

## LARGE HADRON COLLIDER COMMITTEE

### CMS INSTALLATION REVIEW

September 2002

#### 1. EXECUTIVE SUMMARY

The first of the LHCC Installation Reviews of CMS took place on 10-11 September 2002. The Review Committee addressed the projected schedules and milestones, the required resources to carry-out the installation as well as identifying any potential risks for the installation. In particular, the Committee was charged with reviewing the following issues: details of the planned activities and work packages, origin of the resources, both in terms of money and manpower, critical path items, assessment of risks, survey and alignment and safety.

Membership of the Review Committee:

Chairman: R. Cashmore, CERN Director for Collider Programmes

Representatives from the LHCC: W. Bartel, J. Dainton, P. Lebrun, K. Potter (rapporteur)

Representatives from the Technical Sector: P. Ciriani, A. Scaramelli

External Reviewers: R. Kephart, P. Lazeyras

CERN Technical Director: J. May

LHCC Chairman and Secretary: M. Calvetti, E. Tsesmelis

EP Division: J. Salicio-Diez, D. Schlatter, V. Vuillemin

TIS Division : W. Weingarten

The Review Committee congratulated CMS on their excellent presentations and team spirit and was impressed with the well thought out approach to the installation of the CMS detector at Point 5.

The over all impression is that the CMS detector has been engineered from the start to facilitate installation. The concept of large slices, which can be opened without having to disconnect cables and services, gives good access to sub-detectors and hence eases both installation and maintenance.

This modular concept also allows assembly on the surface and lowering in large pieces. As a result of changes in the schedule and late delivery of underground caverns this concept has been extended to include extensive installation and testing of detectors, which again is seen as very positive. This concept, introduced to cope with delays in the delivery of the underground caverns, also allows some flexibility to handle possible detector delays.

Although not the object of this review the Committee heard a detailed explanation of the cost sharing of the CMS installation of which the major components are the LHC Area budget and supplement as included in the CERN cost to completion plan, the CMS general infrastructure and sub-detector budgets, as scrutinised by CORE (Cost Review Committee of the LHCC), and the C&I and M&O budgets of CMS, as examined by the relevant scrutiny groups and accepted by the RRB. It was understood by the Review Committee that the baseline installation plan of the CMS detector and its breakdown into work packages is consistent with this global financial plan. The general infrastructure and the different sub-detector installation plans have been well thought out and all costs seem to have been included.

The excellent progress in the heavy engineering for the magnet was noted, with the yoke assembly and trial insertion of the inner cryostat of the coil successfully completed. The better than expected geometrical precision will also facilitate detector mounting and alignment.

The Committee was pleased to hear that it may be possible to deliver the SCX5 building early, in addition to the USC55 service cavern and wish to underline the importance of these critical items. The commissioning of the DAQ is an item of considerable concern and any increase in the time available will be very well worthwhile. **The CERN management should support this move**, up to the limit of additional costs.

The proposed installation team, composed of "field service" type contracts, staff from user groups and locally recruited staff, which will provide basic support to institute teams installing sub-detectors, was discussed at length and it was judged to be a sound principle offering the necessary flexibility. The Committee considered this team to be of adequate size. The detailed composition as a function of time was appreciated, but it is suggested that their continued presence, for some time after first beam, followed by a gradual reduction over a somewhat longer period than currently foreseen by CMS, may be necessary.

The Committee was pleased to hear that safety considerations are being fully implemented at all stages, and in all cases, including by the visiting teams. Nonetheless, they also wish to support the questions concerning seismic safety in the assembly stage on the surface. It is also **recommended that emergency exit procedures are very carefully worked out for the underground phase**, taking into account any maximum presence figures which may be imposed by the CERN safety authorities. The Review Committee also supports the request for INB guidance and **recommends CERN to organize a dedicated unit to deal with INB matters** in a common central manner for all the LHC experiments, as well as the machine.

## 2. COMMENTS ON THE CMS INSTALLATION CONCEPT

The CMS installation schedule appears realistic assuming first beam on 1 April 2007, although more **work is needed to define the details of the nine-month period needed for Trigger and DAQ integration**. The statement that this would be an important topic for future electronics integration meetings was noted and the Review Committee was pleased to hear that a detailed plan will be available shortly.

