model is collider bunch pattern configuration. It is not clear that 36 bunch operation optimizes performance from the perspective of the experimenter. Once a model has been derived, and trade-offs between luminosity, luminosity lifetime, and interactions per crossing have been established, it will be much easier to judge, for example, whether the removal of the D-Zero Roman pots would have a net beneficial effect.

To date there are still stores that for unknown reasons have poor performance.

The Tevatron Run II luminosity performance will greatly profit from enhanced integrated planning across all machines. The Committee therefore suggested consideration of the following accelerator integration initiatives:

1. Identify a "Beam Study Coordinator", who will ensure medium- to long-term strategy, overview, and priorities of all machine experiments and studies, to complement the Run II coordinator in the efficient integration of beam studies schedules in multiple accelerators.

2. Set-up a Task Force for "Emittance Preservation", to systematically monitor the longitudinal and transverse emittances in all machines and beam lines, and to perform emittance reduction studies and activities.

3. Set-up a Task Force for "Machine Impedance" (the "Impedance Police"). This task force would systematically measure the impedance of all machines and of any new equipment prior to installation, and propose impedance reduction campaigns where appropriate.

4. Set-up a "Machine-to-Experiments Interface Working Group", to ensure a direct exchange of technical information between accelerator and experimental physicists, and to address medium- to long-term constraints, priorities, and optimum conditions, during Tevatron luminosity production. The implications of experimental constraints (such as the minimum number of bunches, and changes of helix polarity during beta-squeeze dictated by D-Zero Roman pots) can be discussed, and alternative scenarios can be considered, in terms of the associated losses of integrated luminosity.

The head of the Accelerator Integration Department must be given sufficient authority to recruit people from other departments for temporary and/or part-time assignment in such task forces.

Simplifying Tevatron operation is a key element to ensuring machine reproducibility and maximizing integrated luminosity, especially in the short- and medium-term. To this end, the Committee suggested that the Accelerator Integration group (and others) work to:

1. Give a high priority to optics studies to minimize the antiproton emittance at injection into the Tevatron, and to maximize proton and antiproton beam lifetimes. These studies can immediately profit from the better understanding of the Tevatron optics (coupling).

2. Actively pursue helix optimization studies, and clarify the dependence of long-range beam-beam effects on relative versus absolute beam separation distances.

3. Establish a simplified/optimized procedure for shot set-up, to shorten the Tevatron turn-around time and to enable more operators and physicists to master the machine complex.

4. Support the Assistant Division Head for Controls and Instrumentation, and the Associate Division Head for Engineering, in the assessment and review of high-level controls improvements and upgrades.

2.1.3 Recommendations

1. Clarify and expand the "horizontal" role of the Accelerator Integration Department, in support of the individual machine groups. Consider the establishment of task forces or working groups for emittance preservation, machine impedances, and for the machine-experiment interface.

2. Create, maintain, and exploit an integrated depository of basic configuration data for each accelerator and beam line. This should include optics information, survey and alignment data, magnetic imperfections, and apertures. It should also include simulation software available to a broad public of users.

3. Target a doubling of the number of expert operators and physicists who are fully qualified to operate the Tevatron complex, capable of being on-call, and of preparing, performing, and analyzing beam studies.

4. Develop a comprehensive model of the Collider complex, to analyze baseline and fall-back luminosity scenarios under various conditions, to help establishing evolving target performance parameters for each accelerator, and to help in establishing relative priorities for beam studies or new equipment.

5. Explore a scenario with a reduced number of bunches (say 18 instead of 36) for a given total antiproton intensity.

2.2 Proton Source

2.2.1 Findings

The recommendations of the October 2002 review committee were responded to in a positive manner, in particular concerning the understanding of the Booster and using outside expertise.

The proton source continues to operate with excellent availability (better than 90 percent) delivering the required beam intensity, albeit with emittances slightly larger than nominal.

A potentially serious supply crisis of TETRODE 7835 radio frequency (RF) power tubes for the five drift tube tanks of the Linac could only be averted by borrowing spare tubes from Argonne and Brookhaven National Laboratories. It is planned to build up the spare tube budget over the next few years (WBS 1.2.1.1) and to pursue alternative options together with the other users of this tube.

The 8 GeV Booster is the workhorse of the complex with proton beam intensity per pulse of up to $5\text{x}10^{12}$. Nevertheless, the Booster will remain the beam intensity bottleneck of the complex. The machine has recently started to produce beams for the fixed target experiment MiniBoone, which requires a much larger throughput than for collider operation. This causes additional beam losses, which are controlled by a loss monitor system that switches off the beam when losses exceed 400 W.

The losses are caused by space charge during the first 3 ms of acceleration, as well as at transition crossing. A small team of accelerator physicists was introduced to do computational and experimental beam studies to address these limitations, with a spectacular result—the four magnet dogleg to by-pass the extraction septum magnet causes strong edge focusing that completely changes the lattice and reduces the horizontal acceptance from 16 to 8 mm mrad. A new dogleg system, largely eliminating this effect, will be implemented in the forthcoming shutdown, which may potentially lead to a significant increase of the intensity per pulse. The Committee congratulates the team for this great success.

The implementation of the gamma transition jump system awaits commissioning of the ramped orbit correction system. This would be highly desirable to further reduce losses.

A collimation system to localize beam losses in a specially shielded area was not installed because of difficulties with serviceability. Improved collimators will be installed in the forthcoming shutdown.

The MI captures and coalesces protons with 80-90 percent efficiency, mostly independent of the intensity. Coalescing efficiency is only slightly better for five-bunch coalescing than for seven-bunch coalescing (87 vs 83 percent) but at present only the seven-bunch coalescing can provide adequate bunch intensity for the Tevatron (300×10^9 protons per bunch). However, the longitudinal emittance for seven-bunch coalescing exceeds the desired value (3 eVs vs 2.5 eVs).

A previously seen vertical emittance blowup has been traced to saturation effects in the beam profile monitor. The actual emittance growth during acceleration is a reasonable 2 π mm mrad. The observed enlarged emittance in the Tevatron must therefore be due to emittance growth during transfer from MI to Tevatron.

Proton intensity for p-bar production will be increased by up to a factor of two by "slip-stacking" two Booster batches into the same slot in the MI. Recently, this has been successfully tested at a stacked intensity of 4.5×10^{12} with encouraging results even at twice this intensity.

At present, the longitudinal emittance in the Booster at extraction is increased by a factor of two to avoid beam instability in the MI. Installation of longitudinal dampers planned for the fall 2003 shutdown is expected to control this instability and remove the need for the emittance blowup in the Booster. This will allow reducing the longitudinal emittance of the Tevatron proton bunches.

2.2.2 Comments

The number of spare 7835 tubes needs to be maintained at a level that allows operation for two to three years, which is not fully funded in the present plan. Doing so would allow adequate time to develop an alternative option in case Burle Industries is not able to supply any more new or rebuilt RF power tubes.

With MiniBoone becoming operational now the throughput will gradually increase from, at present—$4x10^{16}$ particle per hour to $1x10^{17}$ per hour, and later—$1.8x10^{17}$, with the advent of the Neutrinos at the Main Injector (NuMI) project. This fourfold increase has to be accommodated without additional beam losses, which is a formidable challenge. The beam physics work, which has successfully started, has to be continued vigorously in order to continue to progress towards this goal.

It should be noted that this work is also very useful for the quality of the beams for collider operation (pbar production and protons for the Tevatron). The Committee is convinced that vigorous effort should continue on improving the beam intensity/emittance ratio, which has been shown to have direct benefit for the Tevatron performance.

The MI is able to capture and accelerate the beam intensities required at present and as anticipated in the Run II plan. Required upgrades for slip-stacking, beam-loading compensation, and feedback systems are ready to be installed during the fall shutdown in 2003. At present, support of this system appears to be adequate.

The slip-stacking results are very encouraging, indicating that this scheme promises to help increase antiproton intensity by a factor of up to two. The team should be proud of this achievement. Commissioning of slip-stacking and beam-loading compensation should continue at high priority.

Commissioning of the longitudinal bunch-by-bunch feedback system, to be installed in fall 2003, should proceed with high speed. The Committee fully endorsed the chosen architecture using common hardware and state-of-the-art digital technology for a number of these systems.

The Committee encourages the team to continue looking for ways to reduce the beam emittances, especially the longitudinal emittance. Not only would smaller emittance increase the luminosity, but smaller longitudinal emittance—down to 2 eVs, by extrapolation—has also been shown to be of benefit for injection and acceleration efficiency of the Tevatron. Likewise, shortening the bunch length for pbar production may significantly enhance the pbar yield. Alternative bunch-coalescing schemes could be of benefit.

The Committee encourages the MI and Booster groups to work closely together to solve problems arising at the beam transfer from Booster to MI in the most efficient way. The same applies to beam transfer from MI and to the Tevatron and p-bar source. The presented emittance budget should be completed by including Linac and Booster emittances in order to better assess machine performance.

2.2.3 Recommendations

1. Test operation of pbar production using slip stacking, including cogging necessary for multi-batch transfers and beam-loading compensation, before the upcoming shutdown.

2. Re-examine the operating parameters of the whole collider facility to fully exploit the potential capabilities of the proton source by the next review.

3. Continue to aggressively improve the bunch intensity and emittances, especially longitudinal, of the proton beam for the Tevatron and the pbar production target.

4. Continue the successful work on quantitative understanding of the beam dynamics and losses in the Booster.

5. Continue to adhere to the present policy of limiting machine activation to allow hands-on maintenance of the Booster.

6. Consider increasing the plan for spare 7835 tubes to a two-year supply.

2.3 Antiproton Source

2.3.1 Findings

The Run II Upgrade Plan envisions substantial increases in the number of antiprotons in the Tevatron Collider. Consequently, upgrades to the antiproton source are key elements of the plan. The stack sizes required for the Collider exceed the antiproton storage capabilities of the Accumulator. The Recycler, in which large stacks can be stored, must be integrated into

Tevatron Collider operations. The longitudinal density required in the Collider, when operating with 36 bunches at high luminosity, necessitates the use of electron cooling in the Recycler. The antiproton source upgrades currently included in the Run II Upgrade plan are comprised of:

- Improvements to the target optics ("beam sweeping") to allow the use of high intensity "slip-stacked" batches from the MI for antiproton production;
- An increase in the aperture of the AP-2 line, the Debuncher, and the lithium lens gradient, to allow a larger fraction of the antiprotons to be collected;
- Improvements in the longitudinal and transverse cooling systems in the Debuncher to accommodate the larger emittance and increased flux of antiprotons;
- Improvements in the Accumulator stack tail stochastic cooling system to allow the higher flux to be stacked, at the expense of a reduced total stack capacity in the Accumulator; and
- Improvements to the antiproton extraction and transfer process, to allow rapid transfer of stacks to the Recycler.

