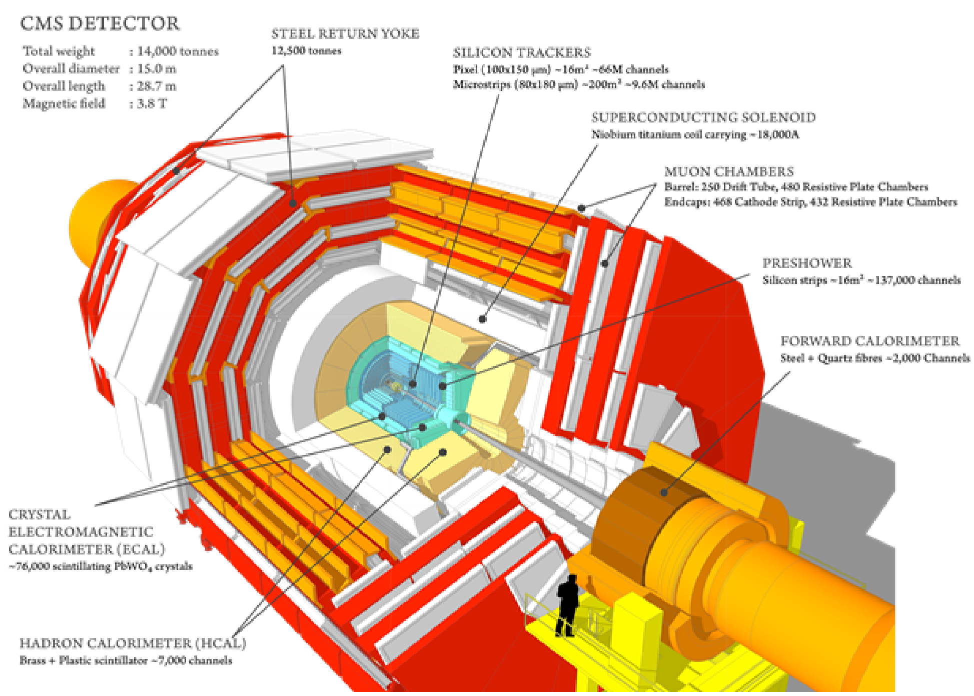
U.S. CMS Compact Muon Solenoid Operations Program
Quarterly Report for the Period Ending March 31, 2018

U.S. CMS Operations Program



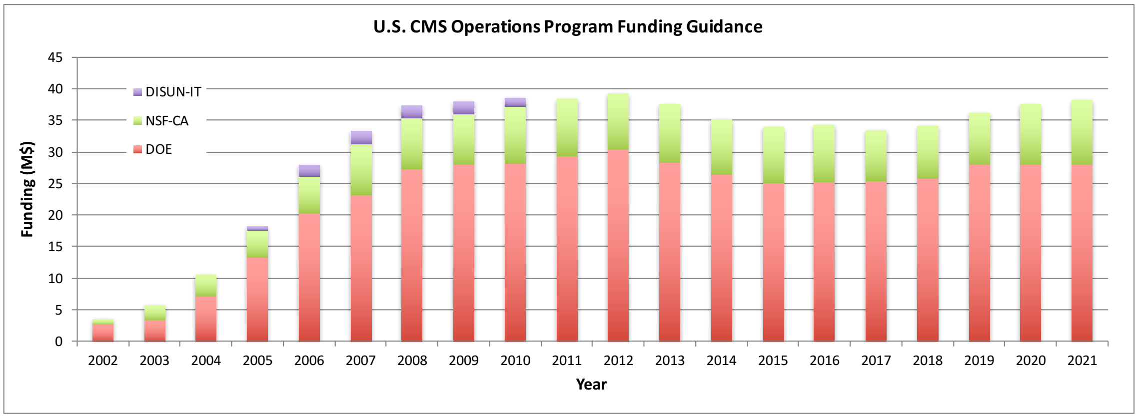


Figure 1: The annual U.S. CMS Operations Program funding provided by DOE and NSF. For 2002 through 2018 the chart shows the actual funding, while for 2019 onward the current funding guidance is shown.

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 2018, as well as the funding guidance for 2019 through 2021, is shown in Figure 1. The allocations shown for 2018 and beyond do not include any NSF funds designated for preparations of the MREFC HL-LHC project.

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 2018 took place in September of 2017. As an additional source of input to the planning process, the Resource Allocation Advisory Board met in the Fall of 2017, 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 information from the funding agencies.

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 2018, a total of 43 SOWs (24 DOE and 19 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 CY18 spending plan, as of the end of Q1, is shown for DOE and NSF funds in Figure 3.

U.S. CMS Detector Operations Change Control Activity

WBS	Subsystem	Change Request Number	Description of Change	CY18 Q1 Plan	Change $	CY18 Q2 Plan
11	Endcap Muon	CR-031, 032, 033	Increase UC Riverside COLA and UC Davis Labor, decrease Rice labor	$1,793,564	$8,618	$1,802,183
	Endcap Muon MEX/1	Adjust	Additions prior to SOWs	$2,000,000	$106,618	$2,106,618
12	Hardon Calorimeter	CR-044, 045, 046, 047, 048	Iowa engineering labor, CERN TA COLA and travel, Florida State M&S for nitrogen laser, Maryland engineering labor	$1,963,686	$141,434	$2,105,120
13	Trigger	CR-021, 022, 023	NEU undergrad travel, Notre Dame CERN TA COLA for rate monitoring, decrease Rice engineering labor	$847,319	($4,000)	$843,318
14	Data Acquisition	CR-009	Adjustments and UCSD CERN TA COLA	$1,105,839	$19,521	$1,125,360
15	Electromagnetic Calorimeter	CR-019, 020	Move Caltech travel to CERN TA, add Minnesota CERN TA COLA, reduce CERN TA engineer support	$768,034	($12,419)	$755,615
16/17	Tracker (Fpix & SiTrk)	CR-011, 012	Adjustments and Catholic University CERN TA travel and COLA, Fermilab travel for DCDC replacement	$916,196	$60,766	$976,961
18	Detector Support			$121,058	$0	$121,058
19	BRIL	CR-004	Adjustments, Princeton M&S, Rutgers labor & M&S	$264,231	$35,108	$299,339
11-19	**Detector Operations**			**$9,779,926**	**$355,646**	**$10,135,572**

