

Report of the Scrutiny Group to the LHC RRB, October 2021

Membership of the Scrutiny Group

At the end of 2020 William Christie (BNL), Georges Vasseur (CEA) retired from the group. The Scrutiny Group (SG) wishes to thank them all for their dedicated service over many years.

The membership of the Scrutiny Group in 2021 was: Michael Campbell (CERN), Hans Danielsson (CERN), Dominik Dannheim (CERN), Renee Fatemi (Kentucky), Ariane Frey (Göttingen), Joel Goldstein (Bristol), Pasquale Lubrano (Perugia), Edoardo Mazzucato (CEA/IRFU), Roman Pöschl (LAL), Sylvie Prodon (CERN/FAP-RPC; Service Contracts), Heidi Sandaker (Oslo; chair), Burkhard Schmidt (CERN; Secretary), Christoph Schwanda (HEPHY), James Yeck (BNL).

1 General remarks

The pandemic situation due to Covid-19 continued during 2021, demanding a large extra effort and coordination, in particular making travels for users difficult. The results of the pandemic on the costs and future budgets has been kept to a minimum thanks to the important efforts of the collaborations and their managements.

2021 was the third year of shutdown of the LHC, Long Shutdown 2 (LS2) with extensive work to upgrade and maintain existing detectors and their computing systems as well as to install and commission new detectors. In spite of the current difficult situation most of this work has taken place. Other work includes improvements of infrastructure and services for a stable and safe operation of the detectors and optimal working environment for staff and students.

The Scrutiny Group congratulates the LHC and the experimental collaborations for their extraordinary efforts and achievements in 2021.

The Scrutiny Group would like to express a special thank you to the TOTEM collaboration for their many years of successful experiment operation and great physics results.

2 Upgrade Cost Group

Members of the Scrutiny Group have contributed to the Upgrade Cost Group (UCG), reviewing cost and schedule of LHC detector upgrades. This year the CMS TDAQ/HLT TDR was reviewed by the UCG and has ultimately been recommended for approval:

- CMS Data Acquisition and High Level Trigger (CERN-LHCC-2021-017, UCG-036).

3 Scrutiny process and general matters

Following the RRB meeting from April 26-28 the SG held its Spring Meeting from May 10-11. Both in the RRB and SG meeting summary reports on 2020 expenditures and 2022 requests were presented by the collaborations. The SG met with the LHC experiments ATLAS, ALICE, CMS, LHCb and TOTEM, represented by their respective Resource Coordinators and other members of the senior management. The SG and experiment representatives discussed the closing of the 2020 accounts, the status of the 2021 spending, the budget request for 2022 as well as plans for the future. Additional in-depth discussion with each experiment took place in June and July, except for TOTEM for which the last meeting was the May SG meeting. During these meetings each experiment was reviewed by a subgroup of the SG, who summarised the findings in internal reports. The Scrutiny Group met again from September 13-14 with the collaborations to discuss and resolve any remaining outstanding matters. In addition to the scrutiny of the M&O A and B budgets, the SG also discussed the status and spending profiles of the Upgrade Common Funds (Phase-1 and Phase-2) with the experiments, following the agreement in 2015 (see RRB-2015-086).

The SG thanks the Resource Coordinators and the collaborations as a whole for the excellent cooperation and the constructive spirit of the discussions.

As a follow up of the RRB discussions in April 2021 and previous years, a few specific items were discussed in more depth with each experiment; the details are in the respective experiments' section:

- The M&O A cash balance discrepancies between the CERN Financial reports and the cumulative internal SG budget tables maintained by the collaborations were resolved in a dedicated effort in the past (RRB-2017-070). The SG is very pleased to note that for the 2021 budgets, the trend continues with perfect agreement.
- A follow-up on long-term projections for the special online computing replacement account. These accounts are allowed to go negative, and should not accumulate excessive cash reserves.
- In RRB-2017-070 it was agreed that carry-over on subdetector M&O B accounts should aim to stay below approximately 30% of the yearly budget. The SG continues to follow these developments and reduction is progressing for all subprojects where substantial reserves are present.
- Tracking of entry fees: ALICE, ATLAS and CMS charge "entry fees" for new institutes that wish to join the collaboration, to compensate for the lack of contribution to the original detector construction. In the interest of transparency, the SG has asked the experiments to report the status of and plans for these funds. These fees are not subject to the same level of scrutiny as M&O expenditures.
- Common funds: The SG was asked to evaluate if the collection of Common Funds is proceeding according to plan or if it represents a risk, in particular for Phase 1 Common Funds where the accounts are likely to be closed now in 2022 and funds need to come in to be spent in time.

- During this third year of LS2, the experiments, in particular ALICE and LHCb, are installing new upgraded detector systems. This results in potential changes in maintenance and operation costs towards LHC Run 3. Such changes have been discussed with the experiments during 2020 and 2021. The SG will monitor the evolution of these costs closely in the years to come, as the upgraded systems go into operation.

The following additional items came up during this year's scrutiny cycle:

- The RRB is concerned about the cost increase of some experiments. This will be addressed in the individual experiments' section when appropriate.
- Over the last two years the SG sees a general development of late payment of contributions affecting several of the experiments.
- During the 2021 SG cycle experiments have expressed concerns about the level of subsistence for users which may effectively be reduced by the different application of the existing French tax laws. Such a reduction may impact both the cost for and the availability of experts at CERN in the future.

4 Budget requests for 2022

Table 1 gives a global overview over the 2022 budget requests of the experiments. The requests are detailed in the relevant experiment subsections.

Table 1: M&O requests for 2022 in kCHF, without and with power costs.

Experiment	without power	with full power
ALICE M&O A	4,983	7,529
ALICE M&O B	1,418	1,418
ALICE M&O A+B	6,401	8,947
ATLAS M&O A	13,982	16,182
ATLAS M&O B	5258	5258
ATLAS M&O A+B	19,240	21,440
CMS M&O A	13,366	15,066
CMS M&O B	6,089	6,089
CMS M&O A+B	19,455	21,155
LHCb M&O A	3,070	3,370
LHCb M&O B	1,150	1,150
LHCb M&O A+B	4,220	4,520

5 ALICE

ALICE M&O A closing report for 2020

The ALICE M&O A closing report was submitted to the RRB meeting in April (CERN-RRB-2020-036). The 2020 budget as approved in 2019 and the closing report presented in 2021 are shown in Table 2.