Integration of the Recycler into Collider operations requires:

- Commissioning of the Recycler storage ring, and achieving the required goals for longitudinal and transverse emittance growth; and
- Completion, installation into the Recycler, and commissioning of the electron cooling system.

The Committee was not presented with a complete plan for operation of the Tevatron collider with the Recycler. Development of this plan has been delayed by the vacuum incident in the Recycler, which effectively prohibited Recycler commissioning since January 2003. In addition, one of the consequences of the abandonment of the 132 nsec collider bunch spacing is an increase in the longitudinal density requirement in the Recycler by a factor of three. This increase has made it mandatory that electron cooling be fully functional in the Recycler before the machine will provide any enhancement to the luminosity of the Tevatron collider. Operational scenarios for this situation are still being considered.

2.3.2 Comments

Recent work on identifying optimal target materials, and a relaxation of the target spot size requirement, allow operation in the current configuration up to batch intensities of at least 5×10^{12}. Further intensity increases, expected with slip-stacking, may require the use of beam sweeping. The target sweeping system has been under development for a number of years and is close to being ready for commissioning. Nevertheless, given the relatively minimal gain in antiproton yield (a few percent) that the sweeping system can provide and the added operational complexity it introduces, the Committee recommended that its actual deployment be re-evaluated.

A significant increase (2.1) in overall antiproton yield is anticipated from a combination of aperture increases in the AP-2 line and the Debuncher, together with an increase in the gradient of the lithium lens, from 745 T/m to 1000 T/m.

Careful study and diagnosis of failed lenses has been done, leading to a re-design based on a diffusion-bonded body fabricated from a titanium alloy with improved fracture toughness. This improvement looks promising, and has a reasonable chance of resulting in a lens with improved lifetime and/or gradient performance.

Detailed planning for the aperture improvements to the AP-2 line and the Debuncher is underway. The currently measured apertures (at zero momentum spread) are 20x12 mm-mrad (HxV); the goals of the aperture increase are 35x35 mm-mrad (HxV). There are plans for new beam line surveys, improved modeling, improved orbit control, and rebuilding of certain elements identified as aperture restrictions. However, solid experimental procedures to identify aperture restrictions have yet to be developed. Moreover, there have been repeated efforts in the past to improve the aperture of these systems, with limited success. Given this context, the Committee considers the goal of 35x35 mm-mrad to have significant technical challenge. To help meet this challenge, the Committee recommends the development of a beam-based Debuncher ring aperture limitation identification procedure as soon as possible.

For the Run II Upgrade, the longitudinal 4-8 GHz cooling system in the Debuncher is required to reduce the 95 percent momentum spread of the beam to about 6 MeV. Current performance is closer to 8 MeV, but improvements are underway to improve the notch filter characteristics, believed to be responsible for the performance deficit. The effective bunch length, including phase modulation and jitter of the proton beam used for antiproton production, determines the initial Debuncher energy spread. This is also a key parameter in the final Debuncher energy spread. The current specification is for an effective width of 1.5 nsec, but reduction below this value would be beneficial. The Committee recommends that the Antiproton and Proton Source Departments work together to collectively optimize the process of delivering a small-energy-spread antiproton beam to the Accumulator.

The final Debuncher energy spread is a very important parameter that has significant impact on the Accumulator stack tail cooling flux limitations and the degradation of stacking rate with stack size. To reduce the RF voltage requirements for pbar bunch rotation and optimize the Debuncher cooling bandwidth, the Debuncher has been designed with a small η value. The final asymptotic $\Delta p/p$ value is linked to the $\Delta f/f$ dispersion of the notch filters through the value of η. To further reduce the final $\Delta p/p$, a higher η value at the end of the Debuncher cooling cycle would be beneficial. The Committee recommends investigation of whether a modulation of the η value during the Debuncher cooling is feasible. Modulation of the transition gamma is commonly used in accelerators that are crossing transition. The increased η value also improves the transverse cooling towards the end of the Debuncher cycle.

The Accumulator stack tail cooling system will be upgraded to a design antiproton flux of 90 mA/hr; operational requirements in the Run II upgrade are at the 45 mA/hr level. A step toward this goal may be made by moving the pickup and kicker locations; the full upgrade requires the fabrication and installation of 4-6 GHz pickups and kickers. Either of these steps restrict the total stack size in the Accumulator to <100 mA, so the Recycler must be fully functional before theses improvements can be made. The Committee concurs with the overall philosophy adopted for the stack tail improvements, i.e., effectively trading storage capability for flux capability, when the storage requirements can be shifted to the Recycler. However, the Committee remains concerned that the phenomena currently limiting stack tail performance at high stack sizes (stack tail gain limitations due to longitudinal instabilities generated by stack-tail-core-crosstalk) may be present to some extent in the upgraded system, and recommends continuing strong efforts to better understand and suppress these effects. Increased transverse heating in the upgraded systems should be able to be handled, if necessary, with the stack-tail betatron system that is currently held in reserve as a backup option.

The relatively small antiproton storage capacity and high flux of the upgraded Accumulator stack tail system will necessitate rapid transfers of antiprotons to the Recycler. The Run II upgrade goal is transfer taking one minute, every half-hour. Such a rapid transfer is a challenging task. Plans have been developed for modifications to the current antiproton extraction and transfer procedures and power supply regulation of transfer line magnets that should achieve this goal. Many of these plans can be implemented gradually over the next year and a half, and will benefit current operations. The Committee did not identify any major issues here, and generally felt that there was a good chance that this effort would be largely successful.

As noted above, operational scenarios for electron cooling in the Recycler are still being developed. A number of viable options have been identified, all of which meet or exceed the Collider's requirements, but there remain significant issues to be settled. These can be broken down into issues related to the performance of the Recycler as a storage ring, and issues related to the implementation of the electron cooling system in the MI-30 straight section.

The performance of the Recycler vacuum system remains a point of concern. The original system design had serious limitations; for example, a ringwide bakeout required to achieve the ultrahigh vacuum takes six weeks, due to the lack of availability of installed AC power for the (non-magnetic) heaters. This feature has delayed recovery from the January vacuum incident until a six-week window was available (now planned for late August 2003). In the longer term, it represents a significant risk for extended downtime should another vacuum incident take place after the Recycler is integrated into Collider operations.

The influence of the MI fields on the stored beam in the Recycler continues to be a serious issue. Substantial longitudinal emittance growth has been observed, driven by MI-field-induced orbit and tune modulation of beam stored in the Recycler barrier buckets. This growth must be eliminated before the Recycler can be useful for improving the Collider luminosity. Moreover, there may be additional effects of the MI fields on the Recycler beam that have yet to be discovered.

All the scenarios foreseen for Recycler electron cooling rely on operation of the stacked beam in a condition near thermal beam equilibrium, in order to suppress energy transfer between planes driven by intrabeam scattering. This is a novel idea that should work in principle, but has never been tried in practice.

Progress in development of the high-energy electron cooling system continues to be very good. The scheme for reducing the trip rate at full energy by reducing the high-voltage stack gradient seems well-motivated and likely to succeed. Plans for the beam tests, with the solenoid at the Wide Band laboratory, appear sound. The installation and commissioning efforts in the MI seem to have been well planned. Nevertheless, an electron cooling system at this high energy has never before been commissioned and operated, and surprises should be expected.

Given the known problems and potential unknowns in both the Recycler and the electron cooling systems, the Committee considers this aspect of the Run II Upgrade to have substantial technical risk at this time, and it is difficult to assess the likelihood of timely success.

The Committee's review of the resource-loaded costs and schedule did not reveal any major issues, with the exception of the AP2-Debuncher aperture increase. The scope of this work is not well defined at this point. The $1 million (including contingency) for as-yet-unidentified items in the AP-2 line and/or the Debuncher that need replacing to attain the required aperture could be an underestimate.

The Committee is concerned about the level of scientific manpower resources applied to the Recycler commissioning and to electron cooling. These technically critical and challenging areas should receive a great deal of attention. The Committee recommends a thorough review of the scientific staffing needs in these areas, and encourages particularly efforts to engage experienced accelerator physicists in these important projects.

The Committee notes that Recycler commissioning needs will consume about 25 percent of the pbars in FY 2004. (i.e., 0.06 fb^{-1} of integrated luminosity). This “pbar tax” is well worth the potential payoff.

There have been a number of management changes in the groups responsible for these areas recently. The Committee viewed these changes as potentially positive, although it is still to early to be able to see specific improvements. One of the Committee’s concerns is the scientific staffing issue noted in the previous paragraph. This issue may have become even more pressing with the assignment of management duties to technically expert scientists.

Response to Recommendations from October 2002 DOE Review

1. Verify stack tail cooling rate with protons up to $5x10^{11}$ per hour (50 mA/h) to verify that the modified Accumulator stack tail system can digest the higher flux of antiprotons resulting from Main Injector slip stacking, Li-Lens, AP3 and Debuncher acceptance upgrade.

This was not done due to lack of scheduled study time. It is scheduled to be done in fall 2003.

2. Continue to support the electron cooling R&D with adequate funding and manpower to ensure completion within a useful timeframe.

This continues to be done.

3. Integrate the Recycler into normal operation as soon as the performance is adequate for breaking even in integrated luminosity.

This has been delayed for technical reasons, as discussed above.

2.3.3 Recommendations

1. Re-evaluate the need to deploy the target sweeping system, in view of the relatively minimal gain in antiproton yield (a few percent) that it can provide, and the added operational complexity it introduces.

