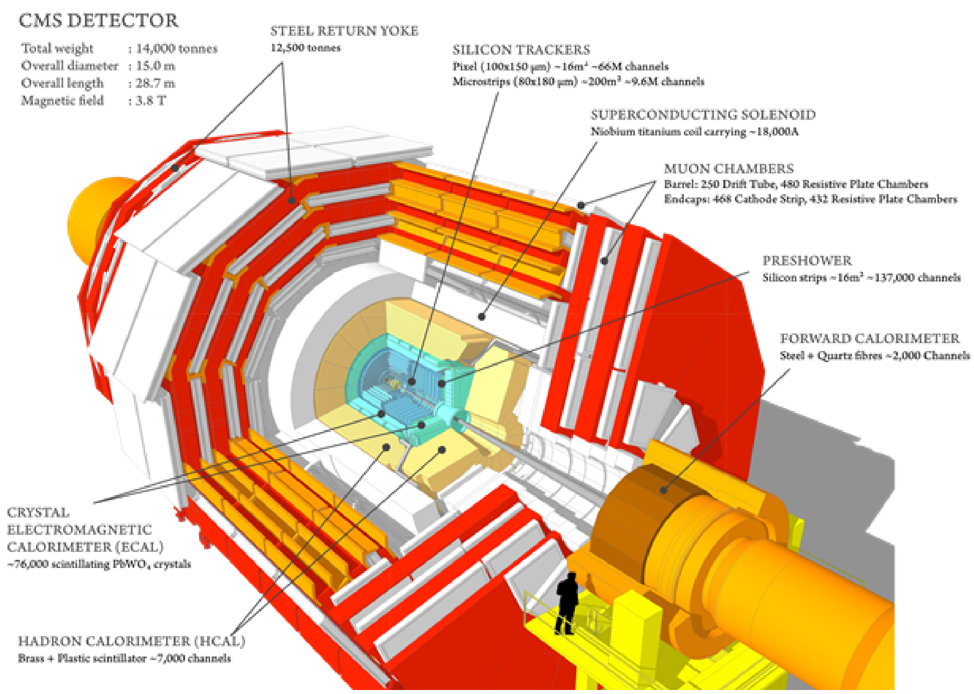
U.S. CMS Compact Muon Solenoid Operations Program
Quarterly Report for the Period Ending March 31, 2018

U.S. CMS Operations Program



Program Manager's Summary

During this quarter, the first quarter of **calendar year 2017** (2017Q1), the LHC was in an extended year-end technical stop (EYETS), giving CMS opportunity for major repairs and installation of detector replacements and upgrading detector components delivered by the Phase-1 upgrade project.

The primary goal for the EYETS is the installation of a completely new pixel detector, with U.S. CMS having responsibility for the forward pixel detector component (FPIX). The EYETS also allowed for the installation of the forward hadron calorimiter (HF) upgrade, and for extensive repairs of other subsystems. Recommissioning of the whole detector and readout started in March with so-called Global Runs that allowed recording of cosmic data for commissioning and calibration of detector components.

Computing facilities were in heavy use, to support processing and analysis of data taken during the 2016 run, with large peaks of activities related to the preparation of results for the March "winter conferences". As reported previously, the 2016 proton-proton run resulted in 30% more data than originally projected, resulgin in additional stresses on computing systems to deal with the additional data. However, U.S. Facilities performed well, allowing the data samples to be prepared in time for data analysis for the conference results.

The technical stop also allowed transitioning of important computing systems to new version, in particular installation of the Singularity virtualization layer on US facilities, decommissioning of the Fermilab LPC BlueArc storage system and replacing it with NSF mounted disk arrays, retiring of obsolete information systems (GIP/BDII) and incorporating a more efficient compression algorithm in ROOT.

Regarding CMS demographics, in 2017 the U.S. fraction of PhD Physicists in CMS, and thus the expected U.S. share to M&O Cat-A cost, remains almost constant with respect to 2016. DOE supports 308 individuals or 22% of the CMS total, the NSF supports 75 individuals or 5.4%, and DOE Nuclear 27 or 2% of the total. There are also 11 individuals at U.S. CMS institutions that have support for M&O-A through other funding sources. The overall fraction of U.S. PhD physicists in CMS is 30.0%

The project office has developed a workflow for a Risk Management Plan, which is being put in place during this quarter. This is described in the Resource Manager's section of this report.

Based on the U.S. CMS budget process with budget reviews during the previous year and with input from the Resource Allocation Advisory Board received in December, 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. The following Resource Manager section outlines this activity based spending plan for the calendar year 2017.

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 funds designated for HL-LHC OPC in the case of DOE or HL-LHC R&D in the case of NSF.

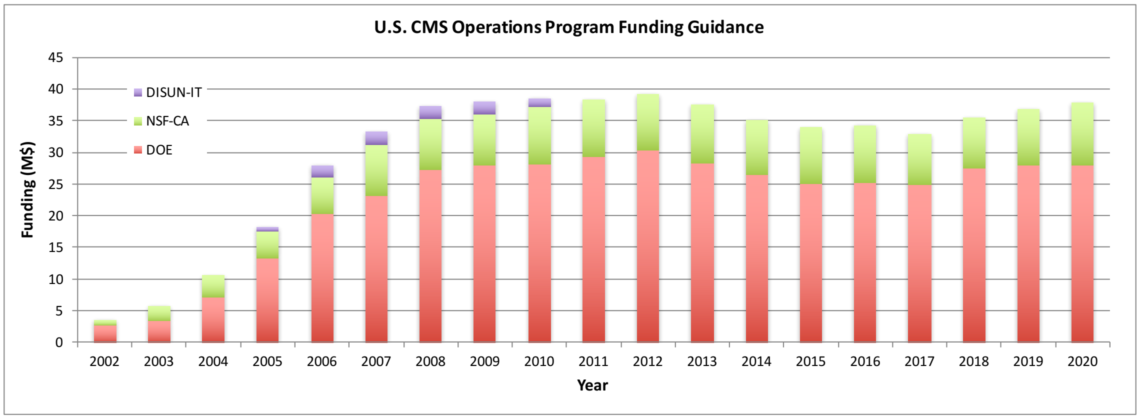


Figure 1: The annual U.S. CMS Operations Program funding provided by DOE and NSF. For 2002 through 2017 the chart shows the actual funding, while for 2018 onward the current funding guidance is shown.

