REPORT ON THE FINAL DESIGN REVIEW OF THE
SCT END CAP MODULES FOR ATLAS

CERN, 6 August 2002

The Atlas SCT End Cap team has fabricated 18 prototype modules, which have been used to demonstrate the mechanical and electrical performance of their design. The reviewers strongly recommend undertaking rapidly more irradiation tests on finished modules to prove full accordance with their specification. In parallel preparation for the series shall go on, but a two step process using pre-series components for further system tests seem essential. A PRR to be held within the next half year will help to reconfirm the validity of the design and shall give the green light for the series production.
1. Introduction

The Final Design Review for the SCT End Cap Modules of ATLAS was held at CERN on 6 August 2002. The Agenda and Scope of this review were defined in detail in ATLAS project document ATC-RI-ET-0038, together with the documents upon which the review was based and the list of reviewers and participants from the SCT team. Also a very fruitful and dense preparatory discussion between the reviewers and some members of the SCT team, took place the day before the review itself.

2. Matters Discussed

The Atlas SCT project has fabricated 18 prototype modules, which have been used to demonstrate the mechanical and electrical performance of the design, to start system testing, and to measure the performance after irradiation at the dose required for LHC experiments (10 years of operation). The project is now planning to move rapidly into the production phase.

Four questions were addressed in the review:

2.1. Does the design meet specifications?

While there are still issues to be resolved in the details of the module mounting to satisfy the alignment specifications and thermal performance, the prototype modules demonstrate that the module design and assembly procedures meet the mechanical specifications for the module itself. The one outstanding concern is for the electrical performance after radiation. Testing of two irradiated modules indicates that they fail the signal/noise specification (defined in terms of efficiency and occupancy for the binary readout). These modules passed the specification before irradiation. After irradiation, a price must be paid in either the noise occupancy or the tracking efficiency. It should be noted that this result is inconsistent with earlier testing of barrel modules, which use the same readout chips and very similar silicon detectors.

2.2. Are the module components of production grade?

Only minor changes are being made to the module components as a result of the experience in building the 18 modules. An order for a pre-series batch of hybrids and spines has been placed and will be used for site qualification.

2.3. Are the interfaces to other detector systems (cooling, mounting, cabling) sufficiently defined?

While the initial system tests are encouraging, more complete testing is needed to understand:
- Reproducibility in the alignment and thermal performance of the module mounting
  This impacts the specifications for the cooling system to ensure that all modules are adequately cooled.
- Sources of electrical noise in the system
  Initial studies indicate that the cabling and cooling plants could introduce significant external noise into the module readout. Every effort must be made to make the system as robust as possible from noise sources external to the modules. The grounding scheme for the system is being studied in these tests. There is one question, which could in principle affect the module components, in the power filtering on hybrids.

2.4. Is the project organized and ready for production module assembly?

Seven assembly sites are established and are completing the necessary equipment and tooling. The project plans a pre-production assembly of about 50 modules (in total) to qualify the assembly sites, tooling and procedures. The schedule presented shows the production orders being placed before this qualification phase is completed. This is required to meet the tight overall SCT schedule.

3. Conclusion and Recommendations

3.1. Testing of modules and components (2.1 and 2.2)

- Two more modules should be irradiated and measured in the August test beam to measure their S/N.
- The next test beam should be made with at least three (ideally four) irradiated modules to allow a realistic determination of tracking performance after irradiation. If it is demonstrated that the compromise in tracking performance is acceptable, then the signal to noise specification can be relaxed.
- If the two new irradiated modules meet the tracking specification, production should proceed but additional pre-series modules should still be irradiated and tested.
• If the two new irradiated modules do not meet the tracking specification, a crash program (including new irradiations and source tests) should be undertaken to understand the problem. Any difference to the barrel tests should be understood. It might be useful to irradiate a module to 1.5\times10^{14}.

• It is possible that changes to power filtering on the hybrids might be desirable as a result of system noise studies (see below 3.2). This question should be answered as soon as possible using the pre-series components which would allow any necessary corrections before full quantities are produced (see below 3.3).

• All modules should be tested to 500V (as in barrels), which is done already at burn in tests of the hybrids, as we understand. Keep the distance of the wires from the HV, e.g., sensor edge, to more than 500 microns, in order to avoid shorts/leakage due to humidity.

• Keep close track of failures of any kind.

• Post-cure the room-temperature-cured epoxy at an elevated temperature.

• All tests should be done using the final "spring washers" as designed to hold the modules.

3.2 Integration Issues (2.3)

• After further measurements of the reproducibility of the mounting scheme the specifications should be updated to ensure that the specifications will be met for all modules in the system for the module mounting & cooling blocks as well as for the operating temperature range of the cooling system.

• Thermal cycling tests with full power should be carried out with a sufficient number of cycles (like 50), keeping within the safe highest temperature of the ASIC’s, to confirm that the out-of-plane deviation along the cycles is within specification.

• Thermal runaway measurements should be repeated for other K5-hybrid modules and include the dependence on the environment temperature.

• The mechanical integrity and operation of modules at lowest possible temperature (-30C) should be tested.

• At least one module should be run long term (see below)

• The noise path through cooling pipes power tapes etc to be further checked in system tests. The question of whether any modest adjustments to filtering in the hybrid circuit can help reduce susceptibility to external noise sources should be answered urgently.

• Show that repeated connector disconnecting does not distort the mounted modules differently along the cycles.

• How is the thermal grease applied to the blocks and how is the thermal contact to blocks checked?

3.3 Planning and schedules (2.4)

• The program to build the next 50 modules should proceed and be used to improve understanding as proposed above.

• It is recommended that the placing of production orders be phased to allow further learning from the qualification assembly, and corrections if necessary. It is however important that the production orders for the major components (the hybrids and spines) be placed within the next few months. If open issues remain, the production orders could be placed with a first partial delivery (say 10%) before release of the remaining order (with feedback to ATLAS management).

• There are a few chip failures on the prototype modules, which may be a result of the use of sub-standard chips, or could be significant for module assembly yields. Especially in the early stages of assembly it is particularly important that all failures be understood. Statistics are very limited and failures might indicate more widespread problems. The quality of parts used in the qualification phase should not be compromised.

• The accounting of “spares” should be revisited. Spares are needed to cover breakage during assembly, various module testing, and to provide long-term system tests to study operational issues throughout the full life of the experiment.

• The full system of 2000 modules must operate reliably for 10 years. It is important to build up even limited experience with longer-term operation as soon as possible. It is recommended that the project establish a long-term test setup, perhaps including both forward and barrel modules, which is operated continually. As modules become available the system should be expanded. (These modules need not meet full mechanical specifications.)

The SCT End Cap team has to be thanked for the large amount of high level work presented to that Module review. The reviewers also are grateful for the very useful preparatory discussions they had with some team members. To run this FDR will certainly help the community to take all necessary steps to reach production phase soon with a PRR to start with. The team is invited to come back with results to the reviewers before the PRR.