2. Optimize the delivery of small-energy-spread antiproton beams to the Accumulator, in collaboration with the Proton Source Department.

3. Develop a beam-based Debuncher ring aperture limitation identification procedure as soon as possible.

4. Re-evaluate the benefits of a η modulation in the Debuncher with respect to costing rates and asymptotic $\Delta p/p$ value (by the end of calendar year 2003).

5. Continue strong efforts to better understand and suppress effects that currently limit stack tail cooling performance at high stack sizes.

6. Perform a timely and thorough review of the scientific staffing needs in the Recycler and electron cooling areas, with particular efforts to engage experienced accelerator physicists in these challenging projects (by the end of calendar year 2003).

2.4 Tevatron

2.4.1 Findings

The Tevatron performance has made good progress over the last year. The peak luminosity has increased from of 2.6 x 10^{31} $cm^{-2}sec^{-1}$ to above 4.5 x 10^{31} $cm^{-2}sec^{-}$, the integrated luminosity per week has almost tripled, from 3.7 pb^{-1} to 9.2 pb^{-1}. For the experiments the total integrated luminosity delivered in Run II is now approximately 300 pb^{-1}, which is more than a factor of two over the total luminosity integrated in Run I. Considering present performance, the Tevatron will most likely deliver the base goal integrated luminosity (200 pb^{-1}) for FY 2003 by the end of August. This will be achieved in spite of significant setbacks during the year due to equipment failure. The Beams Division crew is to be congratulated for their commitment to achieve these goals under these difficult circumstances.

The increased emphasize that was put on accelerator physics has resulted in a better understanding of Tevatron performance. Systematic beam studies and careful evaluation of the corresponding data have identified magnet alignment errors as one of the sources of poor performance of the Tevatron. These misalignments are the cause of strong coupling between the horizontal and vertical betatron oscillations, residual orbits, strong excitation of correctors up to their limits, and presumably optical distortions, and provide today a qualitative understanding of the emittance blow-up after injection due to orbit coupling. The analysis of these data revealed a number of alignment deficiencies such as systematic vertical position offsets of dipole cold-masses in the iron yoke and tilts of the superconducting magnet system of the Tevatron. These alignment issues are addressed in a systematic way. The first step is to realign the accelerator and remove and repair the technical shortcoming that caused the misalignment. The second step consists of installing equipment such as tilt meters and a level system to monitor and maintain a well aligned machine. A plan to realign the Tevatron and a schedule was presented. Realignment of the dipoles and quadrupoles will be done during the fall shutdown in 2003.

With a better focus on accelerator physics, including the generation of a Tevatron task force, efforts in several areas start to show results and feed into a parametric model for Tevatron performance that helps to optimize the luminosity. The integration of outside expertise, as done in the Tevatron Department, is encouraging and should continue in the future. Support of the Tevatron Department by horizontal integration with the newly created department for "Accelerator Integration" should be fostered

The Tevatron Electron Lens (TEL) has been significantly improved. It was found that the non-Gaussian transverse distribution at the edge of the electron beam induced an emittance growth in the proton or pbar bunches. A new gun was built and the TEL can now run without a significant reduction of proton and pbar lifetimes. While in most tests the proton or pbar emittances were still increased due to an improperly centered electron orbit and inaccurate beam position monitors (BPM) in the TEL. There were also stores where the emittance growth rate was significantly reduced. An upgrade of the BPMs should allow a simultaneous accurate measurement of electron, proton, and pbar. Frequently, there are stores in which a subset of bunches show a strong emittance increase. It has been shown that the TEL can be used to shift the tune of selected bunches and reduce their emittance growth rate. A decision on a second TEL is pending, depending on new measurements in November 2003. During this discussion, the Committee learned that there are difficulties associated with tuning the Tevatron beam in an optimum way to achieve maximum peak luminosity and lifetime, and an optimum burn-rate of the antiprotons.

These difficulties arise from the subtleties of the necessary tuning operations that cannot be performed by the current operators. There is not sufficient qualified scientific staff available to provide optimum tuning.

Largely automated measurements in the Tevatron are available now for the proton orbits, the bunch length, the emittance and the tunes. Chromaticity and coupling can be measured.

The Committee learned that 70 hours per week (on average) are spent in colliding beam and luminosity operation. Nearly 60 hours (on average) are lost to technical failures including recovery time; 18 hours per week are necessary for cycling, injection, acceleration, and tuning; and approximately 20 hours are used for accelerator tuning. The hours lost to technical failures cannot be considered as completely lost time, since unscheduled interruptions are used to perform necessary maintenance that would have to be otherwise scheduled and subtracted from the available beam time. The availability of accelerator reliability and efficiency data appears to be limited.

The Committee noted that vulnerabilities due to missing or inadequate spare parts have been recognized as an important ingredient to assured efficient and reliable accelerator operations on the medium term. Emergencies, such as shortage of TETRODE power tubes due to problems of the supplier and availability of high quality ceramics on the market, are addressed vigorously.

A reference magnet system, as part of the Tevatron main current bus, was considered to continuously monitor the magnetic field during Tevatron operation. The original ambitious and costly plan, to feed the evaluations of these measurements into the Tevatron correction circuits to provide compensation of the dynamic field distortions during the magnet ramp, was abandoned after careful evaluation. The reason for this decision is lack of sufficient data available on the magnets as installed in the Tevatron to select a magnet that represents the Tevatron sufficiently. The plan has been changed to provide continuous measurements that can be checked and benchmarked off-line against measurements with the beam. This is expected to improve the understanding of dynamic effects that should enable better corrections and help to reduce beam losses during the early stage of acceleration.

2.4.2 Comments

The improvements in the Tevatron that have been achieved over the last year in peak and weekly integrated Luminosity have not completely paid off as projected in October 2002. This is partly due to: 1) technical problems that impaired Tevatron operation, and 2) limited increases in anti-proton intensity. While recent improvements in the reduction of the impedance in the ring allowed raising the proton intensity and lifetime, using the increased aperture for larger helix amplitude is currently restricted by the dynamic aperture. The reason for this restriction needs to be investigated and understood as soon as possible.

The increased effort in accelerator physics for the Tevatron needs a more coherent approach to the simulation tools and a controlled database that is used for input into simulations. The different simulation tools that are used in the laboratory should all have access to this common database so that these tools can easily be verified. A variety of effects have been simulated, leading to optimization of operational parameters and effectively increasing the integrated luminosity. Benchmarking of the different codes being used would be useful and should be presented during the next review.

The Committee acknowledged the systematic way in which the issue of misalignment is addressed starting from measurements with the beam, followed by a thorough analysis of the data, and a rigorous program to remove the alignment deficiencies and maintain good accelerator alignment. The Committee is convinced that this procedure will be a substantial part in avoiding dilution and losses of injected beam into the Tevatron.

The overall plan appears to be very appropriate and there are apparently sufficient resources assigned to the job. The resource-loaded plan shows that the Tevatron can be realigned in six weeks if all required resources will be applied—this is strongly encouraged by the Committee.

The emittance increase differs strongly from run to run, and often even from bunch to bunch. This effect needs to be understood in detail and mitigation strategies have to be developed. That includes the necessity to justify the beam-beam compensation efforts that are presently in the plan and it has to be shown that there is no simpler mitigation strategy.

It is difficult for the Committee to accept that loss of luminosity is due to insufficient tuning as unavoidable, especially since tunes are optimized on a monthly basis only. This clearly seems to show that there are not sufficient human resources assigned to achieve the maximum possible performance. The Committee does not consider this a temporary problem since the improvements of beam intensity and beam brightness will create new challenges that are expected to require new and more sophisticated tuning procedures.

The Committee considers the reduction of downtime and the reliability increase of the accelerator complex important to achieve more luminosity. The Committee acknowledges the effort to mitigate deficiencies in technical reliability by a flexible maintenance schedule. On the other hand, this way of proceeding may force a compromise on important maintenance issues due to lack of sufficient preparation and lack of time to perform the work in an optimum way.

The Committee understands the reasons for abandoning the ambitious reference magnet plans. There is still some potential for operational improvements to emerge from the reduced project. The Committee considers this a reasonable effort.

2.4.3 Recommendations

1. Develop a more coherent approach to modeling of the Tevatron and set up an input database that is put under configuration control by the next review.

2. Start, immediately, to specify and develop control tools for automated measurement that can be integrated into operations.

3. Involve the accelerator physicists in routine operations to benefit the medium and long term accelerator tuning of performance.

4. Provide written instruction for complicated procedures in the control-room and provide Tevatron specific operator training.

5. Install and commission the planned diagnostics upgrades in the A1 transfer line as soon as possible.

6. Commission the transverse feedback systems as soon as possible.

7. Implement the alignment plan and give all necessary priority to finish this task up in the next shut down.

8. The Tevatron Department head should take an aggressive role in monitoring down times and other sources of inefficiency, and in discussing possible cures and priorities with the technical support groups.

9. Pursue the reduced reference magnet system plan and develop a firm schedule within the next three months.

10. Perform experiments with the largest possible proton bunch currents to analyze the necessity of active beam beam compensation. Quantify the Luminosity improvements that can be achieved by integrating beam-beam compensation (either the Tevatron Electron Lens or the Wire compensation) into operations by the next full review.

11. Finish the resource loading of the Run II upgrade plan to ensure that there is no over-commitments of specific individuals.

12. Expedite the construction and installation of the Tevatron BPM electronics as much as possible.

13. Make use of the existing expertise in the laboratory as much as possible.

2.5 Instrumentation

2.5.1 Findings

Linac and Booster

The existing instrumentation appears to be adequate to meet demands and the group aims at reliable accelerator performance. Uncontrolled beam losses limit Booster performance, and monitoring and controlling these losses is the primary concern. Analysis tools are either in place, being developed, or being improved to support these aims.

It is noted that the Booster ionization profile monitors provide the only measurement of transverse parameters during acceleration. They seem to perform well despite being in place for about ten years.

Main Injector

The present beam position monitor system involves four detectors per betatron wavelength in both horizontal and vertical planes. The 100 μm resolution is limited by the 8 bit anti-coincidence detectors.

