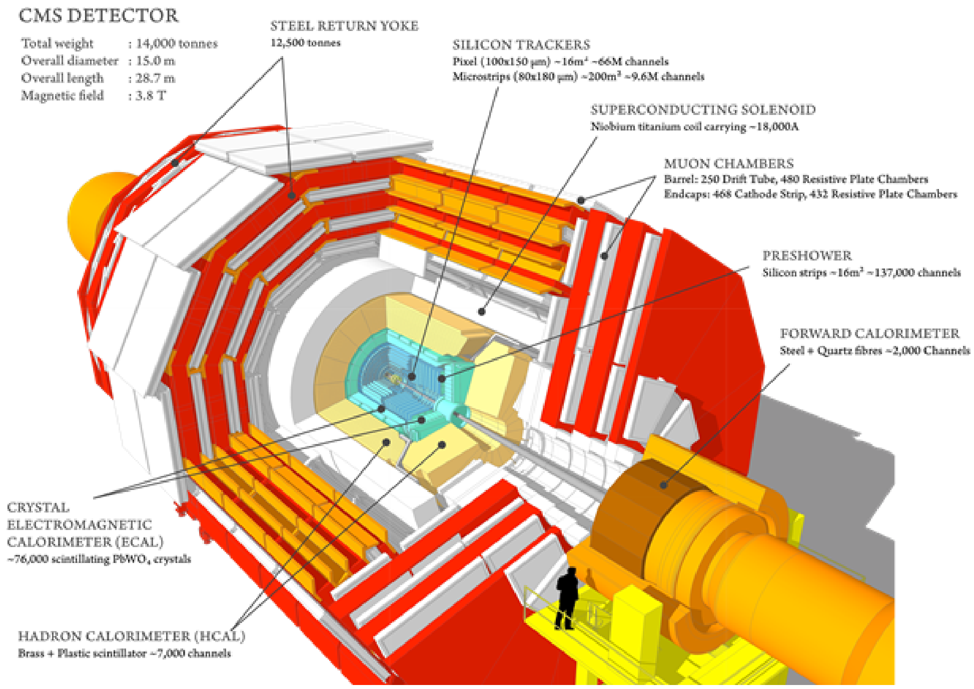
U.S. CMS Compact Muon Solenoid Operations Program
Quarterly Report for the Period Ending June 30, 2017

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.

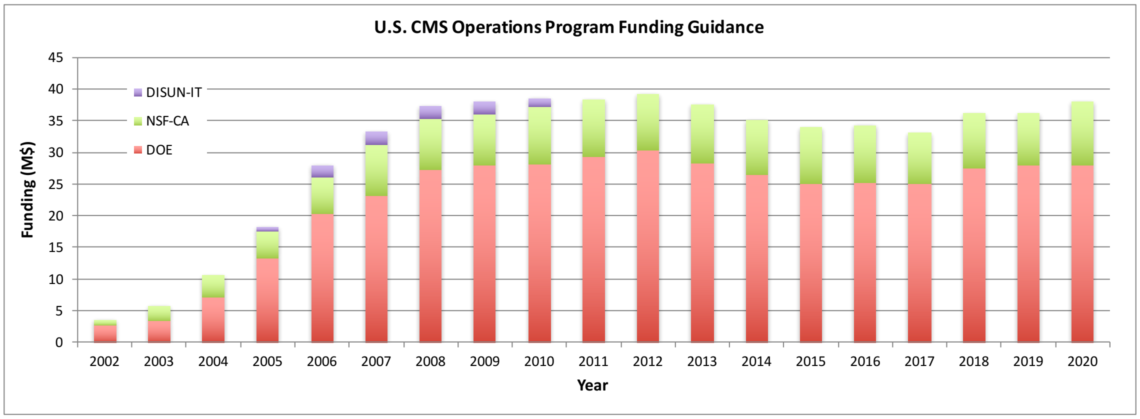


Figure 1: The annual U.S. CMS Operations Program funding provided by DOE and NSF. For 2002 through 2017 the chart shows the actual funding, while for 2018 onward the current funding guidance is shown.

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 June 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 Q2, 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, $3.3M 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 Q2 averaged 0.98 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. The Risk Register was initially populated with 33 risks spread across the program. At the end of the quarter, there were 31 risks, with threats summing to $7.8M and opportunities summing to $0.5M. Figure 7 shows the top few risks at the end of the quarter, ranked by *Probability* $\times$ *Cost Impact*, as well as risks added or 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, 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 mitigation activities into the plan. If appropriate (again factoring in the probability and impact of the

U.S. CMS Detector Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q2 Plan**	**Change $**	**CY17Q3 Plan**
11	Endcap Muon	CR-030	Additional UC Davis labor support for Deputy Project Manager for CSC	$2,129,391	$58,762	$2,188,153
12	Hardon Calorimeter	CR-040	CERN TA COLA reduced for Princeton and added for Maryland for Prompt Feedback Group	$1,980,700	($6,747)	$1,973,953
13	Trigger			$912,537	$0	$912,537
14	Data Acquisition	CR-008	CERN TA support for Rice computing professional	$871,151	$15,149	$886,300
15	Electromagnetic Calorimeter	CR-016, 017, 018	Add CERN TA COLA for U. of Minnesota, U. of Virginia and Notre Dame, and Florida State	$831,737	$27,549	$859,286
16/17	Tracker (Fpix & SiTrk)	CR-004, 005, 006	FNAL M&S to travel; M&O-B adjustment for actual exchange rate; CERN TA COLA to travel	$886,362	($25,328)	$861,035
18	Detector Support			$92,119	$0	$92,119
19	BRIL			$265,930	$0	$265,930
11-19	**Detector Operations**			**$7,969,928**	**$69,385**	**$8,039,313**

U.S. CMS Common Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q2 Plan**	**Change $**	**CY17Q3 Plan**
21.2	Common Costs (M&OA)	CR-102	M&O-A and CT-PPT M&O-B adjustments for actual exchange rate	$4,315,183	($309,547)	$4,005,636
21.3	Run Coord. and Monitoring			$440,073	$0	$440,073
21.4	LHC Physics Center			$819,726	$1	$819,727
21.5	Operations Support	CR-100, 103	CERN TA travel support for Physics Performance and Dataset coordinator; CERN TA support for fast timing sensor technology	$2,053,196	$116,066	$2,169,262
21.6	Program Office			$1,323,397	$0	$1,323,397
21.7	Education and Outreach			$110,585	$0	$110,585
21	**Common Operations**			**$9,062,159**	**($193,480)**	**$8,868,679**

U.S. CMS Software and Computing Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q2 Plan**	**Change $**	**CY17Q3 Plan**
22.1	Fermilab Facilities			$6,048,769	$0	$6,048,769
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-017	Reduce labor support for U. of Nebraska computing professional	$2,408,571	($24,059)	$2,384,513
22.6	S&C Program Management & CMS Coordination			$205,081	$0	$205,081
22	**Software and Computing**			**$15,543,636**	**($24,059)**	**$15,519,578**
U.S. CMS Operations Program Total				**$32,575,724**	**($148,153)**	**$32,427,571**

Figure 2: Spending Plan Change Log for CY17 Q2.

