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BUDGET, PROCUREMENT AND RISK MANAGEMENT FOR THE HL-LHC PROJECT

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Abstract

The HL-LHC project covers the upgrade of the LHC, aiming at collecting an integrated luminosity of 3000 fb-1 in the first 10 years of operation, equivalent to a 10-fold increase of the nominal LHC performance. Approved in 2016 for a 950 MCHF budget, the project is shaped by 19 work-packages, covering all expertise areas, from beam dynamics to technical infrastructures. A truly international effort is deployed, where 38 institutes collaborate to supply key technologies, equipment, and manpower. Compensating overcost with saving and descoping, the Budget-at-completion changes have been limited within +10%. The Make or Buy plan drives procurement, ensuring optimal and timely acquisition conditions through transparency, equality, and competitiveness, in accordance with CERN Procurement Rules. Differently from US DoE projects, HL-LHC features no risk contingency, whilst being a technology driver, hence exposed to a non-negligible intrinsic risk. Risks are catalogued and followed up, aiming at building resilience, supporting decision making, and applying appropriate cost and schedule risk mitigation measures. The paper describes the methods used in cost, procurement, and risk management, as well as the evolution and challenges in these areas.

INTRODUCTION

Today's major project at CERN, the HL-LHC Project [1] is committed to excellence in project management (PM), respecting the best PM practises, in the framework of CERN's rules and principles, corporate culture, and mission. This paper describes the strategies, methods and processes applied in Budget, Procurement, and Risk management for HL-LHC. It completes a series of 2 papers on PM for HL-LHC, where structures, committees, configuration, schedule, and quality management were presented in [2].

COST MANAGEMENT

The presently approved Budget-At-Completion (BAC) of the HL-LHC project (the Project) amounts to 1,140 MCHF. This budget covers all material and all manpower required to complete the Project, including hardware commissioning up to the hand-over to operation with beam, with the exclusion of CERN staff cost. It also includes the "core value" of all external contributions, evaluated as the equivalent budget CERN would need, to complete the same deliverable and work. This core value may therefore differ from the cost, borne by the external institute, to complete the collaboration's contract with the Project. Thus calculated, the core value of the external contributions amounts today to 93 MCHF, the largest contribution being the one from the US, with core value 66 MCHF.

The Project was approved in 2015 with a BAC of 950 MCHF, to which 83 MCHF of spares were later added, under the HL Consolidation label. Since then, the Project budget has undergone several re-baselining stages. Infrastructure cost, initially evaluated top-down, was re-evaluated more accurately in 2018 and accompanied by a severe scope reduction, to palliate the resultant cost increase. A further re-evaluation of infrastructure cost was approved in 2019, together with the integration of new scope following the entry of Russia in the Project. In 2022, to mitigate the schedule delays incurred by the Project due to the belated release of funds by the Russian agencies, a part of the original Russian scope was descoped from the Project and another part was insourced, with a budget overhead to cover new cost estimates and internal manpower.

Keeping all these successive scope evolutions in mind, the Project's BAC – including the spares part – has increased by 107 MCHF since the first Cost & Schedule review (CSR) in 2016. The major scope changes are listed in [2]. Table 1 summarizes the breakdown of the HL-LHC budget, while Fig. 1 captures the BAC evolution along the successive baselines.

Table 1: HL-LHC Budget at completion breakdown

	[MCHF]
CERN funded BAC	1,047
In-kind core budget	93
Total BAC	1,140

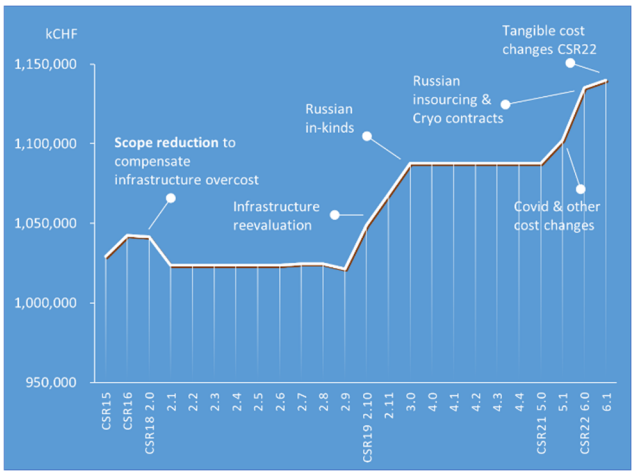

Figure 1: Evolution of the Budget-at-Completion of HL-LHC along successive baselines.

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The budget is distributed in a Work Breakdown Structure (WBS), the highest level of which is the work-package (WP). WP budgets span from some millions CHF – e.g., the Energy deposition computation WP – to the 259 MCHF of the Technical Infrastructure WP.