Table 2: Summary of the 2020 book closing of ALICE, listing the M&O A budget as approved in 2019 and the actual spending report in this years' scrutiny cycle. All numbers in kCHF.

M&O A Categories	Budget for 2020	Actual in 2020
Detector related	1,588	1,581
Secretariat	193	173
Communications	0	0
Core computing	537	510
Online computing	1556	1556
Test beams & calibration facilities	40	27
Laboratory operations	255	272
General services	718	477
TOTAL without power	4,887	4,596
Power (MS + NMS)	40	42
Grand Total	4,927	4,638

Comments on spending: Total expenditure in 2020 excluding power was 4,596 kCHF, 291 kCHF below the budgeted sum of 4,887 kCHF. The total expenditure with power is 4,638 kCHF of which the NMS share is 11 kCHF. Open commitments from 2020 are 267 kCHF. This means a positive result of 24 kCHF without power and including commitments. The outstanding commitments are mainly related to ongoing shutdown activities. The negative balance for Laboratory Operations is mainly due to higher actual costs than what was budgeted in the open commitments from 2019. During the 2020 CERN closure less manpower was available and thus General Services has a positive balance.

Carry over: The accumulative difference between budgeted amounts and the actual expenditure at the end of 2020 is 1,458 kCHF without power and without open commitments. This amount has to be considered together with the received contributions, mentioned below, which show that there is no cash carry over.

Online account: During 2020, 910 kCHF was transferred to the special online replacement account and payments amounted to 451 kCHF, bringing its balance at the end of the year to 5,576 kCHF.

Contributions: The invoiced total is 4,896 kCHF; of this 306 kCHF are outstanding from the funding agencies for 2020. This trend with outstanding contributions or late payments in 2019 continues for 2020. ALICE carried over a year-end deficit of 266 kCHF due to unpaid M&O

A contributions, and outstanding contributions at the end of 2020 as per finance report are 1,730 kCHF, 35% of the M&O A. This is a cause of concern as it threatens the experiment's financial viability.

CERN finance report: The SG confirms that the numbers reported by the experiment correspond to the figures reported by CERN finance.

The Scrutiny Group recommends approval of the ALICE 2020 M&O A closing report.

ALICE M&O B closing report for 2020

The M&O B budget for 2020 was 970 kCHF, while the actual spending reached 1,012 kCHF, corresponding to an overspending of 4% of the approved annual budget. The overspending for the last three years has been intentional in order to reduce the accumulated reserves from recent years.

Those systems which will not continue in Run 3 are aiming to spend their funds by the end of 2021, and other systems have reduced their cash reserves to less than 20% of their annual budget by the end of 2020. We congratulate ALICE for this achievement.

The Scrutiny Group recommends approval of the ALICE 2020 M&O B closing report.

ALICE M&O situation in 2021

The spending of the 2021 M&O A budget proceeds according to plan. As of September, 52% of the budget of 4,910 is spent, 69% including commitments, which is close to normal despite the effects of Covid-19. This year the trend of very late payment of contributions continues, but some progress in payment of outstanding contributions is made compared to last year. The planned transfer of 829 kCHF to the online replacement account has not yet been done due to late arrival of contributions. If possible the funds will be transferred at the end of 2021.

ALICE M&O A budget request for 2022

The budget request for 2022 is shown in Table 3 together with the previously approved budget for 2020 and the projections up to 2025.

The M&O A budget request for 2022 is 4,983 kCHF excluding power. The total power cost is 2,546 kCHF of which the NMS share is 686 kCHF. There have been no significant changes to the projections for future M&O A since the 2020 RRB. Small changes are mainly due to the changes to the CERN Service Level Agreements (approximately 80 kCHF), and the effects of Covid-19. There is an increase of 0.5 MCHF per year for Run 3 in the overall computing budget (split between offline and online), due to the new O2 data centre, as agreed in 2018.

The Scrutiny Group recommends approval of the ALICE 2022 M&O A budget request.

ALICE Online Replacement Account Projections

During LS2 the current online system will be replaced by the substantially bigger O2 system (~ 9 MCHF), resulting in a substantial increase of replacement costs in the long term (this differs from other experiments). These costs are partially funded through the online replacement account, consistent with direct replacements. In 2021, 2,088 kCHF will be spend on the O2 hard-

Table 3: ALICE M&O A budget request for 2022, shown together with the 2021 budget and the projections up to 2025. All numbers in kCHF.

M&O A Categories	2021	2022	2023	2024	2025
Detector related	1,271	1,192	1,166	1,166	1,428
Secretariat	193	193	193	193	193
Communications	0	0	0	0	0
Core computing	776	776	776	776	776
Online computing	1,773	2,022	2,000	2,000	1,505
Test beams & calibration facilities	50	50	50	50	20
Laboratory operations	245	245	245	245	255
General services	602	505	553	553	806
TOTAL without power	4,910	4,983	4,983	4,983	4,983
Power (MS + NMS)	717	2,546	2,502	2,502	593
Grand Total	5,627	7,529	7,485	7,485	5,576

ware, which reduces the account balance from 5,576 kCHF to 3,488 kCHF. It is also planned to transfer 829 kCHF to this account in 2021 possibly towards the end of the year. After LS2, the online account accumulates funds until the O2 system will be replaced in 2027 (8 MCHF), when the balance is expected to go to -1.3 MCHF. The account reaches surplus again by the end of Run 4.

ALICE M&O B budget request for 2022

The budget requests for 2022 is shown in Table 4 together with the 2021 budget and projections up to 2025. The M&O B budgets of each system are scrutinised internally in the collaboration and also at the national level during approval of the relevant budgets. The SG has discussed the requests with ALICE in detail.

The requested M&O B budget for 2022 is of 1,418 kCHF. The ALICE M&O B budget is normally lower during shutdown years and higher during operation years, so for 2022 the budget is back at the level of operation years. This request takes also into account changes in major subsystems due to the upgrade of detectors in LS2. From 2021 onwards, these upgraded detectors will be in operation.