WBS	Subsystem	DOE Funds	NSF Funds	Total
11	Endcap Muon	$1,628,615	$559,539	$2,188,153
12	Hadron Calorimeter	$1,938,541	$35,413	$1,973,953
13	Trigger	$693,123	$219,415	$912,537
14	Data Acquisition	$886,300	$0	$886,300
15	Electromagnetic Calorimeter	$851,286	$8,000	$859,286
16/17	Tracker (Fpix & SiTrk)	$844,410	$16,625	$861,035
18	Detector Support	$92,119	$0	$92,119
19	BRIL	$129,716	$136,214	$265,930
11-19	**Detector Operations**	**$7,064,109**	**$975,204**	**$8,039,313**
21.2	Common Costs (M&OA)	$3,189,986	$815,650	$4,005,636
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	$1,913,602	$255,660	$2,169,262
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**	**$7,259,548**	**$1,609,131**	**$8,868,679**
22.1	Fermilab Facilities	$6,048,769	$0	$6,048,769
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	$1,359,500	$1,025,012	$2,384,513
22.6	S&C Program Management and CMS Coordination	$94,683	$110,398	$205,081
22	**Software and Computing**	**$9,827,328**	**$5,692,250**	**$15,519,578**
U.S. CMS Operations Program Total		**$24,150,986**	**$8,276,585**	**$32,427,571**

Figure 3: Spending plan at the end of CY17 Q2, for funds from DOE, NSF, and the total.

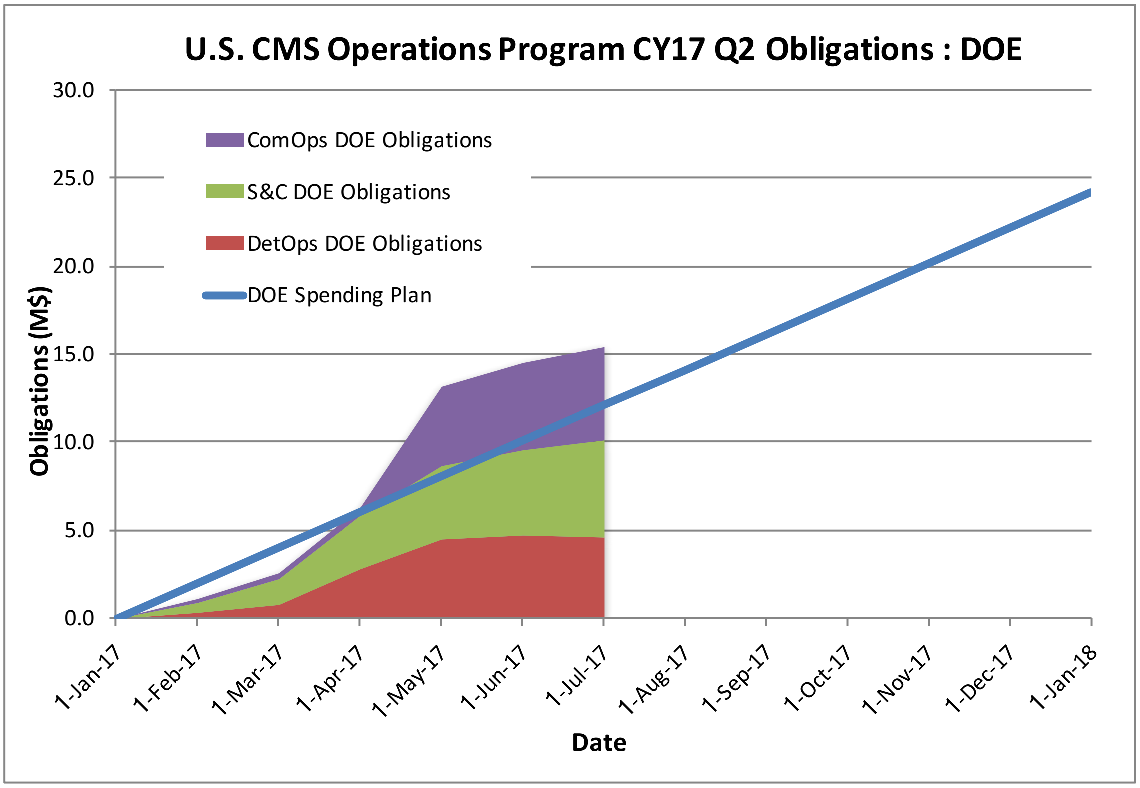


Figure 4: Obligations and spending plan for DOE funds. The spending plan is indicated with the assumption of equal monthly increments just as a rough guide.

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.