U.S. CMS Common Operations Change Control Activity

WBS	Subsystem	Change Request Number	Description of Change	CY18 Q1 Plan	Change $	CY18 Q2 Plan
21.2	Common Costs (M&OA)			$4,373,615	$0	$4,373,615
21.3	Run Coord. and Monitoring			$162,881	$0	$162,881
21.4	LHC Physics Center			$772,936	$0	$772,936
21.5	Operations Support	CR-112	CERN TA M&S for large-area SiPMs for barrel timing	$975,750	$47,250	$1,023,000
21.6	Program Office	Adjust	FNAL finance person moves to Phase1 and HL-LHC	$1,153,222	($95,775)	$1,057,448
21.7	Education and Outreach			$110,585	$0	$110,585
21	**Common Operations**			**$7,548,990**	**($48,525)**	**$7,500,465**

U.S. CMS Software and Computing Change Control Activity

WBS	Subsystem	Change Request Number	Description of Change	CY18 Q1 Plan	Change $	CY18 Q2 Plan
22.1	Fermilab Facilities			$6,141,149	$0	$6,141,149
22.2	University Facilities	Adjust	Caltech labor changes	$3,738,734	($31,574)	$3,707,159
22.3	Computing Operations			$877,578	$0	$877,578
22.4	Computing Infra. and Services	Adjust	Caltech labor changes, Fermilab HEPCloud support	$2,825,390	($94,859)	$2,730,531
22.5	Software and Support			$2,488,770	$0	$2,488,770
22.6	S&C Program Management & CMS Coordination	CR-022, Adjust	UCSD labor for blueprint effort; adjust for FNAL security	$298,407	$117,135	$415,542
22	**Software and Computing**			**$16,370,027**	**($9,299)**	**$16,360,728**
U.S. CMS Operations Program Total				**$33,698,943**	**$297,822**	**$33,996,766**

Figure 2: Spending Plan Change Log for CY18 Q1.

WBS	Subsystem	DOE Funds	NSF Funds	Total
11	Endcap Muon	$1,464,294	$337,889	$1,802,183
	Endcap Muon MEX/1	$2,106,618	$0	$2,106,618
12	Hadron Calorimeter	$2,069,384	$35,736	$2,105,120
13	Trigger	$560,225	$283,093	$843,318
14	Data Acquisition	$1,125,360	$0	$1,125,360
15	Electromagnetic Calorimeter	$755,615	$0	$755,615
16/17	Tracker (Fpix & SiTrk)	$918,893	$58,068	$976,961
18	Detector Support	$121,058	$0	$121,058
19	BRIL	$116,604	$182,735	$299,339
11-19	**Detector Operations**	**$9,238,051**	**$897,521**	**$10,135,572**
21.2	Common Costs (M&OA)	$3,473,774	$899,841	$4,373,615
21.3	Run Coordination and Monitoring	$54,945	$107,936	$162,881
21.4	LHC Physics Center	$772,936	$0	$772,936
21.5	Operations Support	$767,340	$255,660	$1,023,000
21.6	Program Office	$955,148	$102,300	$1,057,448
21.7	Education and Outreach	$0	$110,585	$110,585
21	**Common Operations**	**$6,024,143**	**$1,476,322**	**$7,500,465**
22.1	Fermilab Facilities	$6,141,149	$0	$6,141,149
22.2	University Facilities	$120,904	$3,586,255	$3,707,159
22.3	Computing Operations	$417,330	$460,249	$877,578
22.4	Computing Infrastucture and Services	$1,802,232	$928,298	$2,730,531
22.5	Software and Support	$1,450,849	$1,037,920	$2,488,770
22.6	S&C Program Management and CMS Coordination	$156,852	$258,690	$415,542
22	**Software and Computing**	**$10,089,316**	**$6,271,413**	**$16,360,728**
U.S. CMS Operations Program Total		**$25,351,510**	**$8,645,256**	**$33,996,766**

Figure 3: Spending plan at the end of CY18 Q1, for funds from DOE, NSF, and the total.

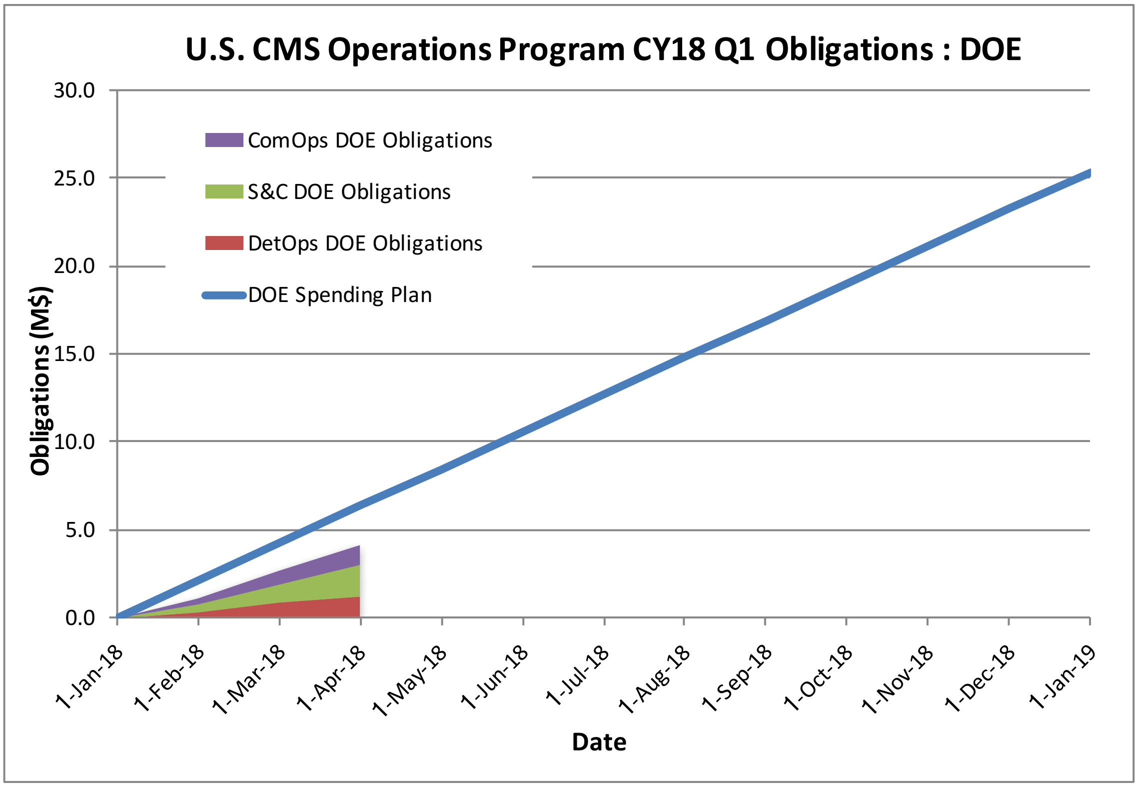


Figure 4: Obligations and spending plan for DOE funds. The spending plan is indicated with the assumption of equal monthly increments just as a rough guide.

