# UCG Report on the ATLAS Phase II Upgrades

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**Introduction**: At the June LHCC meeting it was agreed that the ATLAS and CMS scoping documents must be evaluated in time for the October RRB meeting, for MCHF 275, 235, and 200 configurations**.** Numerous LHCC/UCG interactions with the experiments took place to accomplish this. As we received them, we reviewed outlines and preliminary versions of the scoping document, schedule, and spreadsheets for cost and manpower. We also held Vidyo meetings with ATLAS on July 6 and August 14, interspersed with Email exchanges. We have received marvelous cooperation.
Phase II is completely new ground for the UCG. Phase I efforts dealt entirely with complete, LHCC approved TDR's, whereas here we have a multistage approval process (CERN issued the document describing the process last week). At this step we focus on conceptual designs, cost methodology, past experience, etc., leaving details for the TDR's. The goal is to evaluate as well as possible the costs and schedules for the "Reference Detectors," as this is where the experiments have put the lion's share of their efforts. We leave it to the LHCC report to address the impact of descoping.

**General Observations:**
In sharp contrast to the original construction, the upgrades are based on years of experience with successful detectors: evolution *vs* going where no-one had gone before. The ATLAS reference detector cost estimate is CHF 271 M**.** The cost estimates are very well developed for this stage, and provide a firm basis for our reports to the RB and RRB. Risk analysis and mitigation strategies are underway. *In particular the forward LAr and the Muon system have major technical choices ahead, with possible significant implications on cost and schedule.* We are encouraged to see ATLAS actively exploring opportunities to combine procurements with other experiments for "big ticket" items like silicon, power supplies, etc. The funding outlook is guardedly optimistic, with substantive, relatively encouraging interactions in progress with the FA's, in much greater detail than at this stage of original construction. Large uncertainties remain, and it will take a lot of time to secure commitments. Fortunately there appears to be an almost complete alignment of interests with needs. At our request ATLAS has provided us with a most useful set of key milestones and checkpoints for the period leading up to the production of TDR's.

**We conclude that the ATLAS Phase II upgrade project is ready to proceed to detailed detector design, and to establish a baseline cost and schedule for construction.**

Detector System Summaries:

**1. TDAQ– CHF 43M**
With a mature/robust design, TDAQ consists of a 2-stage hardware trigger Level 0 trigger (cal, muon [incl MDT]) and a new L1 track trigger. Tracking triggers are 40% of total cost. The cost estimate is based on the cost of IT/DAQ equipment as used in ATLAS since 2007 and the Phase-I FTK project, augmented by studies of prototypes to optimise performance and reduce risk. The FTK++ is a large component (~13M). An IDR is scheduled for Q1 2016, with TDR at the end of 2016. We see no obvious areas of concern, and recommend that ATLAS should proceed, retaining close coupling between FTK++/L1-Track in terms of project management and design choices.

**2. ITk – CHF 125 M**
The ITk layout has been optimised for performance vs cost down to |η|=2.5, and continued coverage down to |η |=4. Strip design is more advanced than Pixels, since pixel resources were busy with the IBL. The TDR for the strips is planned for Q4-2016); the Pixel TDR will follow later. The cost of replacing the inner 2 pixel layers is not included in the 125M total but would cost an estimated 6.8 MCHF. There is optimism that future costings will not show large increases because ATLAS has considerable expertise from building the existing IT, and they have been conservative in scaling of costs. The main cost risks are the bump-bonding of front end chips (30% of pixel total cost), and a possible low yield because of thin pixel chips. Current costing of strip sensors (40% of total strip cost) is based only on private communication with HPK. A market survey (with CMS) is underway to firm up these estimates. We recommend that the ITk group should produce a document listing remaining R&D items and associated milestones to help define clear future review points for the project, and conduct performance studies with the final layout. [This has been provided]