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 March of 2017, a total of 74 SOWs (50 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.

Table 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 Q1, is shown for DOE and NSF funds in Table 3.

Once funds have been committed through Fermilab purchase orders (in the case of DOE funding), and sub-awards through Princeton (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. The NSF funding is transitioning from the end of one five-year Cooperative Agreement to another, and due to the complexity of this process and the arrival date of the first protion of these funds, no sub-awards were issued during Q1. Obligations directly at Princeton took place at a level of $33k.

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 Q1 averaged 1.01 CHF/USD. Figure 5 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 5 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 $6.1M and opportunities summing to $1.0M. Table 6 shows the top few risks remaining 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 7.

(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

U.S. CMS Detector Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q1 Plan**	**Change $**	**CY17Q2 Plan**
11	Endcap Muon	Adjust & CR-029	Adjustments prior to SOW, and CERN TA labor support for alt. gas mixture chamber construction	$2,078,111	$51,280	$2,129,391
12	Hardon Calorimeter	Adjust & CR-039	Reductions prior to SOW, and added CERN TA COLA for firmware engineer for front-end FPGAs	$1,997,561	($16,861)	$1,980,700
13	Trigger	CR-017, 018, 019	Adjusts prior to SOW, and reduce Rice engineering labor, add CERN TA COLA, and add RICE travel	$900,230	$12,308	$912,537
14	Data Acquisition	CR-007	Labor support for MIT computing professional	$808,762	$62,389	$871,151
15	Electromagnetic Calorimeter			$831,737	$0	$831,737
16/17	Tracker (Fpix & SiTrk)	Adjust	Adjustments prior to SOW	$889,370	($3,008)	$886,362
18	Detector Support			$92,119	$0	$92,119
19	BRIL			$265,930	$0	$265,930
11-19	**Detector Operations**			**$7,863,820**	**$106,108**	**$7,969,928**

U.S. CMS Common Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q1 Plan**	**Change $**	**CY17Q2 Plan**
21.2	Common Costs (M&OA)	Adjust	Adjustments prior to SOW	$4,281,938	$33,245	$4,315,183
21.3	Run Coord. and Monitoring			$439,714	$359	$440,073
21.4	LHC Physics Center	Adjust	Adjustments prior to SOW	$816,013	$3,713	$819,726
21.5	Operations Support	Adjust & CR-099	Adjustments prior to SOW, and CERN TA labor support for PhaseI Fpix installation and commissioning	$1,938,444	$114,752	$2,053,196
21.6	Program Office	Adjust	Adjusts prior to SOW (primarily for new sub-awards)	$1,212,324	$111,072	$1,323,397
21.7	Education and Outreach			$110,585	$0	$110,585
21	**Common Operations**			**$8,799,018**	**$263,141**	**$9,062,159**

U.S. CMS Software and Computing Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY17Q1 Plan**	**Change $**	**CY17Q2 Plan**
22.1	Fermilab Facilities	CR-015, CR-016	Adjustments; Reduce FNAL M&S for alt arch cluster; Delay FNAL labor for LPC support and disk storage	$6,373,477	($324,708)	$6,048,769
22.2	University Facilities	Adjust	Adjustments prior to SOW	$3,478,053	$2,200	$3,480,253
22.3	Computing Operations			$929,522	$0	$929,522
22.4	Computing Infra. and Services	Adjust	Adjustments prior to SOW	$2,467,188	$4,252	$2,471,440
22.5	Software and Support	CR-015, CR-016	Adjustments; Delay FNAL contractor labor for machine learning; Delay FNAL labor for framework devel.	$2,713,691	($305,120)	$2,408,571
22.6	S&C Program Management & CMS Coordination			$205,081	$0	$205,081
22	**Software and Computing**			**$16,167,012**	**($623,376)**	**$15,543,636**
U.S. CMS Operations Program Total				**$32,829,851**	**($254,127)**	**$32,575,724**

Figure 2: Spending Plan Change Log for CY17 Q1.

WBS	Subsystem	DOE Funds	NSF Funds	Total
11	Endcap Muon	$1,569,853	$559,539	$2,129,391
12	Hadron Calorimeter	$1,945,287	$35,413	$1,980,700
13	Trigger	$693,123	$219,415	$912,537
14	Data Acquisition	$871,151	$0	$871,151
15	Electromagnetic Calorimeter	$823,737	$8,000	$831,737
16/17	Tracker (Fpix & SiTrk)	$869,737	$16,625	$886,362
18	Detector Support	$92,119	$0	$92,119
19	BRIL	$129,716	$136,214	$265,930
11-19	**Detector Operations**	**$6,994,724**	**$975,204**	**$7,969,928**
21.2	Common Costs (M&OA)	$3,499,533	$815,650	$4,315,183
21.3	Run Coordination and Monitoring	$332,137	$107,936	$440,073
21.4	LHC Physics Center	$819,726	$0	$819,726
21.5	Operations Support	$1,797,536	$255,660	$2,053,196
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**	**$7,453,028**	**$1,609,131**	**$9,062,159**
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	$1,383,559	$1,025,012	$2,408,571
22.6	S&C Program Management and CMS Coordination	$94,683	$110,398	$205,081
22	**Software and Computing**	**$9,851,387**	**$5,692,250**	**$15,543,636**
U.S. CMS Operations Program Total		**$24,299,139**	**$8,276,585**	**$32,575,724**

Figure 3: Spending plan at the end of CY17 Q1, for funds from DOE, NSF, and the total.

