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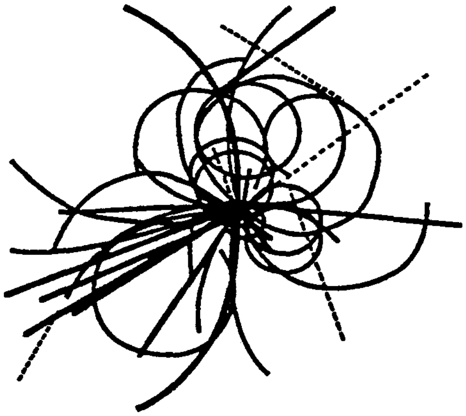
REPORT OF THE
SDC REVIEW PANEL



SSC LABORATORY

MAY 4-9, 1992

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SUMMARY

Introduction

A panel composed of members of the PAC and other experts met at the SSC Laboratory from May 4 to 9, 1992 to begin the Stage I review of the Solenoidal Detector Collaboration's (SDC's) proposed detector project. The Stage I review is to be completed during the scheduled PAC meeting, from July 10 to 15, 1992. The panel studied the Technical Design Report (TDR) and associated documents and heard presentations by members of the collaboration on the physics goals, the design, construction and expected performance of the key elements of the detector, as well as the management, cost, and schedule of the project. A list of panel members and the organization and agenda of the week-long review are given in Appendix J.

The detailed reports prepared by the subcommittees on detector subsystems and global issues are attached to this report as Appendices A through I. The subcommittee reports also outline some concerns and questions that should be addressed by the collaboration. Appendix K contains the report of a separate panel that reviewed safety aspects of the detector.

In the following sections, the main conclusions drawn from the subcommittee reports and from the deliberations of the group as a whole are summarized.

General Comments

The panel was very impressed by the broad scientific and technical base of the SDC and by the high quality of the SDC Technical Design Report. The TDR is based on a strong R&D program that has been supported in part by SSCL and the Texas National Research Laboratory Commission, together with significant support from international SDC collaborators, and carried out by the collaboration to develop new technologies and study technological choices for SSC detector subsystems. Many of the difficult choices of technologies for the various subsystems have been made and the collaboration is clearly focused on the remaining issues. The appointment of a Project Manager and soon a Project Engineer are very positive steps toward the goal of creating the SDC detector. While some important technical questions remain open at this time, the panel is convinced that the collaboration is capable of building a powerful detector and doing world class physics at the SSC when the collider begins operations.

It is the panel's consensus that the design of the detector described in the TDR is well matched to most of the physics goals stated by the SDC. However, we are seriously concerned about the lack of a credible funding plan for the TDR design. We strongly urge the SDC to examine its actual resources from the SSC project, under the previously stated guidelines, and from other institutions in the United States and abroad, and to address methods of reducing or delaying project costs.

Scientific and Technical Issues

In the following, comments and major concerns with regard to the various detector subsystems and their expected performance are given. More detailed discussions and a list of questions and concerns are presented in the summary reports by the various subcommittees.

Superconducting Solenoid Magnet

The design of the superconducting coil has some innovative features that are cause for concern:

- To minimize the material of the coil in front of the calorimeter, a rather high ratio of stored energy to cold mass is being proposed.
- The end of the coil is separated from the flux return iron, resulting in large compressive forces on the coil, which is supported by an epoxy bond between the coil and the spool.

The panel commends the proponents for building a prototype to test many of the design concepts and construction techniques.

Tracking

At the core of the tracking system is a silicon strip tracker that provides pattern recognition and b and τ vertexing. This inner tracking system is used in conjunction with an outer tracking system (straw tubes and gas microstrip detectors or scintillating fibers), which improves the momentum resolution and provides a Level 1 trigger selecting charged tracks with a minimum transverse momentum. The panel was impressed by the progress in the design of this system, but is concerned about the following issues:

- The forward-backward reach of the silicon tracker adds considerably to the complication and cost of the tracking system. It is not clear that the forward tracking system (i.e., silicon plus gas microstrip detector) has been optimized for cost and performance. The necessity for high-quality tracking in the forward region should be better justified.
- The calculated occupancies for the innermost layers of straw tubes are very high at design luminosity. The fiber system offers an attractive alternative that could, in principle, be more effective at high luminosity. Although considerable R&D must be performed before the fiber system can be considered viable, recent progress with fiber read-out has been impressive. The panel recommends that the R&D on scintillating fibers be continued.

Calorimeter

The calorimeter, which has been considerably descoped since the submission of the LoI, has a segmentation, thickness, and coverage that are appropriate for the proposed physics program. Further significant descoping would not be wise. The main concerns are:

- Some of the estimated costs of the calorimeter—such as ~ $10/kg for steel and $48 per scintillating tile—are high. A re-examination of the fabrication techniques may result in substantial cost savings and should be done.
- In the forward calorimeter, which must operate in a high radiation environment, two technologies have been proposed and the choice remains to be made.

Muon System

The physics goals of the SDC experiment require a robust and efficient muon trigger with a reasonably sharp threshold in transverse momentum. This is the driving force behind the large muon toroid system, which is among the costliest subsystems of the detector. The panel recognizes the importance of muon triggering and measurement, but also sees a potential for staging parts of this system. Concerns about the muon system include:

- The system foreseen to measure the alignment and monitor the motion of different components is complex. It is not certain that it will provide the desired level of precision. The system should be re-examined.
- The assembly and placement of the drift tube modules will be a complicated process that needs to be carefully planned in advance and monitored during assembly.
- The barrel toroid thickness of 1.5 meters may be larger than is necessary for an efficient muon trigger. A reduction of the iron thickness toward 1 meter may be feasible and would reduce the cost.

Electronics, DAQ, and Computing

A substantial amount of excellent R&D and design work has been done in the area of electronics and data acquisition, combined with detector simulations. Systems that are adequate for SDC's needs have been defined and an implementation plan has been developed. Much of the front end electronics is on the critical path of the detector assembly. The very tight schedule for the final design and construction of these systems must be maintained. We encourage the SSC Laboratory to provide strong support for this important effort.

Interaction Hall, Surface Facilities, Installation, and Safety

The interaction hall and its associated surface facilities are well planned, but given the complexity of the assembly and installation tasks, the SDC is advised to nominate a person responsible for this whole area and the planned activities.

- Procedures for detector maintenance need to be integrated into the overall design.
- Problems related to accelerator-detector interface need to be addressed in more detail.
- The installation and commissioning is linked very closely to the collider commissioning and operation, and this may result in severe scheduling conflicts.

Physics Performance, Trigger, and Detector Integration

Several subsystems (mainly in the central region) have been simulated in detail and have been found to perform as expected. Work has begun on simulating the others. At this time it appears from simulation studies that the Level 1 trigger will achieve adequate rejection. The detector should be capable of addressing most of the important physics goals of theSSC program; it is not optimized, nor should it be, to search for low-mass Higgs particles or for supersymmetric Higgs particles. Most of the subsystems have been "locally optimized"; however, a more global optimization, including the forward detector elements, may reveal possibilities for cost savings.

Collaboration Management

From its beginning the SDC has been an international scientific enterprise. Intensive R&D studies are being performed in many countries. They have been essential in refining the detector design and making choices among technologies. Throughout this difficult process, the collaboration has demonstrated the ability to make hard decisions without loss of cohesion. Collaborators whose detector options were not chosen for the final design have joined other activities. Substantial progress has been made in defining the contributions of all groups to the detector construction. International collaborators share responsibility for major components such as the superconducting coil, the muon system, the intermediate tracking detector, and the central and forward calorimeters. The large involvement of institutions from many countries is reasonably well reflected in the management structure of the collaboration, with broad representation on the Executive Board and Technical Board.

Collaboration meetings and subsystem group meetings have been held in Japan, Italy, and the United Kingdom. These meetings are an important aspect of the collaboration, bringing its members closer together. Frequent communication is a vital part of the collaborative efforts. Television and computer links have been tested and proven to be effective among institutions in the United States, Japan, and Italy. In this regard, the committee strongly endorses the request by the collaboration to install such links to other major institutions, including those in Russia and China.

Substantial contributions in intellectual as well as material support from the participating countries are essential to design, construct, and operate the proposed detector. Special requests for funds have been made in several countries. DOE and the SSCL have been assisting those collaborators in negotiations with their governments. It appears reasonable, at present, to expect that a substantial fraction of the total detector cost will be provided by countries other than the United States.

Issues of Cost, Schedule, and Resources

The TDR submitted by SDC describes a detector that is well matched to its physics goals and capable of providing a substantial and exciting research program at the SSC, commencing at accelerator turn-on. The panel reaffirms the PAC's previous recommendation for two large collider experiments at turn-on. We expect the SDC collaboration to carry out one of those experiments.

The panel appreciates the efforts of the collaboration to reduce the overall cost of the project, but is very concerned that the TDR cost estimate greatly exceeds the funds that can be identified now for this detector.

> The panel strongly urges the collaboration to examine its actual U.S. resources and those that can be reasonably anticipated from foreign countries, and present in July a plan to construct a detector within the available funds and with adequate capability to execute a strong physics research program at the start of the SSC operation.
>
> The panel discussed various methods of achieving this goal (streamlining fabrication, staging of one or more U.S.-funded components, descoping), but believes that it is the right and duty of the collaboration to perform this task.

The cost estimate presented by SDC is generally good, but detail and clarity vary from subsystem to subsystem. The schedule is well planned, but it does not permit any major delays in fabrication, installation and commissioning. The panel strongly recommends that SDC prepare a reviewable cost and schedule document that addresses engineering and manufacturing strategies, and that this document be reviewed on a uniform, line-by-line basis. The panel suggests that the SSCL assist the collaboration with additional resources to complete this task by the July PAC meeting.

If the SDC collaboration can provide a credible plan to design and build a detector for the initial stage of SSC operation that is consistent with the available resources, a positive recommendation by the PAC would be possible, and probable, in July. If such a plan is not provided, Stage I approval will likely be delayed until the entire experimental program with two major detectors can be examined. Such a delay would jeopardize the ability of the collaboration to be ready in 1999.

APPENDIX A

SUPERCONDUCTING SOLENOID

H. Desportes, D. Gross, G. Mulholland, R. Palmer, S. Smith

Introduction

The SDC solenoid magnet has been reviewed quite extensively with the co-leaders of the SDC magnet working group, Akira Yamamoto (KEK) and Robert Kephart (FNAL). They are recognized as fully competent, in view of their experience with similar magnets (e.g. TOPAZ, CDF), to carry out the task of producing the required solenoid and the associated cryogenics and instrumentation.

The solenoid characteristics are not exceptionally demanding as compared to existing, indirectly cooled, solenoid magnets of similar size and type. However, two of the particular constraints imposed on the solenoid by the SDC have led to new technical approaches that require special R&D and need to be carefully examined.

Those SDC constraints are:

1. The overall radial thickness of the winding, coil support and cryostat are limited to a radiation length of 1.2 X_0.
2. The magnet return iron, formed by the hadron end cap calorimeter plates, is quite far from the coil ends. The current design reduces the axial winding compressive force by 400 tons, but still leaves the relatively high value of 1300 tons.

The Technical Design Report meets the first of these constraints with two significant design innovations:

a. The use of a conductor whose mechanical strength is enhanced by the development of a special Zn-Al alloy stabilizing material, and

b. the use of a lightweight, structural shape, outer vacuum vessel wall of brazed honeycomb, or a ribbed structure machined from a solid aluminum plate, called "Isogrid."

The TDR meets the second of these constraints by connecting the coil to the support cylinder by epoxy bonding. The details of the method are not completely clear, except to say it uses B stage epoxy impregnated insulation and is not vacuum impregnated.

Comments

The Prototype Magnet

This effort is seen as crucially important in the development of the magnet design and construction methods. It tests the coil winding concepts of prewinding edge bending and insulation, the winding from below the source spool, the winding equipment, the *in situ* interconnections and their insulation, the structural epoxy techniques, the stack packing and modulus, and the expected performance of a significant portion of the magnet.

If the prototype magnet and prototypical winding test pieces are to serve to guide the final design, they must be completed in time to be useful. The electrical insulation and structural test windings need not include the superconductor in the zinc alloyed (or mechanical equivalent) aluminum. The subcommittee recommends that the prototype/prototypical magnet/winding schedules be accelerated as required to meet the design needs comfortably.

Coil Design

The committee sees the current high strength conductor, small radiation thickness, and high axial and hoop load coil design as sufficiently aggressive to require a similarly aggressive test program (see Prototype Magnet above.).

High Stored Energy/Unit Mass, Quench Warming

The magnet design exploits the very small low temperature expansion coefficients of the coil materials below about 75K. If a portion of the coil should go normal and the quench not propagate sufficiently fast, the local temperature differences between the support spool and the coil might rise above 75K and the thermal stresses would rise very rapidly. The performance of the quench propagation strips should be verified.

Internal and External Axial Stops

The solenoid is acted upon by large, balanced forces. A magnet fault or an iron misassembly could create a serious unbalance of these forces, easily reaching the 10's of tons. A set of internal and external stops are recommended to address this possibility.

Return Lead

The committee failed to ascertain how the return lead is handled. The concern is for the magnetic field disturbance at the beam line, the cooling of the lead, and its mechanical stability. These important details should be worked out.

Winding Method

The winding method is based on the technique developed for the TOPAZ solenoid, but significant changes necessitated by the use of the stronger, stiffer, conductor may lead to serious difficulties. The difficulties that may exist will not appear until the first trials of the coil winding method are possible. This issue is seen as one of the most crucial items of the R&D program. Particular attention must be given to the ability of the winding technique to ensure a radial prestress of the conductor against the support cylinder and sufficient axial compression, eliminating possible waviness or tilting of the conductor as it is laid in the winding.

Structural Epoxy in Highly Loaded Structures

The coil is highly loaded, 1100 - 1700 tons, depending on iron location and geometry, in the axial direction. The loading is supported by the shear in the coil-to-spool epoxy joint and the loading of the compressive modulus of the half winding. The present scheme relies on B-stage epoxy impregnated fiberglass insulation with additional epoxy injected at the joint location during winding and intermediate curing under moderate axial pressure at regular intervals as the winding progresses. The distribution of load and the ultimate stresses have been calculated assuming a 0.5-mm insulation thickness, idealized geometries and perfect bond. The subcommittee recommends that the epoxy bonding technique be carefully re-examined to make sure of its perfect integrity, and that epoxy vacuum impregnation be reconsidered as an alternative.

