SESSION 6 – INSTALLATION

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CERN, Geneva, Switzerland

Abstract

The installation session treated seven subjects of immediate interest to the LHC project: scheduling, safety, LHC and SPS access system issues, progress in the QRL installation and first experiences of QRL operations, progress of the TS-MME work packages, Electrical Quality Assurance and magnetic circuit verification. The sessions gave a good overview of the progress and the important issues in this phase of the project. Safety remains as always an important subject with so many concurrent activities in the tunnel.

ARE WE STILL ON TIME? – S. WEISZ

The presentation gave an overview of the project status as it was a year ago, showed the impressive progress made during the last 12 months and discussed finally what delays can be expected if the current installation rates were maintained. S.Weisz also gave a perspective of some of the presently well-understood “hard” limits that have to be overcome if the current delays are to be recuperated. Earlier delays have been handled by excluding some extensive tests from the schedule e.g. the planned cold tests for the entire QRL complex have been restricted to sectors (7-8 & 8-1). It is assumed that these tests are representative of the other sectors**.** Another strategy change is to install magnets completely in parallel with the QRL installation and leak tests**.**

Today however, the QRL installation is about three months behind schedule. In sector 7-8 the sub-sectors A & B were expected to be ready in July, the cold tests started mid-September and the completion of the full sector which was expected for September, was finally done in December In sector 8-1 the cold tests were expected for September, and were done in December 2005. Here a delay of three months exists with respect to the schedule.

The Distribution Feed Box project has suffered delays that still are not completely recovered, despite concerted efforts from AT, TS and IHEP, a six months delay exists relative to the schedule.

Magnet transportation capacities have been improved from a nominal 10 magnets/week to 20 magnets/week. However in 2005 although it was expected to transport ~600 magnets, only 249 were handled. This implies a 4 months delay assuming that the transport rate 20 magnets/week is maintained.

In 2005, despite the progress, delays between 3 and 5 months have been introduced, sometimes for reasons of missing/late equipment and sometimes due to overoptimistic estimations of actual work duration and an underestimation of the impact of co-activities. The project has gained much experience with new activities: QRL pressure and associated cold tests, large scale magnet transports, interconnect issues, the installation and tests of power converters, etc. It is now well understood that leak tests and leak finding in the QRL are very delicate activities and that they consume more time than initially expected.

The known “hard limits” for the LHC installation originates in the following subprojects or activities: QRL, magnet transportation, special SSS procurement and DFB.

The present schedule for QRL installation indicates that the QRL installation in sector 1-2 is finalized by November 2006. Any leak testing and repair delays have to be added to this date.

The magnet transport rates are given by the following elements: LHC has 1232 main dipoles, 24 Low-β, 24 long special SSS, 16 D1/2/3/4 = 1296 main magnetic elements that are transported with CTV and MCTV convoys. Of these, 240 dipoles are in place today, leaving 1056 elements on the surface. With an assumed transport rate with CTV & MCTV convoys of 15 elements/week until Easter and an accelerated rate with 18 elements /week, transportation will last for 61 weeks (end date March 2007). By using Point 6 for SSS elements going to sector 5-6 and 6-7 the delay expected can be reduced to three months relative to the present schedule.

The rate of production of special SSS has to increase; presently the last special SSS will be installed in the tunnel at the end of March 07.

The present schedule for the DFBs are indicating a lag of up to four months in the installation compared to the magnet installation – this issue has been acknowledged and steps are being taken to remedy it.

The scenario for interconnection and handover of the sectors to the Hardware Commissioning team has been worked out and presently it assumes a minimum of 95 days between the end of the magnet transport and the availability of the sector for HW commissioning. In addition to this constraint the complexity of the DFB’s are such that it is assumed that a minimum of 80 days between the installation of DFBA’s and the sector becoming available for HW commissioning is required.

The schedule presentation’s first conclusion: many new activities were successfully ramped-up in 2005: QRL repair, installation and tests; surface logistics, preparation and underground magnet transport; alignment, and

interconnection in a difficult environment (tight space with many co-activities).
The conclusion on the status of the installation today versus present planning shows that actual delays span from 3 to 4 months. Certain equipment or subsystems are late: DFB's, special Short Straight Sections. Certain activities take presently longer than expected initially, in particular leak tests and leak finding.
The Hardware commissioning planning is presently as follows: Sector 7-8 should be ready for hardware commissioning by August 2006; the hardware commissioning of Sector 8-1 will not be finished this year. The last Sectors (1-2 & 2-3) should be ready for HW commissioning by August 2007. The present DFB schedule imposes severe constraints on the HW commissioning as regards time and location.

