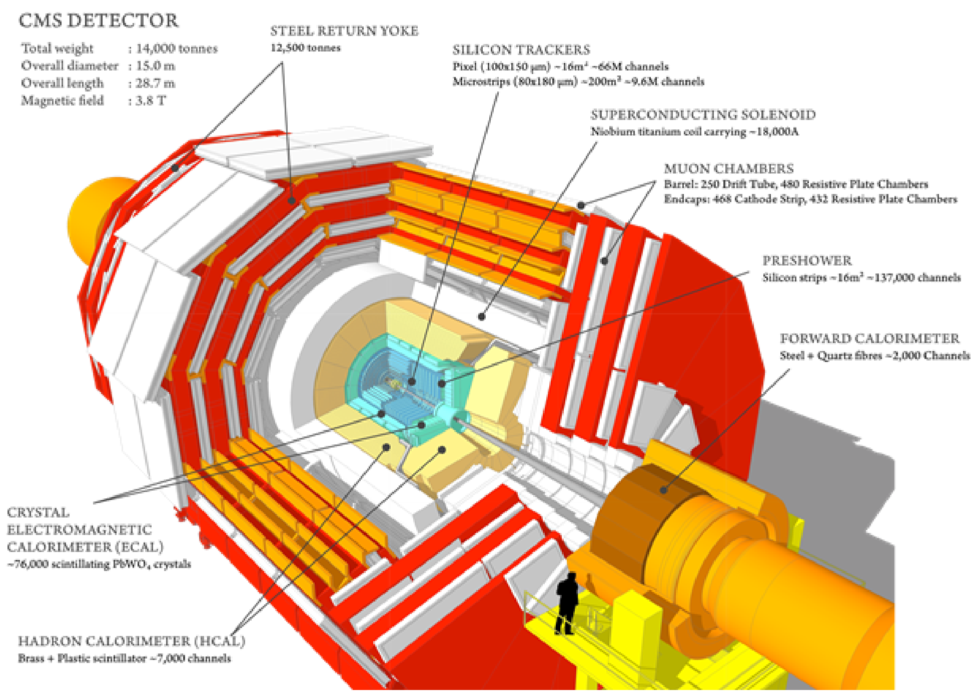
U.S. CMS Compact Muon Solenoid Operations Program
Quarterly Report for the Period Ending September 30, 2017

U.S. CMS Operations Program



Report of the U.S. CMS Resource Manager

The funding provided by DOE and NSF to the U.S. CMS Operations Program for 2002 through 2017, as well as the funding guidance for 2018 through 2020, is shown in Figure 1. The allocations shown for 2017 and beyond do not include any funds designated for HL-LHC OPC in the case of DOE or HL-LHC R&D in the case of NSF.

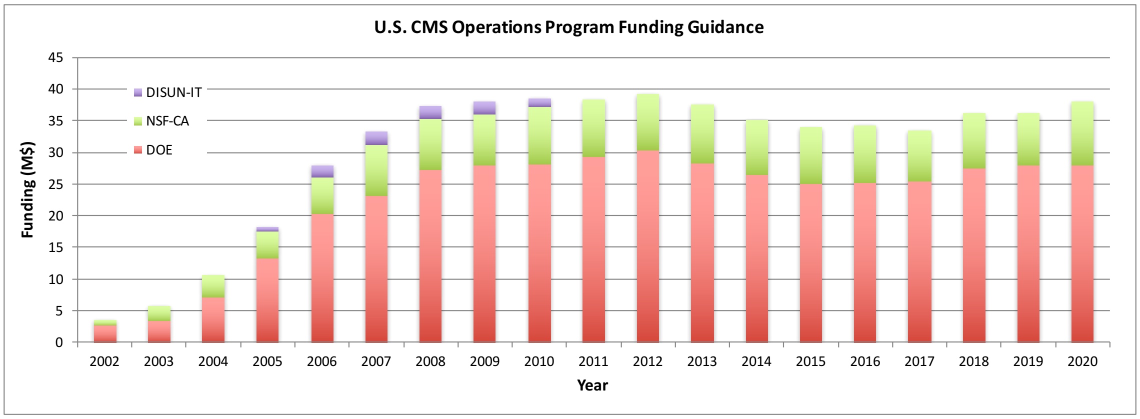


Figure 1: The annual U.S. CMS Operations Program funding provided by DOE and NSF. For 2002 through 2017 the chart shows the actual funding, while for 2018 onward the current funding guidance is shown.

Resources are distributed and tracked across the three areas through which the Operations Program is implemented: Detector Operations (DetOps), Software and Computing (S&C), and Common Operations (ComOps). ComOps is a category for items that would otherwise belong in both, or neither, of the other two categories.

Internal budget reviews for calendar year 2017 took place in July and August of 2016. As an additional source of input to the planning process, the Resource Allocation Advisory Board met five times from September through December of 2016, and issued a report of findings and recommendations. Through these processes, U.S. CMS Management developed a detailed spending plan, while taking into account updated guidance from the funding agencies. This plan was further refined through the January 2017 joint NSF/DOE Operations Program review.

Primarily during the first quarter of the calendar year, Statement of Work (SOW) agreements were established with each institution that is providing a deliverable in exchange for Operations Program funding. The SOWs specify the tasks to be carried out, as well as any portions of salaries, materials and services (M&S), travel funding, or cost of living adjustments (COLA) to be paid from the Operations Program budget. The SOWs must be approved by U.S. CMS Operations Program management, by the Fermilab Director Designee, and by representatives of the collaborating group and institution. Through September of 2017, a total of 78 SOWs (54 DOE and 24 NSF) were produced and approved. After a SOW is approved, any additional changes are considered and, if approved, enacted through a Change Request procedure.

Figure 2 shows the Spending Plan Change Log which captures revisions that were made prior to SOW approvals, as well as modifications implemented through Change Requests. The information is reported here down to the level-2 subsystem categories within DetOps, S&C, and ComOps. The

CY17 spending plan, as of the end of Q3, is shown for DOE and NSF funds in Figure 3.

Once funds have been committed through purchase orders, in the case of DOE, and sub-awards, in the case of NSF, they are considered obligated. Figure 4 shows the obligations in the areas of DetOps, S&C, and ComOps, as compared to the spending plan, for DOE funds. The spending plan is plotted as if expenditures are carried out in even allocations each month, but this is intentionally not the case due to equipment purchases and the larger of the transfers to CERN-based Team Accounts, the latter of which are targeted for when exchange rates are favorable. Spending through Universities and CERN Team Accounts is budgeted and tracked according to the calendar year. Spending at Fermilab has historically been budgeted according to the fiscal year, however this is the third year that we are reporting all activities based on calendar year. Figure 5 shows the total obligations and the spending plan, for NSF funds. Of the $8.1M in NSF funding, $1.3M in subawards went out this quarter, in addition to spending directly at Princeton.

Resources deployed at CERN, and paid directly in Swiss francs, account for approximately 27% of the 2017 spending plan. This carries considerable exposure to the exchange rate. A rate of 0.9 CHF/USD has been used for planning, while the actual rate in CY17 Q3 averaged 0.96 CHF/USD. Figure 6 shows the allocated budgets and year-to-date spending through the Team Accounts that are used for expenditures at CERN. Spending for labor and cost of living adjustments occurs at a fairly constant rate. Figure 6 does not include the 3,668K CHF M&O-A payments, as these are made through multiple payments to a separate Team Account.

A Risk Management Plan is being implemented for the U.S. CMS Operations Program, with many aspects drawn from the Fermilab Risk Management Plan. A Risk Register is updated quarterly, according to the workflow described in the following subsection. At the start of the quarter, the Risk Register contained 31 open risks spread across the program. At the end of the quarter, there were 33 risks, with threats summing to $8.0M and opportunities summing to $0.5M. Figure 7 shows the top few risks at the end of the quarter, ranked by *Probability* × *Cost Impact*, as well as risks added, realized, and retired this quarter.