Cryogenics

The committee would encourage consideration of a dedicated helium refrigeration system for the SDC solenoid to assure its continued and uninterrupted operation. Other loads could find their own source of helium refrigeration.

Integration of the Solenoid in the Detector

A vital part of the solenoid is the long chimney containing all the feeding and safety circuits, both electrical and cryogenic, as well as the external components such as service port, control dewar and transfer lines. Special care must be taken to secure and protect these elements from hazardous interference with other parts of the detector. In particular, after final installation, they should never be reopened or dismounted for need of accessibility to such other parts.

The same applies to the external suspension of the solenoid from the iron structure.

Cost Estimate

The cost estimate has been fairly evaluated, though the part concerning the solenoid itself is not supported by a detailed breakdown and seems to include a high contingency. However, in view of the important R&D and prototyping effort that is needed before final design, the cost appears justified and should be sufficient.

The refrigeration power has been largely over-sized because of the uncertainties of the sharing with the VLPC operation. Even so, the cost of the refrigerator seems rather high.

Risk Reduction

Several large solenoid coils have, in the past, suffered electrical failures. Such a failure in the SDC could be very serious for two reasons. Firstly one notes that the axial forces that could be induced might cause considerable damage to components beside the coil itself. The second problem is that the time to disassemble the detector in order to replace a damaged coil is likely to be very long.

In view of the seriousness of such an occurrence, great care should be taken to avoid taking unnecessary risks. It should be noted that, in at least two previous cases, failures occured after more than a year of operation. Successful testing of a coil prior to its installation does not guarantee that problems will not develop later. In this context we recommend that:

a. A risk analysis be performed, using as data a review of previous failures.

b. A more detailed structural analysis be made of the stresses on the epoxy and coil elements in the region of ends of the solenoid. The analysis should include allowances for imperfect epoxy filling and consequent reductions in ideal Young's modulus and strength of the filling.

c. Consideration be given to increasing the insulation between the coil and ground planes.

d. The need for such a low radiation length thickness and consequent use of Zn-Al alloy be reconsidered.

e. Consideration be given to extending the central part of the end cap calorimeters into the ends of the solenoid. This would greatly reduce, and could even eliminate, the large axial forces on the end turns of the solenoid.

APPENDIX B

TRACKING

G. Bowden, M. Danilov, S. Dawson, G. Haller, P. Karchin, K. McDonald,
S. Olsen, F. Sauli, and M. Witherell

Introduction

The charged particle tracking system is a key element of the SDC detector configuration. This system is expected to provide pattern recognition, momentum resolution, vertex information, a charged-particle p_T trigger, and electron/hadron separation. It is expected to interact strongly with the other detection elements: it will be the device that provides the momentum resolution for muons, which are identified in the muon system, and comparisons of results from the charged-particle tracker with the calorimeter response will be essential for electron identification. Moreover, electrons and charged hadrons will be used to maintain the calibration of the EM and hadron calorimeters.

The current "baseline" system consists of a rather elaborate silicon-strip tracker, extending to $r \cong 40$ cm and covering the pseudorapidity range $|\eta| \leq 2.5$, in conjunction with an outer tracker consisting of straw tubes in the central region ($|\eta| \leq 1.8$) and gas micro-strip detectors in the forward region ($1.8 \leq |\eta| \leq 2.8$). The silicon system provides the pattern recognition and vertex determination. The outer system provides the Level 1 charged-particle p_T trigger and provides significant improvements over the capabilities of the silicon system alone for momentum resolution and the extrapolation of tracks to outer detector elements. A scintillating fiber system covering $|\eta| \leq 2.3$ is under consideration as an option to the baseline outer tracker.

Physics Requirements

The tracking system has been optimized for the study of the decay Higgs → 4 leptons and meets this goal admirably in the mass region $130 \text{ GeV} < M_H < 800 \text{ GeV}$. Over much of this region, the signal is unmistakable. The restrictions on the momentum resolution and the rapidity coverage imposed by the SDC on the tracking system are largely driven by the desire to observe the Higgs in this mode in the mass range between around 160 GeV and 180 GeV, where the rate is small. It is not clear, however, that a Higgs existing in this small mass region could not be observed with a somewhat more restricted rapidity range.

A strongly interacting electroweak symmetry breaking scenario may manifest itself in the $W^+W^+ \rightarrow W^+W^+$ channel. In order to observe this signal, it is necessary to determine the particle charges at 1 TeV to 1 part in 1000. Even this may not be sufficient to observe the signal. It would be nice to see the necessary simulations to justify the need for this capability.

Another physics possibility that challenges the tracking system is the measurement of forward-backward charge asymmetries for new heavy Z bosons, should they be discovered. Measurements of these asymmetries, which will be needed to determine the couplings of the new Z, place a premium on charged particle tracking in the high η region. However, the value of the inner tracker for such measurements is not demonstrated in the TDR. For these measurements, the forward muon system may be more important.

Comments

The Silicon Tracking System

Reconstructing tracks close to a collision point of the SSC will be a formidable task, for which the SDC group places a heavy reliance on a rather elaborate silicon tracking system. A considerable amount of R&D has been carried out on double-sided silicon detectors, the associated front-end electronics and the mounting, alignment and heat removal schemes. The work in each of these areas is of extremely high quality and excellent progress has been made.

Double-Sided Silicon Strip Detectors

The prototype silicon microstrip detectors produced by Hamamatsu meet nearly all the specifications of the experimenters. The silicon detector structures seem optimized for performance and satisfy the radiation damage requirements. The break-down voltages should be increased to insure reliable operation; it was reported that this is being worked on by the manufacturer.

Front-End Electronics

The overall systems concept for the silicon tracker electronics is sound and well documented. The signal from the silicon strips is conditioned by an analog, bipolar amplifier/shaper/discriminator. The hit/no-hit information is then buffered and sparsified in a custom CMOS device. Signals are transmitted via low-mass Al/Kapton ribbon cables to fiber drivers located at the outer shell of the tracker.

Work on the preamplifier chip is very impressive and appears to be going very well. Key performance parameters such as noise, time resolution and power dissipation meet or surpass the goals. Attention is being given to improving the dead-time. Calibration circuitry still has to be incorporated. Radiation resistance is satisfactory through the choice of intrinsically hard bipolar processes. Several potential vendors with suitable processes have been identified, so future production will not rely on a single source.

For the digital CMOS time-slice buffer, various schemes have been simulated and test circuits are in fabrication. A final complete circuit has still to be selected and needs to be prototyped by the end of this calendar year. The device has to be fabricated in special radiation hard technology.

The design of the module which combines detectors, electronics, and cabling looks promising and a lot of effort has gone into preventing digital crosstalk to the analog front-end. A critical test that remains to be done as soon as possible is the performance of an assembled module including cabling and cooling.

Technically the silicon tracker electronics seems well understood. The next crucial step is to use these detectors with prototype readout chips to test the operation of the proposed mounting scheme. A major concern is the schedule, which is very aggressive.

Mechanical Structure, Alignment, and Heat Removal

The proposed silicon tracking system, which occupies a cylindrical volume that is approximately 80 cm in diameter and 5 m long, is nearly 10 times bigger than previous storage ring devices. A precise and stable mounting system that locates the detector elements with 25 μm precision and maintains it at the 5-μm level is proposed. The material in the tracking volume must be minimized; the proposed scheme corresponds to 3% of a radiation length. In addition, the detectors and front-end electronics, which dissipate about 6kW of power, are to be maintained at a stable temperature of 0°C.

The proposed solution is to bond silicon wafers together into "ladders" and mount the ladders onto a space frame made from a carbon fiber-metal matrix material. Cooling is provided by evaporating butane from polystyrene wicks in a channel mounted directly to the circuitry. A holographic alignment system is being developed. We think that the design is elegant and well conceived. However, the implementation will require considerable development. In light of this fact, we deem the schedule to be quite aggressive with little room for any setbacks.

The Straw Tube Tracker

The straw-tube tracker covers the range $|\eta| \leq 1.8$, providing a Level 1 charged-track p_T trigger and improvements in momentum and track extrapolation resolution. The proposed system is an extrapolation from previous detectors. We expect that the system would work approximately as planned and could be built within the cost and schedule presented.

A major concern for the straw-tube system is the large occupancies, particularly for the inner layers. In simulation studies the probability of finding a track segment drops to about 71% at a luminosity of 3×10^{33} cm^{-2}s^{-1}. There is a concern as to whether this degradation would occur at lower luminosity under real conditions. Another concern is the possibility of vendor-dependent aging characteristics of the straws.

The Intermediate Tracker

The Intermediate Tracking System (ITS) covers $1.8 \leq |\eta| \leq 2.8$; the upper limit of 2.8 is chosen to cover the fiducial extent of the intermediate EM calorimeter. The ITS provides a Level 1 trigger with a sharp threshold turn-on at $p_T = 10$ GeV. This increases the acceptance for Higgs → $4l$ by 15% for a single lepton trigger. It also improves the resolution for extrapolating tracks to the EM calorimeter from 4 mm (silicon alone) to 0.4 mm, and improves the momentum resolution at 100 GeV from 18% (silicon alone) to 6%.

The proposed system, which is based on gas micro-strip detectors, meets the localization accuracy and rate capability requirements in the intermediate region: $100\mu m$ accuracy and rate capabilities in excess of 10^5 mm^{-2} s^{-1} (at 10 times the nominal SSC luminosity near the beam pipe). Lifetimes above 10 years at nominal luminosity have been demonstrated; more work is needed (and is in progress) to extend the limit. However, although several prototypes are under extensive testing in a dozen laboratories, only one medium-term (six-month) operation in an experiment has been reported.

The electronics appears to be in hand, but is a critical path item. It depends largely on the development of amplifiers-discriminators for silicon or for the straw chambers, but may need some modifications to cope with the readout density, incorporation of spark protection, and a Level 1 trigger structure.

There is a considerable amount of R&D effort still pending, particularly in the areas of long term stability and reliability tests, as well as for developing an optimized manufacturing technique. Several groups are cooperating on the effort, and the basic operating principles, which are very close to those for conventional wire chambers, are well understood.

Other than silicon, gas multistrip chambers are the only type of detector that can satisfy the tracking requirements in the intermediate region, and the large area to be covered (close to 100 square meters) precludes the use of silicon. Since these devices are rather new developments and there is little solid operating experience with them, a large R&D effort is planned. The R&D program seems adequate and well organized. It should provide the necessary information within a year.

The Scintillating Fiber Option

Scintillating fibers are being studied as an alternative to the baseline outer tracking system. In the system being studied, both the straw tube and gas micro-strip trackers would be replaced by a single cylindrical scintillating fiber system covering the $|\eta| \leq 2.3$ region. The proposed system would provide all of the functions of the baseline system, albeit over a somewhat more restricted η region. The fiber system is attractive because it would have lower occupancy and higher speed than the straw tube system. On the other hand, it would add more material before the calorimeter. More importantly, additional R&D is needed before the collaboration could safely decide that a scintillating fiber system is ready to be built.

The recent developments in infrared-blind Visible Light Photon Counters (VLPCs) have been very encouraging: it is reasonable to anticipate quantum efficiencies of 80% and a "reasonable" cost of ~ $25/channel. However, these devices are new and there is limited experience with them; it is not clear yet whether one could keep a large system up and running with good efficiency. The present devices have a narrow margin between operating and breakdown voltages and they have to run at cryogenic temperatures, which introduces operational complications. The existence of only one vendor makes the cost estimate and delivery schedule less reliable.

Although there is a considerable amount of R&D needed before the scintillating fiber option could be adopted by the group, the advantages are attractive and recent progress in the R&D program has been impressive. We support the continuation of this option for the outer tracking system, and encourage the collaboration to conduct a comprehensive review before deciding which system to adopt.

Summary and Questions

1. The integration of the mechanical mounting systems for the various tracking subsystems (silicon, straws, and gas microstrips) is an important part of the tracking system design and as such may require an engineer-in-charge to coordinate the effort. Since the materials used for the mechanical structure of the various subsystems are similar, it is natural to have close communication between subgroups.
2. The designs of the intermediate tracker and the forward section of the silicon tracker do not appear to be integrated and optimized. In particular, simulation of pattern recognition using information from both detectors has not been done. We recommend further work in this area.
3. In the baseline design, the resolution of the tracking degrades significantly in the $|\eta| > 2.3$ region, and the silicon tracker only covers the region out to $|\eta| = 2.5$. With the fiber option, the $2.3 \leq |\eta| \leq 2.8$ region has no outer tracking. The collaboration should study and document the relative physics performance of the two configurations.

APPENDIX C

CALORIMETER

M. Albrow, H. Hoffmann, S. Iwata, F. Pauss, J. Pilcher, J. Sandweiss,
R. Schindler, F. Takasaki

Overview

The subcommittee heard 14 scheduled talks, plus 4 talks added at short notice on topics of special interest to the subcommittee. The proponents were professional and forthright throughout the review and the subcommittee wishes to acknowledge their full cooperation.

The proposed calorimeter is of a sound, relatively low risk design with realistic performance goals. While the expected performance is good and well suited to the physics, it is in no way excessive. On balance, the subcommittee feels it would be unwise to further reduce the capabilities of the calorimeter. These issues are discussed in the sections below.

Physics Issues

The proposed calorimeter (central and forward), including the shower-maximum detector and massless gap, appear to be adequate to address almost all the physics topics considered by the proponents.

One area of concern is the ability to detect a light Higgs in the $\gamma\gamma$ channel even when accompanied by a prompt lepton from associated $t\bar{t}$ or W production. Additional potentially serious backgrounds to this process have been indicated to the proponents and will be considered by them.

Possible physics signals, as well as backgrounds contributing to other processes, from τ decays have not yet been investigated in sufficient detail to judge their impact on the design considerations.

The detector has good potential for missing energy signatures because of its design with minimal cracks and little inert material. The forward calorimeter is an important ingredient in this capability.

Technical Components

EM Calorimeter

The EM calorimeter in the barrel and endcaps consists of 10, 368 towers of size $\Delta\eta \times \Delta\phi = 0.05 \times 0.05$. The degree of segmentation is justified, in part, by considerations of shower size and the desire to identify high p_T Z decays to e^+e^-. The segmentation is coarser than that of several existing large detectors but, nevertheless, appears adequate for the physics. The proposed energy resolution is $\sigma_E/E_T = 14\%/\sqrt{E_T} \oplus 1\%$ and this appears feasible.