SAFETY IN TIMES OF INTENSE CO-ACTIVITIES – M. VADON

In view of the unprecedented co-activity and tension the compressed schedule imposes, M. Vadon – the LHC project safety officer - was invited to give an overview of how to best ensure that project engineers always give safety priority. The speaker presented a list of accidents reported, ranging from falling off scaffolding to fatal incidents. In too many cases the written procedures have not been followed, in some cases non-conform machinery have been used, resulting in fingers being cut off etc. Many incidents concern electrical cabling, cables are being cut without the worker having ensured that no power is present. M.Vadon reported that 45 accidents or incidents were declared in 2005, 14 were followed by an inquiry, and he presume that probably many more were not declared. After investigation it often appears that procedures are incorrectly applied, changed at the last minute, not followed or even worse non-existing. The personnel involved are from sub-contractor companies, or are interim man power or experts being over-confident with many years of experience.
Typical recurrent problems identified are related to the PPSPS (Plan de Prevention de Securité) which must be up-to-date, accurate and adapted to the situation at hand; works are not declared, or continue beyond what has been declared or authorised; the safety perimeters not respected; a lack of supervision and preparation; smoking and missing personal protection equipment etc..
The documents related to safety conditions are required for contractual and legal reasons. The consequences of accidents where the legal situation is not correct can be catastrophic for the project – an accident at SLAC shut down the accelerators for a 6 months period.
The presentation underlined that work that is not well prepared before-hand, work that is difficult, has a high risk to induce loss of time, quality and accidents.
The LHC Safety team has been given extra resources – 4 more safety specialists will be available from March 2006. These specialists are available to all LHC project engineers for consulting in matters of safety. The hierarchical responsibility is however always maintained in all cases – neither the LHC safety engineers nor the SC can be considered responsible in case of accidents. An LHC project engineer is the person responsible for ensuring that his/her project is a safe project.
The presentation concluded: An accident may have catastrophic consequences on the whole project; the compression of the planning must be done without compromise on safety. The responsibility for this is borne by the LHC project engineers.

LHC ACCESS – WHERE DO WE STAND? – P. NININ

The LHC Access System project was restarted in November 2004; in January 2006 the pilot installation in the old TCR was assessed by the LHC, AB and TS top management and given production approval. The LHC Access control system comprises two separate subsystems LASS and LACS, see Figure 1.

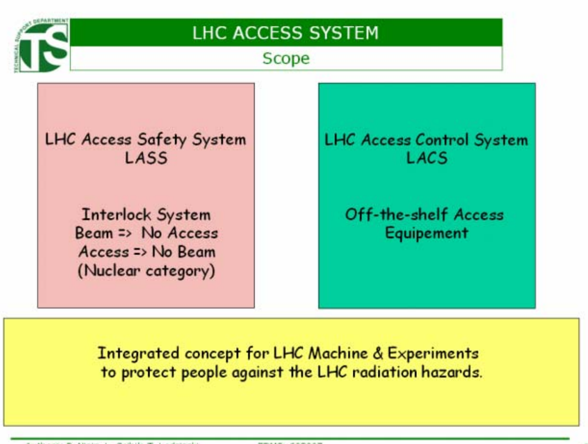

Figure 1 - LHC Access system concept

The LHC Access system is large, see Figure 2 which shows the scope of the project. The goals of the system can be summarised: the system shall protect human beings from radiation first and foremost by ensuring that if a person is inside there shall be no beam in LHC and if there is a beam in LHC no person shall be inside. A major difference of the LHC access system compared with earlier access control systems at CERN is the LHC INB status. The French INB authorities have the right and the duty to inspect and give their reasoned opinion on the proposed LASS system architecture before any implementation is launched. The architecture was reviewed at a number of occasions with the authorities and a major modification in the form of an extra independent cabled loop was added. The resulting architecture now offers redundancy and has no common mode of failure.

The status of the LASS is as follows: the hardware and software architecture prototyping is terminated; the identification and documentation of the interlocked LHC machine elements is completed; the INB documentation has been completed and the required safety studies are completed.