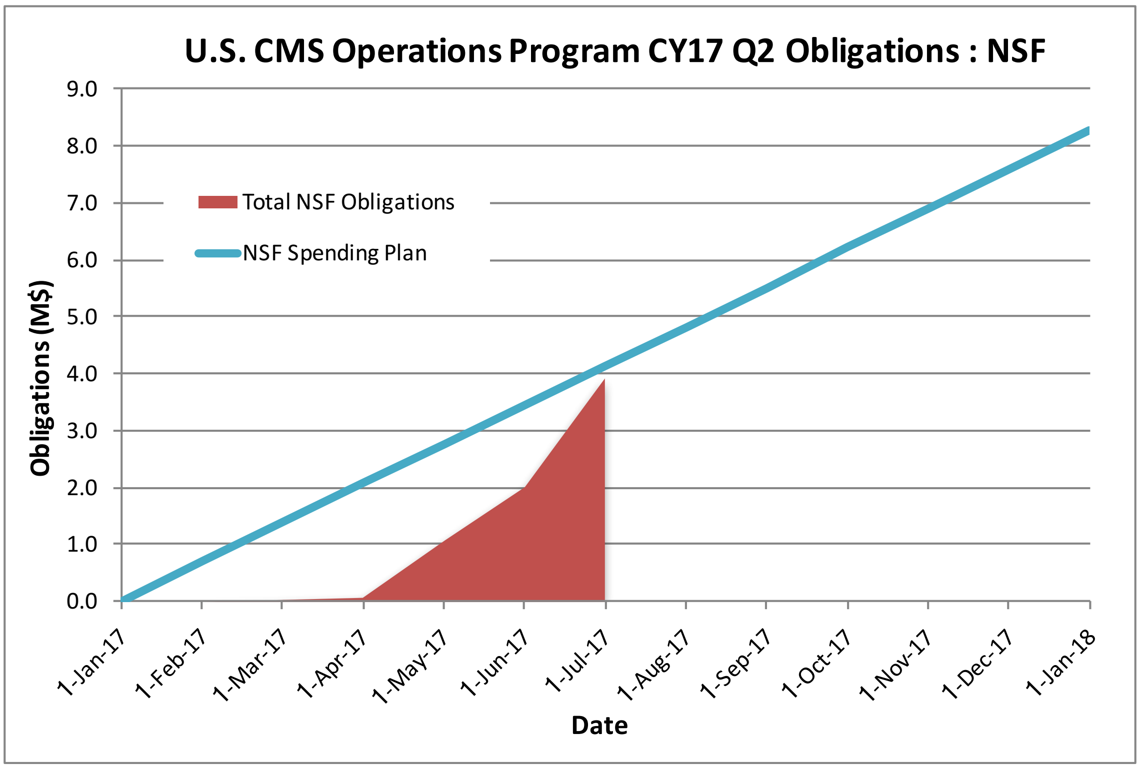


Figure 5: Obligations and spending plan for NSF funds. The spending plan is indicated with the assumption of equal monthly increments as a rough guide.

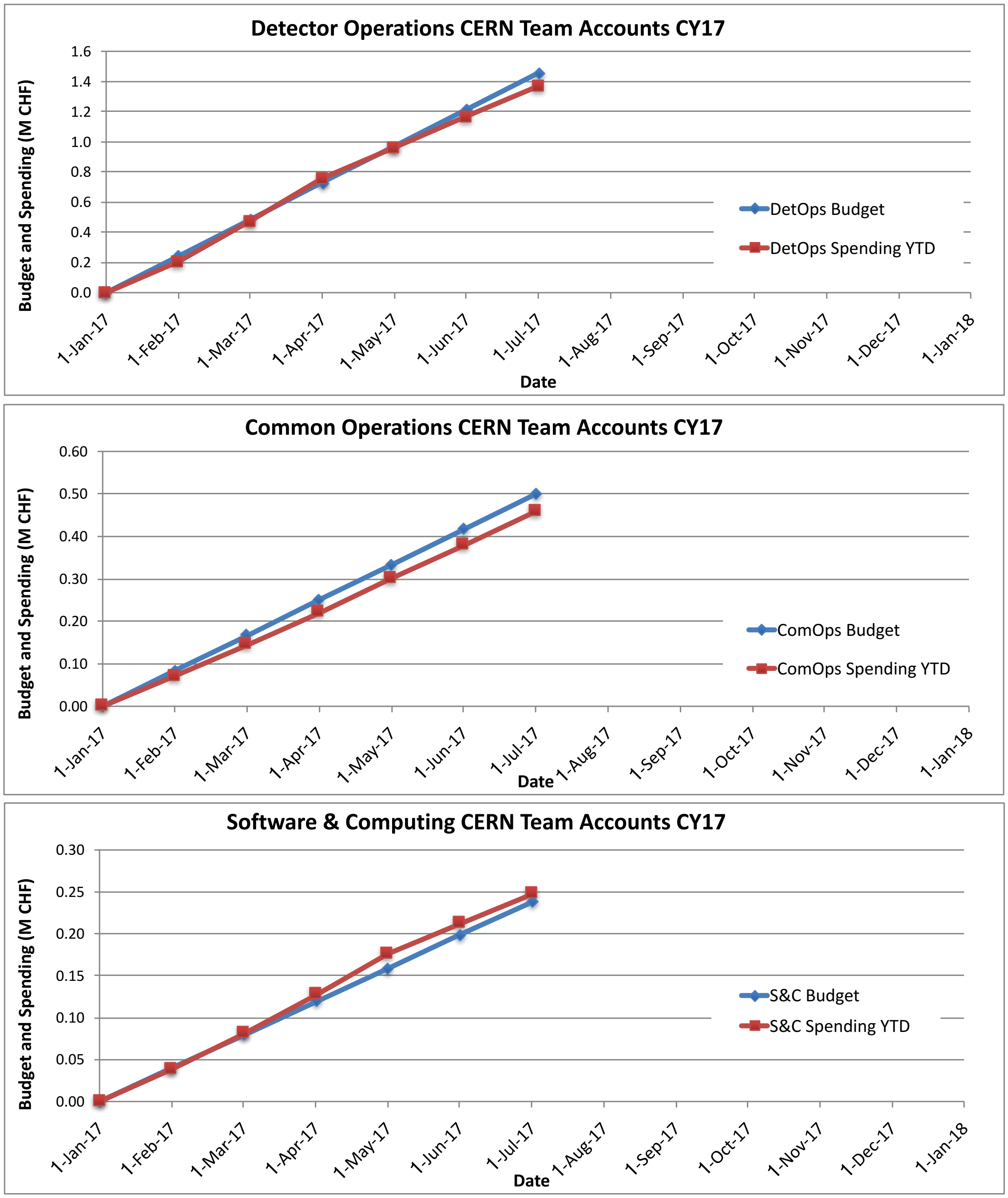


Figure 6: Budget plan and year-to-date spending, in Swiss francs, through DetOps (top), ComOps (middle), and S&C (bottom) Team Accounts.

CY17 Q2 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 - Open Science Grid services no longer provided externally	2%	0 months	$1750k
Risks added this quarter			
HCAL - LV Supplies	20%	0 months	$35k
EMU - cooling system water leaks	5%	2 months	$400k
Risks retired this quarter			
DAQ - Replacement HLT units not commissioned in time	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 and retired this quarter.