Application programs are available for diagnostics, operation, and accelerator physics studies.

An upgrade of the front end electronics is justified on the basis of the age (approximately 20 years), obsolescence of some components, obsolescence of the computer interface, and the variety of operating modes. In particular the present system is blind to 2.5 MHz time structure. This mode of operation will be needed with 2.5 MHz acceleration for antiprotons that in turn would provide a smaller longitudinal emittance. The time schedule foresees the start of this upgrade after the new Tevatron BPM system is in place and working in April 2004. In this case the MI system would not be operational before May 2005, i.e., two years from now.

Recycler

A new BPM system is in place as a result of a successful multidivisional effort. Portions of the system are operational now and have performed well. The remainder will be available for beam measurements as soon as there is tunnel access needed to complete installation.

Integration and operation of the Recycler will require, among other topics, the development of dedicated software to perform automated measurements, especially for beam transfers. This represents one of the sought steps towards reducing the turn-around time between stacks, as an essential requirement to improve the beam time on for physics.

Transfer Lines

Rapid transfer capability is essential to reduce the present setup time (more than two hours) for loading of Tevatron and (about one hour) to set up and send antiprotons to the Recycler. Upgrades of the P1, P2, AP1, AP3, and A1 BPMs are required to automate transfer processes.

The upgrade, which represents one of the key ingredients for a successful reduction of the dead times between stores, is planned for FY 2004.

AP2 Line and Debuncher

Both the AP2 line and the Debuncher suffer from aperture limitations. An appropriate diagnostic of the problem requires support from reliable instrumentation. The aim is to improve the BPMs for lattice studies and beam-based alignment procedures.

The present secondary emission monitor system can be used for protons in both forward and reverse mode, but the BPMs do not yet work for reverse protons.
It is arguable why the beam loss monitors were removed several years ago. Beam losses diagnostics would clearly help lattice studies in the presence of limited transmission/aperture.

There is an ongoing effort to characterize the optical properties of the present lattice of the AP2-line. Some experiments with beam will be proposed to perform aperture studies and improve transmission.

Electron Cooling

The diagnostics of the present electron cooling setup was complete for the beam operations performed last year. The instrumentation required for full length commissioning is installed.

Some BPM and scraper improvements are foreseen when electron cooling is incorporated into the Recycler. Routine operation will require instrumentation to be controlled through ACNET.

Tevatron

The Tevatron instrumentation projects in the upgrade plan will give essential measurement capabilities. These projects include:

1. A BPM upgrade for orbit measurements, orbit corrections, and lattice diagnostics
   GHz Schottky pickups for measuring tunes, transverse emittances, and chromaticities;
2. Tune trackers for measuring tunes and chromaticities;
3. An ion profile monitor for measuring turn-by-turn profiles at injection and thereby matching the injected beam;
4. A pinger to excite transverse oscillations for tune and chromaticity measurements;
5. An abort gap monitor to measure beam that has migrated out of the RF buckets; and
6. Longitudinal dampers to control beam oscillations.

Shot Data Analysis

The Shot Data Analysis package is a powerful and useful system to acquire, archive, analyze, and display data from stores of both operation and accelerator studies. There has been considerable progress since the October 2002 review, and the system continues to be developed as part of the Accelerator Integration Department. This effort needs to be maintained and supported because of the value of the Shot Data Analysis for understanding Tevatron stores.

2.5.2 Comments

There has been a substantial increase in emphasis on instrumentation since the October 2002 review. Needed resources were made available in FY 2003 and/or are included in the luminosity upgrade plan. Communication has improved between the Instrumentation and Systems departments, and other divisions are contributing significantly to the instrumentation.

The BPMs in the Recycler, MI, Tevatron, and antiproton source are either completed or included in the luminosity upgrade. The BPM systems would benefit from common technical approaches to the extent possible.

The Tevatron system should have the capability of measuring antiproton orbits during routine operation. It is unlikely that the entire orbit can be measured because of time overlap with proton bunches, but it should be possible to measure portions of the orbit through the combination of time gating and pickup directionality. This needs to be considered, and requirements and specifications are needed for measurement of antiproton orbits.

The luminosity upgrade plan has identified and allocated needed funding for instrumentation when contingency is taken into account. The manpower called for in the plan is reasonable, but specific individuals are yet to be identified. Therefore, it is unclear that people with the required skills will be available when needed in the schedule. The schedule for instrumentation is credible, provided people are available when needed. Of course, there would be performance benefits if some of the instrumentation upgrades were completed earlier.

The instrumentation projects will improve reliability and maintainability by replacing old, outdated electronics, connectors, etc.

The Assistant Division Head for Controls and Instrumentation, who is part of the management team, does not have responsibility for the Accelerator Controls and Instrumentation Departments.

Instrumentation and diagnostics will be critical for success of the Tevatron, and there will be a continuing need for new instrumentation after the present plans are completed.

2.5.3 Recommendations

1. Develop specifications and requirements for measuring antiproton orbits during routine Tevatron operation and include the capability to make such measurements in the Tevatron BPM system. The specifications and requirements should be complete by September 1, 2003.

2. The Assistant Division Head for Instrumentation and Controls should have line responsibility for the Accelerator Controls and Instrumentation Departments.

3. COST ESTIMATE

3.1 Findings

The Management Team has developed a plan that identifies and organizes the activities proposed for Run II. The plan contains a summary of a Resource Loaded Schedule developed to support the Upgrades' cost and schedule estimates.

Task managers using a standard template and a set of general guidelines established by the Management Team developed the cost and schedule estimates in the resource-loaded Schedule. Costs can be rolled up using a WBS. At the review the Committee was provided a WBS Dictionary and Basis of Estimate document that supports the estimate and provides information on activity duration, labor categories and materials and supplies. Cost bases are a mixture of historical experience, expert opinion, vendor quotes and, in some cases, detailed parts lists.

The Committee views the Upgrades' estimate to be complete in that the majority of cost elements and major cost drivers have been identified. However, the quality of the cost estimate is preliminary – it is not a project baseline quality control estimate. Scope not yet fully defined (e.g., AP2 and Debuncher Acceptance, Recycler and electron cooling) has been highlighted and representative estimates have been included.

The Management Team is forming a dedicated "project controls" group to assist the task managers in applying project management tools and to provide project status to the Management Team. An initial task for this group is to review the cost and schedule estimates in detail, ensure the guidelines were consistently applied and improve the overall quality of the estimates. The Committee endorses this effort.

The Upgrades' schedule has been developed in MS Project. The schedule contains over 600 activities. Many of the scheduled activities are performed in parallel and a critical path analysis has not been performed. Activity durations have been estimated and are documented in the Basis of Estimate.

Approximately 50 milestones (between July 2003 and September 2007) have been developed that represent physical progress evaluation points, major scope decisions and planned internal technical reviews. The timing, nature, number and sequence of milestones seem appropriate.

3.2 Recommendations

1. Present a detailed progress update of the internal cost and schedule estimate review at the mini-review scheduled in October 2003.

2. Establish, by December 2003, cost and schedule estimates that can serve as "baseline" for measuring progress against plan and tracking variances.

4. MANAGEMENT

4.1 Overall Management

4.1.1 Findings

The Laboratory has a high quality staff working extremely hard on the operation, commissioning, maintenance and upgrading of the Tevatron complex.

The stakeholders need Run II performance expectations that they can count on with a high degree of confidence. The credibility of the Laboratory and of the whole field hangs in the balance. The Laboratory has developed a bottoms-up plan to support two new integrated luminosity projections to be achieved through the end of FY 2009.

These two level projections are a "design projection" of 8.6 fb^{-1} and a "base" projection of 4.4 fb^{-1}. The "design" projection does not fully account for performance margins and does not include schedule contingency. The "base" projection uses more conservative parameters and includes schedule contingency of approximately six months.

Both projections assume successful integration of electron cooling in the Recycler—a very significant uncertainty. The commissioning plan for the Recycler will be re-evaluated to incorporate experience gained in operating the Recycler following the upcoming shutdown, and a revised plan is expected to be completed by February 2004, resulting in an update to the overall plan.

In the past, management has been a limiting factor and serious concerns include:

- Lack of focus on Run II;
- Level of involvement of laboratory management;
- Morale of the staff and trust in management;
- Attrition of technical staff;
- Insufficient communications at all levels;
- Effectiveness of the management (e.g. the level and reality of planning, the effective utilization of planning processes); and
- Ease for new people, both within and outside of Fermilab, to become involved in the effort.

Since the October 2002 review and especially in the past few months, the Laboratory management has recognized these problems and has begun to take steps to address them.

In January 2003 a new head of the Beams Division with extensive experience at the Laboratory and proven management and organizational skills was appointed, and, shortly before this review, a number of other significant changes have been made to the Beams Division management team.

The Laboratory Director is now clearly focused on the success of Run II. He recognizes the need to be directly involved in the setting of priorities, in the making of difficult decisions, and being cognizant of technical progress and issues.

A daily meeting to monitor commissioning progress, chaired by the Associate Director for Accelerators and attended by the Laboratory Director whenever possible, was recently initiated. The Director has also set up and is chairing a Run II task force of very experienced senior people that will help him monitor progress, analyze problems and determine solutions.

There has been a serious problem of expectation management—luminosity projections for Run II have been changing with time in the downward direction. There is also a critical need for additional accelerator physics and engineering manpower in a number of key areas (e.g., the Recycler, modeling, applications software).

4.1.2 Comments

The Committee views a projection of approximately 4 fb^{-1} by the end of FY 2009 as having a reasonable probability of being met. Meeting the design projection of 8.6 fb^{-1} by the end of FY 2009 is very challenging.

The Laboratory's plan for achieving the luminosity projections is very ambitious. It is a significant step in that project management tools have been applied to a complex operations, maintenance and technical upgrade effort that will extend over many years. However, the plan still needs more work. More detail is needed in cost estimates and manpower leveling, particularly in assuring that key people are available for the assigned tasks. Because vacuum problems have prevented operation of the Recycler, it will take a number of months to gain Recycler experience and to flesh out the Recycler commissioning and operations part of the plan. High energy electron cooling, an important feature of the plan, has yet to be demonstrated.