A contract for the implementation of the system was signed in October 2005 and the design of the final hardware and software is progressing with good results. The success of the LHC access project depends also on the involvement of the users, here primarily the AB/OP group.

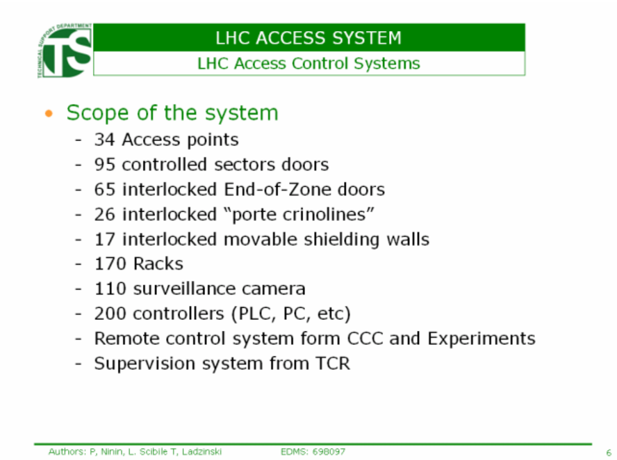

Figure 2 - LHC Access control system scope

The main conclusions: the project is on track; the INB issues had been well managed by ensuring that a comprehensive and relevant documentation was available from the start of the project.

A strong accent is put on configuration management with strict application of ECR methodologies – traceability is an INB requirement. The next challenge will be to move from a functional prototype to a robust system. The continued support and participation from AB is vital to finalise the remaining specification work and TS/CSE is fully mobilised to deliver a well working system.

SPS ACCESS SAFETY SYSTEM – P. LIENARD, E. MANOLA-POGGIOLI

The presentation gave an overview of the present SPS access system. When CERN signed the INB treaty with France both LHC, SPS and CNGS were included inside the INB classed perimeter. The SPS system, despite its excellent safety record is not considered to have a safe architecture by the INB authorities. The system is not designed using diverse, redundant technology, see Figure 3. All safety functions are executed in a Siemens S5 PLC based architecture, and single points of failure do exist while the INB architecture policy is to always have redundancy in all critical safety systems. In order to provide a system that complies with the INB safety policy an upgrade of the SPS access system is thus required.

This upgrade project will eventually result in a completely new SPS access control system, using the LHC access system as model. The upgrade will be deployed in three phases, ideally in sequence in the next major yearly accelerator shutdowns to avoid losing valuable physics time. In the first phase, required for the 2006 startup, compensatory measures will be added to the access system. In the shutdown 2006-2007 a cabled loop, similar to the one deployed for the LHC will be added to the existing system. In the following shutdowns the kernel of the system and the different access points will be upgraded. A detailed schedule will be worked out during the spring 2006.

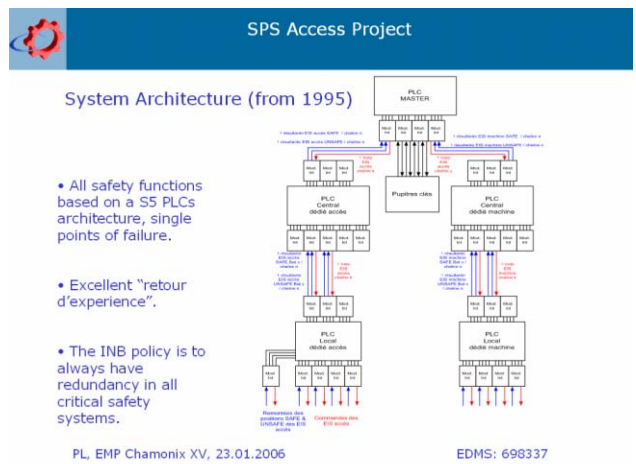

Figure 3 - SPS Access control system architecture

The compensatory measures will necessarily bring inconveniences to the access and operation of the SPS but no other choice exists presently. It was not conceivable to launch a major hardware upgrade within the short delays and with the resources available. The main points of these compensatory measures are described below.

The access doors will have locked caps on their direction of entry – emergency exits will always be maintained and are not concerned by this measure. However a number of sector doors in the transfer lines that can be used as emergency exits will be connected directly to neighboring AUG chains.

The opening of any of these doors will automatically trigger an emergency stop of the SPS machine. The doors will be equipped with a signpost clearly indicating the above condition.