The Scrutiny Group recommends approval of the ALICE 2022 M&O B budget request.

Upgrade Common Fund and Entry Fees

Phase-1 Upgrade Common Fund: The ALICE Phase-1 upgrade Common Fund is 5.8 MCHF. By September 2021, 5.7 MCHF of the funds were collected, corresponding to 98% (105 kCHF outstanding). At the end of 2020, the cumulative spending was 5.4 MCHF, including 402 kCHF of entry fees spent in 2019. The original plan was to spend the remainder of the fund by end of 2020, however due to delay in the LHC schedule the lifetime of the fund was prolonged. The current expectation is that all spend on the 5.8 MCHF upgrade common fund will finish in 2022, with a small (100 kCHF) cash surplus expected.

Table 4: ALICE M&O B budget planning for the years 2021 - 2025. All numbers except the last rows in kCHF. The last row is in staff-months.

M&O B Categories	2021	2022	2023	2024	2025
Mechanics	39	39	37	37	47
Gas Systems	31	28	28	28	23
Cooling Systems	58	52	52	50	
FEE Spares	95	94	79	79	79
Standard Electronics LV/HV PS	138	146	142	154	142
Standard Electronics Crates	37	38	38	38	40
Standard Electronics R/O modules	72	74	74	74	71
Controls (DCS & DSS)	30	29	29	29	29
Sub-Detector Spares	13	13	38	38	39
Areas	51	56	56	56	56
Communications	106	105	106	106	104
Store Items	97	85	77	77	79
Technical Manpower@CERN: Industrial Support	12	8	8	8	18
Techn. Manp.@CERN from Collaborating Institutes	652	652	647	647	707
Grand Total	1430	1418	1410	1422	1483
Techn. Manp.@CERN from Col. Instit.(man months)	234	221	213	213	223

Entry fees: ALICE collects entry fees from new members. These fees are accumulated in the Common Fund account and thus discussed with the SG. The entry fees are normally used for upgrade-related projects or other projects not covered, or going beyond, the Common Fund. For 2020 no funds have been spent. This leaves 367 kCHF remaining at the end of 2020.

6 ATLAS

ATLAS M&O A closing report for 2020

The ATLAS M&O A closing report was submitted to the RRB meeting in April (CERN-RRB-2021-031). The 2020 budget as approved in 2019 and the closing report presented in 2021 are shown in Table 5.

Spending: Total spending in 2020 excluding power was 12,349 kCHF for an approved budget of 13,525 kCHF. This corresponds to an underspending of 1,176 kCHF. While in some areas, e.g. cooling, there was actually overspending, the major underspending stems from the limited gas consumption, as almost none was used due to the change of the LS2 schedule induced by Covid-19. Open commitments amount to 782 kCHF. Power costs were 2,200 kCHF as budgeted, including a NMS share of 718 kCHF.

Carry over: There is no significant accumulation of funds, the cash status went from negative 964 kCHF end of 2019 to positive 22 kCHF end of 2020. In fact, a correction(686 kCHF) to be applied to the expenditure in computing was spotted in 2021, resulting in a larger cash balance

Table 5: Summary of the 2020 book closing of ATLAS, listing the M&O A budget as approved in 2019 and the actual spending report in this years' scrutiny cycle. All numbers in kCHF.

M&O A Categories	Budget for 2020	Actual in 2020
Detector related	5,626	4,710
Secretariat	464	484
Communications	220	303
Core computing	2,354	2,139
Online computing	1,923	1,978
Test beams & calibration facilities	960	1,149
Laboratory operations	90	78
General services	1,888	1,507
TOTAL without power	13,525	12,349
Power (MS + NMS)	2,200	2,200
Grand Total	15,725	14,549

of 708 kCHF.

Online account: In 2020, taken the aforementioned correction into account, 459 kCHF was deposited to the online replacement account, no funds were used. The cumulative cash balance amounted to 3,447 kCHF at the end of 2020.

Contributions: The contributions received from Funding Agencies in 2020 were 14,739 kCHF, 103% of the due contributions of 14,243 kCHF. The outstanding contributions from 2020 went down to 1,523 kCHF from 1,956 kCHF end of 2019.

CERN financial report: Taking the above mentioned correction into account there is agreement between the Finance Department report and the numbers from the experiment. The correction of the online account will only be reflected in the Finance Department report of 2021.

The Scrutiny Group recommends approval of the ATLAS 2020 M&O A closing report.

ATLAS M&O B closing report for 2020

The M&O B budget was 5,795 kCHF including 120 kCHF from provisions, with an actual spending of 5,420 kCHF including 3,215 kCHF for hired manpower at CERN. At the end of 2020 the open commitments were 595 kCHF. With a net underspend of 375 kCHF in 2020, the carry-over, summed over all sub-systems at the end of the year, has increased from 1,847 kCHF in 2019 to 2,222 kCHF in 2020 (1,627 kCHF when subtracting the 595 kCHF open commitments). Globally, the M&O B carry-over is thus slightly below the target limit of 30% of the annual budget.

The Scrutiny Group recommends approval of the ATLAS 2020 M&O B closing report.

ATLAS M&O situation in 2021

The amount spent so far until September 1st, 2021 on M&O A budget, including open commitments, is 7,766 kCHF, i.e. 56% of the 2021 approved budget of 13,759 kCHF (without power). This is in-line with the expected expenditures.

ATLAS M&O A budget request for 2022

The budget request for 2022 is shown in Table 6 together with the approved budget for 2021 and the projections up to 2025.

Table 6: ATLAS M&O A budget request for 2022, shown together with the 2021 budget and the projections up to 2025. All numbers in kCHF.