The cost of each activity contributing to the WBS was estimated in 2015, based on the LHC experience, internal and external experts' advice, and available market prices, wherever applicable. Like in all CERN projects, market cost indexation is at first not included in the BAC: instead, the cost index impact on the Cost-to-completion is traced and considered a risk, or conversely, an opportunity.

While some estimate uncertainty was inherently included, a normalized uncertainty was not added to the cost estimates. For the largest cryogenic refrigeration contracts, tendered in 2022, uncertainty was increasing due to the post-Covid market conditions: the geopolitical situation in Spring 2022 entailed a substantial increase of production cost, which impacted the finally signed contract – requiring an increase of the Project's BAC.

Following CERN's projects funding policies, no risk contingency is included in the BAC. In HL-LHC, contingency is built up by a process of absorbing cost changes via a dynamical budget buffer. Several options were included in the initial scope, which were later dismissed following prototype test results or new insight from LHC beam operation. Also, savings achieved after completion of activities are returned to the buffer, providing leeway to cover over-costs. This dynamical contingency build-up encourages a rigorous budget control by the Project. Cost changes exceeding the buffering capabilities must however be negotiated with CERN management.

Earned Value Management (EVM) is used for work and budget planning and monitoring. Figure 2 presents the EVM metrics at the time of writing.

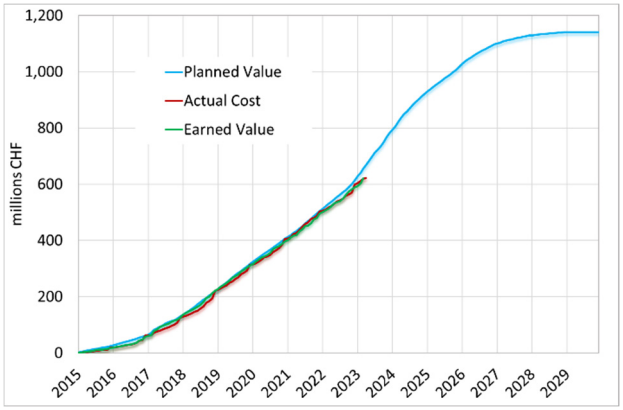

Figure 2: EVM curve of HL-LHC in the current baseline 6.6.

Activities are budgeted in a rolling-wave scheme. All future activities are assigned a lumped budget, which is structured in Planned Value (PV), in an increasingly granular way as the start of the activity approaches. The smallest unit of work, the work-unit, is assigned to a responsible person, who will report progress, thus building the Earned Value (EV) curve. The Actual Cost (AC) is automatically computed from CERN's accounting applications. The intersection unit between budget planning and accounting is the budget code, covering the full budget-at-completion approved for a well-defined scope. Cost Variance is computed as the difference between EV and PV, while Schedule Variance is the difference between EV and AC. The CV indicators are compared to initial estimate to follow cost changes, while the SV indicators are compared with schedule. All actors in the Project are trained in the use of EVM and the EVM metrics is used at all reporting levels.

Expected, yet not precisely assessed, tangible cost changes are tracked via EVM draft work-units tagged "tangible", to indicate the high probability of materialization. These work-units are not included in the BAC, but they are presented to the yearly Cost & Schedule review for endorsement. Likewise, all potential cost changes are announced as early as possible, listed in "potential" work-units and considered as risks or opportunities. This novel approach to management of expected cost changes, implemented since 2021, guarantees timely information to CERN's Financial management and has been valued by the 2022 Cost & Schedule reviewer's panel, which endorsed all tangible cost changes presented until now.

PROCUREMENT MANAGEMENT

Procurement for HL-LHC must comply with CERN's financial and procurement rules, fostering transparency, equity and competitiveness. A Make-or-Buy Plan (MoB plan), run by the Project since 2015, is updated yearly with all WP leaders. All tenders above 50 kCHF taking place within 18 months are included in the MoB plan and integrated as milestones in the WP schedules.

For each highest-level deliverable, the MoB plan is constructed in a full bottom-up approach, to identify items to be produced by industrial partners, by collaborating institutes or which need to be insourced to CERN's services. The sourcing strategy is agreed among the key stakeholders at an early stage, the Technology Readiness Level playing a key role in its definition. Figure3 illustrates this approach for a collimator.

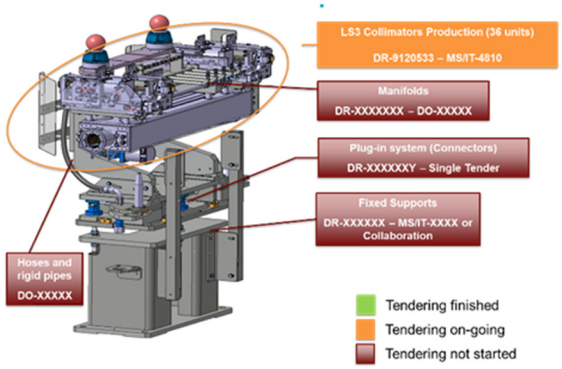

Figure 3: Breakdown of the Make-or-Buy plan for a collimator to be installed during Long-Shutdown 3.