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 fourth 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 $8.4M in NSF funding, $1.0M in subawards went out this quarter, in addition to spending directly at Princeton.

Resources deployed at CERN, which are paid directly in Swiss francs, account for approximately 26% of the 2018 spending plan. This carries considerable exposure to the variable exchange rate. A rate of 0.9 CHF/USD has been used for planning, while the actual rate in CY18 Q1 averaged 0.95 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 3,859K 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

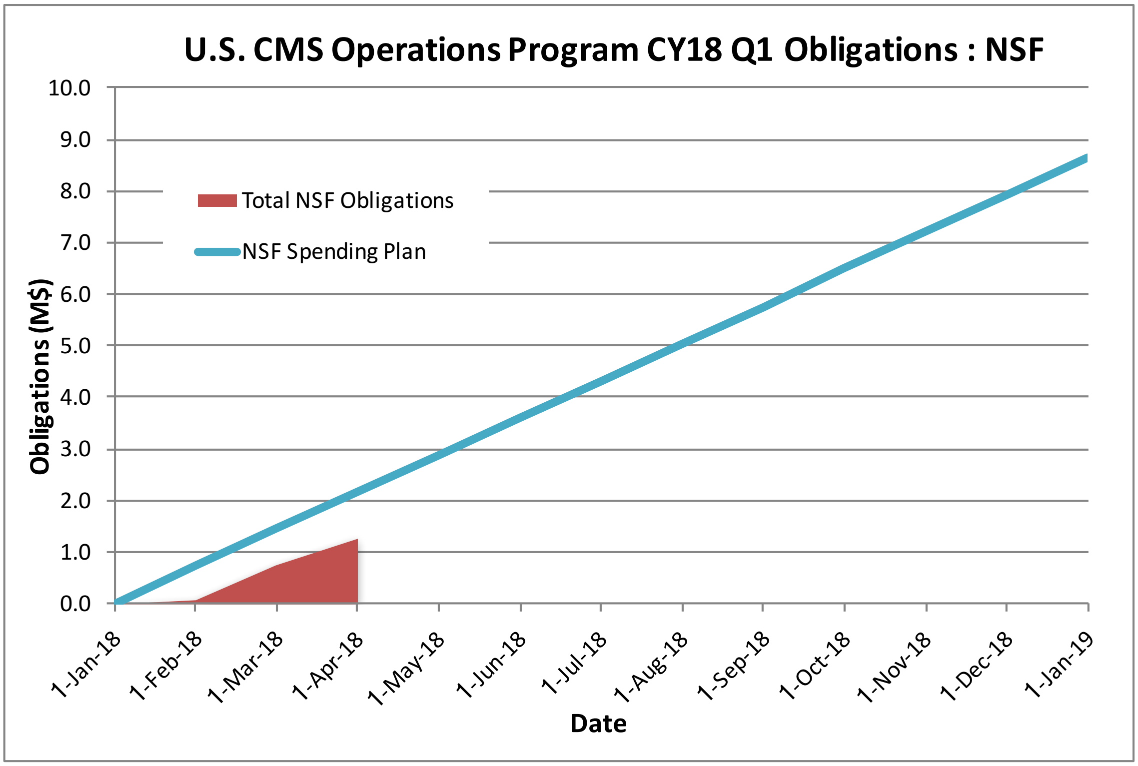


Figure 5: Obligations and spending plan for NSF funds. The spending plan is indicated with the assumption of equal monthly increments as a rough guide.

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 34 open risks spread across the program. At the end of the quarter, there were 35 risks, with threats summing up to a total of \$8.6M, and opportunities totaling to \$0.9M. Figure 7 shows the top few risks at the end of the quarter, ranked by *Probability* × *Cost Impact*, as well as any risks closed or added 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 man-