M&O A Categories	2021	2022	2023	2024	2025
Detector related	4,991	4,806	4,806	5,026	5,306
Secretariat	464	410	410	410	410
Communications	210	185	185	185	185
Core computing	2,354	2,354	2,354	2,354	2,354
Online computing	3,704	4,673	4,260	3,247	2,340
Test beams & calibration facilities	295	220	220	520	1,120
Laboratory operations	90	90	90	90	140
General services	1,651	1,244	1,244	1,282	1,901
TOTAL without power	13,759	13,982	13,569	13,114	13,756
Power (MS + NMS)	2,200	2,200	2,200	2,200	2,200
Grand Total	15,959	16,182	15,769	15,314	15,956

The ATLAS M&O A budget request without power for 2022 is 13,982, up by 223 kCHF compared to the corresponding budget approved for 2021. The power cost is 2,200 kCHF of which the NMS share is 734 kCHF. This total request for 2022 has decreased slightly, by 26 kCHF, from the 2022 budget anticipated last year (in 2020). Some changes in the distribution between different items has been done following the re-evaluation of the long term experience.

It should be noted that the anticipated increase in cost of Helium is not reflected in the budget request. The next 4-year CERN Helium contract will take effect in early 2022.

The projections for the M&O A budgets for the years 2023-2025 show a slightly decreased budget for 2023 and 2024 with a rise in budget in 2025 due to LS3. Comparing the projected budgets to the ones anticipated last year, the main changes are on the one hand the inclusion of the LS3 magnet pack with 300 and 900 kCHF for 2024 and 2025, respectively, and on the other hand the reduced gas consumption projection for 2025.

The impact of the recent re-evaluation of the SLA or ATLAS translates to a net decrease around 22 % of the cooling and ventilation agreement and the costs for 2022 is 1530 kCHF.

In 2022, a moderate withdrawal on the online replacement account is planned of 688 kCHF.

The Scrutiny Group recommends approval of the ATLAS 2022 M&O A budget request.

ATLAS Online Replacement Account Projections

At the end of 2020, the online replacement account had a total of 3,447 kCHF (this is taking the aforementioned correction into account). During the years 2021 and 2022 withdrawals of close to 4,000 kCHF are foreseen (688 kCHF in 2022), mainly to replace about half of the HLT servers. The cumulative cash balance goes thus negative in 2022 and will become positive in 2023 again. Until 2026 the plan is that the online replacement account will accumulate funds.

ATLAS M&O B budget request for 2022

The actual and planned budgets from 2021 to 2025 are given in Table 7. The M&O B budget request for 2022 is 5,258 kCHF, compared to 5,232 kCHF planned last year. The budget invoiced to the funding agencies for 2022 is slightly lower. It amounts to 5,218 kCHF due to the return of funds over the period from 2015 to 2022. The budget increase since last year's meeting is due to the request of additional support for the forward detectors ARP, LUCID and ZDC.

Also the projections of the coming years have increased with respect to last year's estimates for the forward detectors by 77 and 75 kCHF in the years 2024 and 2025, respectively. Another major change is the one year delay of the planned ITK expenditures with the revised schedule, now starting only in 2024. The current Inner Detector ID and the new ITK will have thus cost overlap in 2024 and 2025 with a peak in total cost in 2024 (2,612 kCHF), dropping in 2025 with 2,045 kCHF below the level of the current ID budget.

Table 7: ATLAS M&O B budget planning for the years 2021 - 2025. All numbers except last row in kCHF.

M&O B Categories	2021	2022	2023	2024	2025
Mechanics	47	43	45	50	110
Gas Systems	175	58	58	58	65
Cryo System	0	0	0	0	0
Cooling System	18	18	18	38	38
FE Electronics	132	124	102	104	87
Std Electronics LV/HV PS	584	603	1,128	1,238	1,122
Std Electronics Crates	367	413	480	504	333
Std Electronics R/O modules	279	324	298	368	160
Controls (DCS & DSS)	134	115	115	125	109
Sub-Detector Spares	261	92	58	133	80
Areas	396	408	274	449	394
Communications	36	43	43	47	41
Store Items	230	243	239	289	257
Hired Manpower @ CERN	2,842	2,773	2,773	2,683	2,649
Hired Institute Manpower @ 90 kCHF/FTE	0	0	0	0	0
Total expenditure	5,501	5,258	5,631	6,086	5,444
Return to FAs	-60	-40	0	0	0
Total to be invoiced to FAs	5,441	5,218	5,631	6,086	5,444
Technical Manpower OTP (FTE)	260	242	239	239	241

The Scrutiny Group recommends approval of the ATLAS 2022 M&O B budget request.

ATLAS Upgrade Common Funds and Entry Fees

Construction Common Fund: This Common Fund is used to cover Phase-1 Upgrade spendings and also to deposit the entry fees of new institutions. At the end of 2019 this account had 3,632 kCHF in cash balance. 362 kCHF were spent during 2020, leaving 3,270 kCHF at the end of 2020. The ATLAS Collaboration wishes to finish the Phase-1 upgrades before closing this account. The Common Fund covers mainly the cost for the manpower for the New Small Wheels installation, which is going very well. Both Wheels are now about to or being installed and commissioned.

Phase-2 Upgrade Common Funds: For Phase-2 upgrades, a dedicated Common Fund account is used with a total budget of 24.4 MCHF, to be collected over 9 years from 2018 to 2026 with a flat profile of 2.7 MCHF per year. The spending profile peaks in the years 2023 to 2026. As of September 1, 2021, 9,108 kCHF of contributions have been received and 309 kCHF spent.

Entry fees: ATLAS collects entry fees from new collaborating institutes. The funds are accumulated in the currently still active Construction Common Fund account. The entry fees are used for detector and upgrade-related projects that extend beyond the original scope of the Common Fund.

7 CMS

CMS M&O A closing report for 2020

The CMS M&O A closing report was submitted to the RRB meeting in April (CERN-RRB-2021-017). The 2020 budget as approved in 2019 and the closing report presented in 2021 are shown in Table 8.

Table 8: Summary of the 2020 book closing of CMS, listing the M&O A budget as approved in 2019 and the actual spending report in this years' scrutiny cycle. All numbers in kCHF.

