BaBar SVT Mechanical Review

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Summary

The review committee finds that the SVT mechanical team has defined reasonable design requirements, developed a good mechanical design, and addressed most areas of fabrication, assembly, and quality control. Our detailed recommendations will follow, in an approximate priority order.

Our principal concern is for schedule: the current schedule calls for completed hybrid circuits to be delivered between 12/97 and 3/98, and for all completed detector modules to be delivered to LBL for final assembly by 9/98. This is an aggressive, success-oriented schedule, and the committee would not be surprised to see the final delivery of completed modules to slip by many months.

An experienced and capable team has come together to build the SVT. We commend them for the planning of the Review, and for the complete presentations at the Review.

We recognize that many of our recommendations may have been considered already by the SVT team.

Schedule

The schedule for delivery of the readout IC (the 'Atom Chip') shows all ICs delivered by 10/15/97, and then for all ICs to be mounted on hybrids and available for detector module assembly in the 2 months between 12/2/97 and 2/15/98. All completed detector modules are scheduled to be delivered by 9/98. The relatively late and sudden delivery of the hybrids presents risks for maintenance of the final detector module delivery schedule.

The hybrids are an integral part of the mechanical structure, and so final assembly of the detector modules cannot begin until the arrival of the hybrids. The committee saw no way to remove the hybrids from the critical path.

Assuming perfect success in IC and hybrid delivery and acceptance, and considering the experience of the Pisa and Santa Barbara groups in the construction of silicon detectors, it might be barely possible to meet the proposed schedule. Members of the committee have experienced considerable delays in IC and hybrid delivery and acceptance, however; these delays were outside the control of the detector builders.

Some delays (or advances) in the BaBar SVT schedule should be predictable in advance by the dates of milestone achievements. Readout IC design flaws, problems in the readout IC rad-hard realization, and hybrid design flaws would all cause these types of predictable delays. However, members of the committee have experienced flaws in final production runs. The BaBar SVT schedule allows little leeway for such flaws.

The committee expresses concern over the delivery schedule for the silicon detectors. That schedule shows delivery of detectors gradually over the 19 months between 6/96 and 1/98. Because of the long duration of the delivery period, slippage in the schedule will both be easy to notice, and possible to recover from.

Yields and Spares

The committee recommends that the SVT team undertake a detailed estimation of yields for silicon, fanouts, ICs, and hybrids. Obtaining the yields that have been experienced by other silicon vertex teams would help produce accurate estimates. Our experience is that the cost associated with procuring unanticipated spares argues for erring on the side of ample extras on the first procurement.

We recommend making at least 2 spare modules with active silicon and functioning readout for all layers. The spare modules need not contain components of a quality as high as those installed in the final detector.

We recommend making an accounting of numbers of prototypes of various sorts, including mechanical prototypes without wirebonds, and poor quality, but functional, detector modules.

The SVT team has minimized the number of different designs of detectors and hybrids. Nevertheless, the committee recommends the early negotiation of understandings for additional runs of small quantities of extra components, to avoid surprises in the time-critical assembly period of 1998.

There are many different fanout designs, and it is likely that small runs will be needed to replace flawed or damaged fanouts. The fact that CERN is fabricating the fanouts appears to reduce the likelihood of delays and expense from added runs. Continued improvement of the ability to rework fanouts by bridging opens and melting shorts will help reduce the need for added fabrication runs.

Design and Development of Detector Modules

The 'bent wirebonds' in the arch modules present a challenge to the Pisa group, who are well suited to perform the remaining development. The evidence from prototypes bonded on a 50μm pitch and bent to a $45°$ angle indicates that the specifications for the arch modules, namely, 100μm pitch bent at a roughly $25°$ angle, should be attainable. Detailed exploration of wirebonder parameters, pull test strengths, and maximum strains before breakage need to be executed.

The committee recommends the *consideration* of the encapsulation of all wirebonds. Development work to evaluate an encapsulation compound, which ideally should be clear for visual inspection, and soft for easy removal, needs to be done. In all cases, final encapsulation should be delayed until empirical proof is made that the encapsulated element is fully functional.

