Upgrade Cost Group Review of the Phase II Upgrade of the CMS Level 1 Trigger [1]

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Process: Recognising that the L1 Trigger is smaller and more focused than other Phase II upgrade projects, to expedite the approval process we reviewed the cost appendix and sent CMS a large number of questions in advance of the traditional kickoff meeting. The answers provided by CMS were then discussed at a Vidyo meeting on May 7 and further questions were then sent to CMS. In parallel the UCG chair followed up with Zoom meetings with CMS management. The actual review took place in a virtual meeting on June 3, when we heard 2 hours of presentations from the L1 Trigger group, followed by in-camera discussion by the panel.
The confidential preliminary "money matrix" was reviewed by the UCG and LHCC chairs and the lead CMS referee. Pledges so far total slightly more than the funding needed. Alignment is also very good for the early stage of the project, with a good match to the needs. Only ~200K out of the CHF ~7M total cost is uncovered, and convergence is likely.

Overview: The L1 Trigger project consists of several independent subsystems receiving trigger primitives from several CMS subdetectors (muons, calorimeter, tracker); a particle-flow trigger; and a "scouting system" to search for special event signatures; and a global trigger. The CMS team produced a detailed responsive cost package for the review, and addressed over 35 UCG questions completely and accurately, both in writing and at the May 7 Vidyo meeting. The presentations at the June 3 review were carefully prepared, clearly indicating that CMS took the review seriously and did its best to profit from the exercise. The project is well organised, with strong leadership, management and technical personnel. The cost estimates, personnel availability, and schedule are credible, with "12-month float everywhere." The different trigger subsystems are largely independent of each other, easing issues of critical path. Risks are identified and quantified, with reasonable mitigation plans.

Cost Situation: The total cost of the project is CHF 7.05M, consisting mainly of purchased items: FPGAs, optical fibers, PC boards, crates, power supplies etc. At this point 39% of the cost is for off-the-shelf components (Quality Factor 1), 56% for prototyped electronics with price quotes (Quality Factor 2). The remaining 5% covers optical patch panels, with which CMS has lots of experience from Phase I, but for which the total cost will be uncertain until the connection layout becomes definite. To summarise, the costs are well-understood and reasonable. We have no serious concerns

Schedule: The schedule has been carefully developed in great detail, with 12 months float built in everywhere during design and construction, and 6 months during the installation phase. The schedule risk for the project is low because the different trigger subsystems can proceed independently until the integration phase, and in many cases emulators can serve to temporarily keep the project advancing on schedule if interfaces are not ready. Milestones are appropriate and being met. The critical path is straightforward and well understood, and procedures are in place to monitor the progress of trigger activities in the different detector systems. Finally, the project is much less dependent on access to CERN in its early years, and hence the schedule is less endangered by COVID-19 or other global delays

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Personnel: The project provided us with detailed bottom-up, year-by-year estimates of the personnel required, and tables showing that sufficient numbers of physicists, engineers, technicians and students were available. These resource requirements seem reasonable and the supply appears adequate. The project is deploying 4 production sites, which appear to be adequately staffed. The L1 Trigger institutions and key personnel are committed to the project long term and succession planning has begun, with new people being trained to replace students and postdocs as they move to the next stages of their careers. Close connections and good communication exist with personnel in detector systems working on the trigger primitives and other elements relevant for the L1 trigger system.

Risks: The original risk register presented at the May 7 kickoff meeting contained a thorough treatment of uncorrelated risks, that dealt with performance problems and baseline changes within the separate trigger subsystems. We questioned the fact there were no risks was designated "high" in probability or impact, but after discussion we accepted the project's assessments. The register is now more complete, containing several global risks that would be realised if system-wide performance does not meet requirements. Including system firmware, I/O, and FPGAs, all of these risks have low probability, with credible mitigation plans. As another example of global risk, a change in system latency requirements could trigger a significant (25-50%) cost increase for higher speed FPGAs.

Management: The project is efficiently organized, with a solid management architecture. Interim leadership has produced an excellent TDR, and CMS is well-advanced in populating the future organization to implement the project beyond TDR approval. Good communication between the different levels is promoted by frequent suitable meetings and reviews, and by the strong and strict Change Control process. Similar well-defined synergies and connections are in place with the sub-detector trigger efforts, including trigger primitives, HLT and Offline.

The L1 Trigger project is umbilically connected to all the detector systems, with large numbers of people in the detector groups working on trigger related tasks. Most importantly, the Trigger Primitives are developed by the detector systems, in close collaboration with the L1 Trigger group. CMS considers this structure a strength, a view that we endorse, with the caution that central CMS management must exercise strong oversight as needed should problems arise, and be proactive in anticipating possible conflicts.

We accept CMS' conclusion that the experiment is strengthened by having several independent development and production efforts. However, to ensure the timely completion of a high-quality system, CMS must be prepared to adjust the allocations in the event of delays or production difficulties, and to ensure long-term availability of parts that could be critical to the system, but could become obsolete and difficult to find a few years from now.

Conclusions: We congratulate CMS for developing an excellent TDR and UCG package. The cost estimates and the current and planned resources are reasonable for this stage. Finances appear to be in excellent shape, with sufficient pledges already in place. The schedule, risks and manpower are at normal levels, provided that they continue to be proactively managed. Strong management from L1 and CMS will be needed to keep close track of the several independent production efforts, and to monitor the interfaces between L1 and the detector systems.

We recommend Step 2 approval by the RB and RRB to allow resources to become available, and MOU's to be signed.