The Project has chosen to launch procurement as early as possible, to allow timely identification of alternatives, build schedule margins, and absorb potential delays during

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production. Early procurement also avoids too aggressive production schedule constraints, which impact both cost and risk, and thus limit the number of received bids.

Following CERN's procurement rules, the tendering process depends on the estimated amount of the contract, and might take from 3 months, for contracts below 200 kCHF, to up to 12 months, for contracts estimated at more than 750 kCHF. Expenditure requests trigger the process. For orders above 200 kCHF, a Market Survey precedes the Invitation-to-tender. Contracts above 750 kCHF following a competitive tendering process require final approval of the price by CERN's Finance Committee, whose approval is also required for non-competitive tenders above 200 kCHF. The cost estimate and thus the procedure to follow build the tendering schedule and determine a minimum time to accommodate in planning.

Industrialization is a permanent challenge for an innovative, large-scale research project such as the HL-LHC. For most of the required components, the number of series units is small, while the technical requirements are challenging, and often well beyond standard industrial practices. Intense sourcing campaigns, such as HL-LHC industry days or industry exhibitions at CERN are organized to trigger technical discussions and involve industries from a very early stage of the project life cycle.

With prototypes being completed for the most demanding deliverables of the project, and with civil engineering close to completion, procurement for HL-LHC continues intensively, with 33 competitive tendering processes launched and 25 contracts signed in 2021-2022 and more than 100 contracts above 50 kCHF expected to be awarded in the next two years.

RISK MANAGEMENT

Operating with a constant yearly budget, CERN does not usually reserve a budget contingency to cover the risks catalogue of projects. The risk exercise remains an essential tool to increase resilience and anticipate and mitigate adverse events, identify threats and opportunities, and prioritize high impact or high vulnerability risks. Also, it allows to decrease uncertainties and provides evidence-based analysis and information for decision-making.

The Risk framework was implemented at CERN in 2012, with the support of an external consultant. Out of several available methodologies, the Risk intelligence map was chosen. A yearly exercise is performed with the WP leaders, to update the risk register of each WP, assessing impact and vulnerability for a set of risk categories classified in delivery-on-mission, operations & infrastructures, strategy & planning. Risk sub-categories include safety and environment, production, delivery, installation, quality, budget control, reputation, procurement, recruitment, suppliers, and many more. A MARCI chart (Mitigate, Assure, Redeploy, Cumulative Impact), as the cumulative one shown in Fig. 4, identifies risks with the highest impact and vulnerability, which then require a mitigation action.

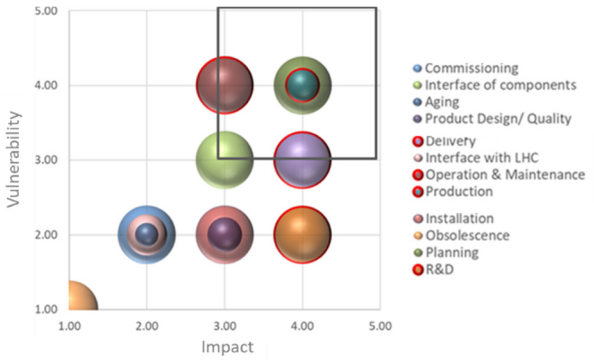

Figure 4: MARCI analysis result for HL-LHC.

This qualitative approach is accompanied by a quantitative exercise covering budget only, excluding technical risk and configuration baseline changes. The yet uncommitted budget of 337 MCHF is classed by expenditure channel, whether internal or external procurement, industrial labour, or associated personnel. Cost estimates have lately been re-evaluated, accounting for today's strained market conditions and labour and personnel contracts status. Risk on committed but unspent budget, 200 MCHF, has been estimated to 5%. The resulting budget risk exposure on a total unspent budget of 537 MCHF is estimated to 67 MCHF.

Risk mitigation includes the search for new in-kind, internal fabrication of critical items and increased use of existing framework contracts. To foster tender competition and reduce margins from bidders, a new approach towards a better risk share with suppliers has been implemented in some large Engineering, Procurement and Construction contracts, implementing price revision formulas based on European standardized price indexes.

CONCLUSION

With a total approved Budget-at-completion of 1,140 MCHF, challenging cutting-edge technologies in accelerator elements and large infrastructure overhaul, HL-LHC requires a rigorous and yet dynamical budget management. The BAC growth has been limited to +10% by recuperation of savings and descoping of options, in cooperation with all WPs. The Make-or-Buy plan has allowed to explore all sourcing possibilities, keep procurement and production in line with schedule, while coping with the tense market conditions of the last years. A qualitative approach to risk management allowing to identify threats and opportunities is accompanied by a quantitative assessment of cost risk and uncertainty on the budget remaining to spend. These strategies ensure an adequate Project's cost control, within the general policies and rules of CERN.

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