CDF's Response to the Technical Review Committee

The following is the response of the CDF Run IIb group to the comments of the Technical Review Committee report, issued in December 2001. We have extracted the comments and recommendations from their report, and added our answers (in italics) after each one.

<u>Technical issues</u>

1. Both proposed silicon trackers are technically sound. The groups have fully exploited the development done for the LHC experiments, producing a design employing proven techniques with minimal R&D. In addition, CDF and D0 are sharing some of the remaining R&D work on mechanical structure, sensors, hybrids, etc. The committee commends the collaboration of CDF and D0 on technical developments and considers that an increased cooperation would be beneficial.

   We agree and are making an effort to continue and/or increase the collaboration wherever possible. The main forum for discussion are weekly meetings organized by the sidet managers and silicon project leaders. An agenda has been set for the next two months (May and June) which covers items such as stave cooling development and tests, L0 design, comparison of analogue cable prototypes, bulkhead and support structure design, module building, radiation tests of epoxies, etc. Further meetings will be held as topics arise.

2. The silicon trackers envision the use of single-sided detectors with edge guard rings, which will allow safe operation in high radiation areas even after type inversion. In a meeting involving the two experiments and a sub-set of the committee, a methodology was established to assess projected radiation damage based on CDF running experience. This should supersede the overly pessimistic projections by D0.

   CDF has not modified radiation damage estimates from what was presented at the November and December meetings. Measurements of the radiation doses in the collision hall agree with the results presented in the TDR and Run IIb Working group report.

3. The acquisition of the silicon sensors is a large part of the budget. At present, other experiments are able to buy silicon sensors with specifications similar to the CDF and D0 requirements for a significantly lower price in quantities of 10,000. A very aggressive acquisition strategy is recommended, which includes the identification of cost drivers in the sensor specs, including the possibility of using thicker detectors. In addition, the sensor purchase should be coordinated between the two experiments, to obtain the lowest unit cost.

We have investigated the possibility of coordinating the sensor purchase, and found negligible benefits. We prefer not to reduce our requirements on sensor thickness since such a decision would compromise the performance of the detector. We however managed to have a significant price reduction (~15-20%) for our sensors based on some modification on the specs (depletion voltage and type of measurements required by the manufacturer).

4. Both experiments will perform ladder assembly using optical alignment of the sensors. We encourage the experiments to explore tightening the tolerance on the sensor dicing, so that sensor edges can be used for mechanical alignment of the sensors on the ladder. This would lead to faster assembly and reduced manpower requirements. This technique is currently used by other experiments. The lower cost silicon mentioned above in Item 3 was obtained with such mechanical specs.

   We have discussed the precision edge cuts with Hamamatsu. They will guarantee an edge precision of +-20um. They agreed that a precision of +-10um is possible and in fact GLAST has received sensors with a mean precision of +-6um in a sample of 15% of inspected sensors. However, Hamamatsu will not guarantee these results. They can only be obtained through inspection and selection of good parts.

   Our alignment requirements are driven by two constraints. First, our intrinsic hit resolution is of order 8 to 10 um and thus we need to reach a strip-to-strip alignment of ~2um to avoid degradation of this resolution. Second, the requirements of the Silicon vertex trigger are very tight. The specification is to have the strips aligned to the beamline to less than 100 urad. This includes all effects such as sensor to sensor, module to module, and the global alignments of the outer barrels. A module (two sensors) is ~20cm long, and thus the strips must be parallel to the beamline to 20 um (+-10um). With an edge precision of +-20um, we could end up with a 40um offset between two sensors in a module. Even if the edge cuts were +-10um, this would use the entire alignment budget.

   Since the review we have built and tested a prototype sensor to sensor gluing fixture. The results are very encouraging. Our technical staff believes that it will take roughly 1 hour/module, including the time for alignment. Use of a precision edge may speed up this process by 20-30 min., but we would still need to measure the resulting alignment of the sensors in each module.

5. In laying out their detectors both groups have made a commendable effort to simplify their design and to keep the number of different parts (HDIs, sensors, cables etc.) to a minimum. Further reduction might be possible at the cost of some performance reduction. For instance, the outer layer stave design might be used in the Layer 1 layout.

   We have adopted the above design as our baseline.

6. The cooperation of CDF and D0 on the development the 0.25μm rad-hard SVX4 ASIC should be applauded. We note, however, that the chips are not yet in hand and the project has already suffered a 4 week delay compared to the October plan. The SVX4 chip remains one of the critical items in the project.

   We agree and are fully aware of the impact the SVX4 chip has on the schedule. The first engineering run of the chip was submitted April 1. It underwent more extensive and exhaustive simulations than any other chip in earlier silicon detectors for CDF. This gives us some confidence that this first chip submission will be a success.

7. The committee encourages the CDF and D0 groups to investigate other potential areas of common development such as hybrids and staves. This could allow savings on budget, schedule, and risk. In particular the groups should consider using the same Layer 0 design.

