October 16, 2006

EMU Alignment Review
Purdue University
October 5, 2006

Summary Report

Introduction

The review charge (excerpt from Paul Padley's message from Aug 8, 2006):

This review is called in order to obtain a fair assessment of the current status of the project and its projected readiness for the time of data taking. The following aspects of the alignment project are requested to be addressed:

- *project scope, schedule, organization*
- *alignment scheme and requirements; "deliverables" (alignment constants to be delivered by the EMU alignment group to CMS)*
- *hardware, sensors, electronics; mechanical integration*
- *calibration during production and in situ*
- *alignment data acquisition*
- *methodology/software for reconstruction of alignment constants ("deliverables") for chambers with and without alignment sensors*
- *storage of alignment data (raw data and "deliverables")*
- *monitoring quality of alignment data*
- *maintenance plan*

Review committee:
Andrey Korytov (chair), Giorgio Apollinari, Norbert Neumeister, Teresa Rodrigo Anoro.

Agenda:

Introduction: Review Charge (10')	*Andrey Korytov*
Introduction, schedule, installation (20')	*Dick Loveless*
Project overview, system requirements, sensors, electronics (30')	*Dave Eartly*
MTCC analog data analysis (20')	*Oleg Prokofiev*
DCOPS monitoring of iron disk bending (20')	*Duncan Carlsmith*
Software, database, COCOA reconstruction (30')	*Marcus Hohlmann*
Summary and plans (10')	*Oleg Prokofiev*

Findings

We wish to open the summary by expressing our thanks to the entire EMU alignment group for their hard work on the alignment project over many years. We also want to thank the speakers for their well organized talks as well as enthusiastic and open discussions.

The committee was very impressed with significant progress happening in the project over the last months. In particular, the alignment hardware appears to be in a very reasonable shape. Production and calibration of most of the elements is completed. About half of the entire system has been installed, commissioned and made operational during the MTCC phase-1. (Some elements were damaged during the closure of the endcaps—remarkably, most of the damaged hardware was repaired/replaced on a very short time scale before the MTCC phase-2.) The reviewers appreciate that new people/groups are joining the effort, which will certainly help make a faster progress. Below, we list some of the issues that, we think, need to be addressed over the next year prior the start of data taking. We hope our recommendations (marked with arrows →) will help the project.

1. Alignment scheme and requirements; "deliverables", design

A complete alignment scheme was found to be missing. A complete alignment scheme should coherently define the interplay between
- "ideal" geometry per drawings,
- "actual" geometry (e.g., strip misalignment determined during panel production, chamber misplacement as given by photogrammetry, mechanical calibration of various alignment hardware elements),
- precision DCOPS and analog sensor measurements (and their calibration),
- and, finally, the offline data tracking (local track connecting overlapping chambers within a station as well as global muons connecting EMU stations to the tracker).

Concerns were expressed with respect to the fact that the error propagation analysis and the overall error budget estimates have not been updated for many years and definitely need a more detailed scrutiny.

→ A CMS Note describing this scheme and defining deliverables required from each part of such an integrated alignment approach (required precision and analysis of its feasibility, frequency of taking data, storage of data, etc.) must be produced in foreseeable future. This is a high priority task, but it is not likely to be a short-term task.
→ All relevant alignment documentation must be collected in one place or made accessible via a single entry point.
→ Alignment geometry description must be well-documented and made a part of the CMS geometry database. Self-consistency of reference points in hardware and software must be checked. This point will come up again in the context of the alignment software task.

During MTCC phase-1, the magnitude of one particular design shortcoming has become clear: due to large disk deformations, the DCOPS system, as it stands now, cannot provide precision measurements both for B=0 and 4 T. Proper tuning of the system at B=0 and monitoring of the deformations with the field ramping up to 4 T is seriously hindered by this. The problem was anticipated earlier. However, in 2002, the decision of not pursuing any final solution had to be taken due to lack of funding to implement more sophisticated "general purpose" solutions. Therefore, it was decided to wait for the magnet test results and implement a solution based on real/measured needs rather than earlier loose estimates.

→ Alternative (compromise) schemes of laser alignment must be considered now. Some raw ideas were presented at the review. More thought should be given to possible modifications to the current system in the future to alleviate this shortcoming.

As the result of the original ME4 descoping and subsequent ME4/1 upscoping, the ME4/1 chambers are now left without any r-connection to the axial laser beam transfer lines. Repercussions of this on the ultimate alignment are not understood. This should be addressed at some point, but is not deemed to be urgent.

During MTCC phase-1, integration conflicts were discovered. Some solutions were implemented (e.g., notches in green structures were cut out to make clearance to the affected lasers). However, other damages seem to arise from out-of-spec movement of disks during endcap closure/opening.

→ Ad hoc solutions to protect alignment hardware must be employed during endcap closing/opening steps during the MTCC phase-2 (being implemented). In long run, the alignment group must either negotiate much smoother disk handling (if this is possible at all) or find long-term solutions for hardware protection.

2. *Project scope*

The hardware part of the project is well defined.

→ We recommend the group to systematically analyze the end game in the context of parts procurement: remaining spare, auxiliary, and backup elements must be procured now. To our disappointment, the remaining project budget could not be produced at the time of the review.

→ CAEN LV is the only serious hardware concern: alignment LV is likely to get a low priority on the CAEN order list. A contingency plan with the current power supplies should be worked out. The claim was made that the cost of such backup would be in buying long LV cables at <$2K.