**3. LAr – CHF 47 M**

The Reference LAr upgrade detector includes a 40 MHz readout system streaming the data off the detector (~31.4 MCHF), a replacement of the current FCal by a finely segmented sFCal (~11.8 MCHF), and a high-precision timing detector (~ 4.6 MCHF) in the η range 2.4 - 4.3. A Full LAr electronics upgrade is mandatory to replace aged components, to provide adequate radiation tolerance in HL-LHC, and to support phase-II ATLAS trigger scheme and TDAQ. While this is well understood, other elements of the Reference design are challenging "works in progress." The initial G4 simulation studies of the sFCal suggest promising physics performance, but more work is needed to develop the case. Also, more prototyping work is essential to demonstrate that this detector will perform adequately in its very high background environment. The removal of FCal and sFCal installation have serious technical risks that must be understood for this project to proceed. Initial calculations indicate potential for improved pile-up mitigation in the forward region via the proposed High-precision Timing detector. However, present studies depend on the use of a crab-kissing collision scheme to achieve very narrow collision time distribution, and the hardware realization of a performant detector has not yet been demonstrated. Significant future R&D is required, and the cost of this detector is highly uncertain.

The forward region presents serious issues in the HL LHC era. If an **sFCal** cannot be realized but the **FCal** is expected to show serious degradation in the HL-LHC, there is an option to add another device called MiniFCal. A rough estimate of costs for the two options are +1.3 MCHF (cold) or +3.6 MCHF (warm). How well it works to mitigate FCal needs more study. In any case, these detectors are not well developed and would need substantial R&D. Perhaps the most serious risk, the radiation environment could make interventions in forward region challenging and/or costly, especially if robotics are needed. In fact the technical unknowns and risks are more worrisome than cost risks.

> **Recommendations:** Work to optimize the full LAr electronics upgrade should proceed. A broad based effort (simulation, design, prototyping, and installation engineering review) to understand the Forward CAL Region should be vigorously pursued during the next 6 months.

**4. Tile Calorimeter – 8.6 MCHF**

The project consists of replacing the readout of the 10k channels (5k cells), to cope with radiation tolerance, high occupancy and new L0 trigger scheme. The steel and most scintillators tiles are kept.
The cost drivers are the FPGAs, complex PCBs: 14-16 layers, ATCA crate system, and the optical fiber system. There is a good level of confidence in the cost estimate, as changes are based on run 1 experience and demonstrator tests in the beam.

**5. Muons – CHF 34 M**

The ATLAS muon system needs comprehensive replacements, partially in response to issues emerging since the LOI: the RPC's and power system are aging, and there is a plan to add muon ID at large η. The RPC and TGC electronics would also be replaced, leading to a system that is cheaper, and easier to maintain and configure. ATLAS prefers to replace electronics everywhere (3 station trigger). There
Is a need to replace MDT by sMDT to save space. The power system is the biggest cost. Cost risks include: the electronics is based on conceptual designs, the plan for high η is uncertain, and the proposed BI layer is very challenging.

**6. Infrastructure/Installation – CHF 17 M**

The demand for resources will be very heavy during peak periods and must be carefully managed. Cost estimates for safety infrastructure (3.5MCHF) assume no robotics will be needed for LS3 installation. Additional costs here could be substantial but have not been estimated. The experiment expects to have a plan and estimate by summer 2016. The installation schedule is very tight and currently exceeds the LS3 time window by 3 months. The sFCal installation (1.8MCHF) is a challenging operation (modification of activated cryostat) with substantial uncertainty in cost and serious technical risk. Precise evaluation of power, cooling and ventilation needs will be done at later stage (requires TDR's). ATLAS requests that common infrastructure, detector integration, and installation be funded through common fund (17.4M CHF) under TC & RC responsibility.

> **Recommendations:**
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> 1.ATLAS should conduct a review of cost and overall schedule for TC, common infrastructure and installations in 2018, when all TDRs will be available, and the cost for safety, power, cooling, etc. will be close to final.
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> 2. An in-depth assessment of ageing critical components should be pursued with high priority.
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> 3. The boundaries of responsibility between the collaboration and the host laboratory should be clearly defined and agreed.