   We are investigating such a possibility. There are however some necessary differences in the designs due to the different beampipe flanges. The D0 flange has a flange with a radius ~2mm smaller than the CDF flange. The inner radius of the L0 silicon is set to the minimum by each experiment given their flange size. Maintaining a design compatible with the existing CDF beam pipe minimizes the risks associated with the fabrication of a new beam pipe. In addition, both experiments have a design which supports L0 off of the outer barrels thus will differ due to different bulkhead designs. Due to these constraints it is unlikely that CDF and D0 can have identical L0 structures. Nonetheless the basic pieces for the two L0 detectors are the same and the U. of Wash.(on D0) has already produced some very nice prototypes. We will meeting with them in mid May to discuss their experiences and will continue to share information on all aspects of the project.

8. The cooling scheme and electrical connections seem generally sound. The analog flex cables used in Layer 0 are a source of concern, both in terms of possible noise increase and digital signal pickup, and in terms of production risks. The groups should use an established technology, a conservative layout, and contemplate multiple vendors. A collaboration of the two experiments on the acquisition would reduce the risks involved.

   We agree. CDF is working with a vendor in Japan and D0 is working with a vendor in Switzerland. We are sharing information and results so that we can quickly choose another vendor with little overhead should that become appropriate.

9. The minimization of repair and rework on the staves due to defective parts (HDIs, sensors) is crucial for the success of the project. We recommend that full QC/QA procedures are specified for all parts and that testing is limited to the crucial steps in the assembly.

   We agree and we are moving in that direction.

10. The industrial fabrication of the simple silicon sensors which both experiments plan to use has matured greatly. The quality of the sensors and the ability of manufacturers to test them result in a product which requires only minimal testing by the end user. We recommend using tight specifications on the overall leakage current, and eliminating time consuming tests of single strip currents. Similarly, the coupling capacitor, I-V and C-V curves of the sensors should be tested by the manufacturer and only spot-checked by the experiments. The total current should be measured before every integration step and coupling caps should be tested after bonding. This limitation of the testing to a few vital parameters will free up personnel for other tasks.

    We agree and that is the way we always intended to proceed.

11. Both experiments plan to use single-sided AC-coupled silicon detectors with polysilicon bias. This will allow safe operation in a high radiation environment even after type inversion. One caveat is that the position resolution may deteriorate after type inversion because intermediate strips are employed for interpolation of the position using charge division. The impact of radiation damage on resolution should be investigated with irradiated sensors. This might be done as a joint project between the two experiments.

    We certainly will investigate the resolution aspect of post-irradiated sensors for runiib as part of a broader program of measurements aimed at establishing the overall performance of our sensors after radiation damage.

<u>Budget, Schedule and Manpower</u>

1. The M&S budget estimates for the two projects appear to be sound. Unfortunately the funding profile proposed by the lab is flat, while a front-loaded budget is needed for the purchase of the big-ticket items. No obvious solution for staging part of the silicon detectors was found. Although most of the budget estimate is based on actual preliminary quotes, the groups are continuing to look for additional savings that may be possible in several items.

   With the further simplification of the design for the L1 stave, the cost reduction of the silicon sensors, and the use of only axial and small angle stereo sensors, the overall cost of the silicon project for CDF was reduced. We are further investigating the possibility of additional foreign contributions as well as other *sources of funds in within the US. However, the budget profile is still problematic and needs to be better understood.*

2. The schedule is very tight. The groups have both assembled detailed schedules, although the methods used for building the schedule and resource loading it differ. These differences make a direct comparison difficult. The groups have developed a set of detailed milestones well distributed in the project time.

   Since the review, meetings to unify the scheduling approach, resource loading, and assumptions used by the two experiments have been on-going. Progress has been made and these will continue.

3. We recommend that both experiments include in their schedules a full sector test of the final detector. This would allow an early detection of noise and other problems associated with system integration.

   We do have time allocated for the full test of the detector before and after installation.

4. The manpower estimates for the two groups are built using very different systems and differ by a large amount, both in engineering and in labor requirements. The committee recommends that the two groups reevaluate their manpower needs according to clear rules to be provided by the laboratory management, starting from the detailed schedule and clearly separating out baseline needs from contingency. The manpower estimate should properly detail as a function of time all work done inside and outside the laboratory, whether or not it is charged to the project.

   Considerable effort went in establishing common ground for labor estimate. We have now a common denomination of the labor force, a common efficiency factor and common rules for the counting. Nonetheless differences remain. These differences are mostly due to the difference in the nature and tradition of the collaborations. In CDF we have many foreign contributors to the experiment and it is difficult to apply for them the same conventions that apply for Fermilab personnel. If we reduce our comparison to Fermilab personnel the two experiments are in quite good agreement on what the needs are.