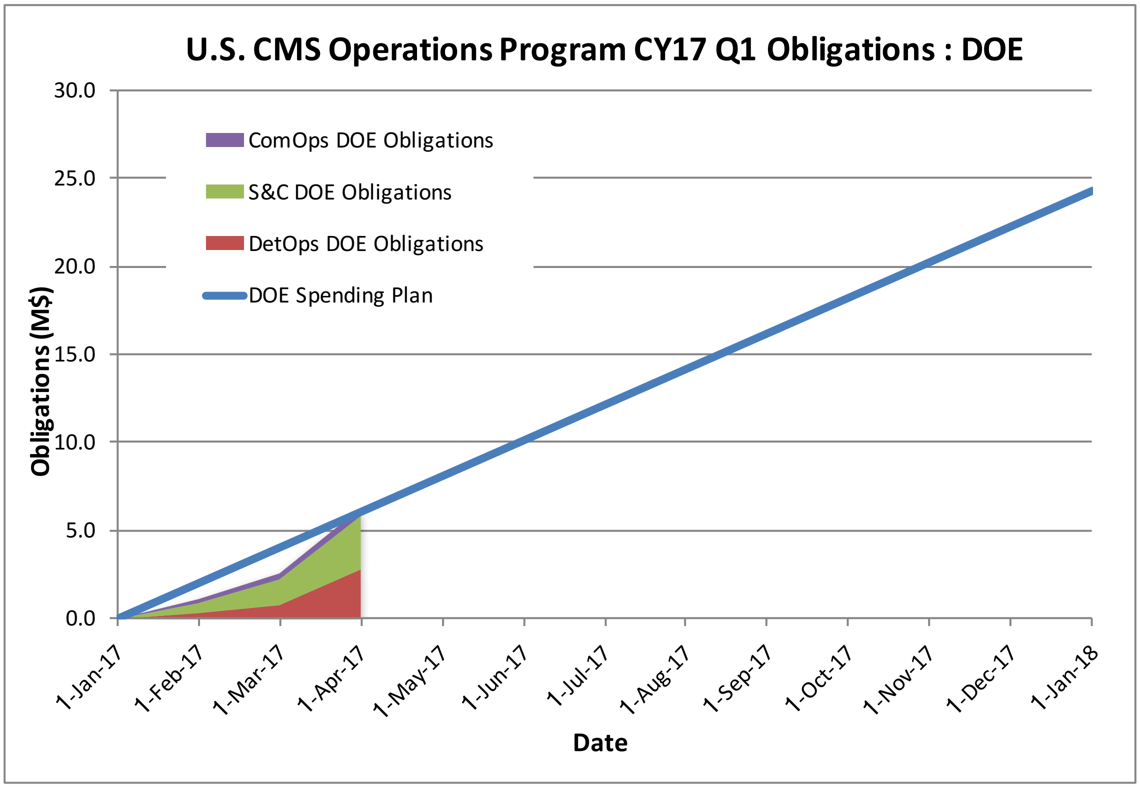


Figure 4: Obligations and spending plan for DOE funds. The spending plan is indicated with the assumption of equal monthly increments just as a rough guide.

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 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.