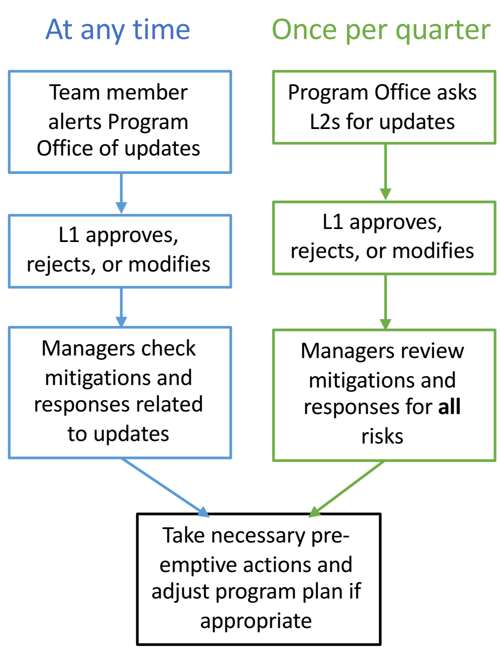


Figure 8: Summary of the two Risk Management Plan workflow paths.

Detector Operations

During the third quarter, the LHC restarted operations and the CMS experiment and after a commissioning period began taking physics quality data. Much of the earliest running has been dedicated to the commissioning of new elements of the detector that have be installed during the year end technical stop. Most significant of these upgrades was the completely new pixel system. The metrics reported for the various subsystems exclude commissioning periods but rather only refer to physics operations. As shown in Figure 9 an impressive 5.33 $fb^{-}1$ was recorded by CMS during this period.

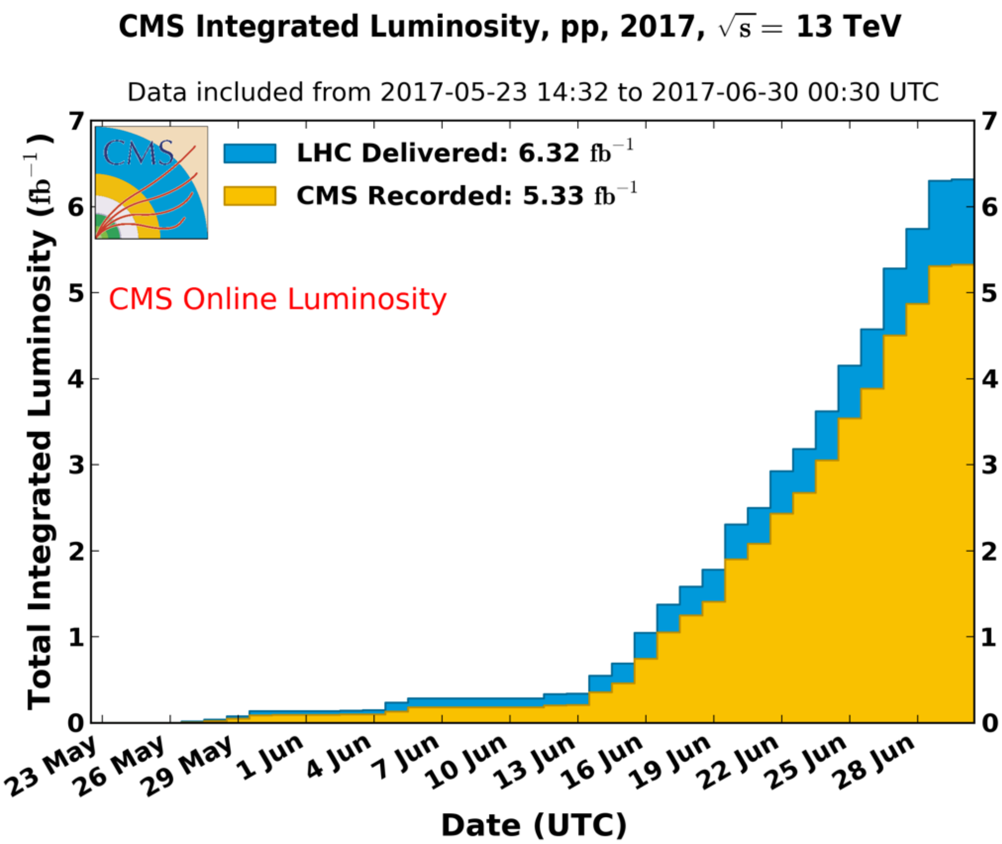


Figure 9: Luminosity, delivered by the LHC and recorded by CMS, through June 30.

BRIL

The Pixel Luminosity Telescope (PLT) together with the fast beam condition monitor (BCM1F) and HF are operational and provided online luminosity measurements since first beams arrived. The PLT has been aligned and the repaired telescopes are functional. The fast readout for all telescopes works but two telescopes exhibit degraded full pixel information that is used for track-based studies. The latter also provided a fast measurement of the beam spot and allows tracking of beam conditions. Publication of luminosity and beam background measurements is continuous. For the calibration of the luminosity a first high-luminosity VdM scan was performed and for the online luminosity now regularly information from a short beam-scan at the beginning and end of the fill is used. Corrections for efficiency and accidentals are obtained with fast turnaround after completion of a fill. Systematic beam studies with LHC were performed and the procedures are setup for the full VdM scan program this month.

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 in preparation 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

The tracker is able to reconstruct good quality tracks and it looks like the performance is as good as the Phase 0 tracker (see below). There are issues, however, with the Barrel Pixel layer 1 detector efficiency and a separate issue with the Token Bit Manager chip freezing up during collisions. These two issues currently limit us from pronouncing the whole Pixel detector ready for physics.

Pixels

Soon after stable beam collisions started, it was discovered during timing scans that the BPiX layer 1 and layer 2, which share a common fine delay setting, could not both be timed in to a common optimal operating point. Instead, a compromise point, at the timing plateau end for layer 2 and beginning for layer 1, was chosen until the timing can be adjusted in hardware at a time when the BPiX can be removed for adjustment. There also appears to be an efficiency loss in the layer 1 chip, yet to be understood, leading to single hit clusters being reconstructed as two clusters (aka “broken hit clusters”). Further, it was determined that the modules closest to the beam in the layer 1 BPiX are already operating at the maximum design luminosity. We are exploring different settings for layer 1 chip operating constants and different timing strategies to try and optimize physics performance. As a reminder, BPIX layers 2-4 and FPIX utilize the PSI46dig readout chip everywhere, while BPIX layer 1 uses the PROC600 chip. The PSI46dig is a minor upgrade to the Phase 0 chip, while the PROC600 is an entirely new chip designed to withstand the fluences expected in layer 1.