<u>Descoping options</u>

The committee examined some descoping option that might be exercised if needed:

1. Partial replacement: The groups have already examined the possibility of replacing only the inner layers and the disks of the present detector with radiation hard modules. Replacing the inner layers is very hard if not impossible mechanically. Another option would be to reuse the current staves on a new mechanical structure that would host the old staves at large radius and new ones at

small radius. This would certainly imply a much longer downtime for the experiments.

Partial replacement and/or reuse of the existing ladders is not considered to be realistic. The technical risk, added complexity of the resulting detector, and increase in down time to the experiment make such options unworkable.

2. Smaller detector: The present design can be descoped in various ways such as by removing layers, reducing acceptance, or reducing segmentation. We recommend the groups study the relative performance of the various options, in the metric of the Higgs search, before baselining the project.

   We have indeed studied the performance of the detector in light of a reduction of the number of layers. Results are in the Technical Design Report.

B. CDF Silicon upgrade

The CDF silicon tracker group presented their proposal for a completely new silicon detector for Run 2b. It represents a descoped version of the TDR version of the silicon tracker presented at the November PAC meeting. A fairly large amount of scientific justification of the proposed detector was presented. In addition, a first optimization study of the number of layers was shown, which demonstrated that the proposed layout is reasonably robust against one layer failing, but that the additional loss of an axial and stereo layer in the COT would compromise the tracking performance. This result is preliminary, but shows that the right questions are being addressed.

<u>Technical Issues</u>

1. The stave design allows considerable flexibility in configuring the detector. The staves will accept either axial, 90-degree, or small-angle stereo modules, so the decision on how to configure the detector may be taken at the time of ordering the sensors. The collaboration should carefully evaluate the benefits and risks associated with the 90-degree option since it implies double-metal sensors, unlike the small-angle stereo option.

   The 90-degree sensors have been dropped from the present design.

2. The cooling scheme and electrical connection seem to be sound. The use of the analog cables for Layer 0 was justified in an analysis of the noise performance of the present Layer 00. The cooling is done with a water-glycol mixture for the 3KW total heat load. The cooling tubes are integrated into the staves and several staves are in series. To keep the temperature rise of the coolant within 1degree C, the flow rate has to be high. This should be prototyped on live detectors to check for sonic vibration.

   This test will be performed.

3. Separate mechanical supports are foreseen for the inner layers and the rest of the detector. This is a commendable feature so that inner layers could be replaced separately if needed. On the other hand, the design of the support structure for the outer layers (L2-5) is such that replacement of a single stave is nearly impossible without extensive disassembly of the detector. The group should investigate the possibility of mounting the staves on the bulkheads without optical alignment as is done by D0. This would make possible the replacement in the clean room of a single stave.

   It is possible to replace a stave without disassembling the detector. However we still think that optical adjustment of staves is necessary in order to achieve the desired alignment. We will test the adjustment and alignment procedures in order to establish to what degree this is really needed.

<u>Budget, Schedule and Manpower</u>

1. The M&S budget was developed based on the experience with L00 because it uses similar technologies. A sizable contribution from foreign sources is expected. The funding profile proposed by the lab is flat, while a front-loaded budget is needed for the purchase of the expensive items. Foreign contributions (e.g. from Japan) may help to even this out.

   The schedule implications of the funding profiles, both U.S. and foreign, are still being studied.

2. The schedule is very tight. There is a believable set of top-level milestones indicating when the first prototype will have to be built, when construction has to start, etc. This hinges on the availability of SVX4 chips, for which two iterations of prototypes are allowed. The schedule shows production of one stave per day, and a 6 month float at the end of construction. The required manpower matches the FNAL allocation, but the simultaneous construction of silicon detectors for CDF and D0 will put a strain on the available facilities at SiDet.

   The resource loaded schedule that is being developed for the silicon detector indicates that our estimated peak labor needs at SiDet are fairly close to the guidance that has been given by the Particle Physics Division.

   The manpower budget was not developed loading the detailed schedule, but rather identifying the basic tasks during the prototyping and fabrication phase and loading these tasks with the required manpower. As such, the man-power estimate of 56 person-years represents a lower limit, since it does not include installation, and it is not fully thought out on the detailed schedule. On the other hand, the committee considers the estimate reasonable for the prototyping and fabrication activities.

A separate resource loaded schedule is being developed for the installation phase of Run IIb. The labor needed for installation will be covered there, and the estimates will be based on the recent Run IIa installation.

Descoping Options

1. The group should be commended for its effort to identify possible further descoping options. With respect to the design presented to this committee they considered dropping one layer and using the standard L2-5 stave design also for Layer 1. The former would cause some reduction in b-tagging efficiency, especially if the inner COT layers do not perform as expected. The latter would result in reduced angular coverage in Layer 1. The committee considers both options to be viable and encourages the group to perform full optimization studies.

   CDF has exercised the descoping options presented to the Technical Review Committee. We have replaced the 90° layers with axial and small angle stereo layers, and dropped a special stave design for Layer 1.