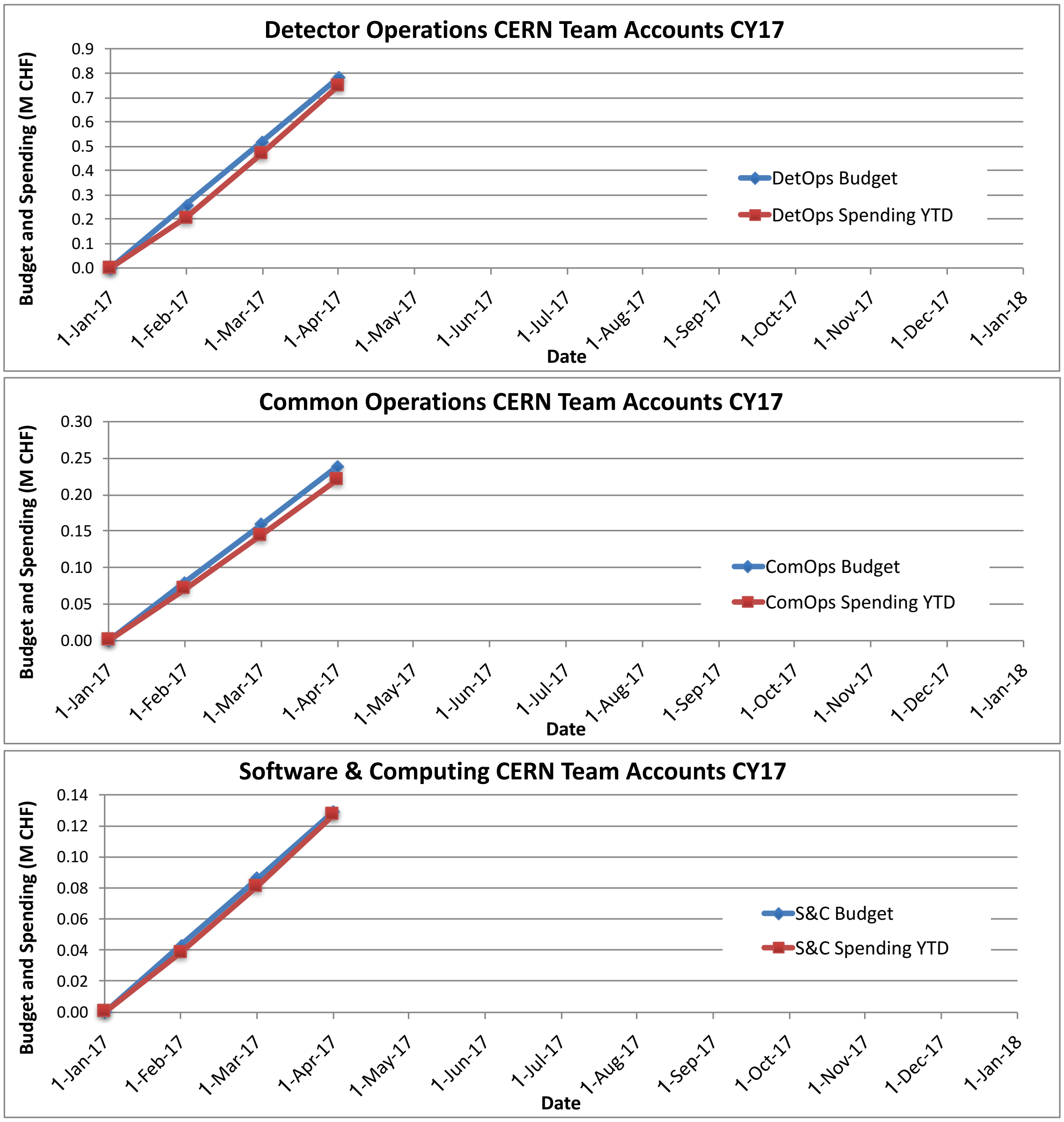


Figure 5: Budget plan and year-to-date spending, in Swiss francs, through DetOps (top), ComOps (middle), and S&C (bottom) Team Accounts.

CY17 Q1 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 - LTO tape media cost is higher than expected	10%	0 months	$366k
Risks added this quarter			
None			
Risks retired this quarter			
DAQ - FEROL40 modules will not be ready in time.	5%	0.5 months	$0
EMU – cooling system water leaks	5%	2 months	$400k

Figure 6: 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.

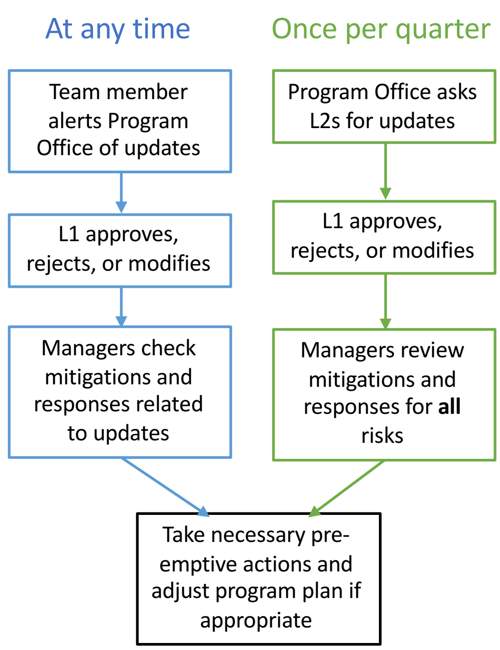


Figure 7: Summary of the two Risk Management Plan workflow paths.

Detector Operations

During this quarter the LHC has been in an Extended Year End Technical Stop (EYETS). For the CMS experiment a primary goal for the EYETS is the installation of a completely new pixel system. The extended stop has also allowed for the installation of the HF detector upgrade and for extensive repairs to other subsystems. Since the experiment has been involved in technical work we will not report performance metrics this quarter as they are somewhat meaningless at this time.

BRIL

In the Pixel Luminosity Telecope (PLT) detector two dead telescopes in one quadrant were scheduled for repair. The detector was successfully extracted and tested, and the dead telescopes were identified, though the cause of failure is not completely established. The original failures occurred after temperature cycling in the CMS detector. Cold-cycle tests with spare components are ongoing.The critical parts are the port cards and the hub on the optical motherboard. Replacement parts were available, however, we are now out of spares for the opto-motherboard hub chip. The two PLT halves were re-istalled successfully.

Two out of sixteen telescopes show partial failure in the readout that could not be recovered yet. The precision of the luminosity measurement with the PLT is not expected to reduce significantly when masking out those two telescopes. The BCM1F detector has been remodeled and re-installed together with the PLT. The detectors are currently calibrated. Software for automatic online corrections such as efficiency and tracks not from the interaction point is commissioned.

Table 1: BRIL Milestones

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

Tracker

The tracker system is on track to be ready for proton physics.

Pixels

During this quarter the old pixel detector was removed and the newly built Phase-1 pixel detector was installed. Both the Forward and the Barrel show about 97% of chanels present, and the decision was made to close CMS. The detectors are currently doing calibrations to prepare for taking cosmic rays for detector alignment prior to proton physics. Tests are also being performed to ensure the pixel detector operates correctly with the rest of CMS.

Strips

At the end of the quarter, the Silicon Strip detector is on and cold. The full set of calibrations done to prepare for running show no surprises. Initial rates and behaviors of cosmic rays in the strips are as expected.

Table 2: 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

In January and February all 136 MARATON low voltage supplies were equipped with a redundant thermal interlock. This followed an incident in July of 2016 when a component failure resulted in overheating and the thermal interlock failed. Only the timely intervention of on-call U.S. staff prevent a major incident. The MARATON crates were removed, transported to Prevessin, upgraded, transported to Meyrin, tested and validated and returned. This was a labor intensive activity that occupied our staff fully during these months. All units were successful upgraded and are fully operational. The laser calibration system underwent routine maintenance and both lasers are fully operational. In March the global runs started and the ECAL team went through the usual procedure to bring ECAL into operation after routine firmware upgrades to the DAQ and trigger system. At the end of March the system was fully operational.

Table 3: ECAL Milestones

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

HCAL

During the first quarter of 2017, the HCAL Operations group focused on installing the HF and partial HE Phase-1 upgrades during the EYETS.

For HF, the upgrade consists of installing dual-anode readout which will add discrimination to reject spurious signals affecting one anode, with the ability to recover energy measurement from other anode. 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. The Co^{60}

sourcing for calibration of the HF minus end was completed the week of March 17. The Co^{60} sourcing for calibration of the HF Plus end was completed March 3. Trigger primitive commissioning is in progress, and is on schedule to be complete in time for beam.

For HE, the plan was to install the new Silicon Photo Multipliers (SiPMs) and upgraded frontend electronics in entire HE during the EYETS. However, it was decided in January not to do complete the upgrade this year due to concerns over firmware readiness. Nevertheless, one upgraded HE readout box (out of 36) was installed to obtain experience with upgraded system. The upgraded HE readout box is operating well, and will remain in place during the 2017 run. 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. The firmware and software for "mixed" HE system is progressing well, and the Co^{60} sourcing for calibration for entire HE is complete.

