

Engineering Design and Electronics System Review

Level 1 Trigger, Phase 1 Upgrade

November 12-13-14, 2013

Committee Report

1 Introduction

At the request of Darin Acosta (Level 1 Trigger project manager) and Alex Tapper (Level 1 Trigger Phase 1 Upgrade project manager) an Engineering Design and Electronics Systems Review was held at CERN on Tuesday 12th, Wednesday 13th and Thursday 14th of November 2013.

Project Reviews are defined in the Constitution of the CMS experiment, Section 6.7, which states that:

“Before launching the construction of major parts or upgrades of any Subsystem, or engaging in major related expenditures, the Technical Coordinator, with the agreement of the relevant Subsystem manager, organizes reviews to confirm the soundness and completeness of the retained design, including the coherence of all interfaces with respect to neighboring sub-detectors or other parts of CMS. The aim is to minimize risks in cost and schedule.

An EDR (Engineering Design Review) or ESR (Electronic Systems Review) is thus held prior to the start of construction or upgrade of a large item or important procurement. Checking adherence to safety requirements is an inherent part of the mandate of an EDR.

A PRR (Procurement Readiness Review) may be held in anticipation of an EDR or an ESR, to authorize significant pre-production or pre-procurement, or where parts of the system are well understood and factorize from the overall design. Such parts can, for schedule reasons, be considered for approval to proceed, providing there is no risk to the satisfactory completion of the overall design needed for the EDR.

The Level 1 Trigger Upgrade project is part of the overall CMS upgrade strategy prior to LS3. It features a number of relevant changes with respect to the present system, including higher effective trigger primitive granularity as well as enhanced final algorithms including topological features. The intention is to preserve low trigger

thresholds in a pile-up environment beyond that for which the original level 1 trigger was constructed.

The Level 1 trigger Upgrade project was approved by the LHCC committee in June 2013 and the Technical Design Report is available here:

<http://cds.cern.ch/record/1556311/files/CMS-TDR-012.pdf?version=3>

Previous relevant reviews:

- 1) Level 1 trigger conceptual design review part 1 (20121004):
<https://indico.cern.ch/conferenceDisplay.py?confId=208762>
Follow-up Calorimeter trigger upgrade (20121031):
<https://indico.cern.ch/conferenceDisplay.py?confId=215062>
Follow-up Muon trigger upgrade (20121106):
<https://indico.cern.ch/conferenceDisplay.py?confId=216219>

- 2) Level 1 trigger conceptual design review part 2 (20121217)
<https://indico.cern.ch/conferenceDisplay.py?confId=217684>
Level 1 trigger conceptual design review part 2 Cost and Schedule
<https://indico.cern.ch/conferenceDisplay.py?confId=223193>

- 3) CMS Calorimeter trigger upgrade progress review (20130815)
<https://indico.cern.ch/conferenceDisplay.py?confId=265363>

2 Scope and Goal

2.1 Scope:

The committee was asked to review:

1. The integrated plan for all changes to the CMS level 1 trigger from present up to LS2
2. The project organization and the resources available
3. The project schedule in relation to the installation constraints, the overall CMS planning, and the targeted/projected LHC machine parameters. Particular attention should be paid to the status and plans for activities which must be completed during LS1.
4. The design and status of the project in the context of the technical specifications (arising from physics performance objectives), in particular:
 - 4.1. the status of common components (HW, FW, SW) of the system

- 4.2. the status of parts (HW, FW, SW) specific to the Calorimeter trigger
- 4.3. the status of parts (HW, FW, SW) specific to the Muon trigger
- 4.4. the status of parts (HW, FW, SW) specific to the Global trigger
- 4.5. the status of and detailed plans for system integration
5. The perceived major technical challenges and the strategy for lowering technical risks and achieving the best possible results within the schedule and resources available.

2.2 Goals:

1. Endorse the overall strategy and plan for upgrading the CMS level 1 trigger
2. Endorse the plan for construction.
3. Endorse the strategy and plan for the installation and commissioning of the system in CMS.
4. Endorse the plan for maintenance and operation of the system

3 Committee

The committee was composed as follows:

Chair:

- Austin Ball (CMS Technical Coordination)
- Wolfram Zeuner (CMS Technical Coordination)
- Magnus Hansen (CMS Technical Coordination)

The chairs consulted closely with Jeff Spalding and Didier Contardo (CMS Upgrade Coordinators).