There is also an issue with all versions of the Token Bit Manager (TBM) chip. Two TBM cores are present in each module. About 20 detector channels (out of 5,000) per hour stop responding to triggers and are only recoverable with a local power cycle of the module containing the TBM. The TBMs closest to the beam are affected the most, and the effect is the same as a Single Event Upset on a vulnerable flip flop in the design. We currently perform the local power cycle when about 4% of the layer 1 channels are not responding. The recovery operation is manual and adds about 5% deadtime to operations. We are adding software and firmware to speed up and increase the automation of the recovery time.

In the metrics it is to be noted that there is an additional 418/pb of luminosity used to investigate the issues with the Phase 1 pixel detector. CMS does not count this as pixel deadtime but adds it to the "General" category of lost luminosity along with tests and such from other detectors (an additional 60/pb).

Strips

The strip detector primary beam on calibrations were completed soon after stable beam collisions started and the strip detector appears to be operating well in 2017 collisions. Some detailed studies of efficiency and performance need the pixels in a stable data taking condition, though there does not appear any cause for concern in the performance of the strips.

Table 3: Tracker Metrics

	Pixels	Strips
% Working channels	95.6	96.2
Downtime attributed in pb^{-1}	48.44	25.24
Fraction of downtime attributed (%)	6.3	3.3

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	

ECAL

The second quarter was devoted to the preparations for running. The detector was bought into fully operational status in the first quarter. In the second quarter no major problems with the detector have been encountered. The standard set of procedures for preparing for the run were conducted. These include a series of cosmic runs to debug the various DAQ/Trigger/monitoring issues that normally arise. New pedestals, pulse shapes, timing constants, laser monitoring corrections and selective readout thresholds have been installed. At the present time we are running with 2016 energy calibration constants. This is because the new constants are derived from data and it takes several weeks to generate the initial values after data taking has begun. The 2016 constants provide a fairly good starting point. The early data looks as expected and plots of the pizero and Z boson mass were approved to be shown at the major conferences.

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}	15.2
Fraction of downtime attributed	2%
Resolution performance	2.5%

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 the second quarter of 2017, the HCAL Operations group focused on commissioning the HF and partial HE Phase I upgrades, and then on calibrating the HCAL and on taking data.

For HF, the upgrade consists of installing dual-anode readout. New front-end electronics was also installed 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. First calibrations have been completed and timing has been equalized for all channels. There are currently two issues with the HF. First, the HF low voltage (LV) power supplies are experiencing a high rate of single event upsets (SEUs) when the beam is on leading to a small amount of deadtime. The problem has been traced to prototype LV supplies which have a factor of 20 higher rate of SEUs than the production supplies. The power supplies will be re-arranged during the Technical Stop in early July so that production supplies will provide all the HF LV. Second, there is noise at HF IETA = -30 and -29. It has been determined that this noise was also present in the 2016 data, but the cause is still unclear.

For HE, one upgraded HE readout box (out of 36) was installed to obtain experience with upgraded system. The upgraded HE readout box (HEP17) is performing well. The gains and pulse shapes from HEP17 have now been adjusted in the reconstruction to match what is observed in the data. (A similar small HF upgrade installation was done last year, and the experience gained with the upgraded system informed this year's HF EYETS work.)

First calibrations for HF, HB, HE, and HO have been obtained.

Planning to install the complete HE upgrade in 2017-18 YETS is in progress, and a draft detailed schedule including personnel needs has been completed, and is being optimized.

Metrics and Milestones for this Quarter
June 1 Milestones
HF Detector Commissioned. This milestone was achieved May 1.
HCAL Ready for Physics. This milestone was achieved May 15.

Table 7: HCAL Metrics

Metric	Performance
Fraction of channels operational: HF	100%
Fraction of channels operational: HE	99.63%
Fraction of channels operational: HB	99.77%
Fraction of channels operational: HO	99.72%
Downtime attributed pb^{-1}	16.3
Fraction of downtime attributed	1.69%
Abs Energy Calibration	5%
Inter-calibration Uniformity	5%

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

EMU

After the detector was closed and the CMS solenoid field was ramped up, water was detected accumulating at the bottom of the detector. After a lengthy processes, the source was localized to a leak in one of the ME1/1 cooling circuits on the YE-1 endcap disk. That circuit was shut off to stop the leak, but this left two chambers (ME-1/1/34 and ME-1/1/35) without cooling, so they remain powered down and disabled. The first opportunity to investigate the leak in more detail should come at the year-end technical stop.

Two other chambers (ME-2/1/3 and ME-4/2/21) 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. They will be investigated further during the first technical stop in July.

In total, the CSC system finishes the quarter with four out of 540 chambers disabled.

Otherwise, the CSC system operated smoothly in the LHC start up and is performing efficiently in global data taking. Occasional problems with corrupt data are being reported by the FED system. These are being investigated, but they do not contribute significant downtime (<0.5%). Some HV instabilities were detected in the high-eta chambers (ME1/1) caused by fast ramping of the luminosity which might lead to Malter currents in some planes. We are recovering from those by lowering slightly the HV and by performing reverse polarity training during the technical stop.

Some of the early collision runs were used to refine the timing constants for the ME1/1 chambers. The timing on these chambers had shifted slightly in the Fall of 2016 due to a correction in the strip comparator threshold settings.

The 5 new GE1/1 demonstrator chambers were installed adjacent to the CSC chambers, and investigations were carried out to understand under what conditions the GE1/1 system induced noise in the CSCs. The parts that induced noise were disabled for the time being.

Data collected on June 14 with a dedicated single-layer trigger were used to study the induced background hit rates. After modifications to the shielding in the forward rotating shielding, done during EYETS, the recorded levels look rather similar to 2016 except for an improved uniformity between -z and +z detector ends and a somewhat lower background rate (20-30%) in the outer rings of the CSC system.

Table 9: CSC Metrics

% Working channels	98.4%
Downtime attributed pb^{-1}	1.5
Fraction of downtime attributed	0.2%
Median spatial resolution	126 μm

Table 10: EMU Milestones

Subsystem	Description	Scheduled	Achieved
EMU	CSC ready for physics	May 1	April 29
EMU	Firmware to mitigate DCFEB EPROM problem	July 1	January 29
EMU	New HV settings for reduced gain	August 1	

DAQ

The DAQ group finished the commissioning of the readout links for the subsystems which are new or have been upgraded during EYETS. New readout links were installed for GEM. Functionality has been added to support multiple DAQ links from the same HCAL backend card, while using a single TCDS link. This was required to accommodate larger fragment sizes in 2017. The new FEROL40 boards used to readout the pixel detector are fulfilling the functional and performance requirements. The troublesome power regulators on these μTCA FEROL40 boards were replace in May, and no problem has been seen since.