It is too early for the Committee to judge whether this ambitious plan is realistic, but by the time of the next review it should be possible to better determine whether the plan is on track and whether the Laboratory is evolving in the way needed to successfully execute the plan.

It is the view of the Committee that the management has been a limiting factor. The entire Laboratory faces a great challenge to effectively apply the considerable human and technical resources available within and outside of Fermilab toward achieving the scientific potential of the Tevatron complex.

The new Beams Division management team is experienced and capable managers, but has limited accelerator experience. For balance, the Beams Division Head has appointed a very experienced and respected accelerator physicist as Scientific Advisor, but her role and level of involvement are not yet well defined. This team may well have the mix of knowledge and experience needed to succeed, but there is as yet no significant track record. The Committee believes that it is essential to add more accelerator expertise to the management team in order to bring the technical strength of the team to the required level.

The roles and responsibilities of the Associate and Assistant Beams Division Heads are not adequately defined. Some positions appear to be closer to staff than line management.

Laboratory management and stakeholders must rapidly evaluate whether the new Beams Division management team will succeed. The laboratory management must define management milestones for the next year to judge the performance of the new team.

The Laboratory and Beams Division management must aggressively establish effective and open communication at and between all levels. Priorities and decisions and the basis of decisions, must be understood at all levels, and ideas from all levels in the staff should be given due consideration. Success of the Plan depends critically on the buy-in of the staff at all levels; the Plan must be perceived as being realistic; and there must be a shared belief in the sustained commitment of the laboratory to reach the goals. Success also requires a high degree of discipline and teamwork across the whole Beams Division as well as encouragement of people from outside the Division (from inside and outside of the Laboratory) to contribute.

In other words—*Run II needs effective leadership to succeed.*

Since the October 2002 review there have been positive management-based changes: there is new emphasis on diagnostic instrumentation by the Beams Division management; horizontal task forces (e.g. integration task force, Tevatron task force, etc) have been set up to address specific cross cutting issues; more modeling is guiding the upgrade strategy; interactions with the rest of the lab and other institutions are improving. However, processes for hand-off of work (e.g. for setting requirements and specs and managing the tasks) need more development.

In the near-term: the critical technical manpower needs require immediate attention; the uninvolved technically skilled people at the Laboratory should be strongly encouraged to participate in Run II; and the users should be encouraged to collaborate and contribute to the accelerator upgrade efforts.

The management should use the plan as a tool to determine whether key people are over-committed and to monitor progress in identifying and bring on needed manpower.

4.1.3 Recommendations

1. The Laboratory should scrub the existing plan by the end of the calendar year. By February 2004, it should incorporate the Recycler to produce a complete and comprehensive plan for Run II.

2. The DOE should review the status and the comprehensive plan for Run II soon after plan has been completed.

3. By September 1, 2003, the Laboratory should define clear <u>management</u> milestones for the next year that can be used as a metric to determine the effectiveness of the new team.

4.2 Management Organization

4.2.1 Findings

Beams Division Organization

Overall responsibility for performance of the Laboratory resides with the Director. Primary responsibility for operation and upgrades of the Tevatron complex resides with the Beams Division.

The Beams Division is one of the four major Divisions of the Laboratory. The others are the Particle Physics Division, the Computing Division, and the Technical Division. The Beams Division has responsibility for operating, maintaining and upgrading the accelerator complex. The Beams Division Head reports to the Associate Director for Accelerators, who in turn reports to the Laboratory Director. There have been a number of recent changes to the division organization. The current division organization defines a Headquarters office that includes the Division Head, the Deputy Division Head, and a number of Associate and Assistant Division Heads. This group of people makes up "The Management Team." The details of the Beams Division organization are shown in Figure 4-1.

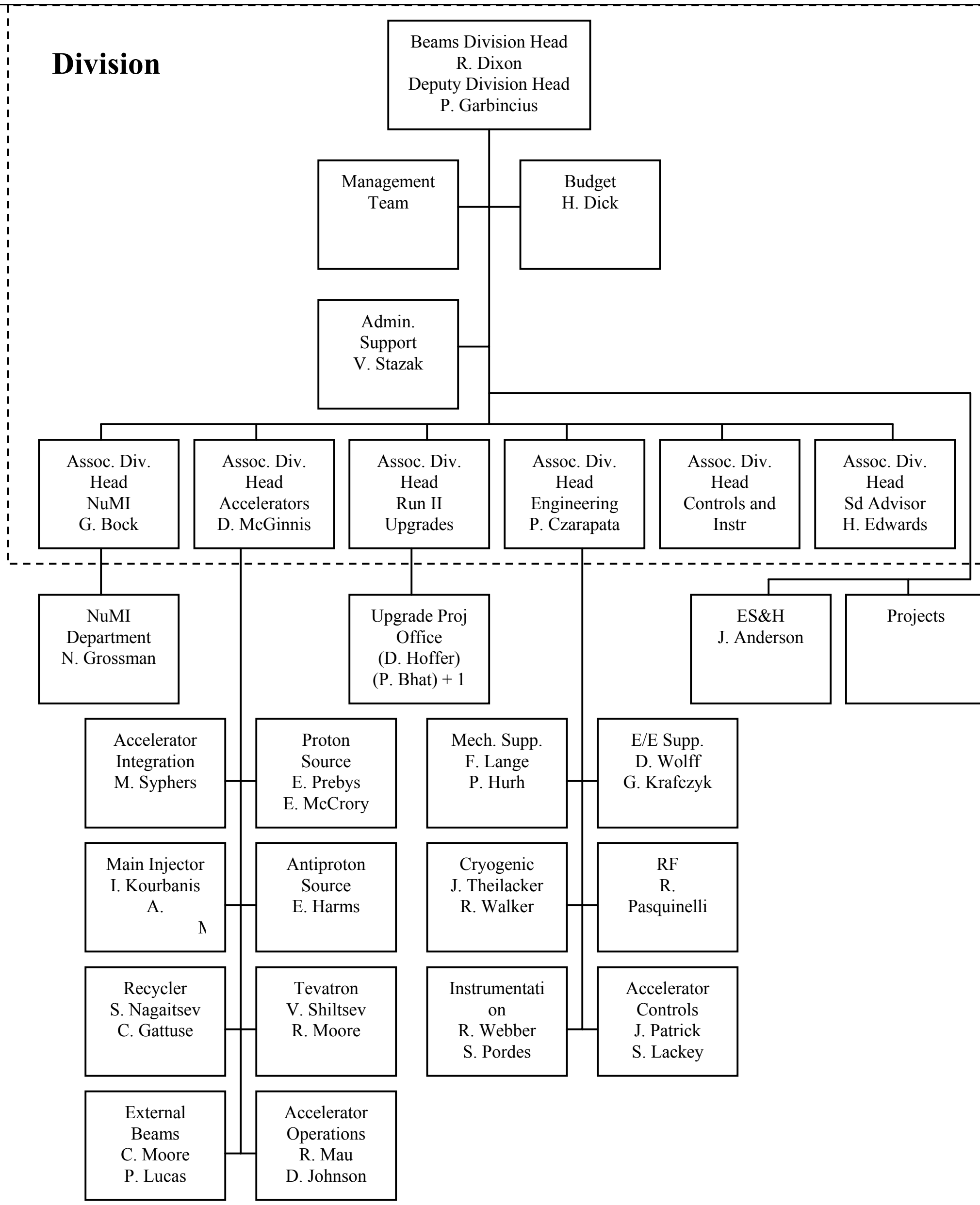

Figure 4-1. Beams Division Organization Chart

Run II Luminosity Upgrade Organization

The Run II Luminosity Upgrade Program is organized as a set of subprojects (see Figure 4-2). The program is managed from the Beams Division Headquarters Office with a project manager and technical coordinator. The project manager reports to the Beams Division Head. The upgrades are organized into four separate activities with a leader responsible for each: increasing the proton flux delivered to the antiproton production target; increasing the acceptance of antiprotons produced from the target; improving the stacking rate and stack size for antiprotons, and the transfers between machines; and, upgrading the Tevatron for operation at higher bunch intensities. This is a heavily matrixed organization. The project leaders are themselves department heads or group leaders in the Beams Division line management, so this project organization is integrated with the department organization.

