Report from the TDC Review Committee

May 30, 2002

1 Introduction

The TDC Review Committee met on May 23, 2002. The charge to the committee, agenda for the meeting and members of the committee are listed as appendices to this document.

The committee was asked to review two main issues:

1. The status of the current TDC systems, spare TDCs and the new TDC order.

2. Issues associated with TDC readout time for both the Run 2a and Run 2b system.

The committee heard presentations from Myron Campbell and Tom Phillips (written communication) on the first item. We heard from Myron, Arnd Meyer, Aseet Mukherjee, Ron Moore, Peter Wilson and Harold Sanders on the second item. The committee thanks all of the speakers for their excellent presentations.

We report on these issues in the following sections.

2 Status of TDC spares and new TDCs

On the issue of the current TDC system, spare TDCs and the status of the new TDC order, we heard a presentation from Myron Campbell and a brief report from Claudio Ferretti. We received written documentation from Tom Phillips on TDC reliability.

Originally, 540 96D TDC boards were constructed, with a breakdown of 405 LVDS and 135 ECL. The first 300 of these boards had problems with plated-through vias. The remaining 240 did not show any via problems. A total of 438 boards (331 LVDS and 107 ECL) are needed in the system.

Claudio Ferretti showed the status of boards under repair at Michigan. There are a total of 55 boards under repair, 44 LVDS and 11 ECL. Of those 55 boards, 15 are at the final burn-in stage and the remaining 40 are at the repair or pulsing stage.

2.1 Current TDC Operations

With respect to the current system in operation at Fermilab and the issues of spares, our findings and recommendations are:

- The TDCs have met their technical specifications in terms of timing resolution and multi-hit performance. We recognize that the entire TDC project has been a tremendous undertaking, and the small-via problem that plagued the first lot of 96D TDC boards was an unfortunate occurrance that significantly slowed progress. The hard work from the Michigan group along with the very successful TDC task force have allowed the CDF experiment to have fully operational tracking systems over the past year.

- The reliability of the TDCs over the past year has been quite good. The observed failure rate is less than ~1 per month for the 438 boards in the system. This specifically includes the "small via" boards which had been a reliability concern, but presently show no trend towards failure. We find this very encouraging.

- The systems that utilize TDCs have continued to operate over the last year with few or no spare TDCs. Currently, the COT + hadron timing systems have 7 available spares at Fermilab (315+16 required) and the muon systems have zero spares (107 required). Although the reliability of the TDCs has been quite good over the last year, the current pool of spares is unacceptable. There are a number of TDCs in the system (~40) that have single-channel problems. (We recognize that some of these are low-level problems and/or calibration problems.) The plan was to swap these TDCs with spare units, and send the problem TDCs back to Michigan for repair. This should begin as soon as possible.

2.2 Construction of the 96E TDC

In the fall of 2000, it was agreed that 200 more TDCs would be constructed to replace many of the TDCs with bad vias. This order would be placed after all of the remaining issues with the 96D boards had been identified and solved. By January of 2001, the major issues had been resolved, and the go-ahead was given to begin construction of the new boards.

Myron presented the status of the design for the new version of the TDC board, the 96E TDC. In addition to presenting status, plans and manpower, Myron also presented a schedule for the construction of the 96E boards. The schedule he presented is reproduced here:

Table I. Schedule for construction of 96E TDC boards.

week	task
May 20	Finish design
May 27	Design review
June 3	Make changes from review
June 10	Artwork to vendor
June 17	Parts audit
July 22	First 20 boards arrive
July 29	Crate test at Michigan
August 5	Crate test at FNAL
August 12	Place order for balance of TDCs
October 7	Balance of boards arrive
October 28	Deliver boards to FNAL

On the construction of the 96E TDC board, our findings and recommendations are:

- The committee is not convinced that the schedule presented for construction of a new batch of TDC boards can be met. It is nonetheless in the collaboration's vital interest that this be expedited, and the committee offers all possible encouragement to all parties to pursue this as aggressively as possible. We note that the team assembled to perform this task over the coming months will be the same team required to alleviate the spares situation in the shorter term. We encourage a coordinated planning effort on both fronts to begin as soon as possible.

- The previous TDC review committee recommended that an extended design review take place before the 96E board is submitted for the fabrication of the first 20 boards. We concur with their recommendation. This review should occur as soon as all of the information is available and all of the relevant parties can come together.

- Although performance improvements were discussed, the committee recommends that no additional modifications, beyond the one discussed below, be incorporated into the 96E design.