One particularly bad HE hydrid photo-diode (HPD) was replaced with better HPD that was originally in readout box that was replaced with the upgrade electronics. The result is that a large fraction of the detector response at high eta in this region has been recovered. This helps confirm the hypothesis that some of the observed signal loss in HE is likely due to HPD aging as well as radiation damage.

Planning to install the complete HE upgrade in the 2017-18 year-end technical stop in progress. No show-stoppers have been found in completing the installation during that shutdown, which will be shorter than this year's EYETS.

Table 4: HCAL Milestones

Subsystem	Description	Scheduled	Achieved
HCAL	HF Phase 1 Installed	April 1	March 15
HCAL	HF Detector Commissioned	June 1	
HCAL	Ready for Physics	June 1	

EMU

A vigorous program of maintenance and repair to the CSC system has been carried out during the EYETS.

The main activity was the preventive maintenance on the cooling system of the ME1/1 chambers. Each chamber was extracted and the brazed joints of the cooling pipes were reinforced. The chambers were subsequently reinserted and tested for gas, cooling, and connectivity of the electronics before going through test runs with cosmic rays. By 22 March, all 72 chambers had been reinforced and reinstalled and all were verified as working in cosmic ray runs. These chambers have been integrated into global runs and are operating steadily.

As the ME1/1 chambers were extracted, the opportunity was used to replace any faulty electronics board or fix any faulty connections. In total, 14 Digital Cathode Front End Boards (DCFEBs) and one Anode Local Charged Track board (ALCT) were replaced. After completion of the ME1/1 repairs, access to Station 2 is anticipated, where a few electronics repairs are needed.

Table 5: EMU Milestones

Subsystem	Description	Scheduled	Achieved

Table 5: EMU Milestones

EMU	CSC ready for physics	May 1
EMU	Firmware to mitigate DCFEB EPROM problem	July 1
EMU	New HV settings for reduced gain	August 1

DAQ

The main focus during EYETS was the commissioning of the new FEROL40 boards to read out the new Pixel detector. All boards were installed and the DAQ and TCDS links and run-control interfaces for the new pixel detector were commissioned. Forward Pixel detector is routinely being read out in global runs while commissioning of the Barrel Pixel detector continues with minidaq setup.

An Expanded Event Builder was demonstrated to handle event sizes expected at a luminosity of 2.25×10^{34} (corresponding to pile of 70 Events) at 100 kHz level-1 accept rate (see figure 8.)

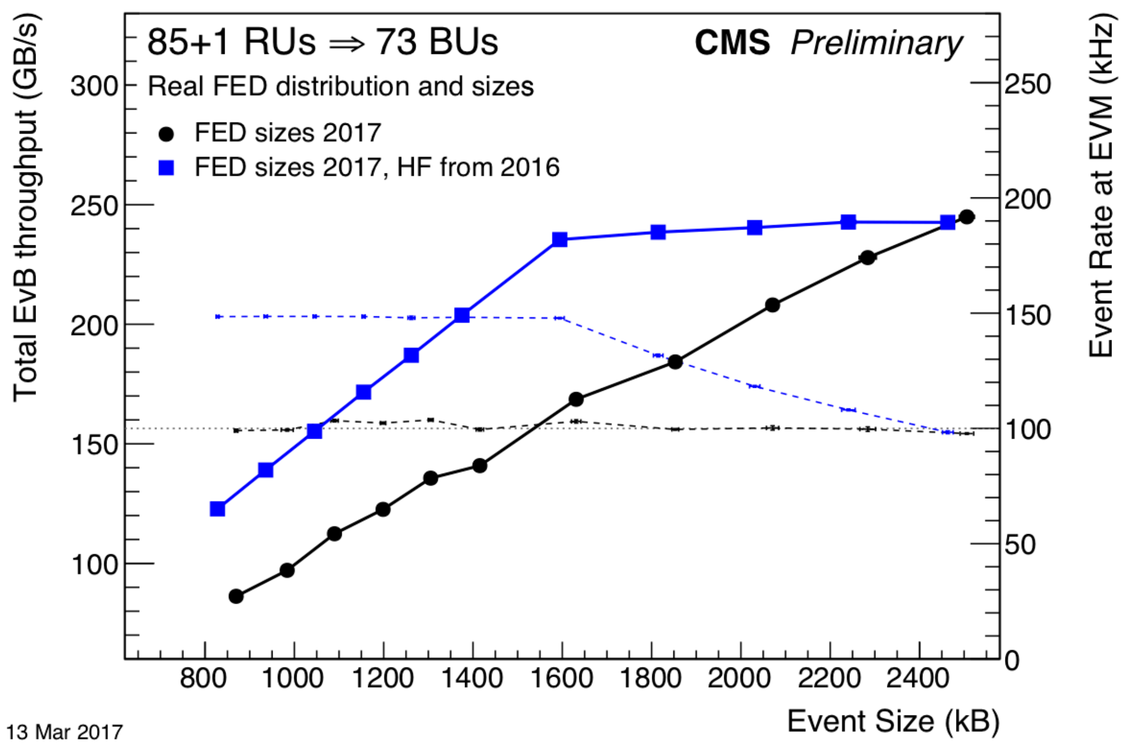


Figure 8: FED-builder measurements for two assumptions about expected FED sizes for 2017. Black points: HF subsystem saturates the 10 Gb links at 100 kHz Blue points: Using FED sizes from 2016 scale to Higher Luminosities. Limit of 148 kHz comes from Calorimeter Trigger FED which sends a fixed fragment size of 7985 Bytes.

Most of the planned improvements and consolidation activities during EYETS have been completed.

The DAQ is being used during Mid-Week Global Runs, in test stands, and DAQ integration and commissioning tests successfully. A proof of principle system to validate the architecture of the new WBM (called the Online Monitoring System - OMS) is on track to meet its milestone.

