Upgrade Cost Group Review of the
CMS Phase-II DAQ and HLT Projects[1]

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Process : The review consisted of three Zoom meetings: July 15, July 30 and August 30, interspersed with questions from the panel. At each meeting we focused on the organisation, management, cost, schedule, personnel and risks for the DAQ and HLT projects. The DAQ/HLT team produced a detailed responsive cost package for the review, and addressed the questions from the panel completely and accurately. The presentations at all meetings were carefully prepared.

The UCG and LHCC chairs and lead CMS referee also met with senior CMS management to review the confidential "money matrix" and other confidential matters. At this point credible sources have been identified for approximately 80% of the cost, and the project management is basically in place. We were satisfied that CMS had sensible plans to marshal the remaining funds, and/or mitigation possibilities to deal with any shortfalls.

Organisation and Management : The management and organizational structure of this project, especially the HLT, are unusually dispersed –by design. HLT must interact and closely coordinate with multiple CMS entities: all detectors and Detector Performance Groups, Physics Coordination, dedicated analysis in the upgrade studies group, large scale MC production used for Phase-2 HLT studies, and Offline Software & Computing coordination. CMS has used this model successfully so far, but the complexity, scale and long-term nature of HL-LHC operation present challenges. Strong and pro-active central management and coordination will be required to make sure nothing falls between stools. Intensive planning and oversight will be required to deal with changing technologies, etc.

The overall CMS software framework, and its organisation and management, are critical for success. The framework extends well beyond the DAQ/HLT project itself, and should be reviewed in conjunction with the review of the CMS Computing TDR. In the meantime progress should be carefully monitored.   HLT milestones should be added to explicitly address the challenge of evolving a heterogeneous processing framework to follow the development of hardware architectures, and to be able to effectively use those different architectures. As technologies evolve over the years it is essential to maintain coherence between purchases of online hardware and what happens on the grid.

Cost Situation : The DAQ and HLT systems consist almost entirely of computing equipment, purchased when needed. The DAQ budget is 21.7 MCHF: 5.7MCHF for DAQ, 16M CHF for HLT. All QF's are 1 or 2, as they are largely based on current quotes. However, the actual cost at the time of purchase assumes cost/performance improvements of 15%/yr for DAQ, 20%/yr for HLT. Mitigation strategies are in place to deal with the risk of less-favourable extrapolations, but we note that recent price increases in ASICS could propagate to networking and GPU's, increasing the costs of DAQ and HLT. CMS has addressed this at some level in the risk registry, but should also consider how to deal with a worst case scenario where prices actually go up and deliveries slow substantially.

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[1] CERN-LHCC-2021-007 ; CMS-TDR-022

The funding sources are 10.7M from Core, 11 M from M&O A, distributed at 1 M/yr beginning in 2021. At this time only 6.6M of Core funding is in place, leaving an overall 4.1M deficit for the project. CMS will continue to seek core funds, but have credible mitigation scenarios should some or all not materialise. We note that the impact of cost increases or delays is easier to mitigate for the DAQ/HLT than for hardware-intensive upgrade projects that depend heavily on R&D, new technologies and rigid completion dates. For example, a one-year delay in the start of Run 4 would cover all the deficit.

Schedule : The detailed schedule presented allows adequate floats "everywhere." Organized along the WBS, the DAQ schedule covers Technical & IT infrastructure, Readout and D2S, Event building, HLT infrastructure and Storage, Timing and Control Distribution System, Detector Control System and Online software. There are 34 milestones, including 9 externals (i.e. external to DAQ). In addition, there is a detailed installation schedule in CMS Merlin. The HLT schedule covers the various tasks to prepare for and operate during Run 3 and Run 4, mainly performed by physicists. We find the schedule reasonable, with sufficient milestones to measure progress. However, as pointed out in the management section above, milestones should be added that address the challenges of adapting to changing architectures, and of ensuring coherence between the online and grid.

Personnel : The project provided us with year-by-year estimates of the personnel required, showing that sufficient numbers of physicists, engineers, technicians and students were available. The long-term nature of the project makes continuity an important consideration, especially given the challenge of recruiting and retaining staff in competition with industry.

Risks : CMS has done a good job in identifying and classifying risks to cost and schedule. The main cost risk is increases caused by lower cost/performance gains than assumed in the estimates. Schedule risks include delays in availability of components and in access to the old control room, and inability to hire and retain sufficient expert personnel. Mitigation plans seem adequate, and the impacts can be tuned by raising thresholds in the HLT and L1, improving performance of algorithms, etc. We see little danger of a "hard landing."

Conclusions and Recommendations : 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. However, they depend directly on large cost/performance improvements over many years, a situation that must be carefully monitored. The schedule, risks and manpower are at normal levels, provided they continue to be proactively managed.

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

2. A review of the software framework in conjunction with the review of the Computing TDR, to ensure coherence as architectures evolve, and to make sure nothing falls through the cracks.