Workflow for Risk Management Plan

The following procedures have been put in place to carry out the workflow for the U.S. CMS Operations Program Risk Management Plan. The workflow is divide into two paths: (1) updates that are made at any time, and (2) a review of risks once per quarter. In all of the following, *updates* mean adding new risks, realizing risks, retiring old risks, or modifying existing risks. In all cases, it is the program office team that edits the Risk Register. The following descriptions are also summarized in Figure 8.

(1) At any time:

Any member of the management team (including Program Manager, Deputy Program Manager, L1 Managers, L2 Managers, Resource Manager, and program office lead) shall alert the program office of any updates. The program office informs the corresponding L1 manager, and the L1 manager approves, rejects, or modifies the proposed updates. This can also involve iterating with the L2 manager. If updates are accepted, the management team reviews the risk mitigations and risk responses that are associated with the updates. The management team takes into account the risk rank and/or position in the risk rank matrix and takes any necessary pre-emptive actions to incorporate miti-

U.S. CMS Detector Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q3 Plan**	**Change $**	**CY17Q4 Plan**
11	Endcap Muon			$2,188,153	$0	$2,188,153
12	Hardon Calorimeter	CR-041	CERN TA COLA adjusted for UC Riverside, UC Santa Barbara, Maryland, Brown, and Florida State to account for current needs in operations and availabilites	$1,973,953	($7,871)	$1,966,082
13	Trigger	CR-020	Engineering & technician labor support at Wisconsin for Calorimeter Trigger Layer-1 operations	$912,537	$117,860	$1,030,397
14	Data Acquisition			$886,300	$0	$886,300
15	Electromagnetic Calorimeter			$859,286	$0	$859,286
16/17	Tracker (Fpix & SiTrk)	CR-007, 008	Add CERN TA travel funds for Purdue Calumet; Add CERN TA travel funds for Nebraska, reduce CERN TA travel funds for UC Davis	$861,035	$6,747	$867,781
18	Detector Support			$92,119	$0	$92,119
19	BRIL			$265,930	$0	$265,930
11-19	**Detector Operations**			**$8,039,313**	**$116,736**	**$8,156,049**
U.S. CMS Common Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q3 Plan**	**Change $**	**CY17Q4 Plan**
21.2	Common Costs (M&OA)	CR-105, 106	M&O-A adjustments for additional author and actual exchange rate applied to software developer credit	$4,005,636	($1,713)	$4,003,924
21.3	Run Coord. and Monitoring			$440,073	$0	$440,073
21.4	LHC Physics Center			$819,727	$0	$819,727
21.5	Operations Support	CR-104, 107	CERN TA support for HCAL Project Manager; engineering and technician labor support at Fermilab for Timing Detector design and prototyping	$2,169,262	$119,663	$2,288,925
21.6	Program Office			$1,323,397	$0	$1,323,397
21.7	Education and Outreach			$110,585	$0	$110,585
21	**Common Operations**			**$8,868,679**	**$117,950**	**$8,986,630**
U.S. CMS Software and Computing Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q3 Plan**	**Change $**	**CY17Q4 Plan**
22.1	Fermilab Facilities	CR-018, 019	Reduce CERN TA labor support for High Throughput Computing; Add support for this person at Fermilab	$6,048,769	$31,058	$6,079,827
22.2	University Facilities			$3,480,253	$0	$3,480,253
22.3	Computing Operations			$929,522	$0	$929,522
22.4	Computing Infra. and Services			$2,471,440	$0	$2,471,440
22.5	Software and Support	CR-020, 021	Add CERN TA labor support for optimizing CMSSW code; Reduce support at Fermilab due to delayed hire	$2,384,513	($19,329)	$2,365,184
22.6	S&C Program Management & CMS Coordination			$205,081	$0	$205,081
22	**Software and Computing**			**$15,519,578**	**$11,729**	**$15,531,307**
U.S. CMS Operations Program Total				**$32,427,571**	**$246,415**	**$32,673,986**

Figure 2: Spending Plan Change Log for CY17 Q3.

WBS	Subsystem	DOE Funds	NSF Funds	Total
11	Endcap Muon	$1,628,615	$559,539	$2,188,153
12	Hadron Calorimeter	$1,930,669	$35,413	$1,966,082
13	Trigger	$810,983	$219,415	$1,030,397
14	Data Acquisition	$886,300	$0	$886,300
15	Electromagnetic Calorimeter	$851,286	$8,000	$859,286
16/17	Tracker (Fpix & SiTrk)	$851,156	$16,625	$867,781
18	Detector Support	$92,119	$0	$92,119
19	BRIL	$129,716	$136,214	$265,930
11-19	**Detector Operations**	**$7,180,845**	**$975,204**	**$8,156,049**
21.2	Common Costs (M&OA)	$3,188,274	$815,650	$4,003,924
21.3	Run Coordination and Monitoring	$332,137	$107,936	$440,073
21.4	LHC Physics Center	$819,727	$0	$819,727
21.5	Operations Support	$2,033,265	$255,660	$2,288,925
21.6	Program Office	$1,004,097	$319,300	$1,323,397
21.7	Education and Outreach	$0	$110,585	$110,585
21	**Common Operations**	**$7,377,499**	**$1,609,131**	**$8,986,630**
22.1	Fermilab Facilities	$6,079,827	$0	$6,079,827
22.2	University Facilities	$118,306	$3,361,948	$3,480,253
22.3	Computing Operations	$397,791	$531,731	$929,522
22.4	Computing Infrastucture and Services	$1,808,279	$663,161	$2,471,440
22.5	Software and Support	$1,340,171	$1,025,012	$2,365,184
22.6	S&C Program Management and CMS Coordination	$94,683	$110,398	$205,081
22	**Software and Computing**	**$9,839,057**	**$5,692,250**	**$15,531,307**
U.S. CMS Operations Program Total		**$24,397,401**	**$8,276,585**	**$32,673,986**

Figure 3: Spending plan at the end of CY17 Q3, for funds from DOE, NSF, and the total.

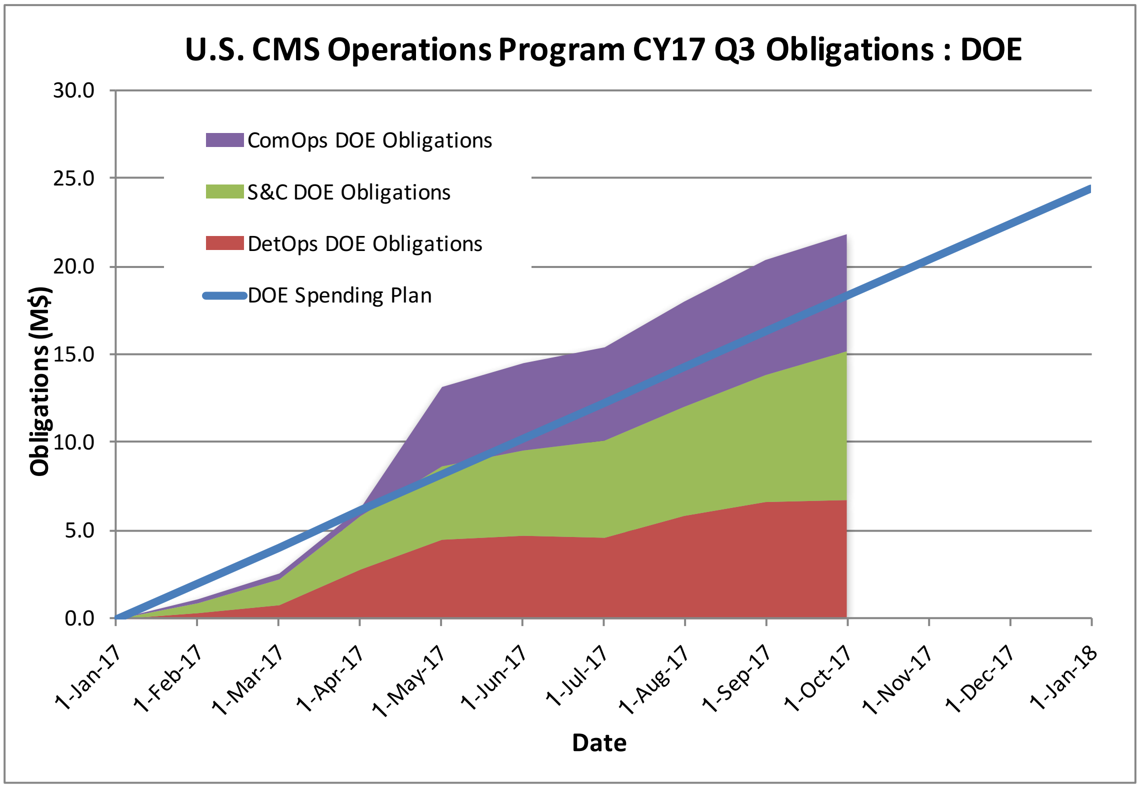


Figure 4: Obligations and spending plan for DOE funds. The spending plan is indicated with the assumption of equal monthly increments just as a rough guide.

gation activities into the plan. If appropriate (again factoring in the probability and impact of the risk), the operations program plan is also adjusted to account for the estimated resources required to execute the risk responses related to the updated risks.