Link Persons:

- Alex Tapper (IC, Level 1 Trigger Upgrade project manager)
- Darin Acosta (UF, Level 1 Trigger project manager)

Members of CMS:

- Jeff Spalding (Upgrade Coordinator)
- Didier Contardo (Upgrade Coordinator)
- Christoph Schwick (Online Coordinator)
- Greg Rakness (UCLA)

- David Petyt (STFC RAL)
- Jay Hauser (UCLA)
- Ignacio Redondo Fernandez (CIEMAT)
- Paris Sphicas (Athens / CERN)

Non-members of CMS, to whom particular thanks for their time and expertise:

- Thilo Pauly (CERN and ATLAS)
- Stefan Haas (CERN and ATLAS)
- Philippe Farthouat (CERN and ATLAS)

4 Organization, Venue and Agenda

All sessions offered the possibility to participate over Vidyo.

4.1 Introduction, Intermediate / Evolutionary upgrades (pre-TDR)

Tuesday November 12th 9h00 – 13h00 in room 40-2-A01. Agenda:

<https://indico.cern.ch/conferenceDisplay.py?confId=279025>

4.2 Level 1 Muon trigger upgrade

Tuesday November 12th 14h00 – 18h00 in room 354-1-019

<https://indico.cern.ch/conferenceDisplay.py?confId=279028>

4.3 Level 1 Global trigger upgrade

Wednesday November 13th 9h00 – 13h00 in room 40-2-A01

<https://indico.cern.ch/conferenceDisplay.py?confId=279026>

4.4 Level 1 Calorimeter trigger upgrade

Wednesday November 13th 14h00 – 18h00 in room 42-3-032

<https://indico.cern.ch/conferenceDisplay.py?confId=279027>

4.5 Committee discussion and Close-out

Thursday November 14th 9h00 – 13h00 in room 14-4-010

<https://indico.cern.ch/conferenceDisplay.py?confId=279025>

5 Documentation and Report

The CERN Indico agenda server is used for long-term storage of raw EDR/ESR documents and presentations. In case there is need to correct slide content the presenters are recommended to upload the new set of slides and leave the old set in place as reference.

The outcome of this Level 1 trigger EDR/ESR is summarized in this report written by the reviewers and signed by the Technical Coordinator. The report will be stored on CERN EDMS and may be distributed to the CMS Steering Committee (SC), Management Board (MB), Collaboration Board (CB), and to CMS LHCC Referees. Particular thanks go to Greg Rakness for assistance to TC in collating material for the editorial process.

6 Attendance

CMS reviews are open to all CMS Collaborators and CMS Referees on simple request by e-mail to the Link Persons. If the request for attendance exceeds the capacity of the available room, then participants are selected by the CMS Technical Coordinator in consultation with the Link-Persons.

7 Report

7.1 General observations

7.1.1 The review committee was pleased to see significant progress in all aspects of the level 1 trigger upgrade project and appreciated the high quality presentations documenting the effort it has taken to achieve this. In addition, the committee appreciated the clarity of responses to questions throughout the review and during the preparation of the report. The Committee appreciated the provision of supplementary information such as the status summary of the 2014 milestones established in the TDR (attached to Discussion and Close-out session, 14 Nov).

The upgrade of the CMS trigger is ambitious, complicated, and necessary for the CMS physics program in Run 2 and beyond. In 2015 the baseline work plan includes operating the legacy level 1 trigger, finalizing and operating the intermediate upgrade of the calorimeter trigger, and in parallel commissioning the full upgrade as outlined in the Level 1 trigger upgrade Technical Design Report.

7.1.2 The Committee fully concurs with the fundamental requirement (stated in the TDR) that the transition from the legacy to the upgraded trigger must never put CMS data-taking at risk. The consequent plan to keep the legacy trigger, including necessary software, available as a fall-back until LS2, in parallel with operation of the upgrade, may require an increase in M & O resources. .

7.1.3 The Committee notes the timelines and resource reviews presented in most of the presentations and the recent additions of manpower to the project.

Nevertheless, the committee believes that the progress of the project as a whole must be tracked more effectively to ensure delivery of the trigger system to CMS on the timescale outlined in the Level 1 trigger upgrade TDR. The committee had difficulty evaluating the impact on the overall schedule of the delays reported in various presentations and supplementary documents (eg 4 month delay wrt TDR in software and firmware for global trigger), and is concerned that resources may not be sufficient to achieve the intended scope of the trigger system available to CMS as a function of time.