The central and all sub-system DAQ systems have been upgraded to CC7 and the latest XDAQ release. Firmware and software are regularly updated to incorporate new features to improve the monitoring and to fix bugs. The new python-based transfer system has been deployed. The reimplemented monitoring tool DAQView and the new expert system DAQExpert are now routinely used in production. The DAQExpert is continuously augmented to diagnose more problems. This helps the DAQ shifter to solve issues more efficiently and reduces the load of the DAQ on-call.

The new HLT nodes which were ordered as part of the replacement campaign were not delivered by the company. The new nodes should have replaced the C6220 nodes bought 5 years ago, and also increase the HLT CPU capacity by 20% compared to 2016. In order to mitigate this problem, the already retired C6220 nodes were reintroduced. In addition, 192 Huawei nodes on loan from CERN IT until the end of 2017 have been installed in the HLT farm. By June 21, we were able to provide the promised CPU capacity of about 0.6 MHepSpec, which is a factor 1.2 more than in 2016.

The work on the new online-monitoring system (OMS) is progressing well. This system shall replace the current WbM. A 2-day workshop was held in June. We got a very positive feedback from test users concerning the user interface. A roadmap for the next steps has been developed. In order to be able to meet the goal to be ready for field tests by end of this year, responsibilities between DAQ and Vilnius group were reshuffled to make best use of available resources.

Table 11: DAQ Metrics

Dead time due to backpressure	1%
Downtime attributed pb^{-1}	0.02
Fraction of downtime attributed	0.15%

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 began data-taking for this year.

Endcap Muon Trigger

The Northeastern, Rice University, and University of Florida groups have re-commissioned the EMTF for 2017 operations and have maintained the system 24/7 during the LHC ramp-up. A new addition for 2017 is the combination of RPC endcap hits with CSC hits for the track-building. The firmware was modified to align the RPC data links, and final synchronization was achieved with collisions during early LHC operations. A new encoding scheme for the PT LUT address was developed, and the firmware and software emulator were adjusted accordingly and debugged to achieve 99.98% agreement. The encoding scheme accommodates the addition of RPC hits, and a new boosted decision tree training was done for the PT assignment. The resolution is expected to be better than in 2016, especially for lower-quality tracks. Preliminary analyses of the LHC data show an increased trigger efficiency in the region where the RPCs have coverage as expected. The forward region efficiency suffers somewhat from some non-operational CSCs, but mitigation methods are under study. The online control and monitoring software was ported to the latest release, 1.0, of the SWATCH libraries. DQM plots to monitor the RPC input to the EMTF have been developed, although still need to be deployed online.

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 has been operating full-time in global runs since the 27th of March. The ngHEP17 and ngHF links are now fully operational and sending valid data. In late April, CaloL1 created a new beam splash configuration with just the ECAL central towers ($±$1 around $\eta = 0$) and data was successfully recorded with high threshold e/γ triggers.

A few ECAL link issues were repaired and an ECAL TCC has been replaced that was causing link errors during LHC Ramp. High LHC luminosity has increased electrical activity on the ECAL TCCs. This is causing more corrupted data sent to CaloL1, and causing CRC and BC0 errors on our ECAL links. This issue is not serious and has been mitigated in firmware so that CaloL1 is not constantly in error on the L1 Page, and the information is still available.

Other updates include the CaloL1 calibrations and SWATCH. Calibrations were updated three times, currently they are 2017 calibrations and the HF scale is set so we can mimic the 2016 response. This is to have a baseline to tune/deploy a new set of calibrations in the calorimeter trigger in July. Also online is a recent update to our online software, SWATCH 1.0.1.

Table 13: Trigger Metrics

Frac of MPC Channels	
Frac of Upgrade EMUTF Channels	100%
Downtime attributed to EMTF pb^{-1}	1.8
Fraction of downtime attributed to EMTF	0.25%
Frac of Calo. Layer-1 Channels	100%
Downtime attributed to Calo. Layer-1 pb^{-1}	0
Fraction of downtime attributed to Calo. Layer-1	0%

Table 14: Trigger Milestones

Subsystem	Description	Scheduled	Achieved
TRIG	EMTF commissioned with		

Subsystem	Description	Scheduled	Achieved
	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 second quarter of 2017 began with a quiet period after preparations for winter conferences, and ended with the start of LHC operations for the year and the incorporation of a new pixel detector into CMS. As usual, the U.S. CMS computing facilities operated at a high level of availability, while also continuing to upgrade and improve services for users. The computing operations team kept those facilities busy with a variety of data processing and simulation tasks, concluding with processing of the first 2017 data and preparations for analysis. The development teams closed out a number of ongoing projects that have improved our operational efficiency and our understanding of system performance, while also starting up several promising efforts that will help us accommodate the strong challenges presented by the HL-LHC.

Date	Milestone
May 15	Ability to have workflows running on a combination of EL6 and EL7 operating systems
June 15	Completed DBS update to track events per luminosity section per file and related WMAgent & DAS code to enable event counts
June 20	SL7 operating system based development capability provided for LPC users
July 1	Allow multiple threads when processing runs and luminosity blocks
July 1	Merged all python packages that are around ROOT into CMSSW
July 1	Integrate geometry changes for 2017 data taking for visualization solution

Fermilab Facilities

This quarter brought about the restart of LHC physics running in June. 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 36 million wall-clock hours of processing to CMS.

During this quarter the facility upgraded EOS storage for the LPC, addressing an issue that caused approximately weekly crashes in the metadata server. This has greatly improved service reliability for the LPC users. Also during this quarter the Tier-1 facility passed CMS site availability metrics 100% of the time. Figure 10 shows the site readiness metrics for the quarter. The black & yellow band along the bottom of the figure indicates the start of LHC physics operaitons at the beginning of June.