Each tower is constructed with 30 scintillating tiles read out by individual wavelength shifting fibers. The light output from the fibers is equalized by a mask placed in front of the common phototube. In the barrel region, a single phototube is used, while two depth segmentations are planned for the endcap. A similar segmentation could be implemented in the barrel as a later upgrade. Two cast-lead prototype calorimeter modules have been constructed and tested. The design of the EM calorimeter appears to be fairly well developed.

Hadron Calorimeter

The hadron calorimeter consists of 3, 328 towers of size $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$, covering the region $|\eta| < 3$. The expected energy resolution is $\sigma_E/E_T = 60\%/\sqrt{E_T} \oplus 4\%$ for single pions, with a smaller constant term for jets. The calorimeter is constructed with two depth segmentations and has a total thickness of 10.2 interaction lengths at normal incidence.

Detailed test beam studies of calorimetry issues have been performed and a prototype hadron section has been built. It appears that further development of the design is needed to minimize costs. The design must also ensure adequate rigidity of the iron which forms the flux return for the magnet. The performance figures of the hadron calorimeter appear feasible and there would be little cost savings by modest reductions in granularity.

Forward Calorimeter

This device covers the interval $3 < |\eta| < 6$ and is necessary for adequate missing energy resolution. Only modest resolution and granularity are needed ($\sigma_E/E_T \cong 100\%/\sqrt{E_T} \oplus 8\%$, $\Delta\eta \times \Delta\phi \cong 0.2 \times 0.2$).

The radiation levels encountered by the forward calorimeter impose special design constraints. Two possible detector technologies have been proposed and are being compared.

Shower Maximum and Massless Gap Detectors

The shower maximum detector is located at a depth of $\sim 6\ X_0$ in the EM calorimeter and consists of two orthogonal layers of 1.2-cm-wide scintillator strips. It is used for an accurate measurement of transverse shower position and to provide some π^0/γ discrimination. The need for robust electron identification in the difficult and uncertain background conditions at SSC underlines the importance of the device.

The proposed design is simple and conservative but the segmentation remains to be optimized, especially as a function of η. R&D is still underway for the readout device and it may be appropriate to delay the choice to profit from these developments.

The massless gap is a single tile at the front of each EM calorimeter tower which is read out separately. This device also contributes to electron identification. The proponents might consider ganging several tiles in each tower to improve the performance.

Calibration and Monitoring

Calibration is performed by three methods. First, a test beam calibration is planned for between 5% and 25% of the modules. This will provide an absolute calibration which can be tracked and applied to the rest of the calorimeter using a system of radioactive sources. A set of source tubes is built into the calorimeter and radioactive sources would be passed through the tubes to illuminate all tiles and towers in the calorimeter. The photomultiplier tubes will be equipped with current monitors so the response from each tile can be monitored. Experience with CDF shows that a source calibration reproducibility of 0.6% can be obtained and that the inferred absolute calibration is good to about 3%. Work is in progress to understand and improve this figure. Finally, an *in situ* tower-to-tower calibration will be carried out using isolated electrons from W and Z decay.

With the detector closed on the beam line, each tower and some fraction of the tiles can be reached with the source tubes. To reach all tiles the end caps must be opened.

This calibration and monitoring system appears reasonable and should work well. The collaboration is aware that careful design and implementation will be needed for effective operation of the source/tube system. We support the on going efforts of the collaboration to improve the performance of the source/tube calibration system.

Mechanical Integration

The collaboration has chosen a largely modular design for the barrel calorimeter elements. This will facilitate parallel fabrication and testing, as demonstrated for several other large calorimeters. It will also reduce the schedule risk associated with the construction. The broad distribution of component and module fabrication will require significant and centralized engineering coordination. This is being developed at Fermilab but only an abbreviated form of the organization is now in place. Aggressive engineering will be necessary to reduce the radiator structure costs, which appear high at present.

Quality control will be very important at all stages of construction. Special attention should be given to planning for mass production methods which could lower the cost. The unit cost of $48/tile appears to be high.

Special support will be needed at SSCL during the final mounting stage. Modules will have to be checked and repaired prior to mounting. Once assembled, the detector offers reasonable access to the photomultilier tubes and the front-end electronics.

Radiation Damage

Extensive radiation damage tests have been performed on construction materials and on assemblies of complete modules. It is concluded that the barrel calorimeter can be used for 100 years at design luminosity. Radiation in the forward directions is more severe and the central parts of the end caps will need replacement with a frequency of a few years. They have been engineered to permit this change. Recent developments in understanding the light loss associated with radiation damage appear promising. It may be possible to incorporate improved materials in the central end caps at a later date.

The level of radiation damage will be monitored with the source calibration system and the effect of modest light loss in some tiles of a tower can be compensated by replacing the masks in front of the photomultipliers.

Electronics

Front-end electronics represent less than 10% of the total calorimeter cost; nevertheless, the requirements are demanding. A dynamic range of 2×10^5 is sought; also, the signal from every channel must be stored from each beam crossing until the trigger signal is available. The capability of achieving this dynamic range is claimed but is so far undemonstrated. Careful systems tests will be needed to show that the dynamic range has been achieved.

Conclusions

The design of the calorimeter is well worked out and prototypes have been built. Further attention is needed to refine the design to minimize production costs.

The performance levels claimed are realistic and should be achievable. Because of the challenging physics goals and difficult experimental environment at the SSC, we believe it would be unwise to reduce the granularity further or to degrade the resolution of the calorimeter.

APPENDIX D

MUON SYSTEM

U. Becker, R. Bell, U. Dosselli, J.D. Jackson, T. Kamae, W. Marciano

Overall Assessment

The muon system is used to trigger the detector on a single muon above some p_T threshold (20-40 GeV), identify a charged track as a muon, and provide a muon momentum measurement.

The external toroid and its detection system, complementing the solenoidal magnet and its internal tracker, represent a robust muon detector with great physics potential. The muon system covers a wide rapidity interval ($|\eta| < 2.5$) with a minimum percentage of inactive gaps (< 5%) and allows independent momentum measurement to reasonable accuracy. The proposed configuration of toroids with redundant drift tube layers is expected to give a reliable muon trigger in a hostile environment.

The toroid thickness, the redundancy in coordinate measurement, and the scintillation counter array all appear to be driven by the desire for a reliable Level 1 trigger for muons. Once this requirement is met, the system will be able to distinguish the muon charge up to the maximum momentum (~3 TeV) and survive to higher luminosity ($L > 10^{33}$ cm^{-2} s^{-1}).

Physics Issues

The detector design described in the TDR appears to be capable of investigating a number of interesting physics processes. In the following, the designed detector's capability is described for several important searches:

$H^o \rightarrow e^+e^- \mu^+\mu^-, \ \mu^+\mu^- \mu^+\mu^-$

For intermediate mass Higgs (approximately 130 - 400 GeV), we expect a better mass resolution for $\mu^+\mu\ \mu^+\mu^-$ than for $e^+e^-\ e^+e^-$. The momentum resolution is, however, not very crucial because the kinematical constraint ($Z^0 \rightarrow \mu^+ \mu^-$) allows one to recalibrate the muon momentum. Poor muon identification, on the other hand, will increase background from $gg \rightarrow t\ \bar{t}$.

$Z' \rightarrow \mu^+ \mu^-$

If we assume that the lower bound for the Z′ mass is around 350 GeV, the mass resolution is expected to be better in the e^+e^- channel. Detection in the $\mu^+\mu^-$ decay will nevertheless provide a very important confirmation of discovery. The forward muon system will also play an essential role in studying the forward/backward asymmetry in this channel and thus help determine the couplings of such a particle.

Top Quark Decays

Identification of muons associated with jets will be important for detecting t → H^+ b and studying standard model top decays. Such events will be triggered by requiring one top in a $t\bar{t}$ event to decay via $t \rightarrow b\ W \rightarrow b\ l\ \nu$ with lepton $p_T > 40$ GeV and $|\eta| < 2.5$.

Gluino + Gluino → $\mu^\pm \mu^\pm$ + 4 jets

Ability to trigger on a high momentum muon ($p_T > 20$ GeV) will be important for discovering or confirming supersymmetry in this channel. It will also allow measurement of the gluino mass. That mode allows discovery of supersymmetry over the gluino mass range ~180 GeV to ~2 TeV.

The inclusion of a high quality muon system is justified by the above physics capabilities and the redundancy it provides for the other detector subsystems. Such a system will be a valuable component throughout the detector lifetime and gain further importance should one of the other systems fail or a higher luminosity upgrade be achieved.

Selection and Implementation of Technology

The proposed detector components are based on well-tested technology and appear adequate to meet the major SSC physics goals. The design given in the TDR is an outcome of R&D efforts on several design choices. The following comments are intended to discuss briefly the major components.

Toroids

The barrel toroid is on the critical path of the entire detector. Efforts should be made to secure its procurement as soon as possible. The fabrication and assembly plans for this toroid are well conceived. The subcommittee can see no reason, other than final determination of the toroid thickness, for not proceeding with an expeditious procurement. The 1.5-m thickness was chosen for triggering reasons; however, the study to justify this choice was made in comparison with a thickness of 1 m. Some intermediate thickness may prove to give acceptable results with potential savings. Should the decision be made to decrease the thickness, the engineering of the joint design of the bolted blocks should be reviewed, particularly with regard to the seismic safety codes.

The fabrication of toroid blocks abroad will require a good QA/QC program in place at the time of contract placement. Frequent on-site inspection will be necessary to ensure iron and fabrication quality. Furthermore, packaging for shipment must be controlled to ensure the same quality when the toroid blocks arrive at the site.

The proposed barrel-toroid support system is complex and costly: $7.3M ($4M for the jacks alone). In light of its infrequent use, the collaboration is encouraged to investigate less costly approaches.

Drift tubes

The design allows easy production and good two-track separation (~5 mm). The projective geometry is implemented simply by adjusting the orientation of drift tubes.

The assembly of modules out of these tubes will require substantial care and manpower. The design will sacrifice some accuracy in the overall alignment or add complexity in the alignment procedure. The subcommittee believes that the outer modules can be aligned to an accuracy needed for the Level 1 trigger.

Robustness is an important feature of the muon system. In this regard the BW1 module may need additional redundancy, e.g., doubling the layer number and reducing the tube diameter. All components must function for more than 15 years. The wire crimping in the drift tubes, for example, will need extra care.

Scintillator

This is well-proven technology and adequate for the Level 1 trigger. Due to financial constraints, the collaboration proposes to use low-light-yield material. In view of the fact that the component must survive for 15 years, mass production of the scintillator must be carefully controlled to assure long-term stability.

Alignment

Due to the complexity of the tube arrangement, the system requires careful alignment and monitoring throughout installation and operation. The proposed scheme appears to be an "afterthought" and probably needs rethinking. The subcommittee urges the collaboration to develop module fabrication strategies for internal alignment, to set priorities as to where alignment is most critical, and to secure an optimized, redundant monitoring scheme.

Calibration and monitoring

At present no specific plan is given by the collaboration. The committee urges the collaboration to design a workable scheme and integrate it into the system.

Forward Muon System

The design choice has not yet been made.

The forward muon system extends the muon coverage and improves the forward muon momentum resolution. Those features are useful for $H \to e^+e^- \mu^+\mu^-$ and $H \to \mu^+\mu^- \mu^+\mu^-$ as well as for Z' discovery and investigation (via forward-backward asymmetries).

The committee examined the possibility of staging the forward muon system as a temporary cost saving measure. Such a scenario would compromise somewhat the physics capabilities of the SDC detector during the first few years of operation. Of more concern may be the disruption of a later installation, unless in concert with upgrades of other sub-systems. The potential cost savings are limited by the fact that Russian collaborators are responsible for this part of the detector.

Fabrication, Assembly, and Installation Schedules

The fabrication and assembly plans for both the toroids and the muon detection system are reasonably well thought out. The stated fabrication costs of the toroid iron, both barrel and forward, are considered low by the committee. Much of this discrepancy can be attributed to an ambitious machining and assembly plan presented in the cost backup.

There is a clear need for more assembly and storage space. Consideration should be given to rental of this additional space locally. However, assurance should be made that transportation from the rental area to the site is possible.

The production of the prototype supertower will provide indications of the validity of the proposed assembly techniques as well as the adequacy of the costs.

The installation schedule is very aggressive and probably unrealizable unless a two-shift operation is planned from the beginning.

Assessment of R&D Efforts, Prototyping, Tests in Beams

The technology used is reasonably conventional and hence not much R&D work is needed.

Prototyping is, on the contrary, a crucial item: The collaboration plans to build a supermodule in the fall of 1992. This will be very important in verifying the overall mechanical stability and positioning accuracy, stability of scintillator, and reliability of the triggering scheme. Prototyping should also be pursued on alignment hardware and trigger electronics.

Not many beam tests will be needed; a normal cosmic ray test will probably be sufficient for most of the work. Beams may be needed to test trigger electronics, for a full check of the electronics, and for a real measurement of the double track resolution. Such beam tests will also give data for a realistic track reconstruction scheme.

Human Resources, Institutional Responsibilities, Management

The TDR is not explicit about human resources, the responsibilities of individual institutions, or the management structure. From the presentations, it appears that there are more than adequate human resources. The subcommittee was favorably impressed by the competence and commitment of the group. Detailed assignment of responsibilities to institutions has only occurred for the toroidal magnets, the scintillation counters, and the forward muon system. They are to be fabricated in Russia, with the Serpukhov group responsible. Magnet sections will be shipped to SSCL for toroid assembly. The drift tubes in the barrel region are to be fabricated at half a dozen institutions in the United States and Japan, and shipped to SSCL for assembly into modules. Electronics development is to be done jointly in Japan and the United States. To implement the schedule, the various commitments, both U.S. and non-U.S., should be formalized as soon as possible.

While the formal management organization of the muon system is just coming into being, some key elements are already in place. A project manager and a project engineer have been designated and are in residence at SSCL much of the time. Engineering support for the magnet design seems good. A tentative management organization chart was presented, demonstrating a commitment to, if not yet the achievement of, an effective organization with tight quality assurance.

Potential Risks

The long term inaccessibility of the tubes in the supermodules (over 15 years from the time of installation) requires high reliability of the wires. To minimize the risk of slippage (breaking is rare) double attachment (glue + crimp,...) is advisable.