7.1.4 Given the objective of operating two calorimeter level 1 trigger systems during 2015 (the legacy calorimeter trigger and the intermediate calorimeter trigger), in parallel with commissioning the full upgrade outlined in the TDR, the Committee is concerned that what must be in place and operational at LHC start-up (consistent with the principle in 7.1.2) has not been clearly defined and agreed. Significant progress was shown in board design, integration tests, algorithms, and a demonstration test of the Time-Multiplexed Trigger (TMT). The Committee also notes that delivery of CTP7 prototypes is imminent. However, the Committee is concerned because there are several new boards required and, as far as could be understood, little contingency remains.

7.1.5 The Committee took note of the progress in LS1 towards allowing commissioning of a slice of the muon trigger upgrade in parallel with the operation of the legacy muon trigger in 2015 and notes that delivery of MTF7 prototypes is imminent. The performance of algorithms, a detailed understanding of the data transfer links, and significant progress on the hardware were shown. In addition, interdependencies between the algorithms, hardware, and links were clarified. However, the committee noted that, during several presentations, key topics were explicitly pointed out as still under discussion. The committee is therefore concerned that a baseline for the muon trigger upgrade has not yet been fully defined (but has been made aware of progress in this regard since the review).

7.1.6 The Committee feels that the plan for software delivery is not sufficiently developed, and may become a very serious issue as physics data-taking approaches. In particular, the project management must ensure that proper resources are rapidly identified and allocated to meet the January 2015 goals.

7.2 Specific Recommendations

7.2.1 Project Management and Oversight

The Committee recommends that:

7.2.1.1 The Trigger Project develop a resource-loaded schedule to help plan activities, track progress, and direct resources towards the priority objectives of the project. It should cover all aspects, including hardware, firmware, data transfer links, algorithms, trigger primitives, online and offline software and a comprehensive testing program. The plan should include well-defined milestones associated with the key steps towards project completion. The responsibilities for each deliverable of the project should be clearly established, with a collaborative approach to optimize use of expertise from the different groups. The critical path in executing the project and the contingencies allowed must appear explicitly.

7.2.1.2 The Project Managers should analyse and track the project with these tools to determine if more resources are needed or if existing resources should be reallocated or priorities changed. Formalized maintenance and updates of the schedule across the whole project should be implemented, and should be reviewed quarterly.

7.2.1.3 Progress reviews should be organized in early 2014 focusing on three specific aspects: project organization and resource loaded schedule, prototype board tests and integration, and software development. It is suggested that the progress review on organization and schedule take place as early as February 2014, the prototype review in Q2 2014, and the software review in summer 2014.

7.2.1.4 Urgent action must be taken to resolve tensions within the project which threaten to compromise success. The involvement of senior CMS management will likely be required.

7.2.1.5 The apparent lack of system level oversight (which contrasts starkly with the engineering expertise focused on individual boards), should be addressed urgently.

7.2.2 Software specific recommendations

7.2.2.1 It is recommended that a follow-up review focusing on software development be organized in early 2014. Milestones for software development must be incorporated into the existing schedule. This review should cover:

- An architectural overview of the software.
- A definition of components split into generic components (used by many trigger systems) and those which are system-specific.
- The workload to maintain the software, to migrate the software if CMS adopts a new version of XDAQ or a new version of SLC Linux (this opens the questions of component dependencies).
- Resources and manpower needed for the common part and for each trigger system. In this respect, the committee does not endorse the SW

development plan shown at the EDR, where the common part is expected to be developed by volunteer manpower from subdetector projects.

- Test software: resources needed and re-use of test software in production system.
- Streamlining of the software development, such as uses of the same system to develop software (repository, makefiles, packaging, ...) and standard xdaq procedures

7.2.2.2 It is also recommended that an expert is identified to take charge of the software development as soon as possible. CMS management should assist the L1 upgrade project in identifying this expert, along with additional software engineering resources.

7.2.3 Calorimeter trigger

The Committee recommends improving overall oversight of this sub-project and applying additional controls on key steps, (in the context of the scope of project presented to this review).

7.2.3.1 A resource-loaded schedule (see 7.2.1.1) consistent with the intended scope should be presented at a follow-up review proposed for February 2014.

The steps on which additional controls are recommended are:

7.2.3.2 Replacement of the SLB – RM copper links with oSLB – oRM optical links: [This step is essential to enable phase-1 upgrade commissioning in parallel with re-commissioning of the existing calorimeter trigger with the legacy GCT].