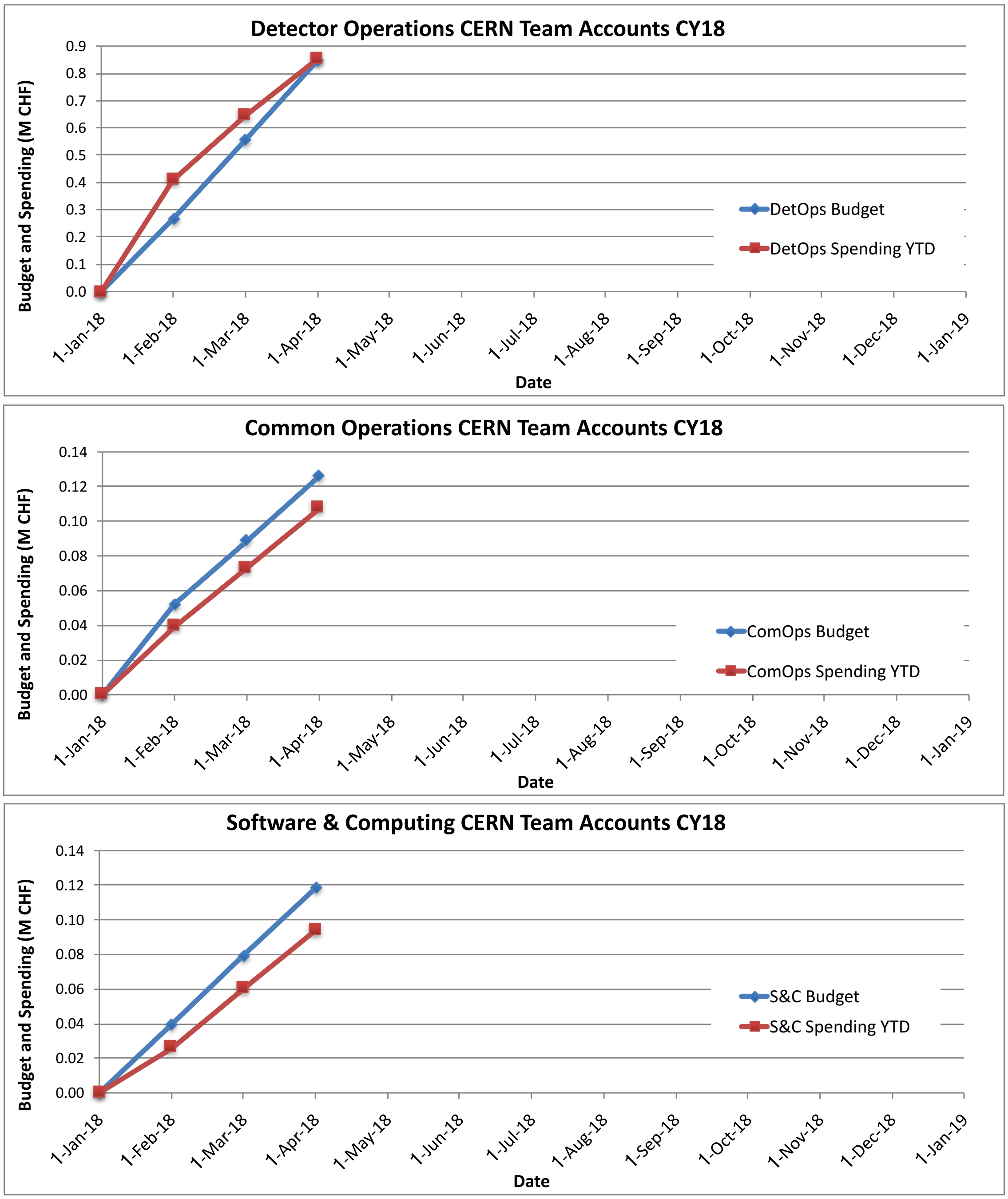


Figure 6: Budget plan and year-to-date spending, in Swiss francs, through DetOps (top), ComOps (middle), and S&C (bottom) Team Accounts.

CY18 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 - Bridge OSG technology evolution staff to new funding	25%	0 months	$200k
Risks Added this quarter			
ComOps - Fermilab overhead rates decrease (opportunity)	5%	0 months	-$40k

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

ager 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 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.

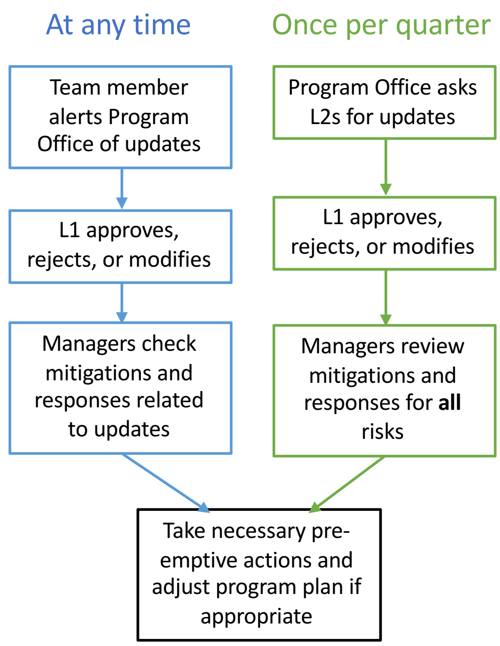


Figure 8: Summary of the two Risk Management Plan workflow paths.

Detector Operations

During this quarter LHC complex has been in a year end technical stop (YETS). The CMS experiment takes advantage of these technical stops to make repairs and install upgrades. Notably during this stop, the "Phase 1" Hadronic Endcap upgrade has been installed and commissioned. By the end of the quarter the detector was closed, taken cosmic ray data and seen "beam splash" events in preparation for physics data running.

BRIL

The Pixel Luminosity Telescope was successfully reinserted. The status of the hardware is the same as before the shutdown. The full performance evaluation requires high-voltage scans that will happen after first collisions. Software is in place to track the efficiency versus irradiation of the silicon. To maintain high efficiency during the 2019 data taking the HV supply range has to be extended requiring the acquisition of modules for the HV crate. All pixel detectors have been calibrated and registered first splash events on March 30. All BRIL (monitors and luminometers) systems are ready for collisions.

Elements of the detector will have to be replaced after this run and in preparation for this the replacement circuit boards have been re-designed and are ready for submission. The optical motherboard, which was the critical component, has been adapted to modernized hub chips and the new design was successfully tested.

Table 1: BRIL Metrics

Working Metric	Performance
Fraction of telescopes fully operational	90%
Lumi lost	0 /pb

Table 2: BRIL Milestones

Subsystem	Description	Scheduled	Achieved
BRIL	Pixel Luminosity Telescope reinstalled	March	March
BRIL	Update Lumi for 2017	March	March
BRIL	Ready for Beams	April	March
BRIL	Preliminary Luminosity for Conferences	July	
BRIL	Improve 2018 Lumi numbers	December	

Tracker

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

All calibrations that do not require LHC collisions have been performed. Good performance has been demonstrated in cosmic runs so far. The aim of further cosmic running is the collection of sufficient tracks for initial detector alignment.

Primary scans with proton beam for timing and bias are expected to be completed in time for the

LHC proton intensity ramp up. At this time we see no show stoppers to meeting our readiness milestone.

Tracker Pixel Detector

The complete pixel detector was reinstalled with new DCDC converters and six (out of eight) severely damaged modules in the barrel (BPiX) layer 1 have been replaced. The plan for this year is to operate at a lower input voltage to the DCDC converters, to try to reduce the probability that the DCDC internals fail in they way they did last year. We have also modified the response matrix to LHC conditions, to try and reduce the number of power cycles of the detector (also a measure meant to reduce the strain on the DCDC chip). We will still need to power cycle parts of the detector though as the Single Event Upset (SEU) issue with the Token Bit Manager (TBM) is still present.

Besides the scans mentioned above, we will be paying close attention to the operability of modules damaged by beam operations last year with high voltage and no current to the transistors in the analog sections (due to the DCDC issues). This will help inform us as to whether or not we need to disable more of the detector if there is a DCDC failure (the granularities are different). We are also working to deploy a much faster way to program the modules and to re-enable the power cycling of modules with the TBM SEU issue during data taking to maximize efficiency.

Tracker Strip Detector

Strips are operating 10C colder this year. This was done to lower the bias current, and hence the heat load, in the detector. Primary calibrations are complete at the cooler temperature and the strips look ready for first beams.

Besides the scans mentioned above, we will be tweaking our data taking of auxiliary information (spy data etc.) for the strips.