(2) Once per quarter:

Within one month prior to the end of each quarter, the program office lead asks the L2 managers whether they have any updates to the risks in their L2 area. The program office then informs the corresponding L1 manager of any such updates, and the L1 manager approves, rejects, or modifies the proposed updates. As above, this can involve iterating with the L2 manager. As part of the quarterly workflow, the management team reviews *all* of the current risks, and takes any necessary actions and adjusts the program plan if appropriate.

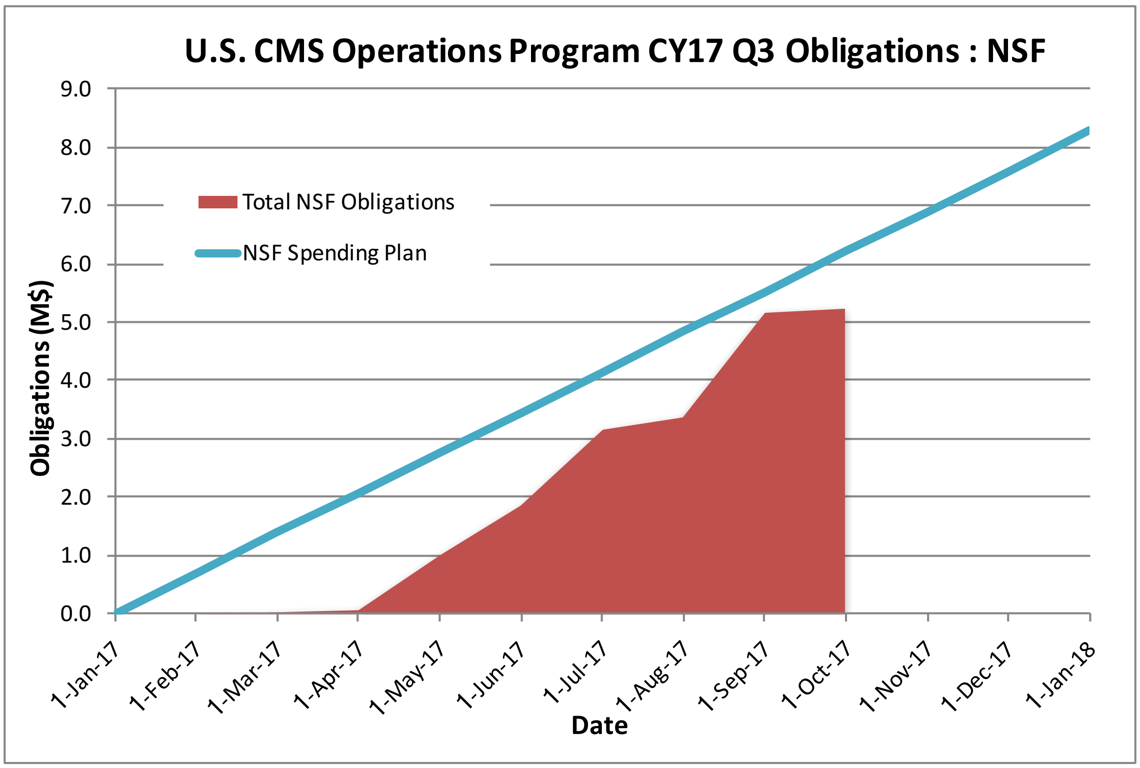


Figure 5: Obligations and spending plan for NSF funds. The spending plan is indicated with the assumption of equal monthly increments as a rough guide.

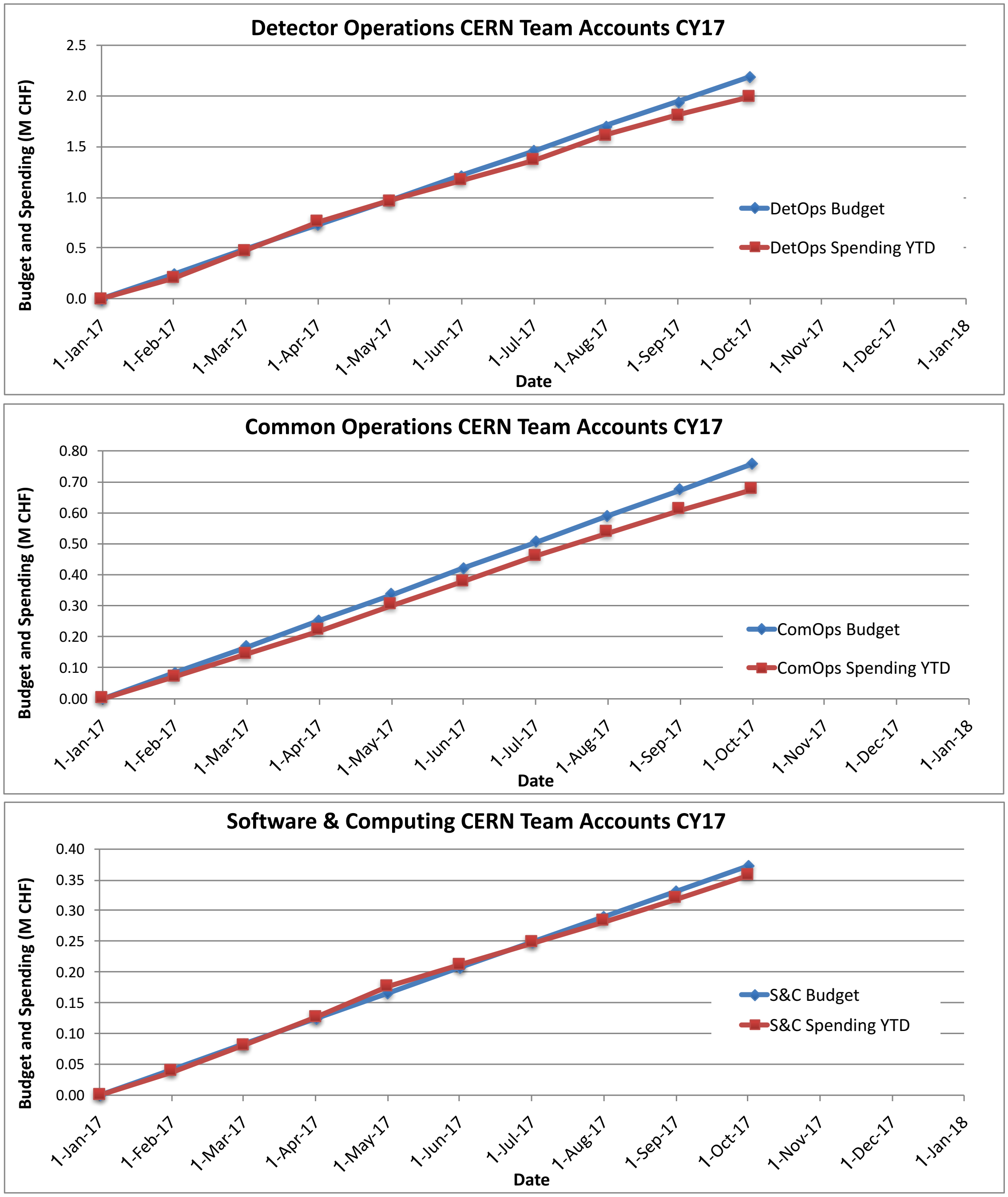


Figure 6: Budget plan and year-to-date spending, in Swiss francs, through DetOps (top), ComOps (middle), and S&C (bottom) Team Accounts.