The replacement, already delayed wrt the TDR schedule, should proceed as swiftly as feasible, subject to an Installation Readiness Review in February 2014

7.2.3.3 Implementation and commissioning of the intermediate calorimeter trigger as outlined in the TDR 7.6.3 and detailed in a draft CMS Internal Note, attached to S.Dasu presentation, 12 Nov at Committee request: [Given the potential LHC performance in 2015, it is essential to ensure adequate interim physics performance for pp and Heavy ion collisions until the full upgrade is ready.]

This sub-project would strongly benefit from rapid (by end January 2014) completion and endorsement of the draft note in the form of an addendum to the TDR. In particular this would require completion of section 6 and resolution of the resource uncertainties and conflicts with the full upgrade alluded to in section 7.

7.2.3.4 Commissioning of the full upgrade (as described in the TDR) in parallel with physics data taking during 2015 in order to be ready for physics collisions in 2016: [The power and flexibility of the full TDR upgrade will provide the best option for

efficiently collecting the data samples required for the CMS physics programme, in LHC runs 2 and 3, given the 100kHz L1 bandwidth restriction.]

It is recommended to completely define the hardware configurations and consequent performance of the calorimeter trigger expected to be available from first collisions in 2015 onwards, based on realistic estimates of availability, grounded on the present status, and predicted from the resource-loaded planning. The implications for physics have to be discussed widely within CMS.

Additional:

7.2.3.5 It is recommended that a US firmware engineer be based at CERN to liaise with the MP7 engineer to facilitate integration of the two layers of the calorimeter trigger upgrade (and maybe other upgrade areas).

7.2.3.6 It is recommended that a detailed consolidated plan for installing the HF off-detector system (microHTR), associated oRM mezzanines, and optical fibres is developed. This plan will form an important input to the overall resource loaded schedule (see 7.2.1.1).

7.2.4 Muon trigger

7.2.4.1 It is strongly recommended to clarify the detailed implementation of the muon trigger upgrade and to develop the associated schedule as soon as possible. The work-plan should include contingency options for factorizing the muon trigger part from the rest of the upgrade, making provision for connection of the legacy muon trigger to the upgraded global trigger.

7.2.4.2 The USC fibre plant of the muon system is an ambitious project whose topology had not been agreed during the EDR. The Committee welcomes the decision (made after the EDR) to concentrate the RPC and DT data in the TwinMux, also allowing the use of the RPC data in the PAC-like trigger, for its many advantages in the context of chamber failures. It also clears the way to design the fibre plant. However, resources should be identified to cover the cost of the additional TwinMux. The designers are also recommended to consider ways to make the system robust against failures of single links.

7.2.4.3 The committee endorses the selection of the sector partitioning scheme for the barrel region (made after the EDR) to be the same as the overlap and endcap regions. Although it will make the migration of the current DTF algorithms more difficult, the overall advantages for sharing algorithms, handling the adjacent regions, and less fibres going into a processor board are expected to prevail.

7.2.4.4 The committee recommends considering the advantages of using the MTF7 board in all three regions (barrel, overlap, and endcap). This is expected to result in a significantly smaller amount of software to write since the boards are the same. It

also opens the possibility to share algorithms involving large lookup tables in all regions, which might turn out to be useful in the future. In addition, expertise regarding the processor board can be easily shared in the muon community. On the other hand, using the MTF7 doubles the space required and increases the cost per board. As the MTF7 does not yet exist, we recommend that the present plan to develop and test the DTF algorithms on the MP7 continue until the MTF7 is available. The porting of the firmware from the MP7 to the MTF7 is expected to be relatively straightforward since both boards are equipped with the same FPGA. The decision on the final board should be made by the L1 management balancing the available resources and relative costs/benefits in hardware costs vs. software savings as soon as the MTF7 is available. The slice test should be built based on the MP7 if the MTF7 is not available by the progress review on prototypes.

7.2.5 TCDS

7.2.5.1 The TTC upgrade to TCDS is critical and may potentially conflict with the planned maintenance and testing of subsystems during LS1. It is recommended that a TCDS functionality workshop and an ESR are organized in early 2014, including a plan for staging installation as well as a fall-back plan. Dead time monitoring should be addressed in order to define the different types of dead time to report.

7.2.5.2 It is recommended that a procedure be developed for subsystems to sign-off on TCDS full functionality when the production hardware is installed.