Table 3: Tracker Metrics

	Pixels	Strips
% Working channels	97.3	96.2

Table 4: Tracker Milestones

Subsystem	Description	Scheduled	Achieved
Tracker	Pixel Phase 1 Detector Removed	Jan 20	Jan 20
Tracker	New pixel DC-DC converters installed	Jan 30	Jan 30
Tracker	Pixel Phase 1 Detector Re-installed	Feb 21	Feb 21
Tracker	Strips and Pixel Phase 1 Detector Ready for Collisions	May 11	

ECAL

This quarter was devoted to a variety of activities in the year end technical stop. These include lowering the operating temperature of the endcap pre-shower to -15^{o}C to mitigate against the increased leakage current in the silicon from radiation damage, installation and commissioning of a new higher bandwidth optical link card (sLink) that connects the data concentrator card (DCC) to the DAQ, a new version of the DCC firmware to exploit the sLink upgrade, and upgrading the DAQ software to the latest version (XDAQ15). In addition, the normal run preparations continued through the quarter, with adjustment of the zero suppression, selective readout and trigger thresholds to accommodate the expected 2018 running conditions. All these activities were completed on schedule and the ECAL is ready for beam.

Table 5: ECAL Metrics

Metric	Performance
Fraction of channels operational: EB	99.1%
Fraction of channels operational: EE	98.4%
Fraction of channels operational: ES	99.9%
Downtime attributed pb^{-1}	42
Fraction of downtime attributed	6%
Resolution performance	2.5%

Table 6: ECAL Milestones

Subsystem	Description	Scheduled	Achieved
ECAL	ECAL fiully powered on with HV/LV fully functional	March 1	March 1
ECAL	Complete sLINK upgrade and tests	March 21	April 1
ECAL	Initial thresholds and calibrations set	April 1	April 1
ECAL	Ready for Beam	April 15	April 1
ECAL	Preliminary Calibration	June 15	

HCAL

During the first quarter of 2018, the HCAL Operations group focused on the installation of the Phase 1 HE upgrades during the 2017-18 YETS, and on preparations for 2018 data taking.

The decision to proceed with the full HE Phase 1 Upgrade was taken in January 2018. The upgrade has silicon photomultipliers (SiPMs) instead of HPDs and has the new version of the QIE frontend chip, the QIE11. In addition, the longitudinal segmentation of the HE is increased to allow for radiation damage compensation. The installation of the plus end (HEP) upgrade was completed by the end of January, and the installation of the minus end (HEM) upgrade was completed by the middle of February. Both detectors were calibrated with Co-60 sources by February 24, essentially one week ahead of schedule. Initial analysis of the data shows phi uniformity improved with the SiPMs by a factor of three compared to that obtained with the HPDs.

The online and offline software needed for the upgraded HE is ready, although improvements are still being made. The prompt and offline reconstruction will run with full Phase 1 segmentation

(6–7 depths instead of the 2–3 in the legacy detector).

The success of the upgrade installation was due to the excellent performance of the HE upgrade team, and to the careful planning and numerous tests that were done prior to the installation.

Work on the HB Phase 1 upgrades which will take place in LS2 also continued. A "trial upgrade" of HBP10 readout modules 3 and 4 was preformed as a test. There were no major surprises, and the new readout modules fit well into the readout box. There was an issue discovered with excess cable length leading to excess height in the cable trays. A decision was made to remake cables L10 and L11 to remedy this.

For HF, firmware updates were made to both the on-detector and off-detector electronics. These proceeded without issue. For HO, the digital readout of 16 fibers was optically split to a μHTR hosted in auxiliary readout crate. 100% agreement between the VME readout and the μTCA was obtained for data acquired in local running. This test was done in preparation for switching the HO readout from VME to μTCA in LS2.

Table 7: HCAL Metrics

Metric	Performance
Fraction of channels operational: HF	100%
Fraction of channels operational: HE	100%
Fraction of channels operational: HB	99.88%
Fraction of channels operational: HO	99.72%

Table 8: HCAL Milestones

Subsystem	Description	Scheduled	Achieved
HCAL	HE Phase 1 Installed and Co-60 Calib. Completed	Feb 28	Feb 24
HCAL	HE Detector Commissioned	Apr 1	March 15
HCAL	Ready for Physics	Apr 15	
HCAL	Data Loss $< 1%$	June 1	
HCAL	1% to 2% Calibration	July 1	

EMU

Operations at CERN

A vigorous program of maintenance and repair of the CSC system was carried out in the year end technical stop (YETS). The highest priority task was the investigation of a leaking cooling water circuit in the YE-1 disk. This leak had forced two ME1/1 chambers to be disabled in the 2017 run. The source of the leak was identified to be at the patch panel on the surface of the YE-1 nose, in a connection between the supply Cu pipe to the ME-1/1/34-35 cooling loop and the CSCs. The leak stopped when the specific connection was redone and all such joints were checked. The disabled chambers were re-enabled and tested, they are now both working fine. The other main activity was the replacement of electronics boards that had failed during the 2017. The majority of these (12 cases) were ME1/1 DCFEB boards where one of the Finisar optical transmitters had failed. Another outstanding issue in the 2017 run was the spontaneous power cycles of some of the Maraton LV supplies on a few occasions. A damaged network cable in the CANbus control system was found and fixed. At the conclusion of the YETS, 99.0% of the channels in the CSC system were working and being read out, up from 98.2% at the end of 2017.

In March, a week was devoted to upgrading the CSC online computers to versions of the operation system and DAQ libraries and ensuring that all of the CSC online software was functioning properly.

Studies were carried out of an observed excess of segments in top of ME4/2 ring. The source appears to be backscatter from an absorber on the LHC focusing quadrupoles located at the entrance of the CMS experimental cavern inside the rotating shielding. This does not affect L1 triggering but does affect the DAQ rate. Mitigation will require additional shielding in forward region.

In studies of CSC gas with reduced CF4, mini-chamber source exposures were completed with 5% and 2% CF4, in place of the standard 10%. No degradation in response was seen, but post-irradiation investigation shows evidence of cathode and wire aging. This will be followed up with a XEM/SEM analysis of sample materials.

Table 9: CSC Metrics

Metric	Performance
% Working channels	99.0%

Table 10: EMU Milestones

Subsystem	Description	Scheduled	Achieved
EMU		April 4	March 29
EMU	New HV settings for reduced gain	July 31	

MEX/1 Detector Improvement

In January, we completed a U.S. CMS cost and schedule review of the CSC on-chamber electronics replacement. The cost estimates and schedule were validated, and the SOWs were submitted and approved. In January and February, the process began of setting up POs between Fermilab and the institutions responsible for the board production.