The plans for handling the very important cabling project as part of the integration task seem to be reasonable, but a great deal more work is needed on the details. **The review Committee wish to underline the importance of a systematic and detailed cabling plan for all detectors**. It was noted that a detailed plan for cabling is being prepared and will be available within a year. This plan must include the details of how excess cable lengths will be stored. The full participation and compliance of all sub-detectors is essential and this will require a strong central technical co-ordination. The use of a CMS-wide norm which conforms to ST and LHC schemes (and is INB compliant) is important. While the advantages of intermediate patch-panels are fully appreciated, the large number of connectors will require **very high reliability connections and attention should be given to this**, particularly where the connectors are relatively inaccessible.

The planned low-voltage AC-DC power distribution system appears to be essential in order to save large quantities of cable and its associated installation and to avoid cableway cooling otherwise needed to minimize thermal losses into the air. It is pointed out that even with this scheme the very high DC currents drawn by the Tracker in the high magnetic field **require careful studies of all possible effects**, including distortion of the magnetic field, forces on the cables and resistive heating.

Communication with the CERN support services in the technical sector and other divisions appear to be very good and expectations realistic. It should be noted that the only way to avoid difficulties arising from lack of shared resources at CERN will be to have an excellent medium term plan with a maximum of information transmitted to the relevant service in good time. Any unforeseen requests will be very hard for overstretched services to handle. As

regards costs and cost-sharing it is **strongly recommended that the work package scheme is refined and agreed with the relevant groups** in as much detail as possible.

The difficult time window in the civil engineering for the installation of lift modules and metallic structures in the PM54 access shaft was discussed at length and the risk of cost overruns and how to handle possible delays should be studied. The importance of starting as early as possible the USC55 infrastructure installation, even if it is in difficult circumstances, cannot be over emphasized, the advantages of an early start on the all-important DAQ integration and commissioning period being the major motivation.

**Quality assurance during installation and change control need to be taken very seriously** and it should not be forgotten that the installation period is a particularly dangerous time for detectors. Proper monitoring and environmental control must be in place ahead of the arrival of expensive detectors. **Safety training and monitoring for personnel must also exist**, together with all **emergency escape plans and facilities**.

### 3. INSTALLATION OF SUB-SYSTEMS

#### 3.1 MAGNET

The final magnet test underground in October 2006 is recognized as very important and it should be maintained if at all possible.

The decision to place the magnet dump resistors on the surface appears unavoidable and the agreement of the MAG group was noted. Nonetheless, the Review Committee wishes to remind CMS of the importance of this system and **urges the greatest care for the safety of the super-conducting solenoid as well as people and neighbouring equipment**.

Following the underground magnet test, the magnet will presumably be kept cold. Any plans to provide magnetic field for detector performance, or data acquisition testing, will give an additional constraint to the installation planning and will be in conflict with the End-cap Electromagnetic Calorimeter (EE) installation and will thus require careful planning.

#### 3.2 BEAMPIPE

Great attention was paid to the installation of the beampipe, which on the base line planning will be installed through the Tracker and other sub-detectors. The installation will be the responsibility of the LHC vacuum group who will provide all the vacuum expertise. They will be assisted by the CMS installation team and use the access platforms and equipment of the CMS installation team. The Review Committee **recommends that the planning, cost sharing and installation responsibilities should all be agreed in the greatest possible detail**.

It was pointed out to the Review Committee that the call for tender for the central Beryllium beampipe has now been launched and no further changes are possible.

#### 3.3 REMARKS TO THE INSTALLATION OF SUB-DETECTORS

The installation of each sub-detector was very well described and the Review Committee noted that in each case the installation and tooling costs had been included in the sub-detector cost book entry. Safety aspects appear to have been taken into account and it was noted that the general safety procedures for sub-contractors was being applied by CMS to the institutes during installation of their sub-detectors. In some cases safety documentation has been translated into Russian.