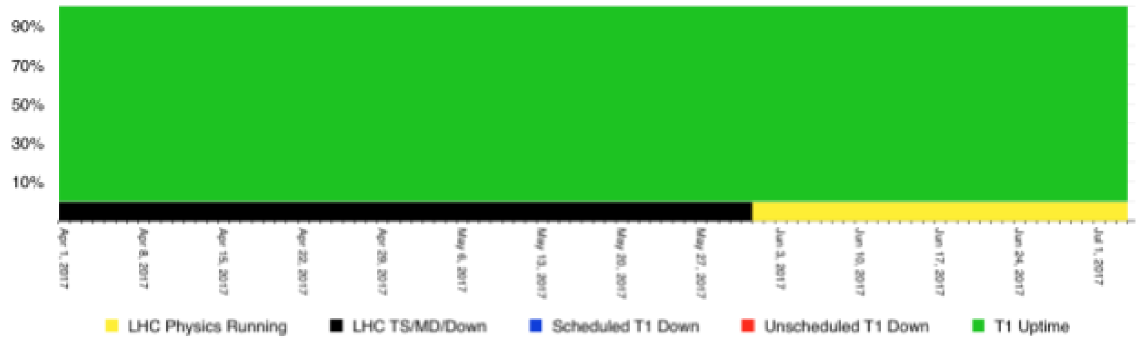


Figure 10: Fermilab readiness metrics for 2017Q2. Green indicates a passing metric, red a failing metric, and blue a scheduled downtime. The height of a red bar indicates how much of the day services were affected. Black and yellow across the bottom indicates LHC machine running. This quarter no yellow appears due to the LHC shutdown. FNAL passed metrics 100% during the quarter.

University Facilities

CMS production and analysis activities this quarter were lighter than typical because the extended year-end technical stop delayed the start of data taking. Nonetheless, all of the U.S. CMS Tier-2 sites operated successfully this quarter. On our two official performance metrics based on CMS test jobs, all sites were at least 90% "available" and 88% "ready". The CMS goal for each of these metrics is 80%, but the U.S. CMS performance goal is 90%. For the one site that missed the U.S. CMS performance goal for "ready," the issue has been identified and should be corrected for the next quarter.

The U.S. CMS Tier-2 centers delivered 52.8% of all computing time by Tier-2 sites in CMS (our commitment to global CMS is > 25%), as shown in Figure 11. This is an increase of 3.8% over the previous quarter.

As for progress on milestones and upgrades, by July 1, the Tier-2 sites had all installed the new CMS disk space monitoring client package and were regularly reporting disk usage and had all (where applicable) replaced the legacy WLCG tools with gfal. Five out of seven sites have implemented load-balanced gridFTP as a replacement for Bestman and four out of seven sites have converted at least one CE to SL7.

Seven Tier-3 sites required assistance from the Tier-3 support team this past quarter on issues including PhEDEx, OSG software, batch system, and basic Linux troubleshooting and support. CMS Connect has reached 45 registered users. The first Tier-3-in-a-box site is being deployed at the University of Colorado, and the feasibility of incorporating resources from the research computing center there is being explored.

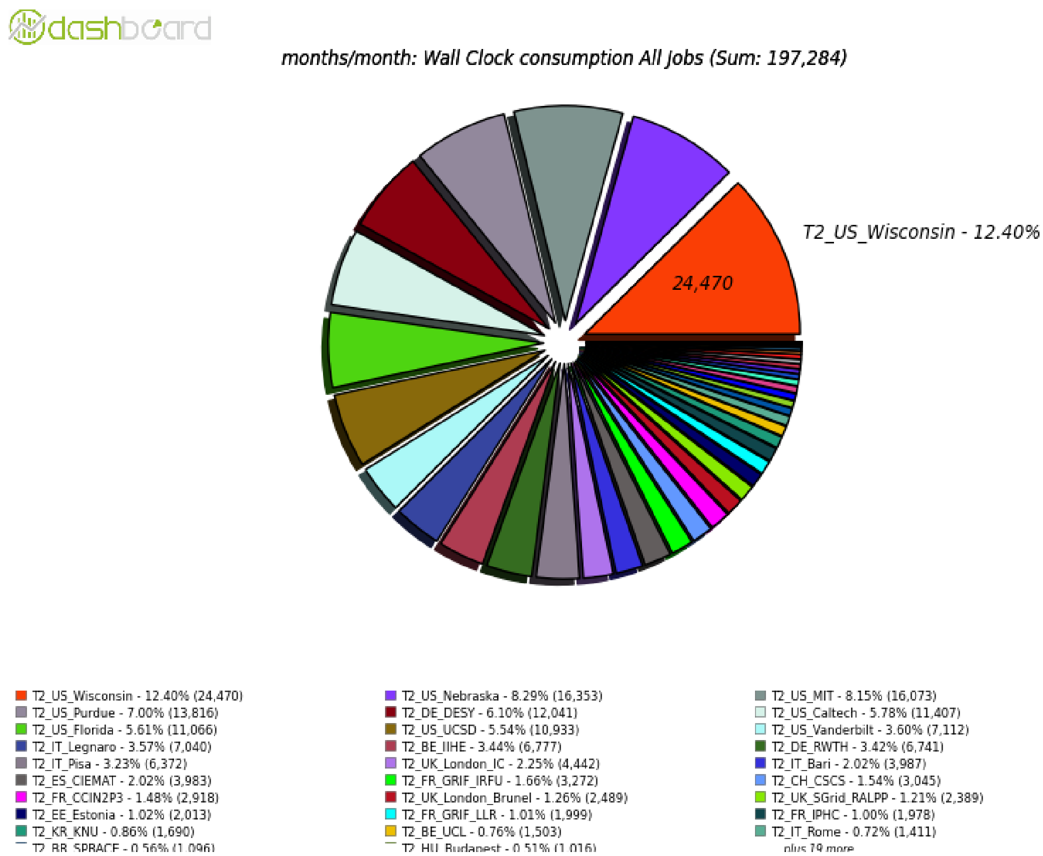


Figure 11: Percentage of total computing time delivered to CMS by Tier-2 sites world-wide, by site.