In the shutdown 2006-2007 with the addition of a cabled loop the SPS system will have an adequate architecture. The cabled loop functionality is however limited in scope – it, in parallel with the present PLC based system, shall ensure that in all cases any intrusion through the external envelope is detected and the SPS is stopped.

TS-MME WORKPACKAGES – V. VUILLEMIN

The TS department provides design, engineering and manufacturing support to the LHC equipment groups in both the AT and AB departments. The presentation gave an overview of the activities particularly linked to the AB department's BDI and ATB groups. The policy of the TS department is to accept work in the form of work-packages, packages that have well defined objectives, clearly understood resource requirements and deliverables. The AB/BDI group is responsible for the LHC beam instrumentation in general, installation issues will be resolved in collaboration with the TS/IC and TS/MME groups. The presentation gave an overview of the different instrumentation types that will be designed, manufactured and installed and the volumes involved. For the "classical" beam instrumentation concerning devices such as beam position monitors, beam tv screens, gas ionization monitors, flying wire scanners, beam loss monitors and current transformers two design engineers and 11 designers are active. The CERN internal manufacturing effort for this package, excluding some BPM's and the BLM's is estimated to be, until March 2006 3'500 man-hours.

The progress of this work-package has been satisfactory, the design work is nearly finished in all cases, and manufacturing is progressing well. Some of the instruments require access to specialized machine tools such as electron beam welding machines which are in general already in strong demand, thus forcing the TS/MME group to set priorities.

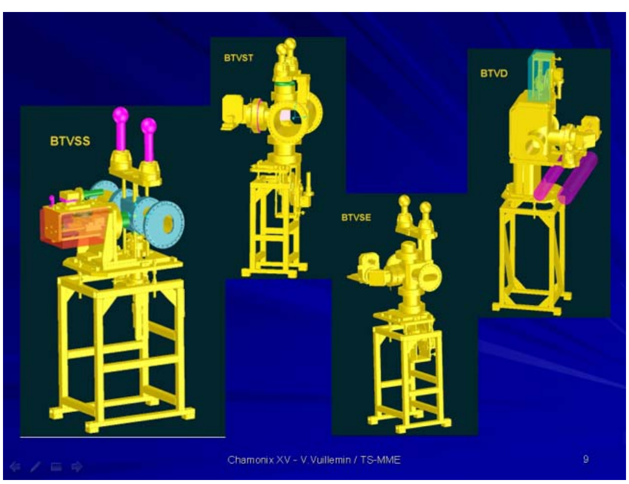

Figure 3 - Beam monitoring devices

Figure 3 above gives an impression of the variety of the beam instrumentation devices that are being designed and manufactured.

The second major TS/MME work-package concerns the LHC collimators. This package and its conditions date back to the EST division era:

"The EST provided output will be the required number of prototype collimators within the required schedule and drawings for the series production".

Since then the requirements have gone through a considerable evolution with the equipment group deepening its understanding of the system. The number of collimators and their associated masks has seen some inflation compared with the original estimates in the project and more than 700 blueprints have been created over the two last years.

The speaker expressed some general concerns concerning the Collimator project's production phase. Since presently TS/MME has no slack in its production facilities nor in its user support team; no additional help for any production/repair/quality control should be envisaged. The AB department must provide its own resources for the complete handling of the 10 collimators delivered by the Contractor each month.

The TS/SU group has made a proposal based on their experience from other accelerators, for a system to make regular control of the alignment of the collimators once they are installed taking into account the highly radioactive environment. The speaker encouraged AB to provide an answer to the proposal without too much delay.

The presentation ended with some general comments on present and planned future activities, priorities and available resources.

For the months of January to April 2006 11.000 hours of work are already scheduled in the TS assembly shops, implying that overtime will be necessary. The LHC has obviously a high priority, but activities for the LHC experiments are equally important and cannot be neglected.

The resources presently allocated to the two AB work-packages are extensive. For the beam instrumentation work-package directly assigned are 11 designers and 6-7 persons from the assembly workshop. For the collimator work-package, directly assigned are 3-4 designers (13 different types of collimators have to be designed) with 3-4 additional designers assigned to the masks design (7 different types). In addition the project coordinators, the outsourcing team from the workshop and the mechanical workshop, the surface treatment team, mechanical engineers and applied physicists are making substantial contributions.

For any new problem, TS/MME will assist in the search for external support but it should be kept in mind that this also requires the use of scarce resources.