ALCT mezzanine prototypes orders submitted in February for both flavors of board: the LX100 (for the ME2,3,4/1 chambers) and the LX150T (for ME1/1 and the outer chambers). The prototypes of the LX100 were returned to UCLA at the end of March, and the LX150T prototypes are expected in April.

The order for the second DCFEB prototype is ready to be submitted. There were some issues that contributed to a delay in these prototypes. The firm that assembled the first prototype (Dynalab) was unavailable for the second prototype, and a new assembly house (Compunetix) had to be found. The FPGAs needed (Xilinx Virtex-6) were out of stock and are not expected until mid-May. The order is expected to go out in mid-April, with prototypes back in mid-May. The CMS Electronics Systems Review (ESR) for the on-chamber electronics relies on the results of the tests of the DCFEB prototypes, and it might need to be delayed from its nominal date of 1 June.

In the process of obtaining new quotes for the full production of DCFEBs, a few components were flagged as having very long lead times. Of particular note is the ADCs, where the distributors were quoting lead times of 28 weeks. In response to this, we re-engineered the production schedule to start the pcb fabrication in early Summer, but to do the assembly in large batches in the Fall when the components become available. We also obtained approval from USCMS for early procurement of these long lead-time components, but the PO may not be in place until May.

The low voltage distribution boards (LVDB), which are a Russian responsibility, progressed according to schedule with second prototypes completed and tested in March. These are ready for production as soon as the required reviews are complete.

Table 11: EMU Milestones - MEX/1 Detector Improvement

Subsystem	Description	Scheduled	Achieved
EMU-MEX/1	ALCT mezzanine prototype received	Apr 30	
EMU-MEX/1	Second xDCFEB prototype received	May 1	
EMU-MEX/1	CSC On-chamber Electronics System Review completed	Jun 15	
EMU-MEX/1	Order placed for Maraton LV supplies	Aug 31	
EMU-MEX/1	Production of xDCFEB PCBs released	Sep 2	
EMU-MEX/1	CSC on-chamber optical fibers ready for installation	Nov 1	
EMU-MEX/1	CSC LV junction boxes ready for installation	Jan 15 2019	

DAQ

The DAQ group used the first quarter of 2018 to consolidate the system and prepare for the 2018 proton and heavy ion runs. A total of 400 new PC servers for HLT, replacing nodes acquired in 2012, have been installed in the beginning of 2018. The acceptance tests and integration into the DAQ system is about to be completed. The new nodes will give an increase of about 20% in HLT computing capacity compared to 2017. This provides additional headroom to handle higher instantaneous luminosities, to reconstruct the data from the upgraded HCAL readout, and to possibly mitigate a non-optimal pixel detector configuration due to failing DCDC converters.

New sub-detector back-end electronics from DT (uROS), HCAL and CT-PPS has been integrated into the DAQ. All ECAL readout channels have been migrated from copper to optical SLINKs. A newly developed mezzanine card with more buffer space reduces the deadtime from the ECAL readout.

The first version of the online monitoring system (OMS) has been released. The OMS is the successor of the web-based monitoring (WbM) system, which will be retired during LS2. Work is ongoing to complete the pages providing the trigger information. The first step to replace the aging SCAL hardware has been taken by creating a new software based facility within the event builder which can inject metadata into the event stream. This data has been made available in CMSSW and will be verified once physics data taking resumes.

Tests and optimization of the throughput of the HLT output to storage and subsequent transfer to remote EOS at IT department are in progress. This activity is important for planning the data-taking strategy for the heavy-ion run and data parking use cases during the last year of operation before LS2.

Extensive measurements have been carried out to understand the Infiniband performance for future DAQ systems. We use the DAQpipe test suite developed by LHCb in collaboration with LHCb colleagues to get a better understanding how future interconnects compare to the current production system. We also carried out MPI (message passing interface) tests to explore the suitability of this technology for future event-builder systems.

The HLT farm was used during the technical stop as a cloud infrastructure for offline data processing and contributed significantly to the production. During the period where all HLT resources were available it provided about 50'000 virtual cores and could run all types of workloads from the EOS storage at the IT department thanks to the high bandwidth link (4x40 Gb/s) between Point-5 and IT Meyrin site.

The configuration of the test system for DAQ3 for run-3 after LS2 has been defined and the equipment has been ordered.

The DAQ Phase-2 upgrade project has achieved the milestone of producing the specifications and design outline for prototype 1 of the DTH (DAQ and TCDS Hub) ATCA custom electronics board. The preparations for the DOE CD-1 review are well advanced.

Table 12: DAQ Metrics

Dead time due to backpressure	0%
Downtime attributed pb^{-1}	0
Fraction of downtime attributed	0%

Table 13: DAQ Milestones

Subsystem	Description	Scheduled	Achieved
DAQ	First version of OMS GUI with limited functionality deployed	Mar 1	Mar 6
DAQ	Specification and design outline for DTH prototype P1	Apr 1	Mar 13
DAQ	New HLT nodes commissioned	May 1	Apr 5
DAQ	Testbed for DAQ 3 installed	June 1	
DAQ	First DTH prototype P1 board	Oct 1	
DAQ	Event-builder and SMTS ready for heavy-ion run	Oct 31	
DAQ	All relevant WbM pages migrated to new OMS GUI	Dec 31	

Trigger

During this quarter the US groups continued their work on the Layer-1 calorimeter (CaloL1) trigger and the endcap muon trigger systems as both continued reliable data-taking during cosmic running. After completion of 2017 data-taking the groups worked on preparations for maintenance to be performed during the year-end shutdown.

Endcap Muon Trigger

The Northeastern, Rice University, and University of Florida groups have made improvements to the EMTF system in preparation for the LHC running in 2018, and have provided operational support for cosmic muon data-taking for the latest recommissioning CMS. On the firmware side, the MPC firmware was updated to the latest version in all trigger sectors, and is expected to reduce the rate of optical link errors at the EMTF input. For the EMTF algorithm firmware, we tightened the timing window (3BX to 2BX) for LCT segments in tracks, as well as the matching window in theta. This will reduce the pileup dependence in the muon trigger rates. Additionally, the core firmware for the PCI Express interface was updated, and a bug fixed, and this has enabled EMTF to pass "stress tests" and avoid previously rare system crashes encountered last year.