The bolted assembly of the central toroid contains many machined parts necessitating quality control (magnetic properties included) as well as shipment from abroad. The toroid is on the critical path; therefore tight procurement is indicated.

Alignment still needs to be worked out. The stated overall accuracy (~150 μm) may be hard to attain. It is urgent to identify the areas where such accuracy is required and to design a realizable alignment scheme.

Design for the forward muon system is not yet complete. Closer collaboration may be needed among the responsible parties to finalize the drift tube design and the triggering scheme in this part of the muon system. The trigger rate in the forward region is the least well known. Should it turn out to be much higher than 10 kHz, triggering on forward muons may become difficult.

The assembly, storage, and test of modules may require more manpower. Insufficient suitable space would add a problem of transport and logistics.

Questions:

1. What are the cost savings for an intermediate size barrel toroid with thickness between 1.0 and 1.5 m? What are the risks and physics capability losses of such a reduction?
2. What problems would result from staging parts of the muon system as a temporary cost-saving measure? How much physics capability would be lost? How much disruption and cost would a later installation entail?
3. How will the collaboration deal with the anticipated shortage of assembly space for the muon system?
4. What is the alignment accuracy needed for the Level 1 trigger to function properly? The subcommittee was not convinced that the proposed alignment scheme works for all detector modules. Which modules would need highest alignment accuracy? How would some redundancy be incorporated in the alignment of these modules?

APPENDIX E

ELECTRONICS, DAQ, AND COMPUTING

M. Breidenbach, F. Dydak, W. Haynes, R. Pordes, T. Schalk, W. Sippach, M. Zeller

Introduction

The electronics and data acquisition (DAQ) systems for the SDC detector must have capabilities to address event rates, event complexities, and data volumes far in excess of what has been encountered in the past. The beam crossing rate of 60 MHz and the luminosity of 10^{33} cm^{-2} s^{-1} will yield a rate of ~10^8 events per second. The design goal of the SDC collaboration is to reduce that rate to 10 to 100 events per second for final archiving. The final event size will be as large as 1 Mbyte, and so for an SSC run of 10^7 seconds (an SSC running year) as many as 10^{15} bytes of data will be recorded.

The data acquisition involves front end electronics to amplify, digitize, and temporarily store low level signals from the ~10^7 detector elements, a trigger system to select events with predetermined characteristics, and a computer system with sufficient power and speed to analyse these events at a useful rate.

The Electronics/DAQ/Computing subcommittee had the task of evaluating the SDC data handling system. The system divides into rather natural subsystems. We present our analysis of each below, and conclude with a discussion of management issues.

Level 1 and 2 triggers:

The Level 1 trigger employs a subset of the detector elements to select 10^{-3} - 10^{-4} of the initial events. Using the calorimeters and shower maximum detectors, it selects high E_T electrons, photons, and hadrons and jets; with the outer muon chambers it selects high p_T muons; and by summing the energy observed in towers throughout the detector, it selects events with missing E_T. Events were simulated, including effects of multiple interactions within a beam crossing and the full luminosity with 60 MHz of beam crossings. From these simulations, rejection ratios and efficiencies of the triggers were determined.

- The algorithms for the Level 1 trigger appear reasonable, and their implementation using the hardware described is feasible. We note that there is wide use of application specific integrated circuits (ASIC's) throughout the electronics systems. These chips require design and prototyping that in most cases has not yet been done. We assume these ASIC's will be successfully implemented, but the progress of their development should be monitored. The interfacing of ASIC's with commercial hardware may also prove problematical.
- The upstairs location for the triggers is a desired feature. The fiber optic data paths provide a reliable means of implementation of this scheme, albeit with a ~2 μsec delay overhead.

- The Level 2 trigger is vague at this time. Simulations are just beginning, so the rejection ratios presented to us should only be viewed as targets. The subcommittee feels that this is not inappropriate, since the collaboration has been concentrating on the more urgently needed Level 1 trigger.
- The Level 3 trigger is to be implemented through a farm of commercially manufactured on-line processors. It will have the capability of full event reconstruction, and is specified to be capable of reducing 1000 Hz of input data to 100-10 Hz. The design is only schematic at this time; we were unable to assess the effectiveness of the trigger.

Front end electronics

The subcommittee was impressed with the engineering work that has gone into the design of the front end electronics for the silicon and straw tube trackers. Because of suitable response characteristics and natural radiation hardness, bipolar technology for the amplifier/shaper/discriminator (ASD) circuits is a good choice. The collaboration has established good relationships with foundries for production of these chips.

For straw tubes, time memory cells are designed with a clever algorithm, and prototypes for the 1 μs chip are promising. A 4 μs chip has yet to be designed. The data collection chip is not yet designed. Spark protection for the ASD has not yet been included; it may degrade the noise characteristics of the chip. The heat load for the electronics is substantial; two designs for cooling were presented, neither is yet thoroughly understood.

The fiber tracker option employs visual light photon counters (VLPCs). While the fiber tracker has advantages, especially at high luminosities, the VLPC technology is not yet well understood. More R&D will have to be done before these devices can be accepted for use in the SDC detector.

The digital PMT concept for calorimeter readout is very attractive. While the DC tests look good, the technique has not yet been proven in an integrated system with PMT signals. We viewed this approach as more speculative than the switched capacitor arrays (SCAs), but felt that R&D in this area should be encouraged. We had reasonable confidence that the SCA concept will work; however, we were less certain about systematic effects in an integrated system.

R&D continues on the shower maximum photodetectors. The collaboration does not yet have a solution; the subcommittee did not have sufficient time to evaluate how close they were to one. The readout will be SCA or digital PMT with a less demanding dynamic range.

The gas microstrip detectors have less demanding requirements on the front end electronics than the silicon detectors. The CMOS ASIC's for time stamp/ data buffers, sparse readout, and differential drivers are still in a design stage. We were not convinced that the forward trigger using these devices will be as effective as the collaboration anticipates.

DAQ and On-Line Computing overview

- The overall architecture for the DAQ system is conservative; the subcommittee believes the goals of the DAQ system can be met.
- The collaboration is utilizing the tools of DAQ simulation to good advantage.
- The collaboration understands the need for standardization of hardware and software protocols; these features are not yet established.
- The milestones are reasonable, but technical choices must be made in the next 12-18 months.
- Bus selection is beginning. The collaboration should be encouraged to thoroughly investigate their options. Since the nature of the standard bus will affect many aspects of the overall electronics design and DAQ system architecture, the group should make its decision as quickly as possible.

Off-line Computing

(N.B. None of the off-line computing costs are in the baseline budget.)

The off-line group has identified the correct set of issues and is attacking them in a reasonable way.

The schedule for acquiring hardware and producing software is reasonable.

The core software is to be written by professional programmers through the SSCL. The subcommittee applauds this approach. Sufficient manpower resources are not yet available at SSCL, but must be made available if the core software is to be written by the scheduled date of the end of 1994.

The group is contemplating regional off-line centers which will be funded outside of the SSC budget. We support the regional center concept for foreign collaborators and note that for this to work, the associated networking will need strong DOE support.

Management

The subcommittee was concerned with the method of decision-making in the electronics/DAQ group, since several technical choices must be made in the not too distant future. The group is in transition from one which writes proposals and does subsystem designs to one which must build an integrated system. A management structure with welldefined responsibilities and lines of authority is being formed. We were assured that this would be done during 1992; we encourage the group to put this structure in place as soon as possible.

The relationship between the SSC research division electronics group and the SDC is understood neither by the collaboration nor by the subcommittee. We urge that this be clarified in the near future.

Summary

- A substantial amount of R&D has been completed. The group has defined the system and basically knows how to build it. The collaboration should be complimented for the work done thus far.
- The work on electronics and DAQ now is entering the phase of system integration, making final choices between technologies, and (all too soon) construction of the system. For this reason the collaboration should give high priority to establishing the new management structure.
- Much of the front end electronics is in the critical path of the detector assembly. The schedules laid out by the collaboration are extremely tight, allowing little room for mid-course corrections. They must be adhered to if the goal of being on-line in 1999 is to be met. We encourage the laboratory to support this effort strongly.
- The subcommittee feels that there are no substantive issues that need resolution for the July meeting. Those concerns which we have pointed out will be addressed on their own time scales.

APPENDIX F

INTERACTION HALL, SURFACE FACILITIES, INSTALLATION, AND SAFETY

R. Bell, H. Desportes, F. Dydak, H. Hoffmann, K. McDonald

Interaction Hall

The SDC interaction hall, to be located at IR 8, will be deep (~ 50 m) underground on the east side of the SSCL ring near the town of Palmer. With an area of 105 m x 29 m, it is serviced by two 100-ton cranes at pit level. Two large service shafts permit sub-assemblies constructed on the surface to be lowered into the hall for installation in the detector. Additional shafts are provided for utilities, data acquisition, and personnel access.

Overall Assessment

This hall is similar to, though larger than those presently used at LEP. The size is driven primarily by the amount of assembly work to be done at pit level. Though not thought to be excessive, the size is well tailored to the needs of the SDC detector. This is particularly true when the forward toroids are withdrawn from the barrel for servicing the internal components of the detector. Under this condition, close to 100% of the floor space is utilized. The number of shafts connecting the hall to the surface for utilities and personnel access was considered to be adequate. The needs of the SDC detector as detailed in SCT 000001 Rev. E appear to be well addressed by the present hall design.

Surface Facilities

The surface facilities consist of an assembly building, a utility building, a detector operations building, and two headhouses located above one of the installation shafts and above the personnel access shaft.

Overall Assessment

In general, the location and the size of the buildings are adequate for the SDC needs. The assembly building, a multipurpose building, will serve concurrently as an assembly and storage area for the muon chambers, an assembly area for the central calorimeter, and an assembly and clean room for the silicon and straw trackers. It will also provide offices for staff who will be resident at the site. It was shown that the area assigned in this building to the assembly and storage of the muon system will be inadequate during the latter portion of the muon assembly process. Potential solutions to this problem are the rental of space in the local area or an expansion of the storage area on the south side of the building. Either solution was considered possible at modest cost to the SDC.

The location of the muon chamber alignment and test stand presents a potential problem. As shown, it would be immediately adjacent to a roll-up door on the east end of the building. The alignment of these chambers is critical. Temperature variations caused by traffic through the door could cause distortions and alignment problems. Relocation of this area to an area that is more central in the building and could be isolated and temperature-controlled is recommended.

During the SDC assembly, the peak population at the detector site is expected to reach 350 people. This includes personnel in the surface buildings and in the underground hall. Parking at the site is limited and will probably present a problem.

After the assembly of the SDC, consideration should be given to converting the high bay of the assembly building into a local shop. The storage areas could be converted into offices for users.

The utility building, the detector operations building, and the two headhouses all appear to well designed and suited to the needs of the SDC.

Installation

Considering the stage of the SDC project, the installation planning is well advanced. The presentation made to the subcommittee covered the entire installation process from delivery of each subsystem to "Top of Hole" to the completed detector in the interaction hall.

Overall Assessment

The installation scenario presented was credible. The schedule presented with it is generous and could be compressed. For example, the three months allocated for magnetic measurements could be shortened to one month. The subcommittee felt that the schedule should be expanded to include cabling, gas system hook-ups, and subsystem checkout to show areas of potential conflicts.

Once installed, the forward toroids make access to the inner components of the detector difficult and time consuming. Because of this, late delivery of the internal components would have serious schedule impacts. Careful attention must be paid to the scheduling of these components to avoid this problem.

Similarly, the time slots allocated for the installation of the muon chambers are chamber-specific. If a particular chamber is not ready when its time slot occurs, one of two things could happen. The chamber could not be installed or the schedule could be delayed, awaiting the particular chamber. If the chamber is not installed, it can be installed at a later date, but only with great difficulty and expense. To guard against this eventuality, the production schedules for the muon chambers must be closely correlated with the installation schedule.

The subcommittee felt that the following should be pointed out:

- The silicon tracker is non-serviceable in-situ;
- BW1 is also non-serviceable in-situ;
- The straw tracker is only semi-serviceable.

These facts place a very high premium on the reliability of these systems.

Because of the complexity of the problem and the many system interfaces, the collaboration is encouraged to appoint an installation manager at an early date.

Safety

An impressive amount of work has been done. A draft Conceptual Safety Analysis Report (CSAR) for SDC was reviewed by a panel of experts on April 23 and 24, 1992. A summary of that report was presented to the subcommittee, and the full report is attached as Appendix K.

Overall Assessment

The subcommittee believes that the SDC has in place a system and an organization which are capable of identifying hazards, assessing their magnitude, and proposing appropriate mitigating measures. We were impressed with the depth and level of detail of the analysis which has been performed to date. The PRD and the SDC should be commended for having on board an ES&H manager at this early date.

The issue of beam loss and beam collimation with subsequent damage to the silicon tracker, the calorimeter, or other detector elements was discussed. The SDC is encouraged to resolve this issue together with the SSC machine group.

General Concerns

Issues of detector servicability and maintenance should be addressed in more detail.

The silicon tracker/calorimeter radiation damage issue should be resolved through a collaborative effort by SDC and SSCL accelerator physicists.

APPENDIX G

PHYSICS PERFORMANCE ,TRIGGER, INTEGRATION, AND OPTIMIZATION

S. Dawson, U. Dosselli, S. Iwata, F. Pauss, S. Smith , M. Witherell, M. Zeller

Introduction

The subcommittee was asked to evaluate the physics performance capability of the SDC detector as configured in the TDR, to review plans for the trigger, and to comment on optimization of the detector to meet physics goals and financial constraints. We heard presentations from members of the collaboration on tracking, trigger, simulation, electron identification, calorimetry, and muon detection. Most of these subsystems had been reviewed earlier in the week by other subcommittees with respect to technical designs, progress, and schedules. We focused instead on the scopes of the subsystems, how they were determined, and whether their capabilities and relative emphases were appropriate.

Physics Capability

Ability to detect the SM Higgs particle serves as a an excellent benchmark for evaluating the SDC detector's performance, because the requirements to detect the Higgs encompass those for many other high-p_T phenomena expected in the standard model or in extensions of it. The subcommittee concluded that the detector was well designed to discover a Higgs particle via the decay mode $H^0 \rightarrow ZZ^{(*)} \rightarrow$ 4 charged leptons, or $H^0 \rightarrow ZZ \rightarrow l^+ l \bar{\nu} \bar{\nu}$. The mode $H^0 \rightarrow WW \rightarrow l^{\pm} \nu jj$ should also be accessible, provided that the forward jet tag works and the dijet mass resolution is adequate.