As a final note it was underlined that experience however shows that urgencies where TS/MME must be present with its specific expertise in e.g. welding regularly occurs (LEIR, SSS in Building 904, ATLAS).

QRL INSTALLATION AND FIRST EXPERIENCES OF OPERATION – G. RIDDONE

The presentation started with an overview of the QRL design, system architecture and implementation. The progress of the installation done by the turn-key Contractor is presented in Figure 4. Data for sector 7-8 are not given since it is installed by CERN.

INSTALLATION - ALL SECTORS (EDMS # 681375)
Week 3

	JR	A	B	C	D	E	F	G	H	I	Progress [%] External supports	Progress [%] Elements
Sector 8-1	5	5	5	5	5		5	5	5	5	100	99.5
Sector 4-5	1	4	4	5	5	Repair header C R	5	5	4	5	99.5	97.4
Sector 3-4	2	3	3	4	4	4	4	5	4	4	99.4	87.5
Sector 5-6		1	2	2	3	2	3	3	3	1	94	52.3
Sector 6-7		1	1	1	1	1	1	2	2	1	87.7	5.8
Sector 2-3		1	1	1	1	1	1	1	1	1	44	2.2
Sector 1-2											0	0
Installation progress (except 7-8)											75	49

Installation of external supports 1	Welding of internal headers 2	Welding of external compensators 3	Pumping and leak tightness test at 3 bar 4	Leak tightness test successfully performed 5	Leak repair R

Figure 4 - QRL Installation progress

The schedule given by the subcontractor and presented by the speaker also takes leak repair delays into account, bringing the final delivery date to December 2006. The last sector to be installed is 1-2. A view of the cryogenics surface installations confirms the industrial size of the project and the progress made, see Figure 5. Another QRL start-up issue mentioned is the flushing and cleaning of the entire installation which will require outmost carefulness and sufficient time to be completed. The performance of the 8-1 sector has been subject to an extensive measurement campaign by the QRL team since it is the first in the series of eight. This campaign is expected to give valuable information of what cryogenic performance can be expected of the complete LHC cryogenic system.

The installation of the QRL, the supporting cryogenics complex on the surface and overall performance so far can be resumed: Cold reception tests have been successfully performed for sub-sectors A and B in 7-8, and sector 8-1. The QRL design in its thermo-mechanical aspects is successfully validated and the cryogenic thermometer accuracy is much better than the specifications required. The heat in-leaks to the 50-75 K circuit (headers E and F) are within specification while for sector 7-8 (sub-sectors A and B) heat in-leaks to the 4-20 K circuit (headers B, C and D) are above specification. Three possible causes for this non-conformity have been identified so far: the thermal shield temperature is higher than expected; the QRL insulation vacuum pressure is higher than nominal; the jumper insulation vacuum is above nominal pressure which has a direct impact on the heat flux through the MLI.

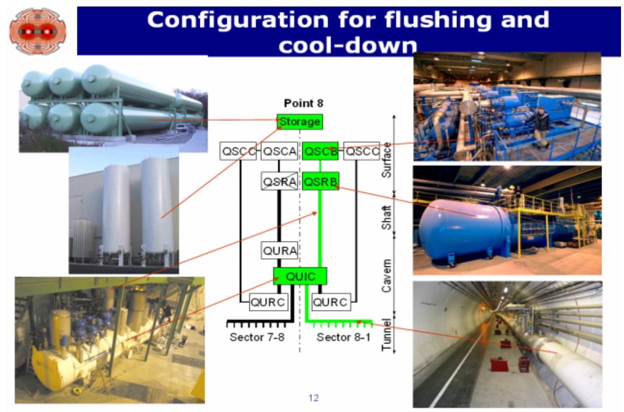

Figure 5 - Cryogenics and QRL installations

For sector 8-1, the heat in-leaks to the 4-20 K circuit are within specification.

ELECTRICAL QUALITY ASSURANCE IN THE LHC TUNNEL (ELQA) AND MAGNET POLARITY COORDINATION (MR. POLARITY) - STEPHAN RUSSENSCHUCK

This presentation was split into two major parts as the title indicates. The speaker gave a concise definition of what is understood by the term Electrical Quality Assurance (ELQA) in this context:

> To ensure the integrity of the electrical circuits during machine assembly and commissioning and to guarantee that the electrical interconnections correspond to the LHC powering layout. To ensure traceability of checks while considering all electrical non-conformities; ELQA is not concerned with the qualification of individual components (polarity, continuity, labeling, electrical integrity, voltage taps, magnet type and position).