CY17 Q3 Risk Register Summary Table			
	Probability	**Schedule Impact**	**Cost Impact**
Top Risks (ranked by Probability x Cost Impact)			
EMU – EPROM failures on DCFEBs	20%	3 months	$1,000k
ECAL - Laser fails	20%	0 months	$250k
S&C - Need to bridge OSG tech evolution staff to new funding	25%	0 months	$200k
Risks added this quarter			
Tracker - US needs to contribute to Phase1 TBM fabrication	50%	0 months	$40k
Tracker - US needs to pay for Phase1 TBM design modifcation	50%	2 months	$20k
ECAL - Need for additional COLA for Post-docs	50%	0 months	$60k
Trigger - CMS TriDAS project COLA Payments	10%	0 months	$50k
Trigger - US CMS Trigger system problem - travel to CERN	25%	0.5 months	$10k
S&C - Need to bridge OSG tech evolution staff to new funding	25%	0 months	$200k
Risks realized this quarter			
CommonOps - Fermilab overhead rates increase	50%	0 months	$80k
Risks retired this quarter			
CommonOps - Fermilab overhead rates decrease	25%	0 months	$40k
HCAL - Problems with Phase1 HF Electronics Upgrade	10%	0 months	$10k
S&C - Partial Failure of T1 Computing facility	5%	0 months	$0

Figure 7: Summary of the U.S. CMS Operations Program Risk Register. Only the top few risks are shown, as well as risks that were added, realized, and retired this quarter.

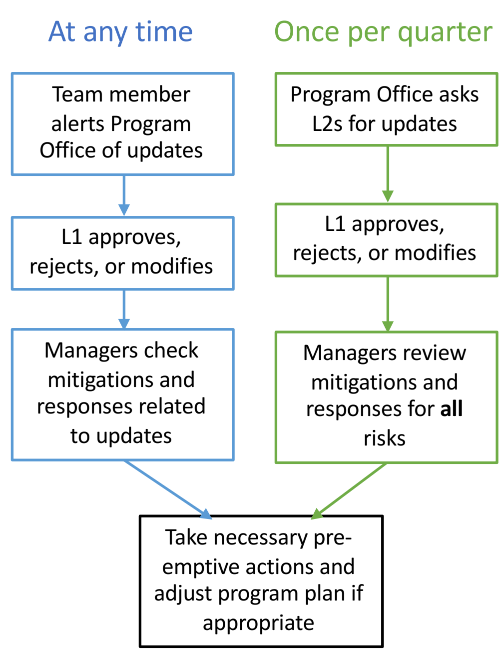
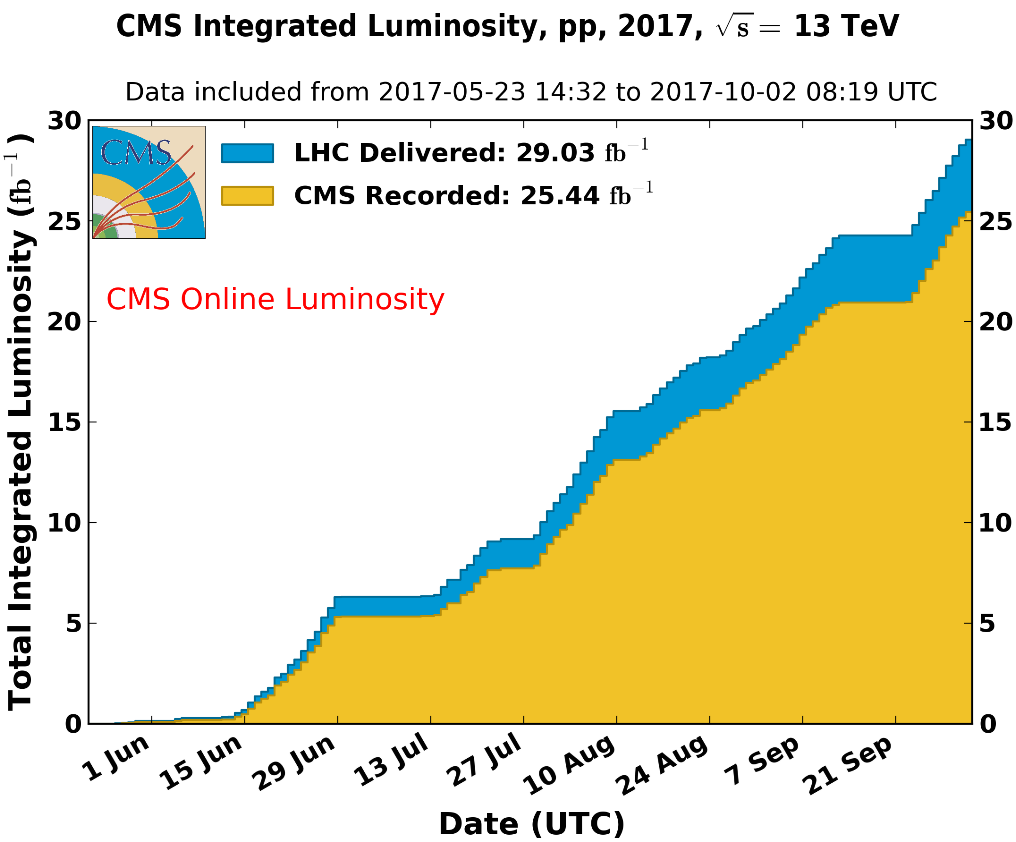


Figure 8: Summary of the two Risk Management Plan workflow paths.

Detector Operations

Through this quarter, CMS has been operating smoothly with no significant issues affecting performance. Since August the data taking efficiency has consistently been greater than the 92.5% average efficiency of last year. It is important to note that the new pixel detector is now working better than the old one and can handle data at higher rates.



Luminosity, delivered by the LHC and recorded by CMS, through October 2.

The performance of the LHC has been excellent although there have been some issues. In 2017, with 25ns bunch spacing and sufficient intensity in the machine, LHC found it difficult to ramp the beams due to losses originating in 16L2 (this is where a dipole was replaced). These losses were "UFO-like" but lasted much longer than a classic UFO. Diagnostics were tuned to identify these losses, and with these new tools they were able to observe that the losses essentially disappeared when they switched to an 8b+4e filling scheme. In this scheme, the LHC has 8 filled bunches followed by 4 empty ones. This reduces the e-cloud to $\sim$ 30% of its value with the same number of bunches but with 25ns trains. This scheme reduces maximum number of bunches in the machine to 1916 (1909 colliding) compared to $\sim$ 2550, which was the aim for 2017, with BCMS.

In order to gain back the lumi lost by having fewer bunches, LHC is doing the following

- reduce β^* = 40cm $\rightarrow$ 30cm

- reduce the rossing angle (both at beginning of and within the fill)
- increase intensity per bunch (fill 6255 has 1.25e11 p/bunch)

This appears to be working, although it is resulting in higher pileup at the detector. CMS is working to modify the trigger menu to cope with the increased pileup, in the meantime, luminosity leveling is being used.