On the other hand, the detector is not optimized to detect a low mass Higgs ($80 < m_H < 130$ GeV) through its decay to $\gamma\gamma$, even for production processes such as W H or $t\bar{t}$ H, where the signature $l^{\pm}\gamma\gamma$ provides additional rejection of background. The subcommittee thinks that detection of the low mass Higgs decaying into two gammas should not be a determining factor in the design of detector systems. The collaboration should neither increase the scope of the detector nor compromise other capabilities solely for this physics goal.

Many, if not all properties of the top quark may still be unknown when SDC turns on. Hence it is important for SDC to be capable of studying the top in detail; to this end the tagging of b decays in the tracker is important. Identification of τ leptons is another important capability which should be considered in final optimizations of the detector.

Trigger

To handle the expected interaction rate of 10^8/sec, the trigger system needs a rejection of about 10^6. G. Sullivan described the 3-level trigger system designed to accomplish this task. Simulations of the Level 1 trigger indicate that acceptable trigger rates for e, γ, μ, jets, and hadrons can be obtained. However, detailed simulations are lacking for track segments in the $\eta > 1.8$ region and the muon simulations are still primitive; for example, they do not include the bending of muons as they pass through the magnetized iron of the calorimeter. Most of the trigger requirements in the barrel region have been simulated and work is beginning on the forward region.

Work on the Level 2 trigger is in progress, but no detailed results of simulation studies were presented. This level refines Level 1 requirements, tags e-γ conversions, matches tracks to 1/1024 in ϕ, and invokes various isolation requirements. No discussion of Level 3 took place.

The subcommittee was pleased by the progress of the trigger group. However, the studies of the forward regions and of Levels 2 and 3 are still very primitive. The collaboration said that more should be known in July.

Tracking

A. Seiden described the procedure by which the parameters of the tracking system were determined. He discussed the various physics and technical factors which influenced the choice of η coverage, momentum resolution, coil radius, and number of tracking layers. He also explained the need for the several separate tracking systems (e.g. silicon, straws, gas microstrips). D. Coupal then described simulation studies of the pattern recognition capability of the tracking system. He had generated events using a GEANT simulation that included most of the detector properties. The results of the full simulation studies generally support the parametrized performance used for physics studies. Notably, the effect of missing channels had not yet been simulated. The silicon and straw trackers have been incorporated into the pattern recognition algorithms; however, the ITD and silicon have not yet been integrated. Progress is limited by available manpower.

The subcommittee concluded that the tracking design is adequate, but not overdesigned. The system parameters seem reasonably optimized, but the group must study the pattern recognition efficiency and resolution for the integrated system as soon as possible. It is particularly important to evaluate the performance and cost effectiveness at large $|\eta|$. The group is working on problems with correct priorities, but could use more manpower.

Calorimetry.

The electromagnetic and hadronic calorimeters in SDC sit behind the superconducting magnet coil (1.2 X_0). The EM calorimeter is supplemented by preshower sampling and by a "shower-maximum" detector. Dan Green reviewed the descoping of the calorimeter from the configuration of the Letter of Intent, which resulted in "bringing the calorimeter to its knees" in reaching its current scope. The depth ($21X_0$, 10λ) was chosen to confine a 1 TeV shower efficiently. Shower sizes, jet sizes and pile-up considerations determined the lateral segmentation (0.05×0.05 for EM, 0.1×0.1 for hadronic). The sampling thicknesses seem well chosen to match the resolution requirements for high-p_T physics, and the system allows easy trigger formation.

B. Wicklund described how CDF experience and prototype test results were used to produce Monte Carlo simulations of the SDC performance. With regard to electron identification, he showed that the shower-max information was essential to reject π–γ overlaps, and that the granularity of this detector was appropriate. However, more work must be done to understand performance in regions of $|\eta|$ beyond the coverage of CDF.

The subcommittee felt that the calorimeter design had been efficiently optimized, and that descoping from the LOI configuration had not compromised important physics. As mentioned above, detection of $H^0 \rightarrow \gamma\gamma$ would not justify enhancing the calorimeter design. More generally, it was felt that a high-performance EM option (0.2 cm sampling) would not lead to significant improvement in physics performance.

In making final optimizations, we suggest that the collaboration simulate and study the identification of "semi-isolated" electrons, e.g. from B decays, *vs* η. It is also important to study the identification of τ's, via such modes as $\tau^- \rightarrow \rho^- \upsilon$.

Muon Detection

G. Feldman described the muon system. The primary design goals were to achieve

1) sufficient momentum resolution for the physics, and
2) an efficient and sharp p_T muon trigger.

In the barrel region, the momentum resolution is primarily obtained from the central tracker, the muon system's role in reconstruction being to point to the muon track. In the forward region, however, the muon toroids and chambers provide the momentum measurements.

The toroid thicknesses were chosen to allow sufficient rejection of scattered low p_T muons in the central region, and to provide adequate momentum resolution in the forward region. In both cases the iron thickness was chosen to be 1.5 m, the group having concluded that 1 m does not give adequate trigger rejection without loss of efficiency at high p_T. The subcommittee suggests that the thickness question be reexamined to determine whether an intermediate thickness might result in cost savings without unduly compromising the aforementioned goals.

Although the muon trigger in the central region is reasonably well understood, and has some reserve capacity to react to surprises, the forward part is less clear. There has been no interaction yet with accelerator people to evaluate the backgrounds. As insurance against higher rates than expected, R&D for the Cerenkov option should continue.

To ensure the timely completion of an efficient muon system, several concerns should be addressed, including:

1) A test of the actual geometry in a beam is needed to verify the rejection of electromagnetic debris from the iron. The test should also examine whether the two-track efficiency at small track separations is sufficient to retain high muon detection efficiency in the presence of debris.
2) The use of Ar-Co_2 in the muon chambers is worrisome, since the efficiency of chambers employing that gas is easily degraded by small contaminations of O_2.
3) The inner chambers (BW1) are very important for the momentum measurement, but the design of these chambers needs further work.

Finally, the groups designing the central and forward muon systems should cooperate to avoid duplicate technologies and to evaluate strategies for staging the systems in the event of a funding shortage.

Superconducting Solenoid

The choice of a thin coil was dictated by its effect on the resolution of the EM calorimeter at and near the ends of the coil. The proponents claim that any cost savings in changing to a conventional thick coil would be small, and that physics would be compromised. The subcommittee was not in a position to challenge these assertions.

Conclusions

The detector as described in the TDR is reasonably optimized. The collaboration is working hard on simulating detector performance, and has found no evidence so far of gross overdesign or underdesign. In the forward region, however, the simulations of trigger, pattern recognition, and resolution are very preliminary, and must be improved in order to understand how important the forward detectors are in measuring various physics processes, and to assess the cost effectiveness of the design. The simulations must be improved overall to integrate into the pattern recognition algorithms the information from all relevant detector systems. Only then can a global optimization be carried out to see if further cost savings may be possible without incurring significant physics loss.

Finally, it appears that the streamlining of manufacturing techniques could reduce the cost of systems which can be mass produced, such as the calorimeter.

APPENDIX H

COST AND SCHEDULE

M. Breidenbach , G. Mulholland, S. Olsen , G. Bowden , J. Pilcher, R. Schindler, D. Jackson ,
G. Haller, D. Hartill

Introduction

The subcommittee heard presentations from M. G. D. Gilchriese and D. Etherton on the cost and schedule strategy and methodology, and heard presentations of about thirty minutes each on the major subsystems or budget categories. The subcommittee then had several hours to discuss the presentations. There was no time for a detailed study of lower levels of the Work Breakdown Schedule (WBS), and the brief analysis was primarily devoted to a discussion of major cost drivers. The subgroup attempted to form opinions on the following aspects of the SDC cost and schedule estimates:

- The realism of the cost and schedule estimates. How did components of the estimate compare with possible "reality checks" based on scaling rules and previous experience?
- The degree of cost optimization.
- The realism of the manpower strategy and its relation to the schedule.
- The analyzability of the budget document. Could lowest level cost assumptions be checked?

It should be emphasized that there was no attempt at an independent cost estimate.

The cost estimate was generally good, but there appeared to be differences among the subsystems in the degree of low level information that was available, and in the impression of how effective internal reviews had been on cost optimization. On average, project management and EDIA costs appeared reasonable. The projected funding profile seems reasonable for the construction of SDC, but it was noted in the presentation that the profile does not match SSCL projections. The cost estimate "begins" with FY93, and the question of FY91 and FY92 funding is noted. Fully integrated schedules are expected by September 1992, but it is already apparent that the muon barrel toroid, the central calorimeter, the underground hall, and the silicon tracker are on or near the critical path. The collaboration is in the process of developing a comprehensive funding plan, and it was not possible to identify the components of the WBS that would be funded by DOE.

The group described a complex methodology for developing budgets and schedules, which is still being developed. Procedures for estimating contingency with minimized subjectivity were described. Labor rates take account of relative pay scales at the various locations.

The following comments on the major systems are the impressions of the subcommittee from the brief examination.

Silicon Tracker

The silicon tracker is budgeted at $41.2M. About 45% of this ($19.0M) is mechanical. The detailed cost binders show that costs for structural components are already very detailed and based largely on vendor quotes. Costs of tests and instrumentation have been included. On the other hand, EDIA is estimated at only 15% of the total cost. For electronics this may be realistic, but not for the mechanical half. Half of the $4.7 M EDIA is only about twenty-four man years. From 1993 to 1999, this is only three full time engineers/designers. The silicon tracker system is not material or labor intensive, but it does require a great deal of development work before final design can begin. Presumably the actual number of engineers will exceed three in the early years and then taper down as fabrication gets underway, but it is not likely that engineering will drop off much when drawings are "released." An engineering staff will have to live with the project through the commissioning. The silicon tracker system should have access to two more engineers over its development life. This would add another $1.2 M to the project.

Unlike some of the other schedules, the silicon tracker schedule has most fabrication occurring after completion of design. If none of the remaining development questions proves difficult, the design could be ready for fabrication as early as the three years shown on the schedule, but this assumes immediate success. Development delays could easily slip the schedule by one year.

Silicon Tracker Internal Electronics

The budget for the silicon tracker electronics is well organized and the estimates for many items are supported by written quotes from vendors. The component list seems to be complete. Packaging and bonding yield losses need to be accounted for by increasing the number of detectors and custom integrated circuits to be ordered. The schedule calls for the start of production by beginning of 1994, which seems very aggressive.

Barrel Tracker

The cost estimates for the barrel tracker (straw-tube tracker) are based in large part on written price quotes and detailed WBS's provided by potential vendors. The only area where such documentation is absent is for the assembly and testing of the straw tube modules themselves, where estimates based on extrapolations from rather limited experience with prototype modules are used. However, since the university groups involved are experienced with the construction of similar devices, one can expect that there will not be any major surprises in this area.

Thus, we believe that a procedure for building the straw tube tracker on schedule and within budget has been identified. However, we are not convinced that it has been optimized. Some cost savings may be possible as construction procedures are refined.

Calorimetry

The group has gathered extensive scintillator-tile calorimeter experience through a broad program of prototypes and simulation. The program has clearly defined the expected performance of a lead and/or steel sampling calorimeter, with scintillator as an active sampling medium and WLS-clear fiber to PMT's for readout. This performance experience has allowed the group to specify the required transverse and longitudinal granularity of the calorimeter, including the shower maximum and massless gap system, to satisfy the overall physics goals of the detector. The group has gained somewhat limited construction experience with larger scale scintillator-tile-WLS fiber readout calorimeters similar to that being proposed through the CDF plug upgrade, and through the cast-lead prototypes.

As a result of this work, the group has assembled a rather complete WBS estimate of the materials, fabrication, testing and assembly costs of the barrel, endcap and forward calorimeters, under a particular set of assumptions concerning fabrication and assembly logistics and the assignment of contingency fractions. With modest additional work, the subcommittee feels that this document is now sufficiently well detailed and well organized to allow it to form the basis of a useful budgetary and schedule tracking document.

Under the particular set of assumptions concerning fabrication, assembly logistics, and contingency fraction, the subcommittee has several areas of serious and significant concerns:

1) The calorimeter budget does not explicitly provide for spare parts for a number of the major items. Examples are photomultiplier tubes and the module radiator structures.

2) The calorimeter sampling and readout contains a large number of individual components which may be conducive to assembly-line production and testing techniques. A number of such facilities are described in the WBS dictionaries. The overall cost for the preparation of facilities at existing laboratories appeared excessive. However, the budget and schedule may not adequately account for the cost of assembly-line startup (training) and shutdown (decommissioning) time, as well as the potential for significant labor cost penalty due to schedule slippage in one or more dependent areas. The group may need to consider alternate fabrication organizations and techniques to alleviate this cost risk.

3) A significant portion of the costs arise in the fabrication of the EM and hadronic radiator structure, and the scintillator sampling system. The fabricated costs assigned by the proponents appear inconsistent with other devices of similar granularity and size that have been built in recent years. The subcommittee is therefore extremely concerned that engineering optimization has not yet been adequately performed, allowing cost reduction through such mechanisms as relaxed tolerances, alternate modularity, alternate fabrication techniques, etc. Tile fabrication, testing and repair were also identified as having potential for significant cost reduction through engineering optimization.

4) The cost of labor in the areas of engineering, technician/laborer and management appeared to the subcommittee to be significantly greater than for previously constructed devices of similar granularity, complexity and size. The construction plan does not appear to factor in the use of physicists in their historical roles, but instead appears to substitute, in many areas, high- and mid-level engineering. The apportionment of high-level technicians and assembler-laborers appeared inverted, in comparison to the previous experience of subcommittee members, thereby escalating costs. The proponents might consider alternate modularity, assembly techniques, management and geographical distribution to take advantage of lower labor costs. The industrialization of the labor-intensive assembly and testing of the calorimeter in industry and the national labs (as opposed to universities) may be contributing significantly to the high projected costs.

5) At the present time the detailed WBS continues to reflect rather high assigned contingencies for major items whose costs are well identified. Insufficient contingency, however, may be assigned to items which are less well understood. Design contingency is not explicitly contained in the budget. The subcommittee feels, however, that the overall base costing of the device already reflects a significant "hidden" contingency, and that the proponents must reconcile and justify this with the explicit assigned component.