Firmware used in DCOPS has no support any more; however, since it allows one to dump raw data, it does not appear to be on the critical path.

DAQ part of the project started ramping up over the last few month; much more work is still needed to bring it to the final system standards.

→ The current DCOPS DAQ would take 2 hours to collect all data; it must be re-designed to allow for a full data acquisition cycle of no longer that 10 min. (Experts on floor said that this should be doable.)

→ DCOPS readout must be implemented in the DCS framework and integrated with the current DCS-driven readout of analog sensors. Data should be logged into an ORACLE database via PVSS. As the next step, the EMU Alignment DAQ must be merged into the overall CMS Alignment DAQ. The group must produce an alignment DAQ document, describing the DAQ, calibrations, data flow, etc. Shifter instructions should be made available on the web.

→ A strategy for monitoring of the alignment data quality and calibrations/validations between runs must be outlined. There is not any effort in this direction at the moment.

General understanding and readiness with the reconstruction software (for alignment hardware data), is found to be a weak part of the project. The COCOA program being developed for the entire CMS muon alignment is basically treated by the EMU alignment group as a black box, which is not acceptable. Questions on which methods are used in COCOA for deriving chamber location/orientation did not find much response. A concern was raised on whether the program is scalable and can handle all the chambers; especially after the analog sensors are implemented (analog sensors will couple many measurements, which may/will considerably increase the analysis complexity). Other related concerns were convergence and needed resources. The alignment geometry and calibration data are yet to be ported in the format required by COCOA. Not having these structures/data ported currently prevents the group from using the program even as a black box. Note that some years ago COCOA was successfully used by a student in the context of the EMU alignment system.

→ Photogrammetry data is available for all ME+ stations (for many of them, the data have been available for quite a while). The analysis appears to be straightforward and we see no excuse of why it has not been done so far.

→ The geometry/calibration structure and constants must be ported into COCOA format on a very short time scale.

→ The trial use of the program on at least some partial MTCC data should start as soon as possible: one, two, three SLM lines (B=0T). COCOA output must be validated against the photogrammetry data.

→ Define the means of validating (cross checking) the COCOA output results before logging them into alignment database.

Most of the chambers actually do not have any alignment hardware—their precise localization hinges on the track-based alignment coupled to hardware. Also, it is the track-based alignment that is believed (based on some very earlier studies) to provide localization of all chambers at the ultimately desired/required (?) precision of better than 100 μm. No results supporting or disproving this assumption were presented at the review.

→ The effort on track-based alignment must start and be integrated in the overall alignment scheme.

3. *Organization*

Project organization is basically centered on hardware.

→ A task with a broader mandate is needed—see the final conclusion at the end.

4. *Schedule*

Schedule towards delivering the final alignment suite by the time of data taking was not presented. Note that all hardware and electronics are already delivered. Installation on YE- side is yet to be done, but this is not perceived as a problem. So the above statement on the schedule mostly refers to DAQ-DCS implementations and Software deliveries.

→ Such plan is one of the high priorities.

5. *Maintenance and Operations*

No plan was presented. In terms of manpower, a few names were suggested on fly.

→ It is about right time to start planning M&O phase of the project after the commissioning is done. Besides usual hardware operation/debugging/repairs, the plan should explicitly address the question of producing/validating alignment constants and delivering them in timely fashion to CMS.

5. Lessons from analyzing MTCC Data

ANALOG sensors. A coherent full analysis of differential changes in analog sensor reading (with field, time, and ambient temperature) was very insightful. It was clear that the measurements could be qualitatively understood within the context of disk deformations. However, to give the measurements a quantitative meaning, they must be confronted with expectations/predictions. The last calculations of disk deformations were made almost 10 years ago and details that would be needed for such analysis are not available, anymore.

→ We recommend exploring an option of redoing the finite element analysis of disk deformations, if this task can be done without destructing the current manpower in the project. One such possibility is being explored right now (Bob Wand at FNAL).

DCOPS data needs much more detailed scrutiny. The review was shown a bunch of plots with not too many conclusions. Many spectra are seriously distorted, the origin of which is not well understood. Drift of measurements with time: is it indeed due to laser tilting? Changes with magnetic field: are they consistent with disk deformations? Do DCOPS trends agree with the analog sensor measurements? A coherent analysis of DCOPS data and their convincing interpretation were missing.

→ We urge the EMU alignment group to perform a thorough analysis and physical interpretation of the trends in DCOPS data and present digested results. Where possible, a consistency check against the analog sensor data should be also performed.

→ As we start taking data in MTCC phase-2, we recommend checking compatibility of phase-1 and phase-2 data, both for analog and DCOPS sensors.

Final summarizing recommendations

We recommend forming an EMU Integrated Alignment Task Force with a mission to provide coordination between the current mostly-hardware oriented alignment project, alignment hardware software, the newly emerging effort of developing a track-based alignment, and CMS geometry databases. The task leader/coordinator should prepare a plan of tasks, identify people/groups, assign them priorities, and present the plan for discussion and approval to the L2 Manager.

The highest priorities for the new EMU Integrated Alignment Task Force should be a delivery of a high-level description of the complete alignment scheme and a prioritized plan for the next 12 months. The plan is expected to take into account, but not limited to the recommendations listed above.

A strong support from the EMU management is needed to consolidate long-term commitments of the existing groups currently involved in the alignment effort and possible new groups, in view of the upcoming maintenance and operation phase. The EMU management should make an effort to find new groups to strengthen the alignment effort.

Signed:
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