BRIL

The Pixel Luminosity Telescope (PLT) together with the fast beam condition monitor (BCM1F) and HF are operational and providing online luminosity measurements continuously, with PLT as primary luminometer most of the time. The fast readout used for online luminosity for all telescopes works but two telescopes exhibit degraded full pixel information that is used for track-based studies. Reconstructed tracks are also used for fast measurements of the beam spot and allow tracking of beam conditions. Corrections for efficiency and accidentals are obtained from analysis of tracks offline, and with fast turnaround after completion of each fill now. These corrections change with beam conditions and expected reduction of efficiency over time. Luminosity based on full track measurements is prepared for broadcasting in the online monitor. After the technical stop (TS) in September PLT observed a few percent higher visible cross section (luminosity). During the TS the detector with the neighboring pixel detector warmed up contributing to this change in working point. Also during this quarter several LHC high-luminosity runs were used to study beam conditions.

The PLT detector is scheduled for replacement in 2019 due to the expected radiation damage. As the detectors use analog readout old parts have to be secured. Critical is the availability of port cards and slow-hub chips for four opto-motherboards – only 4 are left. A design modification for an alternative chip is explored. A test stand for component testing is prepared at Rutgers and CERN.

Table 1: BRIL Metrics

Working Metric	Performance
Fraction of telescopes fully operational	90%
Efficiency of delivery of lumi histograms	$>$ 99%
Uptime of lumi histogram production	$>$ 99%
Lumi lost	0 /pb

Table 2: BRIL Milestones

Subsystem	Description	Scheduled	Achieved
BRIL	Update Lumi for 2016	March 1	March 1
BRIL	Ready for Physics	May 1	May 1
BRIL	Improve 2017 Lumi numbers	Dec 1	

Tracker

Substantial improvements to tracker operations this quarter. Primarily in Pixels.

Pixels

The timing setting strategy for the Barrel (BPiX) layer 1 and layer 2 settled in July and we have been operating in this mode. Some of the issues in BPiX layer 1 performance were due to a mistake in the assignment of constants for unpacking and reconstruction. The mistake was noticed in mid-September and the re-reconstruction will be done with the fix. Another source of broken clusters in the BPiX has been addressed with a patch: a minimum pulse-height for a registered hit is forced in the data. Finally, an automatic reset mechanism was added to recover lost efficiency in the layer 1 chips. The Swiss consortium still plans to have a new layer 1 chip for a replacement of the layer 1 in Long Shutdown 2 (LS2). The submission will consist of the layer 1 chip, a new Token Bit Manager (TBM) chip, and perhaps some auxillary chips for the Pixel Luminosity Telescope.

An automated recovery for non-responsive TBMs was put into production in August. Recovery times of 5-10 minutes were reduced to 30s (similar to Single Event Upset (SEU) recovery in the phase 0 detector). Another recovery method (10s per) was implemented to discover SEU's when a Port Card is non-responsive in the Forward Pixels (FPiX). Both mechanisms are triggered by the number of problematic modules seen in the detector. These recovery mechanisms are triggered on the order of 10 times/fill, and channel status is directly propogated to be available for reconstruction and triggering purposes. We are now in the position of fine tuning of the faster recovery mechanisms. Additionally, the time the detector spends for a fast reset was reduced and the time spent in configuring and Data Acquisition state changes was reduced.

The first data labeled "good" for the pixel detector occurred on June 16 and the milestone for collisions has been indicated for that date. Earler data suffered a bit due to non-optimized seetings, but performance of the phase 1 detector was as good as the phase 0 detector early on and has been improving as we learn.

Strips

The main issues in the strips are ongoing maintenance issues, such as power supply swaps, condition sensors etc. The Operations crew tries to minimize downtimes as these issue pop-up. The strips are now also looking to reduce time spent in SEU recovery and are investigating an issue where the strips DAQ occasionally holds off triggers.

Table 3: Tracker Metrics

	Pixels	Strips
% Working channels	95.4	96.2
Downtime attributed in pb^{-1}	202.4	191.6
Fraction of downtime attributed (%)	13.6	12.3

[TrackerMetrics]

Table 4: Tracker Milestones

Subsystem	Description	Scheduled	Achieved
Tracker	Pixel Phase 0 Detector Removed	Feb 15	Jan 23
Tracker	Pixel Phase 1 Detector Installed	Mar 30	Mar 12
Tracker	Pixel Phase 1 Detector Ready for Collisions	May 5	Jun 16

ECAL

The ECAL continued to operate smoothly in the third quarter with no major issues. The low voltage and laser systems required no significant interventions or maintenance. The high voltage system required the replacement of one failed module. The firmware for oSLB link boards was updated to provide more reliable data transfer to the level 1 trigger. The Detector Control System software was updated to provide more information to the shifter. Refined laser calibrations were applied to both the barrel and endcap to enhance the trigger turn on performance. Updates in the pedestals improved stability and the calibration is improving progressively as more 2017 data is accumulated.

Table 5: ECAL Metrics

Metric	Performance
Fraction of channels operational: EB	99%
Fraction of channels operational: EE	98.4%
Fraction of channels operational: ES	99.9%
Downtime attributed pb^{-1}	91
Fraction of downtime attributed	7%
Resolution performance	2.5%

[ECALMetrics]

Table 6: ECAL Milestones

Subsystem	Description	Scheduled	Achieved
ECAL	Refurbish Maraton to provide redundant thermal interlock	March 1	March1
ECAL	Replace Laser Diode	March 1	March 1
ECAL	Ready for Beam	May 1	May 1
ECAL	Preliminary Calibration	June 15	July 15

HCAL

During this quarter, the HCAL Operations group focused on continuing to commission the HF and partial HE Phase I upgrades, and on taking data.

For HF, the upgrade consists of installing dual-anode readout and installing new ftont-end electronics to support increased number of channels. The old QIE8s (7bit ADC) were replaced with QIE10s (8bit ADC). The new front-end electronics also has an embedded TDC which will be used to discriminate physics signals from showers in the HF calorimeter from spurious signals due to Cerenkov light from particles directly hitting the photo-tube windows.

All the components for the HF upgrades were installed ahead of schedule by mid-March, and the detector was ready for physics by May 1. The low voltage supply trips, which were caused by single-event-upsets, were resolved by replacing the offending supplies and, in the process, reducing the number of supplies by a factor of two. Only 7 pb^{-1} of data have been lost due to low voltage trips in the two months since the supplies were replaced (less than 0.1%). All the new handles to achieve noise reduction are in place and a substantial reduction in missing Et trigger rates has been achieved. Energy recovery using the "other" anode when one anode has an out-of-time signal has been successfully implemented.

For HE, one upgraded HE readout box (out of 36) was installed to obtain experience with upgraded system. This readout box (HEP17) has silicon photomultipliers (SiPMs) instead of HPDs and has the new version of the QIE frontend chip. (QIE11)The upgraded HE readout box (HEP17) was commissioned rapidly, has been calibrated and has performed well throughout the run.

Planning to install the complete HE upgrade in 2017-18 YETS is nearly complete. The HCAL Operations Project Manager recommended installation of the full HE Upgrade during the 2017-18 YETS to the CMS MB on September 4 and to the LHCC on September 12. The feedback from both the MC and LHCC was positive and supportive.

The Installation Readiness Review for the HE Phase-1 upgrade during YETS 17/18 has been scheduled for November 6.

Metrics and Milestones
June 1 Milestones
HF Detector Commissioned. This milestone was achieved May 1.
HCAL Ready for Physics. This milestone was achieved May 15.
July 15 Milestones
Operate HCAL efficiently with less than 1% CMS data lost due to HCAL. Achieved July 10.
HCAL Calibration at the 1% to 2% level. Currently 3% .