6) The schedule of engineering manpower is heavily weighted towards early years, while experience suggests that it may not carry sufficient (experienced) engineering through to project completion.

7) The subcommittee is concerned that design, resource and schedule integration is not yet present between calorimeter subsystems. If properly employed, such integration could lead to cost reductions.

Forward Calorimeter

Two competing technologies are being considered for the subsystem: tubes of scintillating liquid or high pressure tubular gas ionization chambers. A rough WBS was available for the former system.

The principal costs are the iron, liquid scintillator, and readout electronics. In each case, the unit costs are conservative and the contingency generous. The projected total cost of the subsystem is very conservative.

Muon System

All major components of the muon system have a duration of four years from award of contracts to "Top of Hole." This means that the muon system, especially the magnet, defines the control path.

Muon Magnet Systems

Back-of-the envelope estimates, based on experience, suggest that the TDR magnet cost is underestimated by 10 to 15%. [Crude estimates: ≥ $66M (scale-up of L-3), $70M ($1.00/lb, in place), $78 M (CERN experience).] Using the detailed WBS book, an effort was made to deduce the savings from not machining the inner slabs of the blocks. Approximately 2000 man-days would be saved, leading to a cost savings of perhaps $1.5-2.0M (including the savings in other labor costs). However, this does not explain the discrepancy between $60M and the rough estimates.

The question was raised in the technical sessions about savings from a reduced thickness of the barrel toroid. If the thickness were reduced to 1.2 meters instead of 1.5, there would be a reduction in magnet cost of $7 — 8 M. Presumably there would be some additional savings from the reduction in size of the outer layers of the muon chambers.

Muon Measurement System

(a) The drift tube material and fabrication costs seem reasonable, as does the schedule, although fabrication of 90,000 tubes in half a dozen universities is a concern. The present plan has three different tube diameters in the system. In the interests of simplicity it is suggested to standardize on two sizes, for example, 4.5 cm and 9.0 cm I.D.

(b) The supermodule fabrication labor costs may be underestimated. Delay in fabrication because of tight tolerances, uneven flow of tubes, lack of storage space, etc. will prove costly. A real cost estimate will be possible only after construction of the BW2/3 prototype. In any event, the contingency should be raised.

(c) The alignment system has not been fully thought out, as evidenced by the fact that every item in the detailed WBS has a contingency of 34%. Strategies for supermodule fabrication should be coordinated with the alignment scheme to reduce costs.

Superconducting Magnet

The cost analysis has two components: 4.1, S.C. Solenoid and 4.2, Solenoid Cryogenic System. The first represents 80% of the total cost and dominates the cost conclusion.

The solenoid, including a prototype, is to be fabricated in Japan. Detailed cost breakdowns for the solenoid were not provided, but comparisons can be made to historical scaling rules and to a scale-up for energy and inflation of the CDF magnet:

SDC Solenoid	Scaled Solenoid	CDF scaling
$25M	$14.2M, $15.4M	$15.1M
SDC Cryogenics	Scaled Cryogenics	CDF scaling
$4.7M	$2.0M	$2.9M

The magnet does have special constraints that justify some additional costs, particularly the requirement of a total radial thickness of no more than 1.2 radiation lengths, and a small iron flux return. These items drive the high strength conductor development, the "structural form" outside vacuum wall, and the concerns for large axial forces. These special considerations may push the costs to the high side of more conventional magnet scaling. However, the cost of the cryogenic system seems high without detailed explanation and should be carefully reviewed.

Electronics Systems

The presentation of the front-end electronics budget was limited to the highest level and included only the cost per channel for each sub-system. Checks on details showed a non-uniform format and level of accuracy across the sub-systems. More estimates should be checked by obtaining quotes. WBS numbers in the blue book distributed to the reviewers and the white folder available at the review did not match in all cases (e.g., calorimeter baseline electronics).

The numbers of components in sub-systems (e.g., calorimeter) need to be updated and checked. Overall the cost per channel for each sub-system seems reasonable. The schedule seems very tight, especially because it calls for a completion of IC design by October 1992. Manpower loading needs to be studied to ensure a timely completion. The budget for the calorimeter PMT option should be included.

The presentation by W. Smith on the cost and schedule for the trigger system for the SDC detector represents an early look at this important subsystem. The CDF trigger system is the model that was used as the starting point for scaling to the SDC system. Electronics board costs and the crate costs that were assumed for the cost estimate are reasonable. The level of effort to realize the designs for the boards, the ASIC's along with the support for the engineering effort were within the bounds of previous experience in the construction of large detector electronics systems. The quantities of materials, level of effort in manufacturing and EDIA, and contingency assignment did not appear to be far out of line with what would be expected for an electronics system of this size. One area of concern is the cost of the 1 Gbyte/sec data links between the detector crates and the trigger system crates, which all reside on the surface. Although the speaker stated that failures would only remove 1 - 2 % of the detector from the trigger, the evidence presented was at a very high level and by itself was not convincing. Because of the very early stage of design, the 33% contingency may be on the low side unless the base costs have as their basis the upper end of the estimated/quoted costs.

The Level 2 trigger system, as with the Level 1 system, is also at an early stage in its design. Work is underway at the Rutherford Electronics Laboratory to define better the trigger algorithms necessary to reduce the rate from Level 2 to 1 kHz. Based on this early design and scaling from the CDF experience, the projected system costs seem reasonable and the necessary processing power will be available at the estimated cost.

A very aggressive schedule characterizes the presentation of the data acquisition system. Like the trigger system, it is at an early stage of design and there may be opportunities for further cost optimization. The goal of providing portable data acquisition systems with the look and feel of the final version at an early stage for test beam running is to be commended. It will provide early feedback to the designers in time to make necessary changes before final design and production begins. Thirty person-years of software engineering are explicitly included in the cost estimate, which is a first in detector cost estimates. As with the trigger system, cost estimates seem to show no large discrepancies compared to the systems for previous large detectors.

On-line software has reached the level of complexity that requires professional software engineering to develop the kernels for the many tasks which must be correctly and efficiently carried out. The fifty person-year estimate for this task may be somewhat low and the contingency in this category should be increased. The estimated hardware costs for this amount of processing power seem plausible given the rapid evolution in computing technology.

Conventional Systems, Installation & Test, Project Management

D. Etherton presented a summary for conventional systems, installation and test beams, and project management.

The conventional systems include mechanical utilities, electrical utilities, safety systems, and structural support, and are estimated at $14.2M, including $2.7M contingency. While there is a WBS Dictionary defining the systems, careful review will be needed to produce a reliable cost estimate. For example, an electrical one-line diagram for cryogenics was shown. It included motor control centers for argon and nitrogen systems, which are presumably from a once-considered calorimetry option. It also indicated 11 breakers at 4160 volts for the nitrogen and argon systems, which seems excessive. On the other hand, no distribution of emergency power was indicated.

The test beam program is estimated at $7.3M, including $1.6M contingency. The estimate seemed to be based on possibilities for test beam work at BNL, FNAL, CERN, and SSCL, although work at CERN was not included in the cost estimate. The amount of test beam time needed for development and production of SDC detector components was not clearly estimated.

The installation and test component, WBS 8.2, was estimated at $27.3M, including $4.9M contingency. This item takes system components from the "Top of Hole" and covers assembly through integration and testing. No comparison to other detector installation experience was made. A manpower distribution was shown in which the number of engineers often exceeded the number of laborers, and the number of technicians were about twice the number of engineers. This seems unusual. There was no discussion of Davis-Bacon labor rates or requirements. Installation planning is clearly at a very early stage, but the contingency appears low.

The direct project management estimate is $18.4M, including $2.5M contingency. This amounts to about 27 FTE's for 7 years, and is probably reasonable. Inclusion of subsystem project management brings the total cost estimate to about $40M or 7% of the total cost.

Conclusions and Recommendations

The subcommittee recommends that the SDC, with assistance from the Laboratory, develop a reviewable budget that considers possibilities for engineering and manufacturing optimization. That budget should then be carefully reviewed on a line by line basis, preferably before the DOE review.

There may be opportunities for significant savings without descoping, but the relatively large number of uncertainties make it impossible to estimate where a detailed review would come out.

The explicit contingency, based on the SDC methodology, seems thin. There also appears, in some areas, to be contingency in the base estimate. It will probably be easier to manage the project if all contingency is explicit.

APPENDIX I

COLLABORATION/RESOURCES

M. Albrow, M. Danilov, D. Gross, T. Kamae, P. Karchin, W. Marciano, R. Palmer,
J. Sandweiss, T. Schalk, F. Takasaki

Management

As SDC moves from proposal writing to project construction, the organization of the collaboration is in a period of rapid change. The recent appointment of T. Kirk as SDC project manager represents an important milestone in the SDC presence at SSCL. As the on-site manager and co-spokesman for the SDC collaboration, he will coordinate activities at SSCL as well as off-site. We expect his responsibilities to significantly grow in the near future, as the SSCL becomes the collaboration's center of activity. We are pleased to hear that the collaboration intends to name a project engineer in the very near future.

There exists a draft management plan, which will undoubtedly evolve and change over the next few months. The collaboration intends to have a functional and tested organizational structure in place by September. We are somewhat concerned over the number of subsystems that are geographically dispersed and all report to the project manager. Although the plan is very similar to structures that have worked for current generation large detectors, it is not obvious that it will work well for an experiment the size of the SDC. Some level of intermediate responsibility needs to be identified and implemented. In addition, clear lines of individual responsibility must be established within the geographically dispersed subsystems. These are in themselves big projects and will need their own level of intermediate management. We request that the SDC report to the PAC at the July meeting on the evolution of the management structure.

We encourage the rapid build-up of an SDC Division at SSCL and recommend that the Laboratory assist, as much as possible, in this development. In particular, it should provide the support needed to recruit staff and increase the overall SDC presence at SSCL.

Resources

The SDC is an international collaboration with substantial participation of groups from outside the United States. The largest of these are based in Japan, the CIS, Canada, Italy, France, the United Kingdom, and the Peoples Republic of China. The intellectual and material support of these groups is essential for the success of the project.

The panel heard a detailed presentation of the international funding plan for the SDC from the spokesperson and representatives of groups from each of the above countries. We were informed of the contributions that these groups are requesting from their individual governments and the likely amounts of support that will ensue. Except in the case of France, all commitments are pending. Based on the information that we received, it appears that the estimate by SDC of $207M is not unreasonable. There is, however, substantial uncertainty in this number. It might fluctuate, in either direction, by as much as forty percent.

We applaud the success of SDC in forming a well integrated international collaboration. We urge them to continue their efforts in attracting non-U.S. collaborators; it still may be possible to find many able new participants.

APPENDIX J

ORGANIZATION OF REVIEW

Panel Members (* PAC member)

	Michael Albrow	FNAL
	Ulrich Becker	CERN
	Robert Bell	SLAC
	Gordon Bowden	SLAC
*	Martin Breidenbach	SLAC
*	Michael Danilov	ITEP
*	Sally Dawson	Brookhaven
	Henri Desportes	Saclay
	Umberto Dosselli	INFN Padova
*	Friedrich Dydak	CERN
*	David Gross	Princeton
	Gunter Haller	SLAC
	Donald Hartill	Cornell
	William Haynes	DESY
	Hans Hoffmann	CERN
	Seigi Iwata	KEK
*	J. D. Jackson	LBL
*	Tune Kamae	University of Tokyo
	Paul Karchin	Yale
*	William Marciano	Brookhaven
	Kirk McDonald	Princeton
	George Mullholland	SSCL
*	Stephen Olsen	University of Rochester
	Robert Palmer	Brookhaven
*	Felicitas Pauss	ETH - Zurich
*	James Pilcher	University of Chicago
	Ruth Pordes	FNAL
*	Jack Sandweiss	Yale
	Fabio Sauli	CERN
	Terry Schalk	UC Santa Cruz
	Rafe Schindler	SLAC
	William Sippach	Columbia
*	A. J. Stewart Smith	Princeton
	Fumihiko Takasaki	KEK
*	Michael Witherell	UC Santa Barbara
*	Michael Zeller	Yale

Subpanels

	SUBSYSTEMS					GLOBAL ISSUES				
	A	B	C	D	E	F	G	H	I	
	S/C Solenoid	Chg Part Tracking	EM/Had Calorim	Muons Toroids	Elec/DAQ Compute	Int. Hall Fac/Inst	Perf/Trig Integ/Op	Cost Schedule	Collab/ Resources	
PAC	Gross Smith	Danilov Dawson **Olsen** Witherell	Sandweiss Pauss **Pilcher**	Jackson **Kamae** Marciano	Breidenbach Dydak **Zeller**	Dydak	Dawson Pauss **Smith** Witherell Zeller	**Breidenbach** Jackson Olsen Pilcher	Sandweiss Danilov **Gross** Kamae Marciano	
CONSULTANTS	**Desportes** Mulholland Palmer	Bowden Haller Karchin McDonald Sauli	Albrow Hoffmann Iwata Schindler Takasaki	Becker Bell Dosselli	Haynes Pordes Schalk Sippach	**Bell** Desportes Hoffmann McDonald	Dosselli Iwata Sauli	Becker Bowden Haller Hartill Mulholland Schindler	Albrow Karchin Palmer Schalk Takasaki	
	S/C Solenoid	Chg Part Tracking	EM/Had Calorim	Muons Toroids	Elec/DAQ Compute	Int. Hall Fac/Inst	Perf/Trig Integ/Op	Cost Schedule	Collab/ Resources	
	5	9	8	6	7	5	8	10	10	36

Chairperson is underlined

Agenda

	MONDAY 4-May	TUESDAY 5-May	WEDNESDAY 6-May	THURSDAY 7-May	FRIDAY 8-May	SATURDAY 9-May
8:30 AM	PLENARY	PLENARY	PLENARY	PLENARY	PLENARY	PLENARY
9:00 AM	PLENARY	PARALLEL A - E	PARALLEL B -E	PLENARY B - E Summary reports and discussion: Auditorium	PARALLEL F - I	F, H, I Summary reports and discussion: Auditorium
10:30 AM	Break	Break	Break		Break	
11:00 AM	PLENARY	A - E	B -E		F - I	
12:30 PM	Lunch	Lunch	Lunch	Lunch	Lunch	Lunch
2:00 PM	PLENARY	A - E	PARALLEL discussions	F - I	PARALLEL discussions	PLENARY discussion
4:00 PM		PARALLEL		Break		
5:00 PM	PLENARY	PLENARY	PLENARY Summary: A	F - I	PLENARY Summary: G	
6:00 PM						