M&O A Categories	Budget for 2020	Actual in 2020
Detector related	5,807	5,603
Secretariat	312	322
Communications	130	116
Core computing	1,964	1,957
Online computing	2,725	2,655
Test beams & calibration facilities	96	84
Laboratory operations	649	623
General services	2,272	2,225
TOTAL without power	13,955	13,584
Power (MS + NMS)	1,700	1,700
Grand Total	15,655	15,284

Spending: The 2020 M&O-A budget without power costs was 13,955 kCHF. The total power costs were budgeted at 1,700 kCHF with the non-member share (NMS) of 718 kCHF. The total budget was thus 15,655 kCHF. The actual expenditure in 2020 amounted to 13,584 kCHF without power costs, and 15,284 with power. The total amount of open commitments at the end of 2020 was 584 kCHF. Out of this about 59% is for industrial support contracts, and 41% is for consumables and goods to be delivered in 2021.

CMS reports a general underspending in the year 2020 of 371 kCHF (excluding open commitments) corresponding to about 3% of the budget for 2020. Part of the underspending is due to an accounting error of the gas supplier and 100 kCHF are invoiced by the supplier in 2021. Other categories saw an increase in expenditure due to e.g. introduction of the shift crew training scheme, repair of a magnet leak and the purchase of a new dewar for gas storage that complies with today's technical standard.

CMS reported on the impact of the ongoing Covid-19 pandemic. Thanks to policies and procedures put in place in 2020 there seems to be only a limited impact (two months delay for the pixel detector). All in all CMS expects to be ready for the pilot beam in September 2021, and for the start of Run 3 by February 2022.

Carry over: There is no significant accumulation of funds, the carry over stays well below 10%. Taking the open commitments into account the carry over from 2020 to 2021 is of -213 kCHF. The accumulated carry over at the end of 2020 is of 926 kCHF without open commitments. Note for completeness, that the cash balance at the end of 2020 was -200 kCHF.

Online account: In 2020 an amount of 2,428 kCHF was withdrawn from the special online replacement account resulting in an accumulated cash balance of 2,730 kCHF in that account at the end of 2020. This is a reduction of the planned withdrawal, down from 3,340 kCHF to 2,428 kCHF. Note that at the end of 2019 the accumulated cash balance was 5,158 kCHF, the SG recognizes the effort of CMS to spend down the cash reserve in the special online replacement account.

Contributions: As of June 2021, about 9.4% of the contributions received from the Funding Agencies were still outstanding for 2020 and still 4.4% for 2019. By September 2021 the outstanding contributions were down to 8.6%. We see a development of late payment of contributions to CMS the last two years. In the interest of CMS the SG would like to raise awareness to the trend of late payment of contributions.

CERN finance report: There is perfect agreement between the Finance Department report and the numbers from the experiment.

The Scrutiny Group recommends approval of the CMS 2020 M&O A closing report.

CMS M&O B closing report for 2020

M&O B in CMS is organised around detector subsystem groups with varying practices. Certain systems operate completely on an in-kind basis. The 2020 M&O B funds totals 5,953 kCHF. The SG is pleased to note that the spend down of past accumulated funds to below the agreed limit of 30% is proceeding.

The SG recommends approval of the CMS 2020 M&O B closing report.

CMS M&O situation in 2021

M&O A for 2021 is of 12,951 kCHF without power. As of June 2021 about 59% of the funds are spent and the collaboration will make an effort to remain within budget. However, CMS made the SG aware of a number of items that may lead to an overspending such as the handling of GHG emission, strengthening of shift crew team at Point 5, the acquisition of a pump for the magnet vacuum, the repair of the system after a water leak and the movement of the laser barrack of the ECAL in preparation of the Phase 2 upgrade.

CMS M&O A budget request for 2022

The budget request for 2022 is shown in Table 9 together with the approved budget for 2021 and the projections up to 2025.

Table 9: CMS M&O A budget request for 2022, shown together with the 2021 budget and the projections up to 2025. All numbers in kCHF.

M&O A Categories	2021	2022	2023	2024	2025
Detector related	4,398	4,663	4,513	4,213	4,213
Secretariat	312	312	312	312	312
Communications	130	130	130	130	130
Core computing	1,964	1,964	1,964	1,964	1,964
Online computing	3,665	3,665	3,665	3,665	3,665
Test beams & calibration facilities	96	96	96	96	96
Laboratory operations	533	533	533	533	533
General services	1,853	2,003	2,003	2,003	2,003
TOTAL without power	12,951	13,366	13,216	12,916	12,916
Power (MS + NMS)	1,700	1,700	1,700	1,700	1,700
Grand Total	14,651	15,066	14,916	14,616	14,616

The CMS M&O A budget request for 2022 is 13,366 kCHF without power and 15,066 kCHF with power. The total power cost is 1,700 kCHF of which the NMS share is 705 kCHF as of September 2021. The increase of 130 kCHF compared with what was presented in 2020 is explained by the introduction of the shift crew training scheme. This expenditure will be continued in the coming years but overall, it is expected that from 2023 onwards the budget will decrease towards 2025. During the 2021 SG cycle extra expenditures on the CO₂ system (150kCHF) and on surface area development at P5 (167 kCHF) were discussed for 2022. These are expected to be continued at a similar or higher level in the coming years. The recommendations of the SG is that these expenditures should become subject of a wider review during 2022.

In 2020 the SG was informed that CMS envisages to purchase an insurance policy to cover any damages to the Phase 2 equipment when it gets shipped to CERN, resulting in a cost of 150 kCHF starting in 2022 and lasting until the end of shipment. The costs is budgeted in the

M&O A funds (A.7.04 Heavy transport). CMS is the only experiment that considers such an insurance. The SG suggests that a CERN wide solution should be found that applies to all experiments. An update including a cost revision is expected for the 2022 scrutiny campaign.

The cost impact of the new radiation standards and the new greenhouse gas emission goals have not yet been fully clarified, but work is ongoing. The SG asks CMS to assess the cost implications of both these issues. For the greenhouse gases, an initial plan includes efforts to reduce the impact of expected gas cost increases as well as systems to deal with the abatement of the exhaust gases. In addition to the 50 kCHF costs for 2021, 150 kCHF is planned used 2022 for the investigations.

From 2021, there is a decrease in costs due to changes to the service agreements (185 kCHF). In addition, the shift crew scheme set up in 2021 has proven successful and CMS propose to keep the same level of support in 2022 and onward resulting of costs of 130 kCHF.