Table 7: HCAL Metrics

Metric	Performance
Fraction of channels operational: HF	100%
Fraction of channels operational: HE	99.85%
Fraction of channels operational: HB	99.77%
Fraction of channels operational: HO	99.72%
Downtime attributed pb^{-1}	77.2
Fraction of downtime attributed	0.3%
Abs Energy Calibration	3%
Inter-calibration Uniformity	3%

[HCALMetrics]

Table 8: HCAL Milestones

Subsystem	Description	Scheduled	Achieved
HCAL	HF Phase 1 Installed	April 1	March 15
HCAL	HF Detector Commissioned	June 1	May 1
HCAL	Ready for Physics	June 1	May 15
HCAL	Data Loss <1%	July 15	July 10
HCAL	1% to 2% Calibration	July 15	

EMU

As described in the previous quarterly report, the CSC system was operating with a total of four of the 540 chambers disabled: two chambers (ME-1/1/34 and ME-1/1/35) without cooling due to water leaks, and two other chambers (ME-2/1/3 and ME-4/2/21) that are disabled due to low voltage problems. Both have shown similar problem before, but the low voltage connections on these chambers are difficult to access. All four CSCs will be investigated further during the year-end technical stop 2017-18. To mitigate the effect of the disabled chambers, particularly those in station 1, new firmware was introduced to the EMTF trigger to allow some L1 triggers to be generated without requiring a trigger primitive in layer 1. This increased the efficiency with a very minor increase in the trigger rate.

A few isolated issues led to most of the downtime attributed to the CSC for this period. On August 6th, an HV trip was followed by cycling of low voltage on one half of the CSC system. This required some down time for recovering the system. On September 8th, an issue with one FED caused it to be disabled from the run while attempting to debug at the FED crate. Eventually, an L1A error from ME1/1/2 was found to be the source of the issue and the optical fiber for this chamber was disconnected to restore FED functionality. Another incident occurred on September 10th when one LV Maraton supply tripped causing 9 CSCs from VME crate +4/5 to go off. Investigation is ongoing. Moreover, a faulty CANbus line on some of the LV supplies caused the DCS system to issue erroneous error flags affecting data certification. The supply that was causing the errors was identified and replaced in Technical Stop 2. The erroneous marking of data was corrected in the data certification data base.

Additional minor issues with CSC data taking were detected and fixed in this period. A longstanding issue with one chamber not sending data to the trigger system was found to be due to a timing error in an adjacent chamber and subsequently fixed. A strange spatial distribution of muons in cosmic ray runs was tracked down to an automatic synchronization feature that has been disabled in the cosmic trigger configuration; the normal distributions were restored when this was re-enabled. It was also discovered that the EMTF trigger occasionally fails to get the beam crossing synchronization signal (BC0) from some CSCs. A change in the EMTF firmware mitigated the effects of this, but the cause is still under study.

A tag-and-probe analysis of 2017B $Z \to \mu\mu$ data samples shows very high and uniform segment and trigger primitive (LCT) efficiencies in the CSC stations. The offline timing calibration has been completed. After aligning the cathode strip timing the anode wire times of all CSC have been re-aligned after a $\sim$ 2 ns shift of the LHC clock phase had been introduced early in the year. Segment and muon times are properly peaked at zero and their widths are comparable to 2016 data.

The HV settings are under study, in anticipation of find an operating point with a lower gain. A better understanding is required of the interdependencies of gain vs. efficiency before the gains are systematically lowered.

Both chambers (ME1/1 and ME2/1) that were being irradiated at GIF++ since January 2016 have now reached their targets goals of 330 mC/cm and 540 mC/cm of accumulated charge, respectively. These values represent three times the charge expected after 3000 fb^{-1} of integrated luminosity at the HL-LHC. The chambers have not shown signs of aging and are perfectly functioning. They have been switched to a gas mixture which uses only 2% CF4 (instead of 10%), in order to investigate a mixture that meets CERN strategy to fulfill new EU regulations for greenhouse gas emission.

In the management news, Armando Lanaro (U. Wisconsin) was reappointed for an additional two years term as subsystem leader for the CSC. The new deputy manager Manuel Franco Sevilla (UCSB).

Table 9: CSC Metrics

% Working channels	98.5%
Downtime attributed pb^{-1}	50.5
Fraction of downtime attributed	5%
Median spatial resolution	126 μm

[CSCMetrics]

Table 10: EMU Milestones

Subsystem	Description	Scheduled	Achieved
EMU		May 1	April 29
EMU		July 1	January 29
EMU	New HV settings for reduced gain	August 1	Reschedule to December 2017

DAQ

The DAQ system has been working without major problems. The EOS problems which plagued tier0 for a few weeks in summer did not cause any downtime thanks to mitigating actions taken by the SMTS team. The DAQ group continues to maximize the data-taking efficiency, in particular related to the new pixel detector. Run control has been improved to shorten the time before good physics data can be recorded following the ramp-up of the high voltage of the pixel and strip trackers. Several control sequences were added in the TCDS system to minimize the downtime required to reset pixel readout components. Software and firmware have been continuously improved to provide better monitoring and error reporting. The DAQ expert system becomes more powerful in advising the shifter to take the best recovery action in case of problems. The LHC technical stops and machine development periods were used to consolidate the system configuration and robustness. This mitigates the risk of operator mistakes and reduces the workload on the sysadmin team.

The new slink-express sender cards developed for the ECAL readout have been delivered on time.

However, due to firmware problems on the ECAL side, the installation was postponed to the YETS.

The HLT online cloud is now routinely used for offline event processing between LHC fills. The quota of HLT CPUs allocated to the cloud has been gradually increased and has reached 66%, which corresponds to last year's level. The online cloud is number three in the list of number of processed jobs (behind FNAL and T0). We plan to run the cloud on a large fraction of the HLT nodes during most of 2019, the first year of LS2. This corresponds to about 550kHS06.

"The Phase-2 Upgrade of the CMS DAQ Interim Technical Design Report" was submitted to LHCC on time. It documents the requirements on the phase-2 DAQ system as collected from other subsystem TDRs. A baseline system design has been developed, required R&D work is described, a timeline has been worked out, and milestones leading up to the TDR in 2021 were set. In addition, future R&D directions have been identified which would provide a more versatile and cost-effective system.

The development on the new online-monitoring system (OMS) is progressing. All database tables and procedures used by the current WbM were documented. This is a tedious, but important step in restructuring the data aggregation layer. The next step is to understand how to design the new database structure for the OMS system. In parallel, the design and implementation of the meta-data catalogue is ongoing. This catalogue will be the core of the new OMS system. It will be used to map public accessible data to the underlying database tables. A review of the new system is planned for the CMS week in December, where the plan for 2018 shall be developed.

Table 11: DAQ Metrics

Dead time due to backpressure	0.5%
Downtime attributed pb^{-1}	2.8
Fraction of downtime attributed	2.1%

[DAQMetrics]

Table 12: DAQ Milestones

Subsystem	Description	Scheduled	Achieved
DAQ	New sub-systems integrated	Apr 1	Jun 15
DAQ	Event builder expanded, re-optimized for larger events	Jun 1	Apr 1
DAQ	Old HLT Nodes replaced and new nodes commissioned	Jun 1	Jun 21
DAQ	Prototype of OMS (new WBM) ready for field tests	Dec 31	

Trigger

During this quarter the US groups continued their work on the Layer-1 calorimeter (CaloL1) trigger upgrade, and the endcap muon trigger upgrade systems as both continued reliable data-taking for this year.

Endcap Muon Trigger

The Northeastern, Rice University, and University of Florida groups have maintained the EMTF system 24/7 during operations this quarter. An MPC firmware update deployed system-wide has improved robustness of the optical link communication. Additionally, the firmware of the EMTF was revised to more robustly recover the BC0 orbit signal. In an effort to improve the reliability of the online control PC, which on rare occasion has required a reboot because of its PCIe controller, we installed a new PCIe driver into the kernel of the control computer and updated the firmware as well as the online control software accordingly. In order to recover inefficiency from two ME1/1 CSC chambers that had been turned off due to a water leak, new firmware was deployed that had looser tracking requirements in the high rapidity region. The corresponding increase in the single muon trigger rate was about 1%. New DQM plots have been deployed online to monitor the RPC detector inputs to EMTF. A study of the performance of EMTF with the addition of RPC hits in 2017 running shows that we have increased the efficiency back to the level of the legacy trigger (so no reduction in efficiency), and increased the rate reduction further from a factor 2 to a factor 3 for a nominal 25 GeV threshold.