Open

Closed

Presentations

4-May	**PLENARY SESSION**	**Auditorium**
8:30	Executive session	
9:00	Overview and Detector Summary	T. Kondo
9:30	Tracking System Summary	A. Seiden
10:00	Calorimeter System Summary	D. Green
10:30	Break	
11:00	Muon System Summary	G. Feldman
11:30	Electronics System Summary	A. Lankford
12:00	Discussion	
12:30	Lunch	
2:00	Physics Performance Summary	K. Einsweiler M. Mangano
3:30	Responsibilities and Funding	G. Trilling
4:00	Discussion	
4:30	Adjourn	

PARALLEL SESSION A: SUPERCONDUCTING SOLENOID Directorate

5-May **Desportes**, Gross, Mulholland, Palmer, Smith

9:00	Introduction, Physics Goals, General Requirements	R. Kephart
9:30	Design of Detector Solenoid	A. Yamamoto
10:30	Break	
11:00	Design of Detector Solenoid, cont.	A. Yamamoto
11:30	Cryogenic System	A. Stefanik
12:00	Discussion	
12:30	Lunch	
1:30	R&D and Prototype	A. Yamamoto R. Kephart
3:00	Cost and Schedule	R. Stanek
3:30	Discussion	
4:00	Adjourn	

PARALLEL SESSION B: TRACKING **Upstairs**

5-May	**Olsen,** Bowden, Danilov, Dawson, Haller, Karchin, McDonald, Sauli, Witherell	
9:00	Requirements and Overview	W. Ford
9:45	Silicon Tracker Summary	A. Seiden
10:15	Break	
10:45	Silicon Mechanical Systems	W. Miller
11:15	Silicon Electronics Systems	H. Spieler
11:45	Silicon Detectors and Radiation Damage	H. Sadrozinski
12:00	Silicon R&D Plan	H. Sadrozinski
12:30	Lunch	
2:00	Straw-tube Tracker Summary	G. Hanson
2:30	Straw-tube Engineering and R&D Plan	H. Ogren
3:15	Straw-tube Electronics	H. H. Williams
3:45	Discussion	
4:00	Adjourn	

6-May		
9:00	Gas Microstrip Intermediate Tracker Summary	M. Edwards
9:45	Gas Microstrip Intermediate Tracker R&D Plan	G. Oakham
10:15	Discussion	
10:30	Break	
11:00	Fiber Option Summary	R. Ruchti
11:45	Fiber Option R&D Plan	D. Koltick
12:15	Discussion	
12:30	Adjourn	

PARALLEL SESSION C: CALORIMETRY Auditorium

5-May	**Pilcher,** Albrow, Hoffmann, Iwata, Pauss, Sandweiss, Schindler, Takasaki	
9:00	Requirements and Summary of Central Calorimeter Design	J. Proudfoot
10:00	Shower Maximum Detector	R. Hubbard
10:30	Break	
11:00	Summary of Radiation Damage Tests	K. Takikawa
11:30	Test Beam Results	J. Freeman R. Rusack
12:15	Discussion	
12:30	Lunch	
2:00	Organization and Prototype Plan	P. Mantsch
2:45	Design Options	R. Kadel J. Freeman
3:45	Discussion	
4:00	Adjourn	

6-May		
9:00	Scintillator R & D	G. Foster
9:30	Forward Calorimeter Requirements	M. Barnett
9:55	Forward Calorimeter Requirements, cont'd.	W. Frisken
10:20	Break	
10:50	Liquid Scintillator Option	R. Orr
11:20	High Pressure Gas Option	N. Giokaris
11:50	Electronics Options for Calorimetry	A. Lankford
12:20	Discussion	
12:30	Adjourn	

PARALLEL SESSION D: MUON SYSTEM E-311

5-May **Kamae,** Becker, Bell, Dosselli, Jackson, Marciano

9:00	Requirements and Design Summary	G. Feldman
10:00	Magnet Summary	J. Bensinger
10:30	Break	
11:00	Barrel/Intermediate Chamber Design	H. Lubatti
12:00	Discussion	
12:30	Lunch	
2:00	Forward Chamber Design	Y. Antipov
2:45	Scintillation Counters	R. Thun
3:15	Cerenkov Option	V. Kubarovsky
3:30	Electronics and Trigger	J. Chapman
4:00	Adjourn	

6-May

9:00	Alignment Systems	D. Eartly
9:30	Toroid Engineering	J. Cherwinka
10:00	Assembly and Installation	R. Loveless
10:30	Break	
11:00	R&D and Prototype Plan	J. Bensinger C. Grinnell
12:30	Adjourn	

PARALLEL SESSION E: ELECTRONICS/DAQ/COMPUTING Strategy Room

5-May **Zeller**, Breidenbach, Dydak, Haynes, Pordes, Schalk, Sippach

9:00	Overview and Front-End System Summary	H. H. Williams
9:30	Trigger System Overview and Level 1 Summary	W. Smith
10:10	Level 2 Trigger Summary	P. LeDu
10:30	Break	
11:00	Straw Tube and Muon Front-End Electronics	Y. Arai
11:35	Straw Tube Tracker and Muon Triggers	J. Chapman
12:05	Fiber-Tracker Option Trigger	A. Baumbaugh
12:20	Discussion	
12:30	Lunch	
2:00	Calorimeter Front-End Electronics I	G. Foster
2:25	Calorimeter Front-End Electronics II	M. Levi
2:50	Shower Maximum Detector Front-End Electronics	P. LeDu
3:05	Silicon Tracker Front-End Electronics	H. Spieler
3:30	Gas Microstrip Front-End Electronics/Trig. & Silicon Trig.	R. Nickerson
4:00	Adjourn	

6-May

9:00	Data Acquisition and On-line Computing Overview	I. Gaines
9:45	Electronics R&D Plan	A. Lankford
10:30	Break	
11:00	Off-line Computing and Software Development	L. Price C. Day
12:30	Adjourn	

PARALLEL SESSION F: INTERACTION HALLS/FACILITIES/INSTALLATION

Directorate

7-May **Bell**, Desportes, Dydak, Hoffmann, McDonald

2:00	Overview and Schedule	T. Thurston
2:15	Installation Plan	D. Bintinger
3:15	Underground Hall Summary	J. Piles
3:45	Surface Layout Summary	T. Prosapio
4:15	Discussion	
4:30	Break	
5:00	Assembly Building Requirements	T. Winch
5:30	Detector Integration Planning	T. Thurston
6:00	Adjourn	

8-May

9:00	Safety Analysis Status	J. Elias
10:00	Report from Review of Draft CSAR	L. Coulson
10:30	Discussion	
11:00	Adjourn	

PARALLEL SESSION G: PERFORMANCE/TRIGGER/INTEGRATION/OPERATIONS

Strategy Room

7-May **Smith** Dawson, Dosselli, Iwata, Pauss, Sauli, Witherell, Zeller

2:00	Trigger System Requirements and Performance	G. Sullivan
2:45	Tracking Simulation Summary	D. Coupal
3:25	Tracking - Integrated Performance and Design Optimization	A. Seiden
4:00	Discussion	
4:30	Break	
5:00	Electron Identification	B. Wicklund
5:40	Discussion	
6:00	Adjourn	

8-May

9:00	Calorimetry - Integrated Performance and Design Optimization	D. Green
9:40	Discussion	
10:00	Muon System - Integrated Performance and Design Optimization	G. Feldman
10:40	Break	
11:10	Discussion and question and answer period	
12:30	Adjourn	

PARALLEL SESSION H: COST AND SCHEDULE Auditorium

7-May **Breidenbach,** Becker, Bowden, Haller, Hartill, Jackson, Mulholland, Olsen, Pilcher, Schindler

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2:00	Introduction	M. Gilchriese
2:30	Cost/Schedule Procedures	D. Etherton
3:00	Silicon	A. Grillo
3:30	Straw-Tube Tracker	R. Swensrud
4:00	Gas Microstrips	G. Oakham
4:15	Fiber Option	R. Leitch
4:30	Break	
5:00	Central Calorimetry	D. Scherbarth
5:45	Forward Calorimetry	R. Orr
6:00	Adjourn	

8-May

9:00	Muon System	M. Montgomery
9:45	Superconducting Solenoid	R. Stanek
10:15	Break	
10:45	Electronics	A. Lankford H. H. Williams I. Gaines, W. Smith
11:45	On-line Computing	A. Fry
12:00	WBS 7, 8, 9	D. Etherton
12:30	Adjourn	

PARALLEL SESSION I: COLLABORATION/RESOURCES Upstairs

7-May **Gross,** Albrow, Danilov, Kamae, Karchin, Marciano, Palmer, Sandweiss, Schalk, Takasaki

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2:00	Collaboration Management and Draft Management Plan	T. Kirk
2:45	Status of Responsibilities, Resources and Funding	G. Trilling
3:15	Japan	T. Kondo
3:30	CIS	N. Tyurin
3:45	Italy	G. Bellettini
4:00	Canada	R. Orr
4:15	Break	
4:45	United Kingdom	R. Cashmore
5:00	France	R. Hubbard
5:15	PRC	H. Mao
5:30	Discussion	
6:00	Adjourn	

APPENDIX K

SDC CONCEPTUAL SAFETY ANALYSIS REPORT

Review Panel Report

May 15, 1992

R. Bell, J. Bull, L. Coulson, D. Hawkins, B. Hendrix, L. Keller,
R. Macek, E. Verminski

The Physics Research Division (PRD) of the SSC Laboratory called upon a panel of experts to review the draft Conceptual Safety Analysis Report (CSAR). Members of the panel are listed in the attached Appendix. The review panel (Panel) was charged to:

"Evaluate the SDC conceptual design, the technology choices, and the facilities required of the laboratory infrastructure and address the following questions:

- What are the principal hazards of the detector and associated infrastructure during the operation and maintenance?
- Have the hazards been correctly identified and assessed?
- Can the hazards be reduced, eliminated or adequately controlled, and what is the resultant level of risk?"

The Panel met on April 23 and 24, 1992. The documentation given to the Panel for review included the draft CSAR and miscellaneous reports. A full day was devoted to a briefing on the design, safety analysis techniques, design options, and identified possible mitigation techniques. All the documentation delivered to the Panel, as well as the handouts and the agenda of presentations, are available from the PRD as an appendix to this report.

This report represents the results of the Panel deliberations on the oral and written material presented. The report headings largely follow the CSAR Table of Contents. It should be noted that the Panel, as asked, addressed only the operation and maintenance phases of the detector. Specifically, the details of hall construction and the construction and installation phases of the detector are not addressed.

SUMMARY:

The Panel was impressed with the depth of analysis, systematic approach, and level of detail which is contained in the draft CSAR. No show stoppers were detected which the Panel believes would prevent the experiment from being constructed as currently being planned.

The Panel concludes that the SDC has a system and organization in place which will identify hazards, assess the magnitude of the hazards, and assess the impact of proposed mitigation measures. The Panel found few hazards which had not been already identified by the SDC safety analysis process. Because there are still numerous technical choices to be made in the detector components and the SDC is still in the process of identifying and assessing mitigation measures, the Panel did not feel it appropriate to attempt to determine the resultant level of risk. However, it appears to the Panel, that sufficient mitigation

techniques have been identified and can be applied to the final design to lower the resultant risk to acceptable levels.

The Panel also concludes that there are serious environment, safety and health (ES&H) problems to be solved. It is, therefore, important that the SDC continue to utilize the best possible resources in dealing with these ES&H issues. The detailed report below reflects the Panel's sense of the importance and priorities of the problems yet to be solved and provides guidance for development of the PSAR.

PART 1: COMMENTS OF SPECIFIC CSAR CHAPTERS

1. Conceptual Safety Analysis Methodology (CSAR CHAPTER 5.0)

The methodology is based on a proven approach used throughout industry. The system safety process used to influence safe designs and criteria for hazard identification, elimination and control is judged to be adequate. It is a logical and systematic process. The guidelines for hazard analyses, risk assessments, and the process for driving safety designs are qualitative and are adequate for conceptual and preliminary safety documents. However, the methodology needs to be expanded to be more quantitative for final analysis of specific safety problems such as structural integrity, beam line catastrophic events, electrical fire prevention design schemes, etc.

The Panel believes that section 5.3.2 has excellent safety design criteria and system specifications. It is suggested that SDC expand it in more detail to fit specific designs to mitigate risks.

Section 5.3.3 should be expanded to include specific industry standards, codes or best engineering approaches. Guidelines should be developed for dealing with specific problems, such as overcurrent protection of electronics to minimize the probability of fire and subsequent damage to equipment.

Also, there needs to be more information on the process for resolving severe hazards through hazard tracking and risk resolution through management decisions based on safety-cost benefit, trade off analyses, value engineering, risk assessments, etc.

Finally, the methodology ought to touch on the process for safety and verification – especially verifying the design of safety systems, redundancy, safeguards, and safety features. This includes how the system process links with systems engineering, reliability, quality assurance, and vendor safety requirements.

2. Beam Pipe (CSAR CHAPTER 7.1)

The detailed design of the beam pipe will take place in the future, however it would be appropriate in the subsequent reports to address some of the issues concerned with its potential failure modes. Among these are: collapse without loss of vacuum during operation; collapse with loss of vacuum during operation; the same scenarios during the non-operational mode.

3. Tracking Subsystem (CSAR CHAPTER 7.2)

The tracking system is composed of an inner silicon tracker, a barrel tracker, and a gas microstrip intermediate tracker. Individual presentations were made on each of the subsystems.

Silicon Tracker

This tracker consists of silicon wafers arranged in the form of discs and cylinders which are supported by two graphite epoxy support rings. The tracker electronics are mounted on board and are cooled by a novel butane evaporative cooling system. The identified safety issues are:

- **The Adequacy of the Support Structure:**
  The support issue, though introduced, was not discussed. In particular, the ability of the structure to withstand an accidental rupture of a line inside the containment vessel is missing. Also, the design issues of this vessel relative to over pressure introduced by fluctuations in atmospheric pressure as well as fluctuation in the surrounding N_2 pressure is not discussed.
- **The Adequacy of the Butane Cooling System:**
  The adequacy and the safety of the butane system are covered in detail. More detail could be added, particularly emphasizing the small total quantity of butane present.
- **The Electrical Distribution System:**
  Brief mention is made of the electrical distribution system. More detail is required to show how safety issues are being dealt with here.
- **The Presence of Butane in the Detector Hall:**
  This issue is dealt with under normal operating conditions but is not addressed during fault conditions.
- **The Nitrogen Flow System:**
  A potential issue not addressed is that of an over pressure on the containment vessel due to malfunction of the N_2 system.