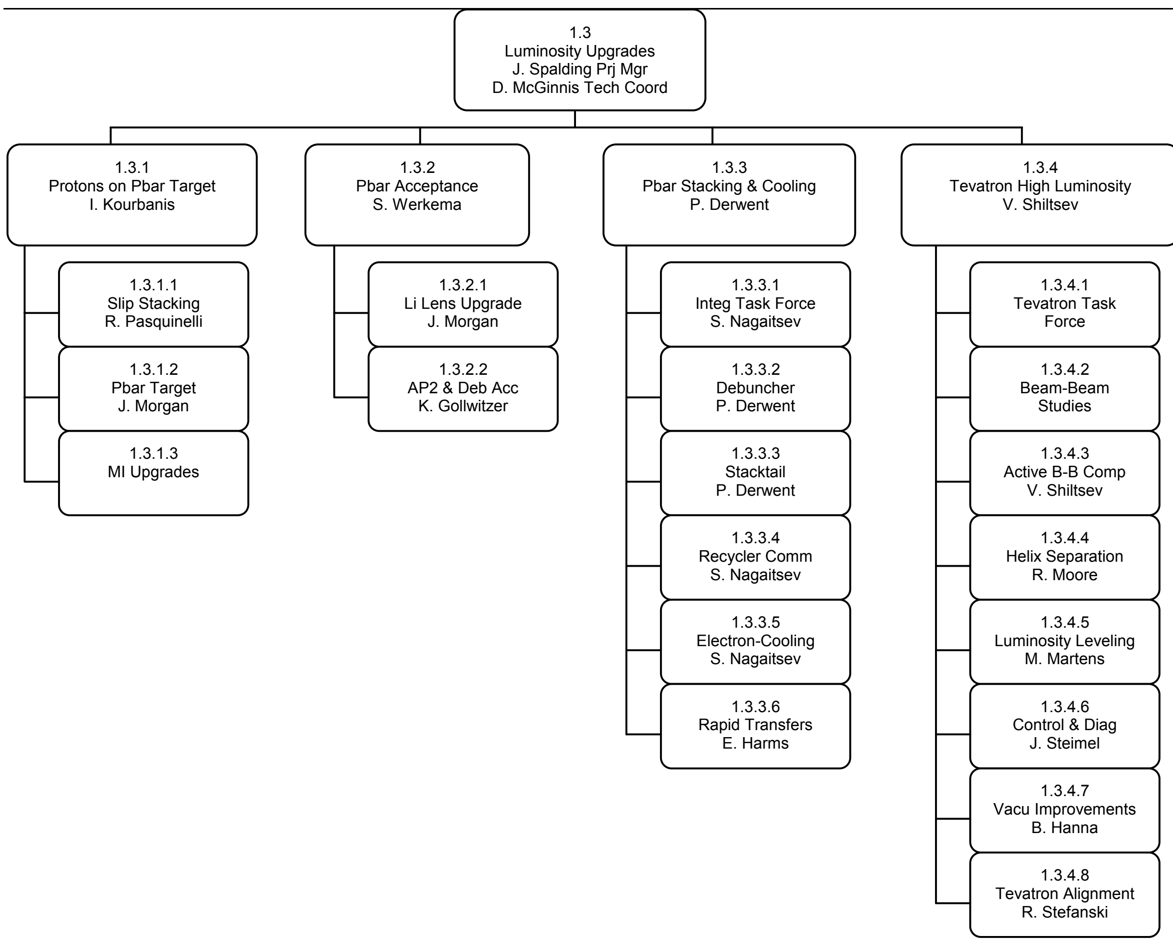

Figure 4-2. Luminosity Upgrade Organization Chart

4.2.2 Comments

The Recycler Department in the Beams Division (which includes electron cooling) has recently been created. The Recycler has about ten people working officially in the department, but the Technical Division is presently providing major engineering and technical support. In addition, the Particle Physics Division is supplying technical support help with Recycler vacuum, and, of course, there is significant support from the Beams Division Support Departments.

The Management Team is in the process of adding physicist manpower to this effort. In addition, efforts are being made to get expert help on high vacuum systems from outside the Laboratory.

The Beams Division and Luminosity Upgrade program are organized in a reasonable way to manage the Luminosity Upgrade program.

The organization of the Beams Division Headquarters and Luminosity Upgrade program are very new. The roles and the responsibilities of the newly appointed managers are not yet fully defined. (For example, the Assistant Division Head for Controls and Instrumentation has no line organization under him; yet there are separate Instrumentation and Accelerator Controls Departments in Engineering.) The Beams Division Head and the Luminosity Upgrade Project Manager should continue efforts to define the roles and responsibilities of the newly appointed managers.

It is likely that the Beams Division and Luminosity Upgrade organizations will continue to evolve as the management works to incorporate additional technical and managerial capabilities into the organization.

4.2.3 Recommendations

1. Clarify the roles and responsibilities of the Associate and Assistant Division Heads for the Beams Division by September 1, 2003.

2. Develop a plan for providing adequate resources to support the Assistant Head for Instrumentation and Controls by September 1, 2003.

4.3 Management Processes

4.3.1 Findings

It will be critical for the successful implementation of the new management strategy to couple effective management processes with the newly established management organization. Clarity, consistency, and transparency in prioritization, decision-making, oversight and day-to-day project management practices can serve to promote credibility in executing the plan and confidence in all levels of the organization.

Laboratory priorities and resource allocations are established at the Directorate level, generally by the Director, Deputy Director, Associate Director for Accelerators, and Associate Director for Research. Considerations in this process include formal laboratory commitments to operating experiments and to construction projects, projections of resources that are likely to be available, and assessments of future opportunities. Priorities are communicated formally to the divisions and sections in the form of budget guidance and an associated scope of work.

Operations and upgrades are in contention for funds, for people, and for accelerator time. The decisions about how to apportion time between running, accesses, and studies for future upgrades are made by the Director in consultation with the rest of the Directorate. They receive input continuously from the experimental collaborations and the Beams Division through a number of meetings described below. The Directorate receives advice from the Physics Advisory Committee and the Accelerator Advisory Committee on the long-term priorities. In addition the Department of Energy communicates priorities to the laboratory both formally and informally.

Two regularly scheduled (monthly) meetings deal with setting strategy. The Run II Accelerator Program Management Group (PMG) looks at the long term. The PMG has representation from the Directorate, the collaborations, the four scientific divisions, and the DOE. Its mandate is to provide management oversight for the collider upgrades and integration with operations. This group was established in January 2003 and has primarily provided oversight of development of the Run II Plan by the Beams Division. This plan is specifically integrated with the laboratory's long-range operations schedule, and reflects a particular strategy that the laboratory has adopted: double the integrated luminosity delivered to CDF and D-Zero over every one year time period. Note: this is a conscious decision which precludes, for example, shutting down for a year now even if it were to result in more integrated luminosity by the end of FY 2009.

The fiscal constraints on the work plan for the immediate future were applied in the final stages of preparing the Run II Plan. The Directorate gave the Beams Division target numbers for the FY 2004 budget and discussed with them the balance between operations and upgrades. The Beams Division reported back to the Directorate with their implementation of the budget constraints, and after some iteration, a preliminary plan was prepared and submitted to DOE.

In the Beams Division, priorities are set and resources assigned by the Beams Division Head with advice from the management team and the constraints imposed by the priorities set by the Director.

The operation and upgrade activities are monitored by the Directorate via: 1) a recently instituted daily operations meeting, chaired by the Associate Director for Accelerators and attended by the Laboratory Director, with BD managers (Division Head, Deputy Division Head, Associate Division Head for Accelerators, Associate Division Head for Engineering, Run Coordinator, Shot Data Analysis Coordinator, and the systems department heads); 2) the weekly "All Experimenters' Meeting"; 3) the monthly Run II Strategy meeting; 4) the monthly Run II Accelerator PMG; and 5) a weekly meeting with the Beams Division and Technical Division heads. The Beams, Technical, Particle Physics, and Computing Division heads all participate in meetings #3 and #4. The Directorate also regularly attends the broader operations' meeting that occurs Monday, Wednesday, and Friday.

A resource-loaded schedule and plan for FY 2004 and the out years has been prepared and reviewed internally. The Run II Plan includes specific milestones for technical reviews and evaluations. These include milestones to review engineering designs prior to proceeding with major procurements, evaluation of R&D programs and decision on proceeding to a production phase, and evaluation of the commissioning plans for subprojects.

The Beams Division has recognized that in order to minimize schedule slippage and optimize resources, it is essential that progress on the upgrades be tracked. They propose to do this in the following ways:

- On an ongoing basis, progress and priorities are to be discussed at a weekly meeting of the Beams Division management team, chaired by the Beam Division head.
- A dedicated "project controls" team is being formed to provide support to task managers in better defining their scope, schedule and costs. This team will proactively track and independently report progress against the plan.
- The upgrade plan encompassed in the resource-loaded schedule will be "statused" monthly with the current status of all ongoing activities checked by the project leaders

and reported to the Assistant Division Head for Run II Upgrades. The results will be reported at the monthly PMG meeting.

- On an as-need basis, and at least every quarter, the resource-loaded schedule will be updated and benchmarked against the previous version, and a report prepared for the Beams Division Head and Associated Director for Accelerators who will approve any scope changes.

4.3.2 Comments

There is not a comprehensive, up-to-date Technical Design Report (TDR) or its equivalent that is consistent with the current plan for the luminosity improvements. Without such a TDR it is not clear how the Laboratory can adequately or efficiently detail the scope of the activity, document key operating parameters, or evaluate overall progress.

The present Plan does reference and provides links to a diverse set of technical notes – performance models, technical papers, and studies. However, the Laboratory should develop a comprehensive, up-to-date TDR or its equivalent that is consistent with the current plan in order to: 1) define in detail the various subprojects and associated designs; 2) serve as a basis for evaluating and controlling the luminosity improvements; and 3) provide an integrated, centralized list of key operating parameters.

A management plan should be developed to articulate the management approach and processes presently envisioned and, in many cases, being implemented. The management plan should be incorporated into the present Run II Plan.

The Beams Division and the Upgrades organization, as planned, must effectively monitor progress against the Plan, respond rapidly and effectively to problems and update the Plan so it remains an effective tool.

4.3.3 Recommendation

1. Document the new management approach and associated processes and incorporate this description in the overall Run II Plan during the next Plan update at the end of the Calendar year.

4.4 Interactions with DOE, URA, within Fermilab, and Other Laboratories

4.4.1 Findings

Fermilab is one of the flagship laboratories of the Office of High Energy Physics (OHEP), and, as such, the success of Run II is of the greatest importance not only to the DOE but to the field of High Energy Physics. There is frequent communication with the OHEP. DOE Office of Science has site representatives at Fermilab who are aware of the day-to-day activities at the Laboratory, and who are in close contact with the OHEP; at the Laboratory, senior managers are also in close contact with the OHEP. Nevertheless, the inability of Fermilab to define success and manage expectations, as demonstrated by the continual erosion of the value of the projected integrated luminosity that is to be achieved by 2009, has created severe difficulty in OHEP's ability to defend its budget requests. It is therefore vital that the current Run II plan be credible and that it be sufficiently conservative that well-defined expectations will be met.

University Research Associates (URA) the contractor for Fermilab has a Board of Overseers to review the Laboratory. Although the Board meets only twice a year, the President of URA and the Chairman of the Board frequently visit the Laboratory and demonstrated to the subcommittee that they were current on Run II issues. To increase their involvement, the Board, at their June 2003 meeting, established an "Advisory Council on Run II" that will meet every six weeks at the Laboratory to advise the Director on big-picture Run II issues. The Council comprised of experienced senior accelerator physicists and members of the Board will have their first meeting in August 2003.

Constructive interactions of the Beams Division with the three other Divisions at Fermilab appear to be getting stronger all the time. This has not always been the case; however, as a result of persistent outreach effort by all Division Heads, there is significant improvement. The three other divisions are contributing about 100 FTE's to the Run II activities: Technical Division, 43; Particle Physics Division, 45; and Computing Division 12.