New HLT nodes as part of the replacement campaign were ordered. The new nodes will increase the HLT CPU power by 20%. The preparation of the racks for power and network have started.

Table 6: DAQ Milestones

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

Trigger

During this quarter the U.S. groups continued their work on the Stage-2 Layer-1 Calorimeter (CaloL1) Trigger Upgrade, and the endcap muon trigger upgrade systems as both prepared for data-taking later rhis year.

Regional Calorimeter Trigger and Stage-2 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 powered-on for 2017 running on the 30th of January. CaloL1 participated in three half-week global runs in February and March and started 24/7 operation on 27 March. In between global runs CaloL1 worked with HCAL, helping diagnose issues on the trigger links associated with the upgraded front-end for HCAL Endcap +17 and the HF. The scaling back of the HCAL Endcap Front-End upgrade has required only swapping 2 HCAL fibers at CaloL1 due to the μHTR firmware mapping change, and has been completed.

Endcap Muon Trigger

The Rice University, Northeastern, and University of Florida groups have worked on planned improvements and required consolidations during the initial period of the extended year-end technical stop (EYETS). The fibers coming from the RPC trigger system via the Beijing CPPF data concentrator cards have been connected to the EMTF optical patch panel, and from there to the EMTF processors. All links have been successfully tested. The addition of the RPC hits to the track-finding logic has been completed in the EMTF firmware. A global data-taking run in mid-March took place, with RPC hits observed in the EMTF DAQ readout. Adjustments to the synchronization of the hits with respect to CSC hits are in progress. The online DQM software is under revision to add additional monitoring plots of the RPC inputs to the EMTF. Changes to the offline software emulator of the EMTF, including the addition of RPC hits, is in progress. Similarly, a new training of the PT assignment for the EMTF PT LUTs using the RPC hits is in progress.

Table 7: Trigger Milestones

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

Software and Computing

This quarter corresponds to the extended year-end technical stop of the LHC, so no new proton-proton collision data was produced. However, Software and Computing activities were very high. The winter conferences were held in March, resulting in heavy use of computing facilities to prepare simulation samples and analyze the 2016 LHC data to prepare physics measurements. The U.S. Tier-1 and Tier-2 facilities performed well throughout the quarter, the operations groups provided the necessary samples, and many interesting results were ready for the conferences. Notably, the simulation production campaign took advantage of pre-mixed pileup samples, which had been developed by the other work areas during 2016, to allow for more efficient sample production. The development areas continued their efforts to prepare for 2017 LHC run, which will include new detector components in CMS, and for longer-term improvements that take advantage of additional computing facilities and modern software tools.

Table 8: Major milestones achieved this quarter

Date	Milestone
January 6	LPC BlueArc storage decommissioned and replaced with NFS mounted disk arrays
February 21	Tier-1 FTS upgrade to v3.5.7
March 15	Deployed Tier-2 pledged resources
March 15	Deployed Tier-1 pledged resources
March 25	Installed Singularity
March 31	Enabled separate settings of CMSSW event streams and threads, optimizing memory usage
March 31	Retired GIP/BDII
March 31	Incorporate LZ4 compression algorithm in ROOT

Fermilab Facilities

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 37 million wall-clock hours of processing to CMS. In preparation for the upcoming LHC run the Tier-1 upgraded its FTS (File Transfer Service) service to the latest production version, and took advantage of the downtime to update its dCache storage servers. To support U.S. CMS user analysis demands for the winter conferences in March, the facility temporarily reallocated 2,000 cores from the Tier-1 to the LPC CAF at the beginning of February. Analyzers fully used those resources through mid-March, when they needed to be returned for the 2017 Tier-1 pledge. The aging LPC BlueArc storage system was also migrated to a pair of newer, better performing NFS mounted Nexsan storage arrays in the beginning of January.

Figure 9 shows the site readiness metrics for the Tier-1 during the quarter. Overall, the Tier-1 passed CMS metrics for 95.3% of the quarter. There were four sets of incidents: In late January there was an issue with proxy renewal in data transfers. The FTS service became disabled in four separate incidents in late February due to off-site security scanning activity. Mitigations now are in place to make this service more robust to these scans. In mid-March job output staging was affected

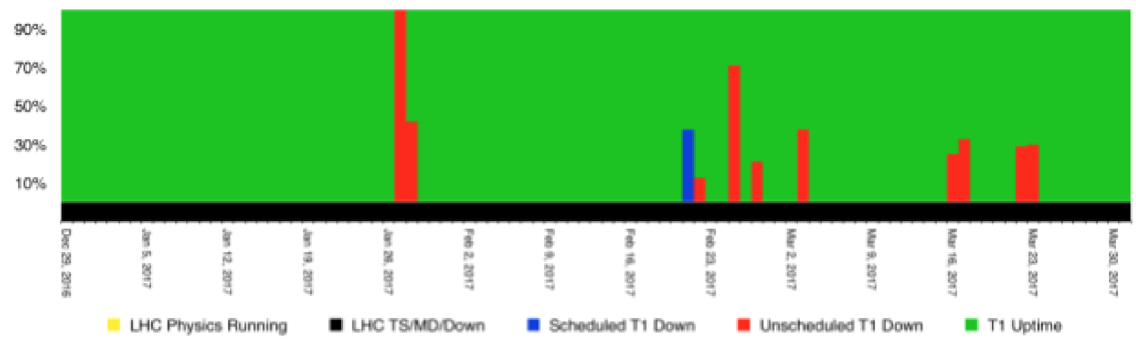


Figure 9: Fermilab readiness metrics for 2017Q1. Green indicates a passing metric, red means a failing metric, and blue a scheduled downtime. The height of the red bar indicates how much facility and services were affected that day. Black and yellow across the bottom indicates LHC machine running. This quarter, no yellow appears due to the LHC technical stop. Fermilab passed metrics 95.3% during this quarter.

by a bug in a new version of xrootd, which was then rolled back. Finally, there was an outage in the GUMS mapping service that prevented grid job authentication for a few hours the following week.