In general the installation plans have been well thought out and are proceeding according to plan with the institute teams being well supported by the general CMS installation team. With many of the delicate operations being carried out for the first time on the surface, there should be few problems. However, the planning is very tight and it should be noted that while two or three shift working is considered as a normal contingency, it was not evident that the increased costs that will result have been evaluated or how they will be covered. It will clearly be necessary to use parallel working as effectively as possible. Both extra shifts and parallel working will put an additional load on the CMS installation team and must be taken into

account. Nonetheless the summary of human resources shown was appreciated and **the Committee consider that the team should be adequate.**

Careful planning of the use of cranes and transport vehicles will also be essential. The frequent sharing of installation tooling among different sub-detectors was considered very positive and indicates co-ordination and excellent team spirit.

The Committee took note that the support divisions of CERN, ST, EST, LHC, and TIS, who were represented by their present or future Division Leaders stated that **adequate provision has been made in CERN** to carry out the installation tasks.

The Committee was also pleased to note that the installation of the TOTEM telescopes was included in the installation plans even though TOTEM have not yet written a TDR and hence changes are probable.

The following are a few of the more important comments to specific detectors.

### **3.4 TRACKER**

The Tracker cabling is a major undertaking which must be carefully included in the comprehensive cabling plan already mentioned. The number of simultaneous operations must be limited and several reviewers felt that a team of thirty may be too large for single shift working. The major difficulties that other silicon trackers have had with condensation on cooling pipes should be examined. The proposal to bury the pipes among the cables was not seen as a perfect solution, if only because it would make dealing with coolant leaks particularly difficult. **All safety issues must be carefully considered before doing this.**

### **3.5 PIXEL INSTALLATION AND BAKE-OUT**

The installation of the Pixel detector at a later date has been carefully checked on the full-scale mock-up provided by the LHC vacuum group. The procedure appears safe and should be reasonably rapid. The Pixel and central beampipe support system including their disposition for bake-out is in the CMS Tracker budget, but the manpower and other **facilities to be provided by the LHC vacuum group**, who will have to carry out many of the operations such as backfilling with ultra-pure gas, installing and operation of bake-out equipment, **should be checked.**

### **3.6 ENDCAP ELECTROMAGNETIC CALORIMETER AND PRESHOWER**

The Committee was somewhat puzzled by the design of the pre-shower (SE) detector whose circular integrity makes the pre-installation on a dummy of an end-cap electromagnetic calorimeter a necessity. The already known late delivery of the end-cap calorimeters, means that they will have to be installed under the greatest pressure, either just before first-beam, or in a time restricted shutdown, before the first physics run. A divided pre-shower detector would help to facilitate this late installation, as well as simplifying future maintenance and avoiding a relatively expensive dummy detector. **The Committee recommends further studies if possible.**

### **3.7 HADRON FORWARD CALORIMETER**

While the transport of the 250 ton modules of the Hadron Forward Calorimeter from the Meyrin site to Point 5 is being investigated, the Committee noted that this transport can be made in a modular manner if necessary, or if it turns out to be more cost effective.

## **4. CONCLUSIONS**

The Review Committee was impressed by the well thought out installation plan of the CMS experiment. Progress so far on the heavy engineering of the magnet and the first detectors show that the Technical Coordination is working well, with a good team spirit between the local support and the sub-detector teams from collaborating institutes. The construction responsibilities of the MOU are being respected and there is a clear agreement on cost sharing between the LHC experimental area, the CMS infrastructure and the CMS sub-detectors.

The installation still has a long way to go and much work remains to be done. The major concerns of the Review Committee are given below. It is hoped that they will allow the

LHCC to follow up outstanding issues and to monitor future progress. It is recommended that the following issues should be addressed in greater detail:

- a systematic and detailed cabling plan,
- the reliability of connectors,
- quality assurance and change control,
- early installation of monitoring and control systems,
- the ‘work package’ approach,
- availability of transport and handling resources,
- occupancy of high risk areas, maximum numbers underground, safety and evacuation procedures and safety training,
- the reliability of the magnet dump resistor system
- inner detector services, including high current cabling in the magnetic field and cooling,
- trigger and DAQ integration and commissioning

The over all planning has very few contingencies, however, and this will make dealing with any possible sub-detector construction delay very difficult. The introduction of multiple shift working can be used to cope with such delays, but will often require additional resources and reorganisation of the C&I funding.

The construction and installation of the CMS experiment has started well. More work is needed on detector services and cabling particularly for the inner detectors and on the final stage DAQ commissioning, but there is every reason to believe that CMS will have a working detector ready for first collisions in April 2007.