Over the last years, CMS has presented their plans for a new CMS Control Room. In 2020, a cost estimate yielded a total cost of 6.012 MCHF, where 58% (3,512 kCHF) is to be paid by CERN and the remaining 42% (2,500 kCHF) paid out of CMS funds. It involves capturing various portions of previously planned resources for the CR upgrade, SVX upgrade, and DAQ funds, significant contributions from the host lab (CERN), some Phase 2 common funds, and finally an allocation from M&O A budgets. The procurement of the control room is expected to start within 2022.

The Scrutiny Group recommends approval of the CMS 2022 M&O A budget request.

CMS Online Replacement Account Projections

After withdrawal of 2,800 kCHF in 2021, resulting in a negative balance, the plan is to deposit funds to the online replacement account equivalent of 600 kCHF in 2022 and 1000 kCHF in 2023. Withdrawals from the account is planned in 2024 and 2025, 300 kCHF each year. This plan is shifted with one year due to the change in LHC schedule. The plan is to replace much of the outdated online computing/DAQ equipment towards the end of LS2 (total cost is about 10 MCHF). Parts of the funds will also be used to fund the new control room (1,000 kCHF). Additionally, CMS proposes to use 1 MCHF/year from the online funds in the M&O A budgets, starting in 2021 and extending through the years to come, and depositing these funds into a separate account to partially fund the DAQ/HLT Phase 2 upgrade. This plan was presented to the RRB (autumn 2020) for approval and no objections were raised that are known to the SG.

CMS M&O B budget request for 2022

The actual and planned budgets from 2021 to 2025 are given in Table 10. The M&O B budget request for 2022 is 6,089 kCHF, similar to the number presented in the October 2020 RRB (6,196 kCHF). However, within the budget request for 2022 and compared with the numbers presented at the October 2020 RRB, the budget request for the ECAL went down by 200 kCHF due to downspending of cash carry-over and that for the Muon system went down by 9 kCHF. On the other hand, the requests by the Tracker and the MTD went up by 77 kCHF and 25 kCHF, respectively, compared with the end of 2020. Overall the 6,089 kCHF are 374 kCHF (6.5%) more than the 2021 budget of 5,715 kCHF. During the June and September SG meetings CMS presented in detail the transition between old and new sub-detectors. There is an steady increase of the M&O B requests that can be attributed to the Phase II Upgrade Projects, However, the SG

notes also that the anticipated requests for 2023 and 2024 (i.e., 6,725 kCHF and 6,982 kCHF, respectively) are about 2% higher than in the 2020 scrutiny cycle (CERN-RRB-2020-103).

The Scrutiny Group recommends approval of the CMS 2022 M&O B budget request.

Table 10: CMS M&O B budget planning for the years 2021 - 2025. All numbers except for the last two rows are in kCHF.

M&O B Categories	2021	2022	2023	2024	2025
Mechanics	125	145	168	153	183
Gas Systems	48	58	58	74	74
Cryo System	n/a	n/a	n/a	n/a	n/a
Cooling System	172	246	368	393	493
FE Electronics	47	47	57	49	64
Std Electronics LV/HV PS	171	251	358	368	363
Std Electronics Crates	74	101	89	89	109
Std Electronics R/O modules	196	166	418	513	538
Controls (DCS & DSS)	68	90	90	90	170
Sub-Detector Spares	153	153	53	23	43
Areas	112	181	241	226	276
Communications	143	153	166	165	175
Store Items	120	130	146	156	176
Hired Manpower @ CERN	4,286	4,368	4,513	4,683	4,922
Material Resources Total	5,715	6,089	6,725	6,982	7,586
Technical Manpower OTP (FTE)	0	0	0	0	0
Core Computing (FTE)	8	8	8	8	8

CMS Upgrade Common Funds and Entry Fees

Phase-1 Upgrade Common Fund: CMS has received all contributions except one. Close to all savings are used, the Phase-1 Upgrade Common Fund is expected to close early 2022, as soon as a solution is found for the last outstanding contribution. All payments for the support of the common facilities used by all sub-systems will be finalised during LS2.

Phase-2 Upgrade Common Fund: The total budget of the Phase-2 Upgrades Common Fund is currently of 25 MCHF and was planned to be collected over 9 years from 2018 to 2026 with a profile dependent on individual agreements with Funding Agencies. At the end of 2020 about 8,6 MCHF contributions have been collected and the spending of the common funds is reported to be 4,739 kCHF at the 2020 bookclosing. The size of this fund was estimated to be around 10% of the total upgrade costs, however CMS informed the SG that this is no longer tenable and will need to be increased. The main reason is the reinforcement of the infrastructure at P5. A precise estimate for the additional funds needed will be available for Spring 2022.

Entry fees: CMS collects entry fees from new members. The funds are accumulated in a general account of the CMS management, with no dedicated accounting for the entry fees alone.

They are used to cover items for which no alternative source of funding is available and that are considered urgent by the management. To a large extent, the entry fees are used to facilitate the integration of the new institute in CMS, for example by funding stays of institute members at CERN, or supporting local facilities. In May 2021 the balance was approximately 270 kCHF.

Additional comment: In April 2018, the merger of TOTEM into the CMS collaboration has been formalized by the signing of a Memorandum of Understanding (CERN-MoU-2018-003). The MOU describes the transition years of 2018 through 2021, which is the year of the last TOTEM run. In 2022 there will only be the CMS collaboration, with the TOTEM personnel, funding, and equipment transitioned into CMS. In autumn 2021, TOTEM was reported as part of the CMS scrutiny.

Additional Comment 2: The Scrutiny Group is concerned by the following three areas for CMS, a) the increase in M&O A and M&O B over the years, b) expenses for which it is not fully clear to the SG whether they belong to upgrade or operation (e.g. the CO₂ cooling system and infrastructure work at P5), c) the need to increase the upgrade common funds. The SG is pleased to see that CMS is already planning in-depth review of the upgrade common funds and the surface area development at P5 to be presented in 2022, and recommend such reviews where needed. The SG will watch closely the development of these areas in 2022.