University Facilities

This quarter began with an extremely busy time for the U.S. CMS Tier-2 facilities during a period of intensive data analysis and greatly increased central production activities for simulated data for the winter conferences. High performance is expected from the sites at all times, but especially during the critical periods before major conferences. 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 91% "available" and 93% "ready". 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 48.9% of all computing time by Tier-2 sites in CMS (our commitment to global CMS is > 25%), as shown in Figure 10. This is an increase of 1.7% over the previous quarter.

As for progress on milestones and upgrades, the Tier-2 sites have deployed their pledged resources for 2017, installed the Singularity virtualization software, and retired GIP/BDII, all in time before April 1. As for milestones, four out of seven sites have implemented load-balanced gridFTP as a replacement for Bestman, and five out of seven sites have installed the new CMS space monitoring client package. Three out of six sites have replaced the legacy WLCG tools with gfal. Four of seven sites have converted at least one CE to SL7.

Nine Tier-3 sites required assistance from the Tier-3 support team this past quarter on issues ranging from PhEDEx upgrades and troubleshooting to OSG Computing Element (CE) and batch system support. The team collaborated with OSG on writing documentation for replacing Bestman with load-balanced grid-ftp configurations. CMS Connect continues to gain users with over thirty now registered. The team is working with the CMS Generators group to adapt gridpack production to CMS Connect to dramatically broaden the range of CMS computing resources that can

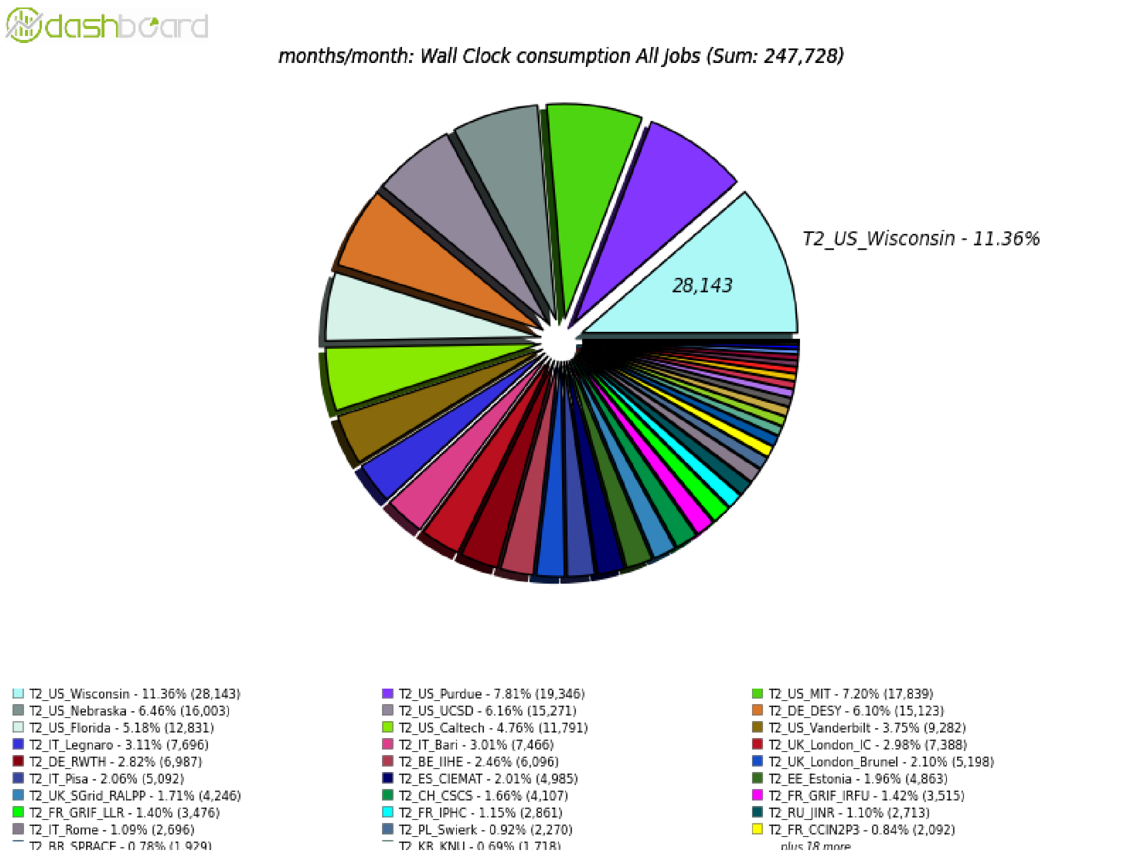


Figure 10: Percentage of total computing time delivered to CMS by Tier-2 sites world-wide, by site.

contribute to that task. Preparations to deploy the first Tier-3-in-a-box site are underway.

Computing Operations

An overview of Computing Operations activities is shown in figure 11. Monte Carlo generation for the analyses targeting conferences in Spring 2017 started in November 2016, with requests from the collaboration arriving through the middle of February. The generation campaign has used an event pre-mixing approach, where individual minimum bias events are generated and combined into a pile-up sample before the start of the campaign. Instead of reading a large number of minimum bias events during the digitization step to simulate the pile-up condition, only one already pre-mixed event is read instead. The pre-mixing approach results in much lower input data rates and also lower CPU usage. Over 9 billion events were generated and provided to the physics groups in time for the spring conferences. About 600 million events with old-style pile-up simulation were also requested and completed by mid-January. About 120K cores were used simultaneously during the campaign, with peaks up to 175K.

Work on refinements to the physics objects used in analysis concluded in the beginning of February. For about 6 billion events the small event format used for analysis, miniAOD, was recreated to include those improvements. The campaign was completed by mid-February, demonstrating our ability for the fast turn around for this kind of processing.

Monte Carlo generation for the Phase-1 and Phase-2 upgrades ran in the second half of February until early March. The Phase-2 upgrade samples stressed the system significantly due to larger event sizes, the required high pileup of 200 minimum bias events, and usage of the old-style pile-up simulation. Job submission had to be adapted so as not to overly stress computing cluster infrastructure.