Similarly, there has been recent progress in harnessing expertise and organizing collaborators from other laboratories: BNL—power tubes (that are currently not available commercially) for the Linac and help on the Tevatron; CERN—help on the Tevatron; LBNL—beam lifetime simulation, debuncher injection, Tevatron dampers, and future interest in the Recycler; SLAC—Recycler beam position monitors, beam lifetime simulations at 150 GeV; ANL—Tevatron optics, Booster, Recycler vacuum, and future interest in electron cooling;

IHEP—Beam-beam compensation; and BINP—alignment. To be most effective, these extremely valuable contributions require the formality of requirements documents, execution plans with milestones and responsible managers identified at both sites. These procedures are still evolving, but some of the laboratories (LBNL and ANL) have already identified liaisons for their institutions. These are steps in the right direction.

4.4.2 Comments

The success of the outreach efforts to the other divisions and laboratories is essential for a technically challenging activity like Run II, and we urge the Beams Division Head to stay focused on this issue.

4.5 Planning and Plans

4.5.1 Findings

Fermilab has developed a plan for Tevatron Run II luminosity Upgrades. The key points appear to be abandoning the Recycler for recycling of antiprotons; developing electron cooling at the Recycler; keeping the number of Tevatron bunches fixed at 36; adding functional Beam Position Monitors and developing a model for the complex; and numerous other small improvements, particularly maintenance and reliability upgrades. The plan features a base luminosity of 4.4 fb^{-1} and a design goal of 8.6 fb^{-1}, integrated through FY 2009.

A project-like Work Breakdown Structure (WBS) and Resource Loaded Schedule (RLS) for the Tevatron Run II luminosity upgrades has been developed.

The plan is incomplete in that it has substantial R&D components and branch points. Some necessary manpower is not explicitly named. The WBS costing is not developed at the level that would be appropriate for a project baseline review.

4.5.2 Comments

The planning is unusually complete and integrated compared to what seems past practice in Beams Division. The upgrade plan is preliminary in nature, and was developed in response to a request from DOE.

4.5.3 Recommendations

1. The upgrade plan should be completed.

2. The upgrade plan should be internally reviewed and updated quarterly.

3. The upgrade cost and manpower estimates should be further developed and carefully monitored by Fermilab and DOE.

4. Necessary critical manpower should be explicitly identified as soon as possible.

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APPENDIX A

CHARGE MEMORANDUM

DOE F 1325.8
(08-93)

United States Government **Department of Energy**

memorandum

DATE: APR 23 2003

REPLY TO ATTN OF: SC-22

SUBJECT: Request to Conduct a Review of the Tevatron Run II Luminosity Upgrades

TO: Mr. Daniel Lehman, Director, Construction Management Support Division, SC-81

I would like to request that you lead a status review of the Tevatron Run II Luminosity Upgrades at Fermi National Accelerator Laboratory on July 21-23, 2003. The purpose of this review is to assess the performance of the Tevatron in FY 2003 and Fermilab's plan to increase the luminosity of the Tevatron collider during fiscal years 2004-2006.

As a result of the action items developed at the October DOE 2002 review, Fermilab is formulating a detailed resource-loaded plan to carry out the luminosity upgrades. Fermilab plans to replace or augment equipment in the Tevatron complex and modify their procedures for running the complex in order to increase the luminosity from its current average initial value of 3.0×10^{31} $cm^{-2}s^{-1}$ to at least 2.0×10^{32} $cm^{-2}s^{-1}$ with possible integrated luminosities reaching a minimum base goal of 6.5 pb^{-1} and possibly achieving a stretch goal of 11 fb^{-1} by the end of FY 2008.

In performance of a general assessment of the current status, the future plan and the identification of potential issues, the committee should address the following specific items:

- Is the Laboratory plan reasonable to achieve the stated luminosity improvements?
- Have adequate resources (i.e. manpower, funding, etc.) been identified and allocated to carry out the plan?
- Is the proposed resource-loaded schedule credible and appropriate in light of the technical tasks required?
- Have the major technical, schedule and cost risks been adequately identified and assessed in the plan?
- Have the issues of reliability of all elements of the Tevatron complex and the site infrastructure been adequately addressed?
- Is the management structure adequate and appropriate for implementing the proposed plan to a successful completion?
- The committee is also asked to assess the laboratory's response to the comments and recommendations from the October 2002 review.

Michael Procario is the program manager for Fermilab in this office and will serve as the DHEP contact person for the review.

We appreciate your assistance in this matter. As you know, these reviews play an important role in our program. I look forward to receiving your Committee's formal report within 60 days of the review.

Robin Staffin
Acting Director
Division of High Energy Physics

cc:
R. Orbach, SC-1
J. Decker, SC-2
P. Rosen, SC-20
L. Dever, SC-80
M. Procario, SC-221
A. Byon-Wagner, SC-223
M. Witherell, Fermilab
J. Monhart, FAO

APPENDIX B

ASSESSMENT PARTICIPANTS

Department of Energy Assessment of the Run II Luminosity Plan at the Fermilab Tevatron
July 21-23, 2003

Daniel R. Lehman, Chairman (DOE)

SC 1 Accelerator Physics	SC 2 Proton Source	SC 3 Anti-Proton Source	SC 4 Tevatron
* Steve Peggs, BNL	* Thomas Roser, BNL	* Gerry Dugan, Cornell	* Norbert Holtkamp, ORNL
Rick Baartman, TRIUMF	Uli Weinands, SLAC	Flemming Pedersen, CERN	Georg Hoffstaetter, Cornell
Francesco Ruggiero, CERN	Karlheinz Schindl, CERN	Fritz Caspers, CERN	Ferdi Willeke, DESY

SC 5 Instrumentation	SC 6 Management and Systems Integration	Observers
* Bob Siemann, SLAC	* Jay Marx, LBNL	Aesook Byon-Wagner, SC-22
Massimo Placidi, LBNL	Klaus Berkner, Consultant	Michael Procario, SC-22
	Marty Breidenbach, SLAC	
	Stephen Meador, DOE/SC	

LEGEND

SC Subcommittee
* Chairperson
[ ] Part-time Subcom Member

Count: 19 (excluding observers)

08/15/2003 q:sc-81:fermilab luminositiy:0307rev:revcomfrmlum.doc

APPENDIX C

ASSESSMENT AGENDA

Department of Energy Assessment of the
Run II Luminosity Plan at the Fermilab Tevatron

AGENDA

Monday, July 21, 2003—Comitium

8:00 am	**Committee Executive Session**	**Lehman**
9:00 am	Welcome and Opening Remarks	Witherell
9:05 am	Introduction	Holmes
9:15 am	Overview of Run II Goals and Organization	Dixon
9:40 am	Overview of the Run II Plan	Spalding
10:10 am	Break	
10:30 am	Current Operations Status and Plans for the Future	Church
11:00 am	Reliability and Maintenance Initiatives	Czarapata
11:30 am	Technical Strategy	McGinnis
12:15 pm	LUNCH	
1:00 pm	Protons on Target	Kourbanis
1:30 pm	Antiproton Acceptance	Werkema
2:00 pm	Antiproton Stacking and Cooling	McGinnis
2:30 pm	Tevatron	Shiltsev
3:00 pm	Project Planning	Spalding
3:30 pm	User's Presentation	
	Breakout Session—Agendas and Rooms to be Determined	
4:00 pm	Accelerator Physics	Syphers
	Proton Source	Kourbanis
	Antiproton Source	McGinnis
	Tevatron	Shiltsev
	Instrumentation	Webber
	Management and Systems Integration	Dixon
5:00 pm	**Subcommittee Executive Sessions/Rooms TBD**	
5:15 pm	**Full Committee Executive Session/Comitium**	
6:30 pm	Adjourn	

Tuesday, July 22, 2003

8:00 am	**Subcommittee Breakout Sessions**
12:00 pm	Lunch
1:00 pm	**Subcommittee Breakout Sessions**
2:00 pm	**Subcommittee Executive Sessions/Rooms TBD**
3:00 pm	**Full Committee Executive Session—Comitium**

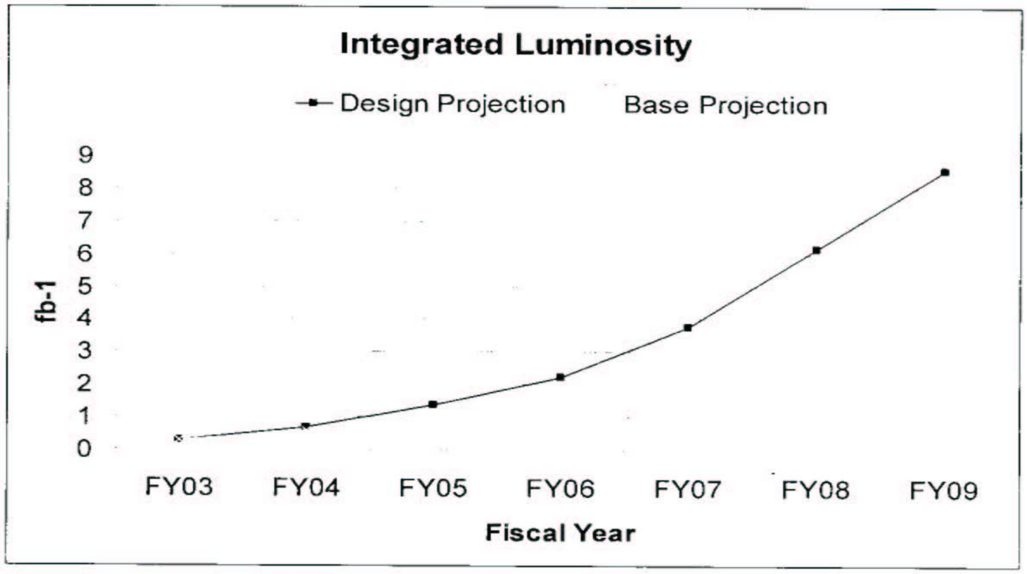
Wednesday, July 23, 2003

10:00 am	**Full Committee Closeout Dry Run—Comitium**
12:00 pm	Lunch
1:30 pm	**Review Closeout Presentation—1 West**
2:30 pm	**Adjourn**