Layer-1 Calorimeter Trigger

The Layer-1 Calorimeter Trigger (CaloL1), built by the University of Wisconsin - Madison, is a part of the complete Calorimeter Phase-1 Trigger Upgrade. CaloL1 was in continuous operation during the LHC proton physics run in the third quarter of 2017.

In late July two updates were made to CaloL1 Look-Up Tables (LUTs). Software and firmware was updated to add a second set of calibration LUTs, previously hardcoded in firmware. At the same time there was an update to properly account for HCAL tower saturation.

A number of link issues occurred during this period. HCAL had a problem with low optical power from one link to CaloL1. The uHTR was replaced. A couple of ECAL links also developed optical power issues, and this was resolved by simply moving the fiber on the ECAL side to the RCT position in the dual-transmitter VTTx.

ECAL oSLB firmware was updated to help mitigate the errors due to the increased electrical activity on the ECAL Barrel Trigger Concentrator Cards (TCCs). This caused more corrupted data sent to CaloL1, appearing as CRC and BC0 errors on our ECAL links. There were some issues with the TCC configuration sequence in the ECAL software at first, but they were fixed without any loss of physics data.

Another update was done to the infrastructure. The Ethernet-RS232 module used with the Rack Monitor Cards was becoming difficult to maintain due to requiring a driver on the DCS PCs. This also prevented having a truly redundant system. This module was replaced with a Moxa NPort Express DE-311 which operates like a TCP server. The DCS scripts were updated and monitoring scripts updated to use TCP.

Table 13: Trigger Metrics

Frac of MPC Channels	
Frac of Upgrade EMUTF Channels	100%
Deadtime attributed to EMTF pb^{-1}	47.5
Fraction of deadtime attributed to EMTF	3.3%

Frac of MPC Channels	
Frac of Calo. Layer-1 Channels	100%
Deadtime attributed to Calo. Layer-1 pb^{-1}	0
Fraction of deadtime attributed to Calo. Layer-1	0%

Table 14: Trigger Milestones

Subsystem	Description	Scheduled	Achieved
TRIG	EMTF commissioned with endcap RPC input	April 1	April 27
TRIG	EMTF ready for Physics	May 1	May 29
TRIG	Calo. Layer-1 commissioned with new ECAL/HCAL/HF Calib	April 1	May 19
TRIG	Calo. Layer-1 Ready for physics	April 1	May 19

Software and Computing

The third quarter of 2017 was an incredibly dynamic period for U.S. CMS Software and Computing. There has been a notable increase in the use of the computing facilities. This is driven in part by strong LHC performance throughout the quarter (even at reduced peak luminosities, the trigger rates are largely unchanged), but even more so by greater demands of Monte Carlo production. The necessary software releases were prepared and deployed, and a new system of prioritized sample production led to a steadier demand for resources. This is visible in the pattern of usage of the Tier-2 facilities, and the Fermilab Tier-1 facility was similarly heavily used. All of the facilities continued their excellent performance in the face of this increase in demand. Many developments supported this performance. CMS has been focusing on improving its overall CPU efficiency, and a number of necessary changes have been deployed. Improvements to the workflow management system have reduced the IO load on facilities, improving the performance of owned clusters and enabling new workflows on non-owned resources. Throughout all of this, work has continued to evolve all software and computing systems, and to make the technological leaps necessary to meet the future challenges posed by the HL-LHC.

Major milestones achieved this quarter

Date	Milestone
15 Jul	Commission “StepChain” workflows to allow single job, multiple executions of CMSSW for all cases where practical.
31 Jul	Release including high-level particle flow corrections for initial 2017 MC production
1 Aug	Usage of PSST result to supplement SAM investigation complete
1 Aug	Test and incorporate in ROOT if useful, usage of hardware based decompression implementation. Conclusion: too early to use it in production (for ROOT I/O)
8 Aug	All Tier-2 sites upgraded to new CMS temporary file clean-up policy.
6 Sep	LPC EOS hardware and software upgrade and move to central SCD configuration management servers.
16 Sep	Release for large MC production and stable RECO for 2017, delayed by ~1 month due to pixel commissioning.
21 Sep	2nd half of 2017 T1 tape pledge deployed.
30 Sep	In-process fast merging of multiple ROOT file produce by concurrent threads have been successfully incorporated in ROOT, shows good performance for CMS.
30 Sep	Allow multiple threads when processing Runs and LuminosityBlocks.
30 Sep	Able to run all central services on EL7/CC7.

Fermilab Facilities

This quarter was dominated by strong LHC running throughout the quarter, and large scale data processing in preparation of physics results for upcoming winter conferences. Throughout this quarter the Fermilab Facilities continued to provide reliable custodial storage, processing and analysis resources to U.S. CMS collaborators. The site was well utilized, with the facility providing 44.3

million wall-clock hours of processing to CMS.

During this quarter the facility upgraded EOS storage, deploying new SSD based servers for the LPC. This has greatly improved service reliability for the LPC users, reducing service restarts from a 20 minute outage to about a minute. Also during this quarter the Tier-1 facility passed CMS site availability metrics 99.9% of the time. The one service affecting incident this quarter involved a failure in the File Transfer Service, and resulted in a few hours of transfer outage. Two downtimes were taken this quarter to move services from old configuration management servers to more centrally maintained services. Figure 9 shows the site readiness metrics for the quarter. The yellow band along the bottom of the figure indicates LHC physics operations continuously throughout the quarter.

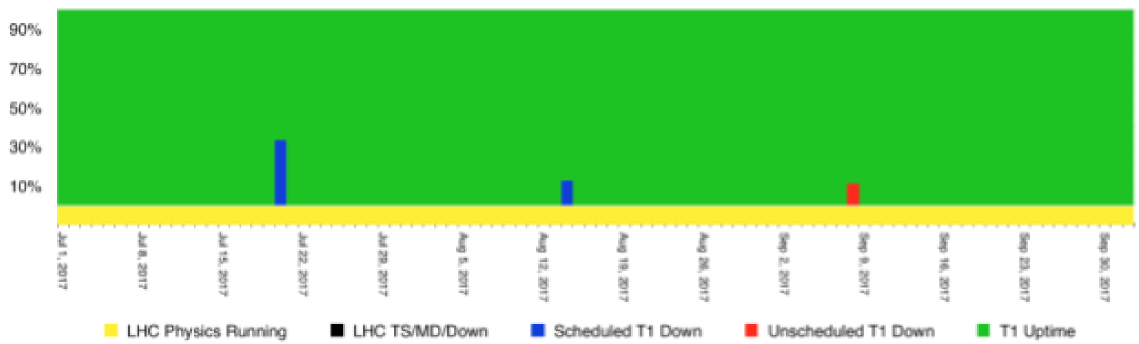


Figure 9: Fermilab readiness metrics for 2017Q3. Green indicates a passing metric, red a failing metric, and blue a scheduled downtime. The height of a red bar indicates how much of the day services were affected. Black and yellow across the bottom indicates LHC machine running. Fermilab passed metrics for 99.2% during the quarter.

University Facilities

As seen in Figure 10, CMS production and analysis activities this quarter ramped up to maximal levels at our Tier-2 sites during this quarter starting from in mid-August. During this heavily used period, analysis processing consumption by U.S. physicists peaked at 75% of the total analysis CPU delivered by our sites during the month of September.

All of the U.S. CMS Tier-2 sites operated successfully. On our two official performance metrics based on CMS test jobs, all sites were at least 93% "available" (an increase of +3% over the previous quarter) and 96% "ready" (an increase of +8% over the previous quarter). The CMS goal for each of these metrics is 80%, but the U.S. CMS performance goal is 90%. The U.S. CMS Tier-2 centers delivered 51.5% of all computing time by Tier-2 sites in CMS (our commitment to global CMS is > 25%), as shown in Figure 2. This is a decrease of 1.3% from the previous quarter.

As for progress on Tier-2 milestones and upgrades, by October 1st all sites had updated to the new CMS temporary file cleaning policy. Four out of seven sites had upgraded to HTCondor 8.6.x and five out of seven to XRootD 4.6.x. Six out of seven sites had migrated to gfal2 away from the deprecated lcg-tools for file transfers.