The recommissioning of the detector in March has resulted in global runs and cosmic data being recorded, the first steps towards regular operations of the Tier-0 facility that will begin in the coming quarter.

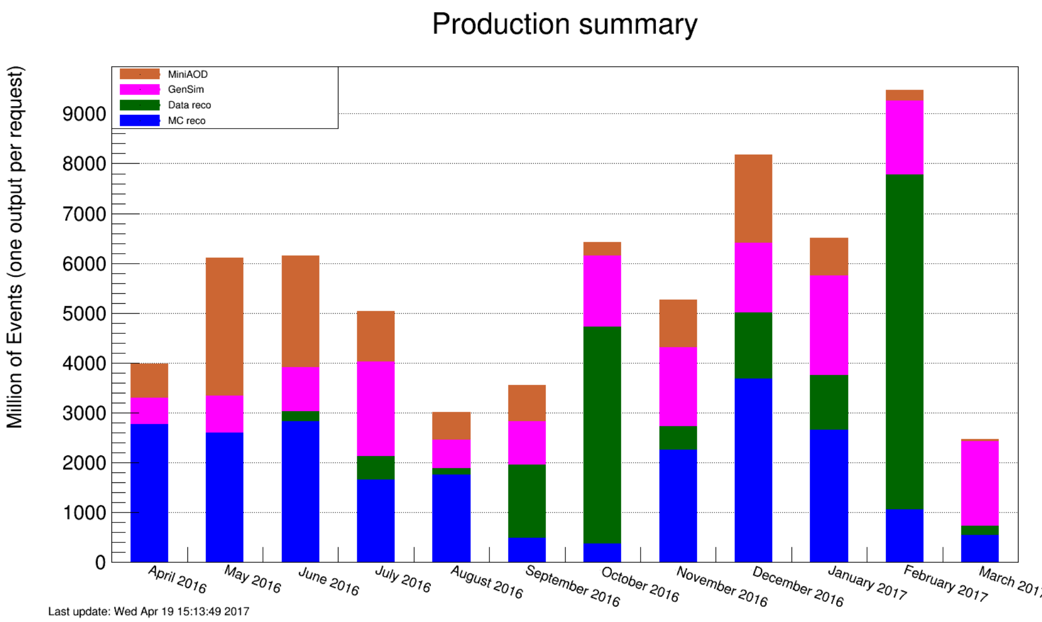


Figure 11: Overview of CMS production activities, showing the number of events produced each month in the different categories.

After observing a bottleneck in staging data back from tape at the end of last year, a staging test was conducted at all Tier-1 sites of CMS. The overall performance was lower than desired due to excessive tape mounts that were triggered by various components of the data management system. Work is ongoing to understand the limits and tune the parameters.

Computing Infrastructure and Services

This quarter was spent in laying some of the groundwork for future developments and needs. WMArchive, the new job-level monitoring, was put into production and significant progress was made integrating this data source into MONIT, the new CERN-provided monitoring infrastructure. WMAgent was modified to allow separate settings for the number of processing threads and simultaneous events under reconstruction, an important part of maintaining both efficiency and the memory footprint of upgrade workflows within current bounds. WMAgent versions 1.1.0 and 1.1.1 were released, incorporating these features. The Tier-0 facility was modified to work with the new data transfer system between CMS Point-5 and the Tier-0, which is based on a state machine rather than message passing.

For U.S. CMS use of High Performance Computing (HPC) systems, our workflows were commissioned for *Comet* on *Stampede*, at the level of the startup allocation we were granted. We also put into production the construction of Shifter images for NERSC, which is being done at Fermilab. GlideinWMS improved its monitoring of payloads which serves as a cross-check of the job-level monitoring information.

During the quarter we formed and began modifying DBS and all related software to be able to track event counts per file per 23-second luminosity section (previously we only tracked events per file). DAS completed modifications to be able to run unmodified on both Python 2 and 3, while also developing a much faster client using the Go language, which moves the data aggregation from the DAS server into the DAS client.

Software and Support

We are focusing on the computational efficiency of the CMS threaded software framework, both for x86 platforms and for very-high thread counts needed for KNL platforms. We made significant improvements in the area of simulation geometry initialization to decrease the application startup time and improved our tools to find concurrency bottlenecks. The work on improving the multi-threaded performance of the I/O layer is on track and progressing well, as well is the work on the C++ modules support in the framework, which will speed up compilation significantly. The integration and testing of extended Python-based analysis toolkit is underway. The latest release cycle now provides access to Theano, TensorFlow and other machine learning toolkits, as well as Jupyter notebooks. The milestone of integrating the LZ4 compression into ROOT was reached. This gives the advantage of 4-7 times faster file reading with only slightly larger file sizes. At this time, CMS prefers to minimize disk usage, so this will not be the default option, but analysts who optimize on speed can also just switch off compression altogether.

In preparation for the start of collision data taking later this year, the calibration and alignment infrastructure (Frontier) now supports the new LHC Run 2 conditions system by supporting HTTP 1.1 chunked encoding. We are on track to optimize the 2017 geometry description, having completed major components, and are now concentrating on medium and small issues. The release for cosmic ray data taking was completed including the final 2017 geometry layout and is now used in the current cosmic ray campaign. The event display was updated with the latest software release to support the cosmic ray data taking as well. We are on track with developments for the releases for initial collisions and the legacy re-reconstruction of 2016 data. We also published releases for the Phase-2 upgrade MC production for the HL-LHC trigger TDR.

Regarding R&D, we are studying concurrency for web-based apps by evaluating Go instead of Python, having already written Go server and client implementation for our dataset aggregation service (DAS). We are also progressing in using ROOT files directly in big data analytics platforms like Apache Spark. The vectorized tracking R&D project progresses well, now being able to reconstruct tracks in different parts of the detector in parallel. We are concentrating both of GPUs and KNL architectures. We submitted various CHEP proceedings and are awaiting their acceptance, and are preparing to submit conference abstracts to ACAT 2017 and other venues.