7.2.6 Hardware Modules (MP7, CTP7, MTF7)

7.2.6.1 The design of the CTP7 is well underway, with delivery forecast about 2 months late wrt the TDR milestone. The committee felt that there is a risk of impacting the critical path.

The design of the MTF7 is well underway and nominally on schedule, but the contingencies available and the resources potentially idle awaiting delivery, were hard to ascertain.

The tests of the MP7 with the TMT algorithms were highly satisfactory, demonstrating that the system can satisfy the latency budget specified in the TDR. Nevertheless, the committee urges that close attention be given to the bulk production deliveries (estimated to be 2 months delayed wrt the TDR milestone) as many groups are waiting for, or could effectively exploit, availability of this board.

7.2.6.2 Considering the fact that the three hardware modules developed for the level 1 trigger upgrade (MP7, CTP7, MTF7) are based on the same main FPGA, the opportunity of harmonizing the low level infrastructure firmware (high speed links, TTC reception and decoding, etc, in addition to IPbus register access) and associated low level software should be exploited if at all possible. The firmware and software

used during the TMT demonstration test with the MP7 module could be used as a basis for common firmware and low level software for infrastructure.

7.2.7 Further observations, comments and recommendations

7.2.7.1 As no detailed plan for installing the 600 oSLB-oRM / uHTR-oRM fibres was presented, the Committee recommends that this plan, including the manpower required, be presented at an Installation Readiness Review in February.

7.2.7.2 The required real estate in USC55, particularly for fibre patch panels, tends to be underestimated. As the legacy trigger will be de-commissioned only by LS2 the new trigger systems require additional space. A plan needs to be developed based on the real estate actually available in USC55 and any requests for additional rack infrastructure made very soon.

7.2.7.3 The uGT will be read in parallel with the GT for test and commissioning. A complete program for this should be developed and documented.

7.2.7.4 The trigger object map to the HLT must be specified by the HLT group. The requirements then need to be taken into account by the GT group for implementation. This issue should be addressed in a dedicated workshop.

7.2.7.5 It is recommended that the optical power budget is established throughout the project and in particular when passive optical splitters are used.

7.2.7.6 It is recommended to proceed with firmware development using MP7 cards where final hardware is not yet available. Layer 1 of the calorimeter trigger can be implemented with the MP7 module that was used for initial tests; the Muon trigger upgrades likewise.

7.2.7.7 It is recommended to use SVN for common firmware and software.

8 Conclusion

8.1 The overall strategy for upgrading the CMS level 1 trigger was endorsed. In particular the project as configured is consistent with the dual focus of ensuring no disruption to data-taking, whilst maintaining or improving efficient event selection from 2015 onwards (consistent with the desired physics programme and the challenges presented by the likely LHC performance). However, some detailed design aspects still require final decisions and the overall project planning and monitoring need urgent attention.

8.2 The plan for construction is reasonable but more work is needed to ensure that resources are available and properly deployed to satisfy priorities.

8.3 The installation and commissioning plans for different parts of the system are at different states of development. Installation Reviews will be necessary.

8.4 The plan for maintenance and operation of the system was not presented in a consolidated way, although many features could be inferred. The intention to keep the legacy trigger and its associated software operational in the medium-term, in parallel with the upgrade, whilst strongly endorsed as a necessary fall-back, will almost certainly require additional M & O resources.

9 Follow-up

9.1 EDR follow-up reviews should be organized in 2014 focusing on specific aspects and components:

- a) project organization and resource loaded schedule (Feb 2014).
- b) oSLB-oRM installation readiness (Feb 2014).
- c) prototype hardware module tests and integration (Q2, 2014).
- d) software development (Q2-Q3, 2014).
- e) other installation readiness reviews as needed.

9.2 The internal note specifying the Level 1 calorimeter trigger for 2015 (and its subsequent evolution) should be completed and presented in the form of a TDR addendum. (end Jan 2014)

9.3 A TCDS functionality workshop and an ESR should be organized (Q1,2014).

9.4 Since the Phase 1 calorimeter trigger upgrade requires the HCAL back end to be installed and commissioned, as well as the front end fibre splitters, an ESR follow-up for the HCAL back-end should be organized as soon as possible (currently foreseen on the 15th of January 2014).

9.5 Numerous large FPGA firmware development lessons have been learnt by different groups. A firmware development workshop will therefore be useful at a suitable moment in 2014.

9.6 A dedicated workshop covering the interface of the GT to the HLT is recommended.