  One modification has already been included based upon discussions at the review. This is a revision to allow for a potential future implementation of a "fast clear" option. If this option is successfully tested and adopted in the future, it will require an external modification (adding jumper wires) to the 96D TDC boards, in addition to the replacement of a set of PALs on both the 96D and 96E boards.

- The observed high reliability of the TDCs in the system leads us to believe that, once the existing spares are repaired and returned to Fermilab, it is unnecessary to fabricate the entire 200 board order for the 96E TDC. An order of 100 new TDCs with an appropriate split between LVDS and ECL models, in conjunction with a repaired lot of approximately 50 TDCs, would give us more than 30% spares for the entire system. Even allowing for a Run 2b addition of TDCs to the EM calorimeters, this number of TDCs would be sufficient for long-term operation of the entire system.

2.3 Summary of Current TDC Status

To summarize the current status of the TDC boards, the committee feels strongly that the two highest priorities for the TDC project are:

- **Repair existing boards with problems and promptly return them to Fermilab.**

  The timescale for producing and testing the first 96E boards is many months. Therefore, the only way to relieve the spares situation is to repair and return 96D TDCs presently at Michigan. An ongoing effort to repair and return boards to Fermilab is crucial.

- **Proceed as rapidly as possible to complete the design and submit the order for the first 20 96E boards.**

  The committee feels that 96E testing and evaluation (at Michigan, in the diagnostic crate, in a hadron TDC crate and finally in a COT crate) will take a considerable amount of time. It is important to get the first 20 boards back as soon as possible.

As a final item for TDC operations:

- The committee finds that effort, coordination and responsibility for the TDCs on site at Fermilab is significantly lacking. We recommend that the CDF Operations Department organize a group to oversee TDC operations at Fermilab. The manpower for this group should come from the collaboration. This group should oversee TDC operations at Fermilab, work with PREP and Michigan to further transfer maintenance/repair expertise to Fermilab, be responsible for the testing of the new 96E boards at Fermilab, and coordinate activities aimed at improving system performance.

3 Data Acquisition Deadtime and the COT TDCs

Much of the review focussed on the issues associated with readout time of the COT TDCs. At current luminosities, the system operates with low deadtime at the Run 2a specified readout rate of 300Hz. However the COT occupancies in the inner layers are approximately two-times higher than design, apparently due to the excess material in the SVX. Therefore, when extrapolating the current system to higher luminosities, the 300Hz readout rate can not be maintained at peak Run 2a luminosities without improvements to the system. There are several issues involved here that involve the TDC and DAQ architecture as well as higher-than-expected COT occupancy.

In Run 2b, we expect the accelerator to switch over to 132ns operation. Along with higher luminosity, there will be more bunch crossings within the intrinsic $2.016\,\mu$s time window written into the internal TDC Level 2 buffers. The Run 2b readout specification is 1kHz.
The committee believes the problem can be factored into two pieces:

a. Optimizing the existing system to maintain 300Hz readout throughout Run 2a.

b. Evaluating additional hardware improvements, if necessary, that could be implemented for Run 2b.

3.1 Run 2a

The committee commends Arnd Meyer for his work in measuring and quantifying the performance of the tracking TDC readout.
We make the following findings and recommendations:

- We are concerned with the readout time associated with the Run 2a system at the design luminosity. We recognize that the limitations of the current system arise from several effects, including the TDC and DAQ system designs and the higher than expected COT occupancy. A number of potential "non-invasive" improvements were proposed by Arnd, Myron, and Ron Moore, such as:

  - getting "TRACER SPY" mode to work
  - getting the dual-ported FIFO option to work
  - reducing DSP processing time by reducing the amount of data formatting
  - restructuring the DSP code.

  We endorse evaluating and optimizing the existing system to continue to meet the Run 2a specification of a 300Hz readout rate. The committee recognizes that the interplay between the TDC chip, DSP and readout system (MVME and TRACER/TAXI) require a "global" optimization of all of these pieces simultaneously. We believe that the structure we have recommended to oversee TDC operations can additionally serve as a forum for open communication on these issues.

3.2 Run 2b

Although the baseline for Run 2b is 132ns accelerator operation, it is also possible that the Tevatron will continue to operate with 396ns bunch spacing. For the TDC, the primary distinction between the two modes is that more of the hits at 132ns are "out-of-time" while more of the hits at 396ns are "in-time". The DSP must read and reject the out-of-time hits, so their impact is not negligible. However, the time to process in-time hits is greater than the time to process out-of-time hits.