An extensive effort has been deployed to create the necessary tools, both software applications and hardware devices to fulfil this challenging task. The team has set up a dedicated test bench which permits the simulation of a complete LHC half-cell electrically and to use it to finalise the various tools for use in the tunnel later.

The speaker mentioned some of the more obvious errors discovered so far and underlined that the traceability of all actions undertaken must be sustained all along during the preparation and installation processes. The examples shown clearly indicate how easily errors creep in during the preparations and how difficult it is to first find the errors and then to correct them once the equipment is installed. In some cases the corrective action is "simply" a change of labels. If however the labels for one reason or another are removed from the equipment, confusion is inevitable. Due to a partial traceability the error detection sometimes becomes pure detective work, trying to understood what the sequence of events have been – something definitely not acceptable when the work will progress on 8 fronts in parallel in the tunnel, see Figure 6.

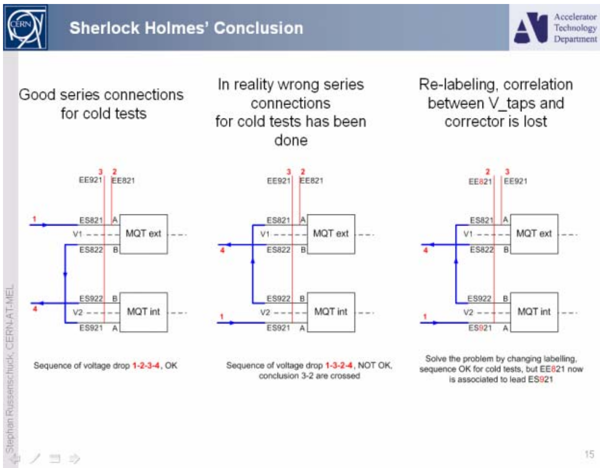

Figure 6 – ELQA - What happened?

The second part of the presentation concerned the activities related to magnet polarity configuration management. This was identified as a critical issue at the last LHC Workshop and the speaker was given the co-ordination task – Mr Polarity.

An instructive overview of the consequences of the different conventions used was given underlining the importance of this task. A specific case of polarity mismatch and the reasons behind it was demonstrated. When doing magnetic measurements tests of the DS-SSS a wrong polarity on the quadrupole of the external aperture was detected. The error causes were traced backwards and the demonstration showed that such errors are very easy to commit when the procedures are not sufficiently detailed and precise.

The presentation concluded that the tools are available and can guarantee the integrity of the electrical interconnections in the LHC tunnel and detect polarity errors in the cryogenic magnets. However the project teams must remain vigilant and ensure the coherence of procedures and definitions (inner triplets, power supplies, controls, warm leads). The team is ready to manage verifications in 8 fronts of arc interconnections, but it is limited in specialists for the follow up of electrical non-conformities and it is suggested to improve the component verifications.

Due to the tight schedule the ELQA of LSS and the LHC Hardware Commissioning will have to be performed in parallel.

CONCLUSIONS

Schedule – good progress has been made but present rates have to be further increased to meet our success oriented schedule. The presentation indicated some areas of concern that are now being attended to. New official schedule will be released during the spring.

Security – accidents can and must be prevented. Responsibilities are DG-DH-GL-project engineer – no parallel hierarchy exists in matters of security.

Access systems – LHC is back on track and doing good progress. The upgrade of the SPS system will be a major challenge to do in parallel with all the other activities.

QRL – the supplier is now getting closer to the nominal rates. The issues about leak detection and repair delays will be permanently present during the installation.

MME support – Presently there is no slack left in the group's resource allocation. The design office and workshops are providing a major effort handling both planned and unplanned activities – Any new incidents or any badly organised projects will have to wait or will cause delays in other important activities.

ELQA and Mr Polarity - Major exercises in quality control in the field, well prepared for a most challenging task.

ACKNOWLEDGEMENTS

The speakers in the Installation session have all made great efforts to present the efforts of their work or their teams in a succinct and clearly readable way. The Chairman and the Scientific Secretary express their thanks for these efforts made despite the speakers' heavy engagements elsewhere.

The Chairman wishes to express his thanks to the Editor in Chief of these proceedings for his patience to ensure a maximum of written contributions.