Interim Report on the Run 2b Silicon Upgrades, May 2002

EXECUTIVE SUMMARY

The TRC reviewed the progress of the silicon upgrade projects during 2-hour phone conferences with each of the experiments. There are many areas of progress and we detected an increasing level of cooperation between the two collaborations. Both experiments are to be congratulated on the progress. At the same time, we believe it important to highlight areas of concern.

SVX4 ASIC
This chip is being co-developed by Fermilab, INFN Padova, and LBL. Its timely availability is essential to the success of the two upgrades and both detector groups have expressed concern. First, more complete documentation is needed to prepare the application testing. Second, during characterization and testing it will be essential to have the chip's design engineers interacting closely with the detector physicists. This may be especially difficult for the LBL designers who could be drawn to other projects. Some explicit planning, together with resource allocation, may be needed.

CDF Radiation accident
The committee is concerned that not enough has been done to understand the electrical failures of the CDF detectors. At present the only mitigating actions taken concern the operation of the machine. The failure appears to be associated with a high rate of radiation rather than the overall level. Excessive internal voltages and currents in the electronics are suggested. The failed components should be identified and mitigating design changes made. The present design appears vulnerable to fatal failure. This may be true for D0 as well as for CDF. Corrective action could be taken now with only minor impact on the schedule but it will soon be too late.

Procurement problems
The D0 schedule for operational electrical prototype staves is now limited by sensor availability, rather than the SVX4 chip. Procurement delays have led to this situation. More attention to timely procurement is needed.

Flex cables
The availability of fine-pitch flex cables has been problematic for many experiments. D0 is pursuing a promising solution but more work remains to be done. A coordinated effort by CDF and D0 on this difficult problem might be helpful.

Layer 0
The layer 0 designs of CDF and D0 have changed to exploit commonality and now use the same sensor design as the current CDF layer 00. This effort should continue in other areas such as fine pitch cables, mechanical support, and cooling.

Cooling issues
The committee has the impression that a reliable solution for the cooling pipe inside the staves has not been firmly established. This problem should be addressed with high priority, preferably in a collaborative effort by the two experiments. A realistic long term test of the stave cooling is recommended for both experiments.

I. INTRODUCTION

Following its April 2002 meeting, the Fermilab PAC asked the Director's Technical Review Committee (TRC) for an evaluation of the responses by the experiments to the earlier TRC recommendations.

In the time available it proved impossible to schedule a full TRC meeting. However, a two-hour telephone conference was held with each experiment and as many committee members as possible. The composition of the discussion groups is given in Appendix 1.

The telephone conferences included a 30 minute progress report on developments since the TRC meeting of December 2001 and a detailed discussion of the responses to the recommendations. Following the common discussion the committee continued in executive session to evaluate the progress report and responses.

II. CDF PROGRESS REPORT

Nicola Bacchetta presented 6 slides on the progress and the CDF team answered detailed questions.

Findings:
The TRC was impressed by the progress, and by the demonstrated willingness of CDF to be engaged in a dialogue with the TRC about technical issues.

Technical Concerns:

1. **SVX4 ASIC**. The TRC is concerned, and CDF agrees, that the SVX4 project is critical for the upgrade but introduces serious risks. One concern is that the SVX4 development is outside the control of the experiments. Already the schedule delay of SVX4 has delayed the first prototypes from May into late August or September. The experiments need the cooperation of the SVX4 development group in getting documentation now in order to prepare for testing, and also help after the chips arrive, to facilitate testing and debugging.
2. **Flex cables**. The TRC is concerned that so far there is no qualified vendor for the fine-pitch L0 analog flex cables. This has been a difficult problem for several other experiments and has required a large effort. The Japanese company Keycom is producing cables which almost meet the specs but

problems remain with the ability to bond to them. For the Belle experiment detailed technical discussions were needed with Keycom to improve and maintain the quality at a satisfactory level. It is recommended that CDF interact closely with Keycom. D0 is working with other vendors but they do not appear to have an acceptable product either. The committee recommends further investigation and the evaluation of alternatives. CLEO III may have used similar cables and J. Alexander could be consulted. It might be possible to use double-sided cables with larger feature size and thereby enlarge the pool of vendors. The D0 work, outlined below, could be useful for CDF.

3. **CDF Radiation Accident.** The TRC was presented with a written report on the accident but there was only very limited time for discussion. Evidence suggests that the failure may be associated with a high dose rate rather than the total dose. This could lead to high instantaneous charges and currents and hence unexpectedly large voltages across capacitances and resistances. The TRC feels that this topic needs continuing attention. The failed part should be identified in order to allow mitigation. The response to a failed chip, a failed capacitor on the detector or a failed surface mount part on the hybrid, respectively, will be different. Past experiences by TRC members (Forti with ALEPH, Sadrozinski with Laser tests) indicate that the damage has to be understood in detail, followed by mitigating design changes. For example, changes to the biasing network could change the impact of the current spike, or protection diodes across the SVX inputs might be called for if the ASICs failed. Minor design changes might mitigate the effect once it is understood but this must be achieved soon to avoid impacting the schedule. The TRC is open to a dedicated discussion with CDF and D0 to help in this question. At the same time, improved control of the beam and shielding of the detector should be pursued to reduce the probability of such accidents.