The online software has been updated to the latest release of the SWATCH framework, and has undergone a number of improvements. Foremost of those is the ability to reliably start the system from a cold start. But in addition have been bug fixes and new features. For ease of expert diagnosis of the EMTF and muon systems, an offline data quality monitoring system known as "Auto-DQM" is in development. It compares DQM histograms to references, and automatically scales the resulting plots to make differences prominent. Given the huge number of muon chambers, each with multiple front-end cards, it is easy to miss new problems. This system will improve upon that.

Finally, studies have been in progress to characterize the trigger rates at high luminosity. Further improvements to the trigger algorithm and resulting rates are expected as we learn which categories of track segments (LCTs) and track types contribute the most to the rate and the least to the efficiency and could be cut.

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 physics run in the last quarter of 2017. Before cooling was shut down on December 6, the system was powered down for the Year-End Technical Stop (YETS) and was powered back on on January 25, 2018.

Before turning on the CaloL1, 70 input fibers that connect output of the HCAL and input of CaloL1 had to be swapped to accommodate firmware modifications at the HCAL side. The fibers were disconnected, cleaned and put in new positions. After turning on, 6 ECAL channels showed low optical power, all of them were fixed or by swapping/cleaning them on ECAL side, or by cleaning them on CaloL1 side. Also 5 output channels to Layer-2 Calorimeter Trigger, CaloL2, were checked and cleaned.

The system software on the SWATCH PC was upgraded and new version of SWATCH was successfully compiled and installed. The DQM required small modifications to accommodate for special

”feature bits” that should be sent from HCAL to the trigger to allow for taking special min-bias events. After consulting with HCAL this information was implemented in CaloL1 DQM software.

During this quarter a discussion with HCAL leaded to decision to use linear scale for trigger primities compression, it required updating the LUTs in CaloL1 and producing a new calibration. The LUTs were updated, the calibration is being done now, since it requires new software release, that has been just made available. Prepared calibration for CaloL1 requires also CaloL2 to modify their calibration, as soon it is done (within a week), both systems should update their calibration constants.

The CaloL1 was also prepared to operate with first beam tests, so called splash events, that are planned for April 1st.

Table 14: Trigger Metrics

Fraction of MPC Channels	100%
Fraction of Upgrade EMUTF Channels	100%
Deadtime attributed to EMTF pb^{-1}	0
Fraction of deadtime attributed to EMTF	0
Fraction 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 15: Trigger Milestones

Subsystem	Description	Scheduled	Achieved
TRIG	EMTF commissioned with endcap RPC input	March 19	March 15
TRIG	EMTF ready for Physics	May 7	
TRIG	Calo. Layer-1 commissioned with new Calibration	April 2	March 29
TRIG	Calo. Layer-1 Ready for physics	May 7	

Software and Computing

U.S. CMS Software and Computing still executed many activities to support the experiment. For the facilities, the relatively quiet period was a good opportunity to implement a number of forward looking technical improvements, while still handling all manner of data processing activities. These improvements have prepared the facilities for 2018 data taking. Utilization levels were extremely high throughout the quarter, as CMS performed re-processing of 2017 data, simulations for both current, future, and far-future LHC runs, and tested out the production of the new NANOAOD data format. There has been good progress in the use of DOE and NSF HPC centers, and in evaluating future data management systems. A variety of software development activities are taking advantage of new technologies and new processing architectures. In this quarter the U.S. computing security effort was re-launched with a reinforced team that is making progress in clarifying procedures, and the blueprint effort continues to evaluate new technologies and how they can be used to meet future resource needs.

Major milestones achieved this quarter

Date	Milestone
Feb 1	ROOT and C++ modules: reduce startup memory use by around 20% (achieved)
Feb 1	Visualization: Implement and support Muon and Barrel Calorimeter TDRs
Feb 13	All Tier-2 sites upgraded to XrootD 4.6.x
Feb 28	Full copy of MINIAOD samples placed in U.S.
Mar 1	USCMS regional xrootd redirector and FNAL local redirector upgraded to v. 4.8
Mar 1	Core framework: allow concurrent Luminosity Block transitions
Mar 1	ROOT: Integrate clad, automatic differentiation library that should speed up roofit- and tmva-related computations
Mar 1	Visualization: Implement and support MIP Timing detector Technical Proposal
Mar 8	Fermilab T1 CPU fully converted to SL7 + Singularity
Mar 31	Machine learning R&D: Define and evaluate performance metrics for benchmarks
Mar 31	Geometry/DD4HEP: Proof of principle example
Mar 31	Tier0 migrated from CERN AI to HTCondor

Fermilab Facilities

This quarter coveres the winter LHC shutdown and on-going 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 40.6 million wall-clock hours of processing to CMS.

Figure 9 shows the Fermilab site readiness metrics for the quarter. During this quarter the Tier 1 facility passed CMS site availability metrics 98.9% of the time. There were some short service

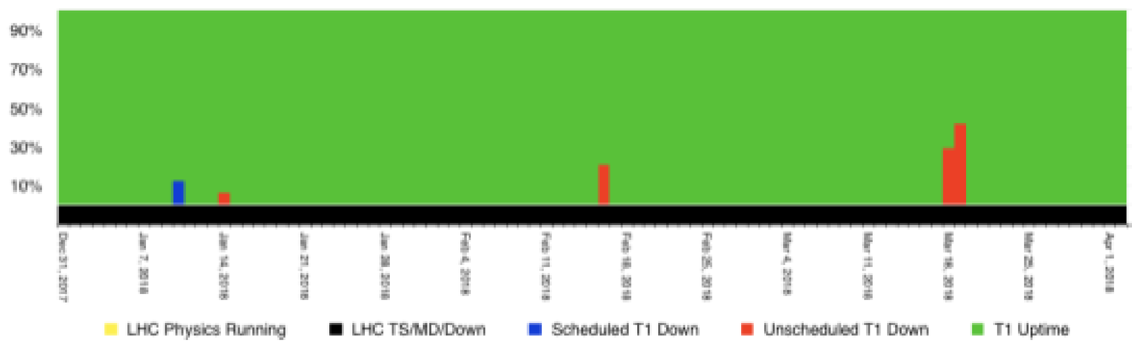


Figure 9: Fermilab readiness metrics for Q1 of calendar year 2018. Green indicates a passing metric, red a failing metric, and blue a scheduled downtime. The height of a red bar indicates how much of each day Fermilab services were affected. Black and yellow across the bottom indicates LHC machine running. During this quarter the LHC was shutdown during the year end technical stop. Fermilab passed metrics 98.9% during the quarter.

incidents in the xrootd and FTS services during the quarter, all of which were solved within a few hours.