APPENDIX D

LUMINOSITY PROJECTIONS

Luminosity Projections



Integrated Luminosity (fb^{-1})				
	Design Projection		Base Projection	
	per year	Accumulated	per year	Accumulated
FY03	0.22	0.30	0.20	0.28
FY04	0.38	0.68	0.31	0.59
FY05	0.67	1.36	0.39	0.98
FY06	0.89	2.24	0.50	1.48
FY07	1.53	3.78	0.63	2.11
FY08	2.37	6.15	1.14	3.25
FY09	2.42	8.57	1.16	4.41

APPENDIX E

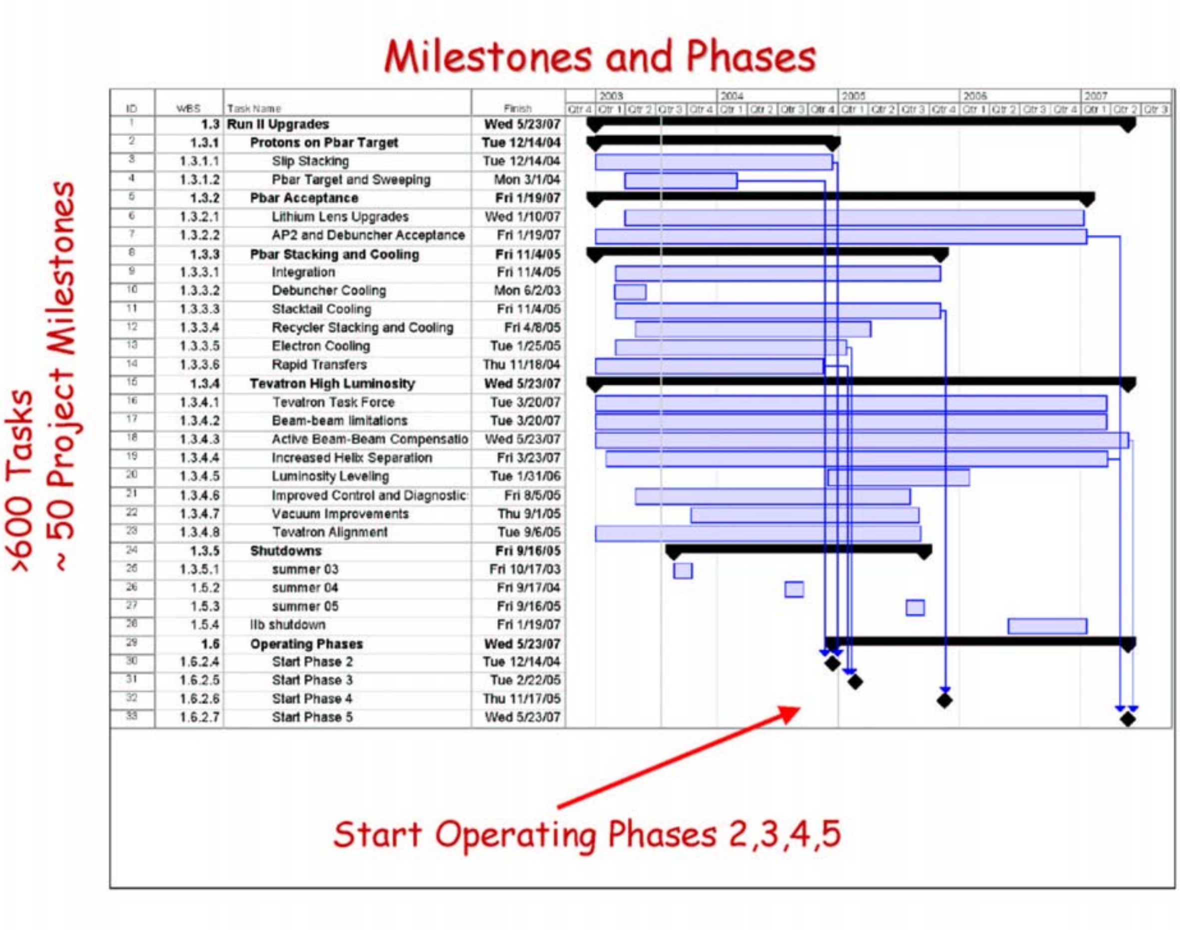
COST
TABLE

Cost (Obligation) Summary by FY in FY03 and Actual Year $

		FY03	FY04	FY05	FY06	FY07	Total	%Cont
WBS 1.2 Maintenance and Reliability								
M&S								
Base Cost	FY03 $K	258	1,288	858	1,000	0	3,404	
Base+ Contingency	FY03 $K	368	1,840	1,225	1,428	0	4,862	43
Base + Contingency	Actual Year $K	368	1,891	1,294	1,547	0	5,100	
(Base + Contingency) + Indirect Costs	Actual Year $K	427	2,194	1,501	1,795	0	5,916	
Labor								
Base Cost	FY03 $K	114	372	403	215	6	1,109	
Base+ Contingency	FY03 $K	184	604	653	349	9	1,799	62
Base + Contingency	Actual Year $K	184	628	706	392	11	1,922	
(Base + Contingency) + Indirect Costs	Actual Year $K	239	817	918	510	14	2,499	
WBS 1.3 Luminosity Upgrades								
M&S								
Base Cost	FY03 $K	1,065	8,307	1,460	730	0	11,561	
Base+ Contingency	FY03 $K	1,171	10,798	3,358	1,460	777	17,565	52
Base + Contingency	Actual Year $K	1,171	11,101	3,545	1,581	863	18,262	
(Base + Contingency) + Indirect Costs	Actual Year $K	1,359	12,877	4,112	1,835	1,001	21,184	
Labor								
Base Cost	FY03 $K	3,386	6,956	4,270	1,886	587	17,085	53
Base+ Contingency	FY03 $K	3,555	9,391	8,540	2,956	1,658	26,101	
Base + Contingency	Actual Year $K	3,555	9,767	9,237	3,326	1,940	27,824	
(Base + Contingency) + Indirect Costs	Actual Year $K	4,622	12,697	12,008	4,323	2,522	36,171	
WBS 1.2+1.3								
Total: M&S + Labor								
Base Cost	FY03 $K	4,822	16,923	6,990	3,831	593	33,159	
Base+ Contingency	FY03 $K	5,279	22,633	13,776	6,194	2,445	50,327	
Base + Contingency	Actual Year $K	5,279	23,387	14,782	6,847	2,814	53,108	
(Base + Contingency) + Indirect Costs	Actual Year $K	6,647	28,584	18,539	8,462	3,537	65,770	

APPENDIX F

SCHEDULE CHART


Milestones and Phases
>600 Tasks
~ 50 Project Milestones
ID
WBS
Task Name
Finish
2003
2004
2005
2006
2007
1 1.3 Run II Upgrades Wed 5/23/07
2 1.3.1 Protons on Pbar Target Tue 12/14/04
3 1.3.1.1 Slip Stacking Tue 12/14/04
4 1.3.1.2 Pbar Target and Sweeping Mon 3/1/04
5 1.3.2 Pbar Acceptance Fri 1/19/07
6 1.3.2.1 Lithium Lens Upgrades Wed 1/10/07
7 1.3.2.2 AP2 and Debuncher Acceptance Fri 1/19/07
8 1.3.3 Pbar Stacking and Cooling Fri 11/4/05
9 1.3.3.1 Integration Fri 11/4/05
10 1.3.3.2 Debuncher Cooling Mon 6/2/03
11 1.3.3.3 Stacktail Cooling Fri 11/4/05
12 1.3.3.4 Recycler Stacking and Cooling Fri 4/8/05
13 1.3.3.5 Electron Cooling Tue 1/25/05
14 1.3.3.6 Rapid Transfers Thu 11/18/04
15 1.3.4 Tevatron High Luminosity Wed 5/23/07
16 1.3.4.1 Tevatron Task Force Tue 3/20/07
17 1.3.4.2 Beam-beam limitations Tue 3/20/07
18 1.3.4.3 Active Beam-Beam Compensatio Wed 5/23/07
19 1.3.4.4 Increased Helix Separation Fri 3/23/07
20 1.3.4.5 Luminosity Leveling Tue 1/31/06
21 1.3.4.6 Improved Control and Diagnostic Fri 8/5/05
22 1.3.4.7 Vacuum Improvements Thu 9/1/05
23 1.3.4.8 Tevatron Alignment Tue 9/6/05
24 1.3.5 Shutdowns Fri 9/16/05
25 1.3.5.1 summer 03 Fri 10/17/03
26 1.5.2 summer 04 Fri 9/17/04
27 1.5.3 summer 05 Fri 9/16/05
28 1.5.4 IIb shutdown Fri 1/19/07
29 1.6 Operating Phases Wed 5/23/07
30 1.6.2.4 Start Phase 2 Tue 12/14/04
31 1.6.2.5 Start Phase 3 Tue 2/22/05
32 1.6.2.6 Start Phase 4 Thu 11/17/05
33 1.6.2.7 Start Phase 5 Wed 5/23/07
Start Operating Phases 2,3,4,5

APPENDIX G

ACTION ITEMS

ACTION ITEMS

Resulting from the July 21-23, 2003 Department of Energy Assessment of the Run II Luminosity Plan at the Fermilab Tevatron

Action	Responsibility	Due Date
1. Conduct mini-review	DOE/Fermilab	October 8, 2003
2. Deliver the updated Run II Luminosity Upgrade Plan to DOE	Fermilab	January 30, 2004
3. Conduct review of updated Run II Luminosity Upgrade Plan	DOE/Fermilab	February 24-26, 2004

Roger L. Dixon
R. Dixon
Beams Division Head
Fermilab

D. Lehman 7/23/03
D. Lehman
Review Chairman
Department of Energy

S. D. Holmes
S. Holmes
Associate Director for Accelerators
Fermilab

M. Procario
Program Manager
Department of Energy

Michael Witherell
M. Witherell
Director
Fermilab

Jane L. Monhart
J. Monhart
Fermi Area Office Manager
Department of Energy