Organizational Concerns:

1. We would like to see updated schedule and costs to see how realistic they are by comparing them to the information supplied last December.
2. The experiment has received guidelines from the lab on procedures to follow for costing and scheduling, and is trying to follow them. It is important that these guidelines remain stable if a satisfactory result is to be obtained in the short time available.

III. CDF RESPONSE TO RECOMMENDATIONS

Observations:

1. Communication and cooperation between CDF and D0
   - A time slot for weekly meetings has been reserved but meetings have been suspended until recently because of the many reviews.
   - Regular discussion is encouraged.

2. Vigorous procurement strategy for the sensors
   - CDF has reduced sensor costs by 15-20%, in part by adapting the specs to constraints of the vendor.

3. Tighter tolerances on dicing of sensors to allow use of the edges for alignment
   - CDF has done a realistic analysis and concludes that the residual tolerance would impact alignment constraints from the trigger.
   - Tooling has been developed to substantially reduce the time for aligning and gluing the sensors. This mitigates the earlier concern.

4. Simplify the design and minimize the number of different parts
   - CDF has eliminated 90° stereo sensors and has adopted the same design for L1 staves as for L2-L5.
   - This will lead to a less expensive and easier to build detector with minimal impact on performance.

5. SVX4 chip development
   - This remains a serious schedule concern as noted above.
   - The experiment is fully aware of the problem and is working effectively to remove from the critical path all other elements needed for the final electrical test of prototype staves.

6. Strive for commonality between CDF and D0
   - CDF may build carbon fiber structures at the University of Washington, a D0 source for this material.

7. Analog flex cables are a serious concern
   - See comments above.

8. Take advantage of high quality production by sensor vendor and use vendor testing to minimize end-user testing
   - Being done.

9. Evaluate effect of radiation damage on spatial resolution
   - As noted above further evaluation of radiation effects is needed.
   - Optimal spatial resolution after type inversion may require a change in bias voltage.
     - There could be an impact on the design of the bias circuit.
   - Significant resources and effort are required for these tests and CDF should analyze the cost and benefits.

10. Develop a plan for partial system tests during construction
   - Tests are planned of each layer as it is completed, together with the layer immediately inside it.

11. Explore descoping options
   - Partial replacement or reuse of sensors appears to be ruled out by the schedule.
   - The impact of a reduced number of layers has been presented in the TDR.
   - Important simplifications have been achieved by dropping 90° stereo and making L1 the same as L2-L5.

12. High flow rate of the coolant could lead to sonic vibrations. Leaks could also become a problem.
   - The experiment acknowledges this and plans to test the prototype staves.
   - A long term test of cooling loops was discussed.

Conclusions:

The TRC commends CDF for the positive and constructive response. The TRC feels that the interaction has resulted in a detector which will be more robust and easier to build. A few points requiring continued attention are noted above.

III. D0 PROGRESS REPORT

Marcel Demarteau and Alice Bean presented 7 slides on the progress and the D0 team answered detailed questions.

Findings:
The TRC was impressed by the progress, and by the willingness of D0 to be engaged in a dialogue with the TRC about technical issues.

Technical Concerns:

1. **SVX4 ASIC**. Comments here are exactly the same as those given in Section II, in response to the CDF progress report
2. **Sensors**. The TRC is concerned about the procurement of silicon sensors. The purchase order for Layer 1 sensors with HPK has been placed, but delivery is only expected in September. This turns out to be the limiting factor in the construction of the first electrically functional layer 1 modules, which must therefore be built with the ELMA sensors that have not yet been fully characterized in terms of radiation sensitivity. Procurement problems (apparently internal to FNAL) have delayed the layer 2-5 sensor order, which begins to be on the critical path for the construction of stave prototypes and the testing of the stave grounding scheme. D0 has tentatively decided to use for layer 0 the same sensor design as CDF. This design is currently in use in the CDF layer 00. Thus a common purchase order should be possible. The TRC commends D0 for this decision.