The stated goal for the Run 2b readout system is 1kHz into Level 3. The committee recognizes that this is a specification that was finalized after the construction of the Michigan TDC.

The committee makes the following findings and recommendations:

- Taking the 1kHz readout rate as a baseline, the committee is concerned about achieving this rate for Run 2b with the existing TDC. We therefore endorse the ongoing investigation of the new TDC option based upon the work presented by Harold Sanders. Most of the work on this front has been to establish the feasibility of utilizing the Altera Stratix as a TDC. Ongoing work must include a full evaluation of the requirements of the Run 2b system, including the TDC and data acquisition system. The committee recommends establishing a steering group to evaluate the specifications and constraints for the Run 2b COT, TDC and data acquisition system.

- For the continued use of the existing TDC system for Run 2b, several options for system improvement were presented:

  - Splitting crate backplanes, either symmetrically or asymmetrically, to increase parallelism of the DAQ readout.
  - Recabling and moving modules to reduce the worst-case loadings.
  - Implementation of a "fast clear" feature on the TDCs to eliminate the need to read out all "late" hits from the 2μs digitization window of the TDC. This fix, if feasible, would eliminate the single largest component of the readout time in high-luminosity scenarios.

  These potential improvements should be investigated and documented prior to a subsequent review.

The committee feels that it is important that the development work on the new TDC continue in parallel with the improvements to the existing system.

4 Conclusion

The committee recommends that another review of this type be held in 3-4 months. This follow-up should review both progress on the 96E TDC order and ongoing work to improve system performance for both Run 2a and Run 2b.

Appendix

A Charge to the committee

The Michigan group designed and built a 96 channel VME based TDC that CDF uses for the COT and the muon systems. The present system works very well. However, we have a purchase order for 200 more TDCs that was written at a time when the operations group was quite concerned that the so called "small via" problem could get substantially worse. In fact the system has worked very reliably. Since then, we have also been informed by CDF note 5824 (Meyer, Patrick and Chlebana) that the TDCs cannot achieve the 1kHz readout specification for Run 2b. Further information can be found in the COT occupancy note CDF 5889 of Martinez, which states that the COT occupancy is higher than predicted by about a factor of two.

The collaboration is very concerned with the lack of sufficient spare TDCs for the COT and shortage of TDCs in the muon system. The collaboration has been awaiting delivery of 200 TDCs since July 2001.

Al, Jeff, Mike and Nigel

Charge:

- Review the plan for delivery of the 200 TDCs. In particular, determine the delivery schedule for the first batch of TDCs such that a "crate test" can be performed at B0. Also, determine the schedule for the delivery of the remaining order.

- Review the manpower available to perform production testing at Michigan and the full-crate test at Fermilab.

- Review the performance of the present system and evaluate the stability and reliability of the hardware for long term operations.

- Review the data associated with the statement that the TDCs are too slow for Run2b.

- Evaluate all the options for making the TDCs readout faster, such as faster DSP code, split backplanes, etc.

- Evaluate the scope of building a new TDC.

- Make a recommendation on the number of spare TDCs needed for COT and muon operations, as well as the number of extra TDCs needed for Run 2b such as recabling options and EM calorimeter timing.

- Make a prioritized list of how best to speed up the TDC readout including the new TDC option.

B Agenda for the TDC Review

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date:  Thursday, May 23, 2002
time:  8am
location:  Wilson Hall 1 East

Agenda:

 8:00- 8:30      Executive Session
 8:30- 9:15      Status of TDC Order                Myron Campbell
 9:15- 9:30      TDC Performance statistics         Tom Phillips
                   CDF Note 5971
 9:15- 9:45      TDC and DAQ readout speed          Arnd Meyer
                   CDF Note 5824
 9:45-10:00      COT operation/TDC requirements     Aseet Mukherjee
10:00-10:15      Speeding up the DSP code           Ron Moore
10:15-10:30      break
10:30-10:45      front end improvements             Peter Wilson
                 (split backplanes, recabling)
10:45-11:15      Design/performance of a new TDC    Harold Sanders
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C Members of the TDC Review Committee

– Jay Dittmann, *Fermilab*

– Bill Foster, *Fermilab*

– Tony Liss, *University of Illinois*

– Aseet Mukherjee, *Fermilab*

– Kevin Pitts (chair), *University of Illinois*

– Evelyn Thomson, *The Ohio State University*

– Rick Van Berg, *University of Pennsylvania*