8 LHCb

LHCb M&O A closing report for 2020

The LHCb M&O A closing report was submitted to the RRB meeting in April (CERN-RRB-2021-046/47). The 2020 M&O A budget as approved in 2019 and the closing figures presented for 2020 are shown in Table 11. The strategy of LHCb, as presented to the SG and agreed, is to keep an as constant budget as possible and not to add extra resources for shutdown operations.

Spending M&O A: The total spending in 2020 excluding power was 2,806 kCHF. With power the spending was 3,106 kCHF, the NMS share was 58 kCHF. This corresponds to an underspending of 124 kCHF. In addition, LHCb has 63 kCHF of open commitments by the end of fiscal year 2020. To reduce its cash balance LHCb had planned to use 170 kCHF of its multi-annual surplus in 2020 but this fund was not needed. The largest underspending was for General services, but also for laboratory operations and Test beams and Calibration facilities, mainly because of somewhat reduced activities due to Covid-19 .

Carry-over: The cumulative cash balance by the end of 2020 is 606 kCHF, about 22% of the total without power. This figure has risen from 2019 because of underspending, non-use of the 170 kCHF to downspend the surplus but also because of advance payments. The balance is expected to be reduced in the coming years without further corrective measures as full activities resume. However, if this is not the case the SG advice to continue with the downspending plan originally put in place.

Online account: In 2020 200 kCHF were transferred to the special online account and 105 kCHF were spent. The balance of this fund, which allows to purchase online computing power “just in

Table 11: Summary of the 2020 book closing of LHCb, listing the M&O A budget as approved in 2019 and the actual spending report in this years' scrutiny cycle. All numbers in kCHF.

M&O A Categories	Requested budget 2020	Actual in 2020
Detector related	1,030	1,033
Secretariat	190	212
Communications	10	4
Core computing	190	227
Online computing	930	880
Test beams & calibration facilities	30	10
Laboratory operations	40	20
General services	510	420
TOTAL without power	2,930	2,806
<i>Multi-annual surplus used</i>	170	0
Power (MS + NMS)	300	300
Grand Total	3,400	3,106

time”, has been brought up to 228 kCHF by the end of 2020 (compared to 133 kCHF at the end of 2019). However, the actual transfer of the 2020 funds to the online account happened first in 2021 see comment below.

Contributions: Requests for contributions to the 2020 M&O A was 2,930 kCHF of which LHCb has invoiced 2,985 kCHF. 3,192 kCHF have been received in 2020, including advance payments. Outstanding contributions are 262 kCHF for 2020 as of July 2021.

CERN finance report: Some M&O A payments were actually delayed to fiscal year 2021 and also the transfer to the online account happened in 2021. If these corrections are applied, the numbers reported by the experiment correspond to the figures reported by CERN finance (CERN-RBB-2021-044/45).

The Scrutiny Group recommends approval of the LHCb 2020 M&O A closing report.

LHCb M&O B closing report for 2020

M&O B in LHCb is completely under the responsibility and control of the subsystems within existing agreements. Spending is constant to the 10% level between years with fluctuations mainly driven by exchange rate fluctuations. The 2020 budget including in-kind contributions was 1000 kCHF, up 20 kCHF from 2019 and the spending followed it well. The transition to post-LS2 levels of M&O B due to the addition of new sub-detectors started in 2020 and will continue until 2022 where the level of M&O B will reach 1150 kCHF.

The Scrutiny Group recommends approval of the LHCb 2020 M&O B closing report.

LHCb M&O situation in 2021

The LHCb sub-detectors are now fully upgraded. The approved M&O Category A budget for 2021 totals to 3,070 kCHF, together with a power cost of 300 kCHF (the NMS share is estimated to be 60 kCHF). The spending as of august 2021 is 2467 kCHF, indicating that the 2021 spending will be in line with forecasts and requests despite the delays in the first half of 2021 due to the Covid-19 pandemic situation. The surplus of 170 kCHF not used in 2020 is expected to be used in 2021 to cover any additional costs due to covid-19 or the prolongation of LS2.

LHCb M&O A budget request for 2022 and beyond

In 2022 the new LHCb sub-detectors will be commissioned and go into operation. The budget request for 2022 is shown in Table 12 together with the approved budget for 2021 and the projections up to 2025. The requested budget takes into account the transition to the new sub-detectors and the foreseen plateau is reached already from 2021 onward.

Table 12: LHCb M&O A budget request for 2022, shown together with the 2021 budget and the projections up to 2025. All numbers in kCHF.

M&O A Categories	2021	2022	2023	2024	2025
Detector related	1015	1015	1015	1015	1015
Secretariat	190	190	190	190	190
Communications	10	10	10	10	10
Core computing	220	220	220	220	220
Online computing	1150	1150	1150	1150	1150
Test beams & calibration facilities	30	30	30	30	30
Laboratory operations	50	50	50	50	50
General services	405	405	405	405	405
TOTAL without power	3070	3070	3070	3070	3070
Power (MS + NMS)	300	300	900	900	900
Grand Total	3370	3370	3970	3970	3970

The budget request for 2022 is of 3,070 kCHF without power and is unchanged from the pre-covid forecast. The power cost is 300 kCHF of which the NMS share is estimated to 59 kCHF. From 2021 M&O A will reach the plateau which corresponds to 1.23 times the pre-LS2 budget. This level is stable from 2022 and later years.

A possible saving due to the delay in the LHC schedule is more than compensated by the costs related to Covid-19 (mainly salaries). A concern for the LHCb M&O A budget are the costs of service level agreements. LHCb foresees 405 kCHF for general services for the years 2021 and beyond. In contrast to this the SLA costs for LHCb have increased to 528 kCHF in the 2021 and beyond. The costs of the new cooling & ventilation SLA have increased by 43% compared to the previous one and it is signed only until December 2021. Negotiations are ongoing but this item needs to be carefully watched by the SG.

The Scrutiny Group recommends approval of the LHCb 2022 M&O A budget request.

LHCb Online Replacement Account Projections

LHCb is currently accumulating funds on the online replacement account in 2021 and 2022, 350 kCHF each year. The plan is to spend 1000 kCHF in 2023 to expand the farm with a new slice corresponding to 300 nodes. In 2024 the account will again accumulate funds, resulting in a longer period from 2018 to 2024 where the online replacement account does not go negative. The cash balance is planned to reach 928 kCHF in 2022.