Eight Tier-3 sites required assistance from the Tier-3 support team this past quarter on issues including PhEDEx, XRootD, OSG software, batch system, and basic Linux troubleshooting and support.

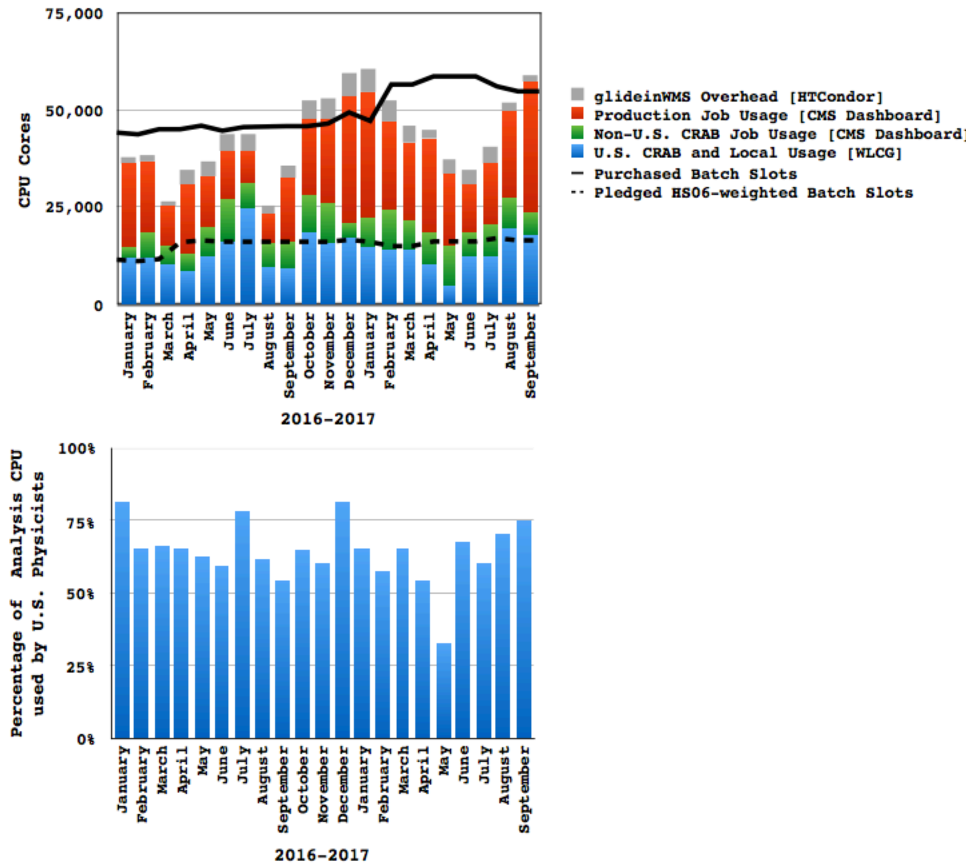


Figure 10: How processing resources were used at the U.S. CMS Tier-2 sites, by month.

A concerted effort was made this quarter to accommodate gridpack production on CMS Connect in support of the upcoming MC production campaign. The first Tier-3-in-a-box site is was deployed at Colorado and basic functionality was established.

Computing Operations

Preparation of pile-up for the 2017 Monte Carlo campaign started in early July and the Monte Carlo campaign itself in the second half of August. As storage resources became scarce, CMS discarded the larger analysis object data (AOD) for some high statistics Monte Carlo datasets and kept only the much smaller miniAOD data tier. The duration for which reconstruction output of new data is kept on disk, for detector and performance studies, was reduced from three to two months. The lifetime of the last copy of data AOD was reduced by 25%. Together with a deletion campaign those brought the disk space situation under control.

Legacy re-reconstruction of the 2016 data started in the middle of August. Since then the CPU resources have effectively been busy with about 100,000 to 140,000 cores being used for central production activities at CMS sites worldwide.

At the end of this quarter, about 90% of the 2016 data legacy re-reconstruction was complete and over a billion 2017 Monte Carlo events were generated for technical studies. The second part of the 2017 Monte Carlo campaign for physics analysis is currently expected to start in October.

During the third quarter first changes to improve CPU efficiency of CMS jobs were implemented: pilots are now filled depth wise instead of the previous cross pilot filling; idle pilots are retired more quickly; queuing pilots are timed out to react faster to decreased demand; and some fixes in the WMAgents were made eliminating very short production jobs. The effort to improve CPU efficiency is ongoing.

Computing Infrastructure and Services

This quarter saw steady progress on our goals for the year. All services (DBS, DAS, PhEDEx, WMAgent) are now supported under CC7 and other RHEL 7 based operating systems, paving the way to deprecating older operating systems. The DAS service is able to be run under python3 as well as python2. The python3 version will go into production before the end of the year.

CMS workflows are now routinely submitted using "StepChain," a new mode of operations where multiple executions of CMSSW are chained into a single job rather than several jobs. This has the operational benefit of lowering site-wide IO rates since intermediate data products are no longer written to and read from site storage. This is also the only mode of operation that is practical for leadership class facilities and cloud resources.

WMArchive is now fully in production, ingesting data from both WMAgent and CRAB jobs. Visualization and refining the system for operations support and resource planning inputs will be the emphasis in the next quarter.

In the area of data federations, progress was made on various design and prototype implementations. Prototyping includes a decision plug-in for the XRootD cache, faster redirection for open requests for files not in the cached namespace, redesign of the client-side monitoring to avoid the need for detailed server-side monitoring, transition planning for migration of MonALISA monitoring to ES/Kibana to be able to aggregate all monitoring by CMS in a coherent place, and design discussions on the interactions between visualization and data federation to achieve response times in visualization servers that is truly interactive on any data known to the global data federation.

Fermilab has begun a review of data management systems for experiments in the HL-LHC and DUNE era. U.S. CMS personnel are active contributors to this effort. A preliminary report is due in the next quarterand a final report in the first quarter 2018. This report will help us chart the future of data management for CMS in the context of work in this area throughout the field.

Finally, discussions on the long term future in the context of a "blueprint activity" have started. This includes events that engage with global CMS, other experiments, OSG, and computer scientists beyond those communities.

Software and Support

The third quarter of 2017 finalized the CMSSW software releases for data reconstruction and large scale MC production for the 2017 data taking period. The final release was delayed by ~1 month due to commissioning of the new pixel detector. For this and other releases to support legacy 2016 data re-reconstruction and production of MC samples for TDR studies at highest pileup, over 100 individual developments were reviewed, integrated and tested into CMSSW. We also built new framework light releases using Spack and Apple clang to support the Fireworks event display distribution on macOS.

We reached an important milestone in CMSSW's multi-threading implementation. The framework can now run modules simultaneously during Run and LuminosityBlock transitions. We made good progress with enabling multi-thread I/O and demonstrated with a prototype that the developed design was feasible. We now have an early production level version of the code.

We are working with the ROOT team to overcome some time and memory performance limitations, and worked on many ROOT issues related to CMSSW and I/O, including reaching two milestones. The expectation is to have the project done by the beginning of 2018.

We further developed a general mechanism for the framework to interact with external computational hardware (GPUs, FPGAs, MICs, …) and supported the definition of the new NANOAOD format through framework developments. As for all these developments, the performance of the software stack was checked and tracked. We defined a test suite for most analysis tools in CMSSW and pushed an initial version of CMS python toolkit to the community python package distribution tool PIP. We also made the C++ API of Tensorflow available within CMSSW to simplify the usage of the most prominent community machine learning toolkit for CMS physicists.

The tracking R&D efforts are progressing nicely, with further optimization of the GPU-based Kalman Filter vectorized tracking implementation. We also have implemented for the first time a complete pass of pixel-seeded tracking using vectorized track finding and fitting which is ~95% efficient with regard to CMSSW and has a low fake rate.