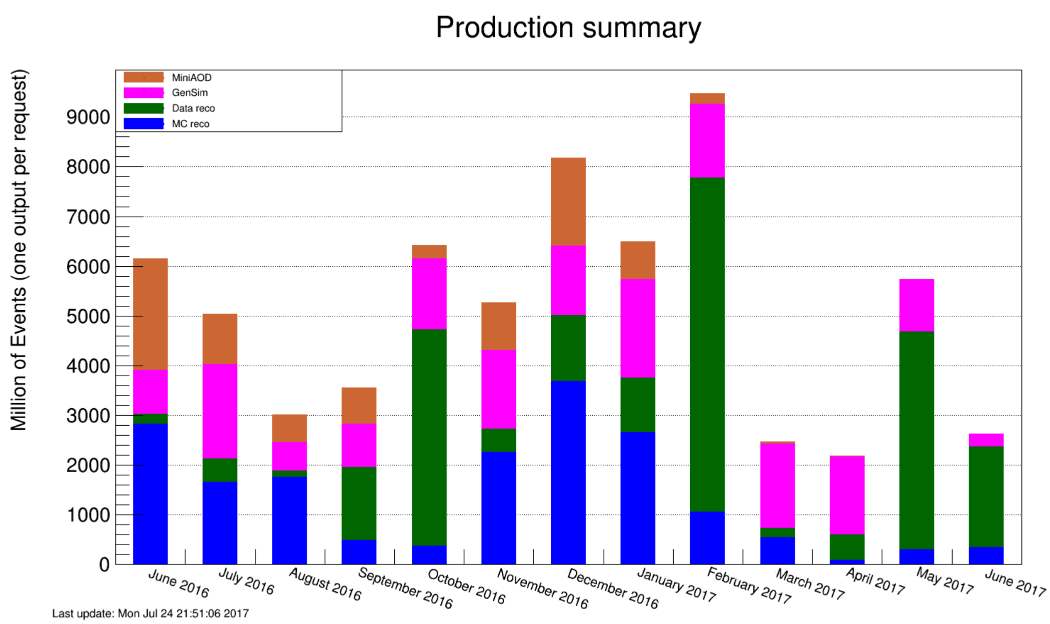
Computing Operations

As CMS was not taking data for most of the quarter, this period was rather quiet in terms of data processing and thus an ideal time to perform tests, implement new tools and commission any necessary changes to procedures in preparation for the 2017 run. A readiness review for the entire operations was performed and successfully completed.

A small number of Monte Carlo samples requested after the spring conferences were completed promptly. Simulations for the Phase 1 upgrades used available computing resources until CMS was ready to re-reconstruct the 6 billion events in the 2016 datasets at the end of April. The worker nodes of the high-level trigger (HLT) farm were used for offline processing while the LHC was in shutdown/restarting. This revealed a bottleneck in authentication against EOS, the CERN disk storage system. The outages impacted operations and were mitigated by limiting more I/O intensive workflows on both HLT and Tier-0 farm and switching EOS from user-based authentication to subnet authorization for the HLT farm. EOS developers addressed the issue and this solution went into operation in June.

CMS discovered missing files in EOS. Two sources of file loss have been identified: during nameserver failover and in case of xrootd writes with retry. Developers corrected the first and an xrootd client configuration, to disable automatic write retries, was deployed to avoid the second case. We are keeping a close eye on files in EOS to spot any additional issues quickly.

With the start of proton-proton collisions in May, the new transfer system, from the experiment to the Tier-0 facility, was commissioned. A few issues were sorted out – without any loss of data – and the new setup was ready for the first physics quality collisions. Additional simulations for the HL-LHC upgrades could be completed before the CMS resumed physics operations. At the end of the quarter, the operations team was preparing for the legacy re-reconstruction of 2016 data by pre-staging the prioritized list of samples.



Number of events processed monthly over the past twelve months, categorized by data type.

Computing Infrastructure and Services

This quarter was spent closing out activities begun earlier. WMArchive, our long term data store of job performance information, began to accept data from CRAB, our analysis system (it already accepts data from WMAgent, the production system). WMAgent was modified and enhanced to enable more workflows to work with the more efficient StepChain workflow and also made some changes be able to increase average job times. Both of these changes are aimed at reducing the number of jobs in the system and increasing the CPU efficiency.

In opportunistic and HPC resources, we were ran workflows on Xeon and KNL nodes at NERSC at comparable efficiencies to what we have been able to achieve on grid sites. We were also able to submit jobs into multi-node GlideinWMS pilots, allowing a better match between requests for CMS workflows and traditional HPC workflows.

This quarter also saw completion of the modifications needed to DBS and all our other software to begin tracking events per luminosity section (23 s of LHC running time) on a per file basis. This gives us the ability to generate better statistics on the makeup of our data and will allow us, in the future, to better split our tasks into jobs and possibly be able to process ranges of events or single events without regard to luminosity section boundaries.

There was development, integration, and debugging activity on Xrootd this quarter. On the development side work was done as members of the international Xrootd collaboration on "serverless caching," i.e. a caching proxy that is run on client side as part of the Xrootd client. For integration, a Tier-2 scale cache was deployed, and integrated with the job submission infrastructure such that jobs submitted with CRAB can overflow to the site that hosts the cache if and only if they analyze datasets that fit the regular expression for the namespace that is cached. Work is ongoing in improving the monitoring of the cache via various grafana pages. This integration work also fed back into Xrootd development, leading to tuning of the cache to improve file placement, and development of tools to better handle disk losses in a distributed Tier-2 scale cache.

In addition, U.S. CMS has started an evaluation project of Ceph. The initial goals are to validate Ceph as a future replacement of HDFS at the full Tier-2 center scale, compare Ceph performance with HDFS and GlusterFS to separate out limitations in the filesystem from limitations in the test-stand, and explore performance of Ceph as a hierarchical storage system, with SSDs for performance and SATA for cost effective volume. The initial tests of Ceph are very promising, but much more elaborate testing is ongoing.

Software and Support

Data taking for the running year 2017 started in earnest. We worked on time-critical software releases for the data taking and commissioning of the new pixel detectors; to prepare for Monte Carlo production campaigns; and to generate simulation samples for the upcoming HL-LHC TDR studies. This included updating the geometry description for the new detector components, especially achieving the milestone for the visualization solution to be ready for the 2017 data taking run. To support various planning activities, we improved our capabilities to query AAA/EOS/CMSSW/CRAB/FTS/DBS/PhEDEx records in Spark and enabled a variety of explorations.

We greatly improved the concurrency of CMS jobs by fully utilizing Intel's Thread Build Block (TBB) tasks to run all modules in the job. This corresponding milestone to allow multiple threads when processing runs and luminosity blocks was completed earlier than originally planned (October 1). The initial prototype of a mechanism to allow parallel writing to one ROOT output file was successful. The milestone of having multi-threaded I/O by July 1st needs to be moved to October 1, as the challenge requires more coordination with external groups (ROOT, GeantV) to guarantee long term maintainability. In preparation for the changes to Frontier that will come in Run 3, we finalized the move of query complexity from the client to the server. This concludes the USCMS development part for the December 1 milestone. We are now waiting for international CMS colleagues to write client applications for the new server mode to start scale testing.

Finally, we made progress on important parts of the vectorized tracking R&D work updating to the new 2017 tracker including the new forward and barrel pixel detectors, and studies to optimize the HL-LHC tracker design to reduce the reconstruction time which were presented in international CMS meetings.