3. **Flex cables**. The TRC is impressed by the level of progress of D0 in the area of fine pitch flex cables. The use of two 100μm pitch cables laminated to form an effective 50μm pitch seems promising, although the 2nd prototype run is still not completely acceptable, and final bonding tests still have to be performed. Two vendors have been identified (Dyconex and Compunetics) and further prototypes are foreseen soon. It appears that a good technical solution is close at hand and the TRC recommends that this information be shared with CDF, possibly leading to a common solution.
4. **Module and stave assembly**. The TRC is concerned about the level of advancement of the module and stave assembly procedures. Although the process has been thought through and some final drawings exist, the assembly fixtures are not yet in hand. D0 is also evaluating the possibility of using the sensor gluing fixtures developed by CDF, which speed up the assembly process by letting the glue cure on a curing block separated from the alignment jig. The delay in establishing and testing a full assembly system has an impact both on the schedule for producing the first stave and on the manpower estimates for the assembly.
5. **Cooling**. The TRC is concerned by the lack of a final solution for cooling the staves. Two solutions are currently being investigated: molded PEEK tubes or carbon fiber tubes. The PEEK solution was the choice given in the TDR but there are concerns about the mechanical stability of the small aspect ratio tubes (6x2 mm^2 with a 100μm wall thickness). On the other hand, for carbon fiber, its long term stability and leakage properties are unknown at this time. The TRC recommends that a vigorous accelerated aging testing program is pursued on cooling solutions. The TRC was not able to establish whether CDF is underestimating the problem. Again, a common effort would reduce the project risk.
6. **CDF Radiation Accident.** The TRC considers the CDF radiation accident relevant for D0 as well, although D0 has not suffered similar accidents yet, mainly because they are effectively shielded by CDF. Investigations into the failure mode and possible corrective actions should be pursued in collaboration by the two experiments.

IV. D0 RESPONSE TO RECOMMENDATIONS

1. Communication and cooperation between CDF and D0
   - As noted above a time slot for weekly meetings has been reserved but meetings have been suspended until recently because of the many reviews.
   - D0 affirmed a serious commitment to share ideas and planning, and where possible techniques and components.

2. Vigorous procurement strategy for the sensors
   - D0 now has a sensor cost of $475 per sensor compared to $675 last December. This has been achieved by dealing directly with Japan.

3. Tighter tolerances on dicing of sensors to allow use of the edges for alignment
   - D0 reiterates that they cannot achieve the tolerances needed for their trigger using edge alignment
   - They are interested in the CDF tooling as a means for accelerating the process of optical alignment and gluing of sensors.

4. Simplify the design and minimize the number of different parts
   - D0 is seriously investigating using the same sensors as CDF for L0. The procurement might be in common.
   - D0 reiterates that it would be very difficult for them to use a stave in L1, as CDF has decided to do. They argue that they have more difficult mechanical problems. They are also reluctant to accept the reduced performance from incomplete coverage in L1.

5. SVX4 chip development
   - This remains a serious schedule concern for D0 as well as for CDF.
   - Unfortunately it now appears that the schedule for full electrical tests of a stave will be limited by sensor availability rather than the SVX4.

6. Strive for commonality between CDF and D0
   - D0 reiterates that their collaborator, the University of Washington, may prepare the carbon fiber elements needed by CDF. This could be in exchange for procurement for the L0 sensors.
   - Progress is being made by D0 on the difficult fine-pitch flex cables and they are ready to interact with CDF on this.

7. Analog flex cables are a serious concern
   - See comments in D0 progress report in Section III.

8. Take advantage of good production quality and testing by sensor manufacturer to minimize end-user testing
   - Being done, following the earlier TRC recommendation. This should lead to a sizeable reduction in the sensor testing cost in the D0 budget.
   - D0 is still requesting vendor measurements of currents on each individual strip. This could impact the price and might not be necessary.

9. Evaluate effect of radiation damage on spatial resolution
   - As noted above further evaluation of radiation effects is needed.
   - Resolution tests may be done at Kansas State.

10. Develop a plan for partial system tests during construction
   - D0 has developed a testing plan which includes system tests.

11. Explore descoping options
    - Partial replacement or reuse of sensors appears to be ruled out by the schedule.
    - The impact of a reduced number of layers has been presented in the TDR and cost/benefits can be evaluated by the PAC.

12. High flow rate of the coolant could lead to sonic vibrations. Leaks could also become a problem.
    - The experiment acknowledges this and plans to test the prototype staves.
    - A long term test of cooling loops was discussed

13. Cost and schedule issues
    - The project manager reiterates that the D0 upgrade has not been designed to cost but that this would be done if requested.
    - D0 attributes the extra $4.2M for their silicon detector, compared to CDF, to extra manpower contributions from Japan and Italy to CDF which are not reflected in the cost. In addition, equipment purchases from the NSF MRI grant seem to be included in the overall cost. The TRC did not try to resolve the details but believes that the question will be asked again more aggressively by the baseline review committee.

Conclusions:

The TRC commends the D0 representatives for their positive and constructive responses during the discussion. They are knowledgeable about all aspects of the silicon project and ready to engage in constructive dialog in an effort to improve the project.

APPENDIX 1

Composition of discussion groups

1. CDF discussion, May 15, 2002

For the TRC: F. Forti, J. Pilcher, H. Sadrozinski, M. Selen, H. Tajima
For CDF: N. Bacchetta, B. Flaugher, Pat Lukens (plus Jeff Spalding and Gino Bolla for a short time)

2. D0 discussion, May 16, 2002

For the TRC: L. Bauerdick, F. Forti, J. Pilcher, H. Sadrozinski, H. Tajima
For D0: A. Bean, M. Demarteau, J. Kotcher