LHCb M&O B budget request for 2022

The request for 2022 and the projections beyond are shown in Table 13. 2022 is the first year of operation after LS2 and will be affected by this. New sub-detectors come into operation and the budget is adjusted to the new level of operation costs. The new systems are PCI-E40, On Line, Scint Fibre Tracker (SciFi), Upstream Tracker(UT) and VELO. All the new systems represent an increase in costs, SciFi being the largest with 120 kCHF extra costs. Moreover, the newly established RTA Project results in a budget increase of 120kCHF from 2022 and onwards. The costs are shared between almost all participating institutes and will be used for short-term on-site experts during maintenance and operation. Table 13 reflects the current understanding of the costs of these new systems.

The Scrutiny Group recommends approval of the LHCb 2022 M&O B budget request.

Table 13: LHCb M&O B budget planning for the years 2021 - 2025. All numbers in kCHF.

M&O B Categories	2021	2022	2023	2024	2025
Mechanics	100	100	100	100	100
Gas Systems	10	10	10	10	10
Cooling Systems	30	30	30	30	30
FEE Spares	120	120	120	120	120
Standard Electronics (all)	200	220	220	220	220
Controls (DCS & DSS)	60	60	60	60	60
Sub-Detector Spares	150	200	200	200	200
Areas	50	50	50	50	50
Communications	30	30	30	30	30
Store Items	30	30	30	30	30
Manpower @ CERN: Collaborating Institutions	300	420	420	420	420
Grand Total	1080	1270	1270	1270	1270

LHCb Upgrade Common Funds and Entry Fees

Phase-1 Upgrade Common Fund: The LHCb Phase-1 Upgrade Common Fund amounts to 15,710 kCHF. LHCb reports that nearly 90% of the funding for common projects are either fully committed or available, outstanding contributions amounts to 1,260 kCHF, taking the adjustment for exchange rate fluctuations into account. As of 2021 all countries except one have started to pay, which is a significant improvement from last year. By the end of 2020 9,943 kCHF of the upgrade common fund have been spent or committed, which corresponds roughly to the expected level (CERN-RRB-2016-039,115). Most of the remaining fund is to be spent

on the farm with components being purchased in 2021-2022, as late as possible.

Entry fees: LHCb currently does not collect cash entry fees from new institutes, there has been no changes to this practice since last year. In-kind contributions for the general benefit of the collaboration are considered but currently not collected.

9 TOTEM

TOTEM M&O closing report for 2020

The TOTEM M&O closing report was submitted to the RRB meeting in April (CERN-RRB-2021-053). The 2020 M&O A budget as approved in 2019 and the closing report presented in 2021 are shown in Table 14. The TOTEM experiment will be completed in 2021, at which point it will be integrated into CMS. The financial aspects of the transition period from 2018 to 2021 are defined in a MoU (CERN-MoU-2018-003, CERN-RRB-2018-062). Until the end of the completion in 2021, TOTEM will have an independent budget. During 2021 the Scrutiny Group has been reviewing the closing of the 2020 expenditures for TOTEM as an individual experiment. The budget for 2022 has been reviewed as part of CMS. During the next scrutiny cycle, TOTEM will be entirely part of CMS and no individual review will be made.

Table 14: Summary of the 2020 book closing of TOTEM, listing the M&O A budget as approved in 2019 and the actual spending report in this years' scrutiny cycle. All numbers in kCHF.

M&O A Categories	Budget for 2020	Actual in 2020
Detector related	116	70
Secretariat	44	44
Communications	3	4
Core computing	92	90
Online computing	78	30
Test beams & calibration facilities	33	18
Laboratory operations	13	5
General services	47	20
TOTAL without power	426	281
Power (MS + NMS)	0	0
Grand Total	426	281

Spending M&O A: The actual M&O A spending of 2020 was 281 kCHF, compared to a budget of 426 kCHF, resulting in a positive balance of 145 kCHF. The positive balance, even with missing incoming contributions, is mainly due to a saving strategy as described below.

Carry-over: The carry-over from previous years is 148 kCHF in total. The plans for TOTEM has been to finish its physics program with a last run at 14 TeV. As the pandemic has shifted this run with one year, a strategy to collect funds has been devised, to save funds in 2020 and 2021 to be used for this particular run in 2022. This strategy makes it possible to finalise the physics

program as planned without having to change the MoU with CMS.

Contributions: The actual contributions received for 2020 are 381 kCHF, 45 kCHF less than the expected contributions of 426 kCHF.

Spending M&O B: Spending on M&O B was 128 kCHF, exactly on budget. There is nothing particular to report.

The Scrutiny Group recommends approval of the TOTEM 2020 M&O closing reports.

M&O A budget request for 2022

As described above, the TOTEM budget request for 2022 is from this year part of the CMS experiment and is no longer reviewed by the Scrutiny group separately.

The Scrutiny Group would like to thank TOTEM especially for the excellent collaboration with the Scrutiny Group over many years. We congratulate TOTEM with the many great physics results and wish all of TOTEM an excellent future as part of CMS.

10 SUMMARY

The LHC Resources Scrutiny Group has examined the closing reports of the five LHC experiments ALICE, ATLAS, CMS, LHCb and TOTEM for 2020. The LHC Resources Scrutiny Group recommends to the RRBs the approval of the 2020 M&O closing reports of ALICE, ATLAS, CMS, LHCb and TOTEM. The Scrutiny Group has scrutinised the requested budgets for 2022 for ALICE, ATLAS, CMS and LHCb. As discussed in the spring RRB, starting from summer 2021, TOTEM will be reported as part of CMS. The requests are summarised in Table 1. The LHC Resources Scrutiny Group recommends to the RRBs the approval of the 2022 M&O budget request of ALICE, ATLAS, CMS and LHCb. The Scrutiny Group acknowledges the central role of the Resource Coordinators of the collaborations in carrying out the annual scrutiny process and wishes to thank them for their time and effort and for their positive and collegial approach.