BARREL TRACKER

Two candidate systems are proposed; a straw tracker and a scintillating fiber option. The identified safety issues are:

- **Electrical Safety:**
  Both high voltage low current and low voltage high current systems are present.
- **Cooling Systems:**
  The use of N_2 gas to cool the tracking volume is discussed. This system must somehow be coupled to the combustible gas system on a pressure basis to insure against collapse of the straw tubes. Mention is made of using N_2 to cool

the straw electronics but it is not clear that this system is independent of the system used to cool the tracking volume.

- **Combustible Gas:**
  The proposed gas for the straw chambers is heavier than air. It is not clear that the flowing N_2 will clear the gas leaks or will the leaked gas simply fall to the bottom of the detector, collect and become an asphyxiate hazard in the future.

- **Support Integrity:**
  Both systems proposed deal with the support issues.

- **Combustibles**
  This issue is mentioned in the scintillating fiber discussion.

- **VLPC Read-Out**
  Cryogenics and electrical issues unique to the VLPC canisters are addressed as are the potential servicing problems associated maintenance in the cold condition.

GAS MICROSTRIP INTERMEDIATE TRACKER

This tracker is in the preliminary design stage. It is expected that the safety issues will be similar to those presented for the straw barrel tracker.

TRACKING SUMMARY

In general the tracking safety issues are addressed very well. A major omission is that of self-damage due to over or under pressures in both the surrounding media and in the tracker itself. This is the case for both the silicon and straw trackers. Also, the question of gases heavier than air and their dispersion should be addressed.

4. Superconducting Solenoid (CSAR CHAPTER 7.3)

Several general hazards were identified including ODH (oxygen deficiency hazard), cryogenic hazards, electrical hazards, magnetic fields, and high mechanical stress points. Special hazards include the risks attendant to exploring new levels in the ratio of stored energy to cold mass. Plans for mitigation include use of quench propagation strips to speed up quench propagation so as to distribute the released energy. The possibility of severing the chimney with the overhead crane and thereby releasing cryogenic gases was mentioned.

As far as the Panel can determine, the hazards have been correctly identified and assessed. On the basis of information presented at this review, most risks are judged to be adequately controlled.

We would recommend that further measures should be pursued to reduce the possibility or likelihood of the crane severing the chimney or other utilities.

The implication of a conductor being stressed at 80% of yield stress was discussed. Since the conductor will push against supports, which will be stressed up to just 30% of yield stress, no support structure failure is likely. The possibility was raised that the conductor yielding could cause a quench. Experts should estimate the frequency of the problem. The planned prototype should adequately address this concern.

5. Calorimetry System (CSAR Chapter 7.4)

The calorimeter presentation dealt mostly with the 2400 ton barrel/endcap lead-scintillator and iron-scintillator calorimeter with brief mention of the forward iron calorimeter for which the detection medium is not yet chosen. The potential hazards in the barrel and endcaps are scintillator fire, lead exposure, high voltage, residual radiation from material near the beam line, and a confined space region between the outside of the calorimeter and the inside of the Muon detector. Since the scintillators are sandwiched tightly between sheets of lead and iron, combustion is not a problem. The lead tiles are wrapped with aluminum foil during construction, so lead exposure is not an issue. The high voltage for the large number of photomultiplier tubes is generated within the tube base, thereby avoiding a large high voltage cable plant. Reducing exposure to residual radiation during maintenance periods will have to be done with barriers and can be helped by special lead shields which are installed for the small angle position of the endcaps. Except for the level of residual radiation, there is a great deal of experience with mitigating these hazards in large calorimeters at other laboratories.

The detection medium in the forward calorimeter will be either liquid scintillator or high pressure argon gas. Besides the normal high voltage and flammable scintillator hazards, for which there is considerable experience, there is the large residual radiation hazard and the possibility of leakage of radioactive liquid scintillator. The collaboration has not addressed, in any detail, the design of collection pans or activation rate studies on the detection medium. In the forward calorimeter, reliability of components is especially important to minimize repair and maintenance time near the device.

The means of access to the barrel calorimeter PM tubes and electronics crates makes it difficult to provide suitable openings, working space, and fall protection. The collaboration has designated this region to be a "permit required confined space" which triggers the requirements for special access procedures and safety training. Besides the difficulty of physically maneuvering within this region, there are a number of other hazards present: radioactive sources, high voltage, flammable materials (cables), and the potential for oxygen deficiency due to nitrogen flowing through the tracking region. The collaboration does not yet have a detailed design of the platforms, walkways, and ladders within this volume. They recognize that this problem needs a great deal more study.

6. MUON SYSTEM (CSAR CHAPTER 7.5)

As indicated in the draft CSAR, the muon system consists of magnetized iron toroids with layers of wire drift chambers triggered by scintillation counters. The gas used in the drift chambers will be a mixture of argon, CO_2. The detectors are large arrays of aluminum walled tubes.

The hazards have been identified – the principle hazards being the fire hazard associated with the scintillator and the confined space between BW2 and BW3. The fire hazard is well identified and assessed. Plans for mitigation are reasonably well developed and progressing.

The confined space problem has been recognized. Assessment and mitigation measures are not well developed. The need for further work is recognized. The SDC is encouraged to evaluate and justify the necessity of the confined space. If the concept survives, a great deal of effort is needed to minimize the hazards associated with access to this space.

7. Detector Maintenance Access Spaces CSAR (CHAPTER 7.7)

The level of hazard identification shown in this CSAR appeared to be very detailed and precise. The CSAR appears to be well along the road to addressing the hazards and solutions involved in the maintenance and operation of the SDC. Although many of these hazards can be reduced or eliminated, several areas have been identified which will require additional analysis.

The issue of Life Safety, as was discussed concerning the detector itself, was shown to be intimately involved with design aspects of the detector hall, as it should be. Resolution of life safety concerns cannot be focused in a single area, and must be evaluated as a complete facility. The principal hazards for operations and maintenance of the detector have been identified. The SDC should perform a formal Life Safety code analysis which systematically addresses hazards associated with personnel accesses to the hall.

8. MECHANICAL INTEGRITY (CSAR Chapter 7.8)

The support system is the foundation on which the whole detector rests and its mechanical integrity and stability are crucial. If this part of the detector fails the whole detector fails. In general this section identifies most of the safety issues that the various support systems present. One issue omitted is that of seismic safety and safety during movement, particularly movement of the forward toroids. An issue which is not addressed is how the barrel toroid is attached to the toroid support system. If this is a welded joint, some form of non-destructive testing (NDT) should be employed to insure the integrity of the weld. The concept of NDT should be introduced into most of the support systems as they are so crucial to the overall structure of the SDC experiment. The use of QA/QC cannot be over emphasized.

9. UTILITIES/SUPPORT SYSTEMS (CSAR Chapter 7.9)

Water systems, heating ventilation and air conditioning, gas system, electrical and cryogenics were reviewed. The focus of this review was on the detector in the hall and not on surface facilities for utilities. Specific hazard analysis for each individual system was not presented. Utilities as they relate to Detector components were discussed with each detector component.

ODH, gas leaks, fire, personnel access, high and low voltage electrical, cryogenic, over pressurization hazards and their mitigations were discussed. An initial qualitative assessment serves as a reasonable starting point to initiate safety design input for these systems. However, due to the significant potential ES&H consequences, these analyses must continue to be aggressively pursued. At this point, the utility area has less safety definition relative to the rest of the detector.

10. MATERIALS CONTROL (CSAR Chapter 8.0)

Nothing was presented in the review on material control. One CSAR document indicates that the collaboration will abide by SSCL requirements whatever they are. The areas of concerns listed in table 8.0-1 are relevant. Future analysis should spell this out in more detail. A graded approach is recommended in which the level of QA is commensurate with the consequence of failure. Critical safety systems deserve a well designed, high level QA plan starting with a QA plan for the design phase and progressing through procurement, commissioning and routine operation, and maintenance. Critical safety systems should be identified early. The SAR process calls for this, and identification of limiting conditions of operations or operational safety requirements, a condition that must be met in order to operate. Candidates for critical safety systems might include the future cooling safety system, oxygen deficiency alarms, access control system, fire protection, and the ventilation systems.

11. FIRE AND SMOKE PROTECTION (CSAR Chapter 9.0)

The SDC has some unique and complex fire protection issues. The combined presentations identified the principal fire hazards associated with the detector. The assessments performed, however, will need to be expanded in order to address all of the fire protection objectives required in DOE orders. Based on the material presented, and the hazards identified, the Panel believes that the hazards can be reduced to an acceptable level. The identified hazards will require creative engineering concepts and approaches. Even so, almost certainly there will be a need for some exemptions and equivalency requests to be submitted to the DOE. The Panel encourages the SDC to proceed with these requests early in the design.

The Panel strongly encourages the SDC to begin the Fire Hazard Analysis (FHA) very soon. The FHA should be performed by a fire protection engineer/group with experience in the process and methodology used by DOE and should be reviewed and approved by the SSC.

If credit is to be taken for life safety in the use of nitrogen or other inerting systems, the system must meet NFPA requirements or an exemption sought.

12. INTEGRATED SAFETY SYSTEMS (CSAR Chapter 10.0)

As stated, this concept is very preliminary. However, the safety systems concept presented is based on a firm foundation. The primary concern is the technology for integrating safety systems. The technology in the late 1990's will be primarily sophisticated hardware and software using programmable logic controllers (the same as today's technology). The firmware and software for controlling detectors, protection, alarms, automatic shutdowns and graceful degradation should be analyzed to minimize false alarms. Reliability and performance verification of such systems are of the utmost importance. Section 10.0 should be expanded to include the design concepts of how the safety systems are configured to detect with 100% reliability mishaps and undesired events and the scheme for containing, alerting, shutdowns, etc.

PART 2: DISCUSSION OF OTHER ISSUES

1. RADIATION

The radiation concerns associated with the SDC detector are numerous. The quantitative information provided to this Panel was primarily concerned with the radiation dose absorbed by the calorimeter components, especially in the forward calorimeter. Hazards associated with the residual activation of these components are planned to be mitigated by installation of temporary shielding around the hottest areas. Structural damage to materials due to the radiation environment, is not expected to be a major concern. Another concern expressed was mixed waste. The production of these wastes will be reduced by limiting the radiation exposure to hazardous materials, such as liquid scintillators. Finally, safety issues were raised associated with the radioactive sources which will be used to calibrate the calorimeter.

Since the a large portion of radiation dose to personnel at high energy laboratories is caused by exposure to activated components, it is the committee's opinion that this hazard requires further consideration. Residual radiation estimates should be made for the hottest detector components, and design should begin soon of temporary shielding needed to reduce these radiation fields to acceptable levels. In addition, the issue of handling and replacing these components should be addressed. Quick-connect/disconnect mounting for the components, as well as remote handling for the hottest pieces, should be investigated. Also, the storage of these activated components as well as the recovery and reuse of parts of the damaged components should be studied.

Activation within the other subsystems should also be investigated. Activation of the butane in the silicon tracker system should be calculated as well as any other gasses or liquids used in the detector. In an effort to reduce the mixed waste produced, the use of non-hazardous scintillators for the forward calorimeter should be considered. Mitigation action to prevent and contain radioactive liquid spills should be addressed. Finally, air activation in the detector hall should be reinvestigated now that there is a better understanding of the airflows around the detector .

The use of a automated system to move the calibration sources through the calorimeter is applauded. However, the choice of the particular source should be made in consideration of the radiation hazards associated radioactive material, and should be no stronger than needed to efficiently perform the calibrations.

The detector should be designed with the need for a systematic search and secure procedure in mind.

Operational radiation protection issues should also be addressed. Concerns in this area include the need for readable dosimeters, conduction of surveys, the personnel access system, placement and integrity of temporary shielding, including procedures to prevent unauthorized movement of these shields once they are in place, handling of activated materials, and methods to reduce the spread of contamination.

2. ENVIRONMENTAL RELEASES

As various options are explored, it is important to also explore the potential for environmental releases. In particular, with the new clean air and clean water legislation there may be some clear preferences in selection of various chemicals because of the restriction on releases to the environment. Spill plans will need to be developed for most chemicals.

3. NON-IONIZING RADIATION

Very likely extensive use will be made of lasers. The impact of lasers and other non-ionizing radiation sources should be evaluated as soon as they are identified.

4. STATIC MAGNETIC FIELDS

The access restrictions which will be required by the need to control the effects of static magnetic fields on personnel and objects should be evaluated.

5. LOCKOUT/TAGOUT

The design of the detector electronics and power systems should complement the development of a lockout/tagout system.

6. CONDUCT OF OPERATIONS

As the design progresses, there is a need to evaluate the impact of design choices on certain operational procedures. For example, design details may have a significant impact on search and secure procedures and the personnel access system.

8. HUMAN FACTORS

The presentations and the CSAR lack proper emphasis on human engineering, ergonomics, maintainability and access issues. Many issues were raised and quite a few problems were generally identified, but few solutions were offered other than building mock-ups, which can be expensive and impractical.

A more cost-effective and reasonable approach is to purchase 3 dimensional computers model programs to evaluate specific space, access, egress, weight dimensions, etc. To enhance this a human factors engineer with experience in experimental psychology, user sciences, man-machine interfaces should be part of the safety engineering effort. Also, someone knowledgeable in establishing maintainability requirement should be an integral part of the design team.

9. DESIGN FOR TESTING OF SAFETY SYSTEM

Safety systems should be designed so they can be easily tested. This includes fire alarms, oxygen deficiency and hazardous atmosphere detectors, and emergency power generators including load transfer switches.

10. USER SAFETY

There is a need to understand the interaction of the design and user safety requirements.

11. INDEPENDENT REVIEW

The SDC is strongly encouraged to continue to seek independent review. The plan to establish an independent standing review panel is excellent.

CONCLUSION:

It is the Panel's conclusion that:

1. The SDC has in place a system to systematically identify and assess hazards.
2. The SDC analysis system systematically identifies mitigation measures and assesses their impact.
3. The SDC has made a successful effort to obtain independent review and advice on ES&H matters.
4. The Panel can not, at this time, assess the residual level of risk. There are many design and mitigation issues yet to be decided.