The committee's experience is that *some* wirebonds should not be encapsulated. The ability to disconnect a detector channel from the preamplifier IC must be maintained. The SVT team should determine, for each module, the best way to retain this ability. However, the committee has had the experience that it is easy, in absence of complete fixturing, to damage unencapsulated wirebonds when they are in widely different locations in a module.

The radiation hardness of the final detectors should be evaluated.

Prototypes of all flexible circuits should be tested for mechanical integrity. Brittle barrier materials such as nickel my crack in unbalanced flex layouts, causing stress concentrations in in conductors which may lead to open circuits. Mechanical flex circuit testing should reflect the actual geometry, materials, and connectors.

The committee was concerned about the dimensional stability of Kevlar, used in the supports, after exposure to high humidity. Kevlar is hydroscopic. Research on the dimensional growth or shrinkage of Kevlar after exposure to water vapor should be performed.

The techniques for gluing detectors head-to-head, and for gluing the fanouts to the detectors would benefit from more development, for reproducibility.

The total temperature drop in the system is 20°, and the fact that the average system temperature will be that of the nearby magnets dictates use of a cooling water temperature of 10°, a bit cool; we recommend reviewing methods to reduce the temperature drop. The largest temperature drop appears to be from the readout IC to the cooling ring. Best technology for the readout IC to hybrid contact (eutectic bonding), as well as an increase in the thickness of the hybrid, should be considered.

The fundamental vibration frequency of the arch modules, 124 Hz, is noticeable close to an overtone of the electrical line frequency in the U.S., 60 Hz; some electromechanical systems vibrate at 120 Hz. Measures to move the arch module fundamental away from 120 Hz should be investigated.

Design and Development of Mechanical Support

It was not clear that applied loads would tend to be supported by the space frame, and would not tend to be transmitted through the detector modules. The good thermal contacts, important for cooling, tend to overconstrain the modules. Mechanical prototyping should be done to investigate whether the detector modules could be damaged by applied loads.

The joining of the two half-cones that surround the permanent magnets may be underconstrained. Added pins should be evaluated.

The details of the joining of the two space frame halves need to be revised: the current conical threaded fastener plan is unlikely to achieve better than 150 micron accuracy.

Testing and Quality Control

In order to maintain the scheduled completion by the beginning of 1999, most of the wirebonding of fanouts to detectors must be complete before the final hybrids arrive at the end of 1997. Most possible mechanisms whereby the wirebonder could damage the detectors have been contemplated, and those mechanisms will be monitored throughout 1996 and 1997 as the wirebonding is performed.

However, the actual noise in the detectors apparently cannot be measured without final attachment of the hybrids. Should there be a mechanism whereby the wirebonder could make a defect that is not caught by the planned tests, a significant loss of detector performance could occur. In the experience of the committee, sources of noisy strips in previous silicon detectors are not fully understood.

The committee recommends generally not to commit material to production without careful prior testing. Specifically, the small number of prototype hybrids that arrive during 1996 and 1997 should be used to establish as best possible that the wirebonding does not compromise detectors. Ideally, production wirebonding at either site (Pisa or Santa Barbara) should not commence until one acceptable detector attached to a prototype hybrid has been produced at that site. After the commencement of production, detectors should be attached to prototype hybrids periodically, to monitor the wirebonding performance.

Surveying

Much surveying data will be accumulated throughout the project. A coordinated database should be established, under the responsibility of one person. Ideally, that person would also coordinate the actual geometric description of the detector in the Monte Carlo and the track reconstruction program.

Monitoring

The goal of stability to 1°C appears to us a bit tight, and attainment of that goal should not be allowed to delay the assembly schedule. The temperature stability necessary to insure uncompromised vertex resolution should be more thoroughly evaluated: we believe 5°C may be allowable, although 'bimetal' effects between the Kevlar and the silicon might induce unusual spatial twists in the arch modules. Study of these effects on mechanical prototypes would be helpful.

The committee recommends placement of strain gauges on the support cones; the strain gauges should be planned into the bonafide monitoring system of the detector.