In time for the 2018 LHC run, Fermilab completed its re-factoring of the Tier 1 compute farm, updating to Scientific Linux 7 and implementing worker node deployment via Docker containers. CMS plans to move to SL7-only releases to process data from the 2018 run, and the containerization improves flexibility in deploying compute resources. During this quarter we also upgraded the xrootd redirectors and FTS services in preparation for the upcoming run.

University Facilities

As seen in Figure 10, CMS production and analysis activities this quarter continued to run at full capacity and even exceeded purchased processing power, taking advantage of the sizable opportunistic processing available at the U.S. CMS Tier-2 sites. During this period of heavy usage, analysis processing consumption by U.S. physicists continued at the level of 72% of the total analysis CPU delivered by our sites during the last quarter.

All of the U.S. CMS Tier-2 sites operated successfully last quarter. On our two official performance metrics based on CMS test jobs, all sites were at least 98% "available" and 87% "ready". The CMS requirement for each of these metrics is 80%, but the U.S. CMS performance goal is 90%. Only one site missed the enhanced readiness goal for the quarter, the rest being over 96% "ready".

The U.S. CMS Tier-2 centers delivered 49.3% of all computing time by Tier-2 sites in CMS last quarter. This is a further decrease of 0.9% from the previous quarter, indicating that our pressure on CMS to diversify the geographical spread of production work may be having a positive effect. However, given that over 70% of our U.S. processing resources for analysis is used by local U.S. physicists, as seen in Figure 10, and that we also take our fair share (~30%) of non-U.S. Tier-2 analysis usage, U.S.-based researchers are doing approximately 50% of the global analysis work in CMS, commensurate with our ~50% resource contribution overall.

As for the list of Tier-2 milestones and upgrades, our sites have made great progress on fully deploying the OS switching in Singularity containers, retiring glexec, and upgrading to OSG version 3.4.

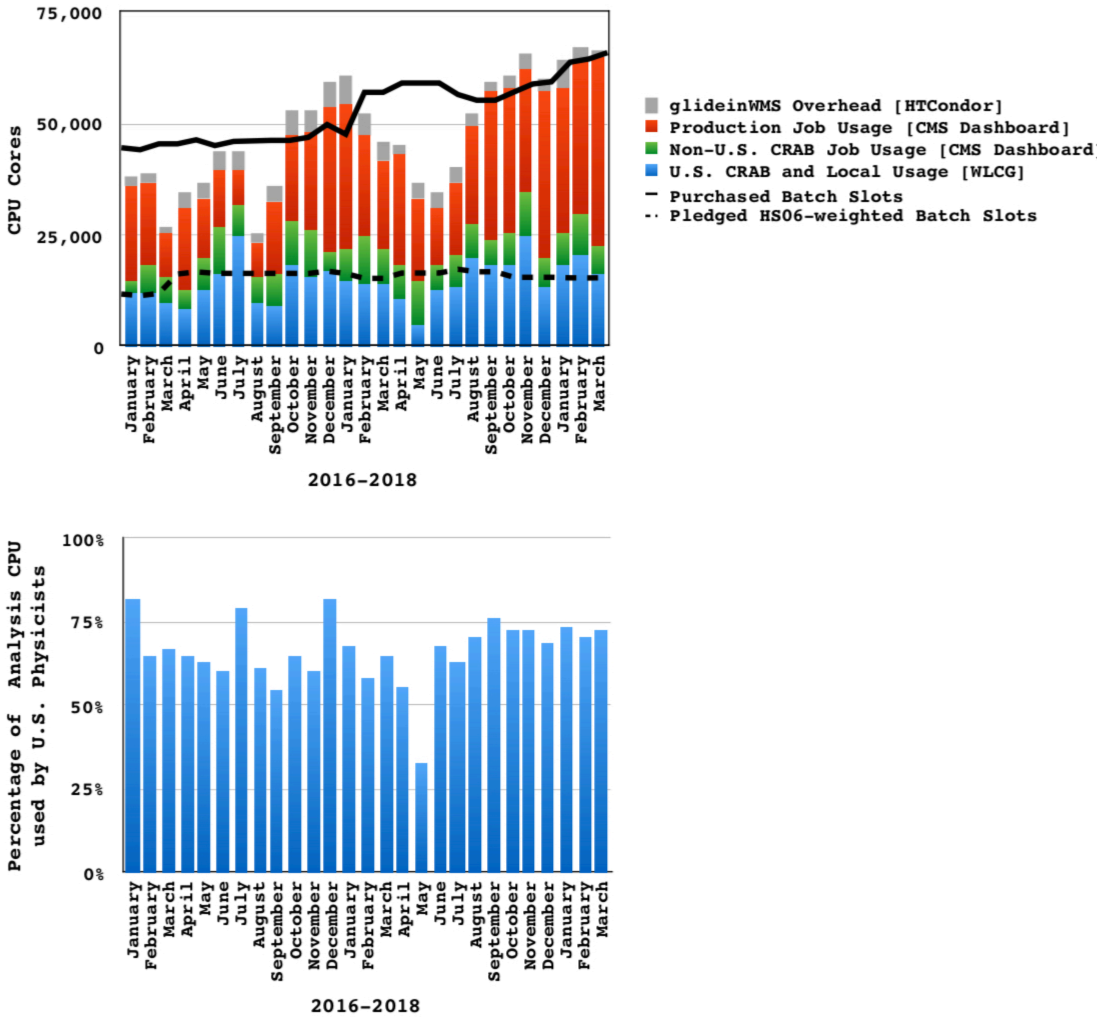


Figure 10: How processing resources were used at the U.S. CMS Tier-2 sites, by month.

One major milestone which was a carryover from 2017, upgrading to XrootD 4.6.x, was completed this quarter at all sites.

The U.S. CMS Tier-3 support team provided help to eight sites on issues ranging from the transition from GUMS to LCMaps authentication, PhEDEx debugging, and gridftp configuration. In addition, routine user support for CMS Connect was provided, and efforts continue to expand GPU resources available.

Computing Operations

Additional re-reconstruction requests of 2017 data came in until mid-February and were one of the main processing activities in the first two months of the quarter. In total 5.6 billion events were re-reconstructed in this campaign that started in November. In March a request to re-reconstruct

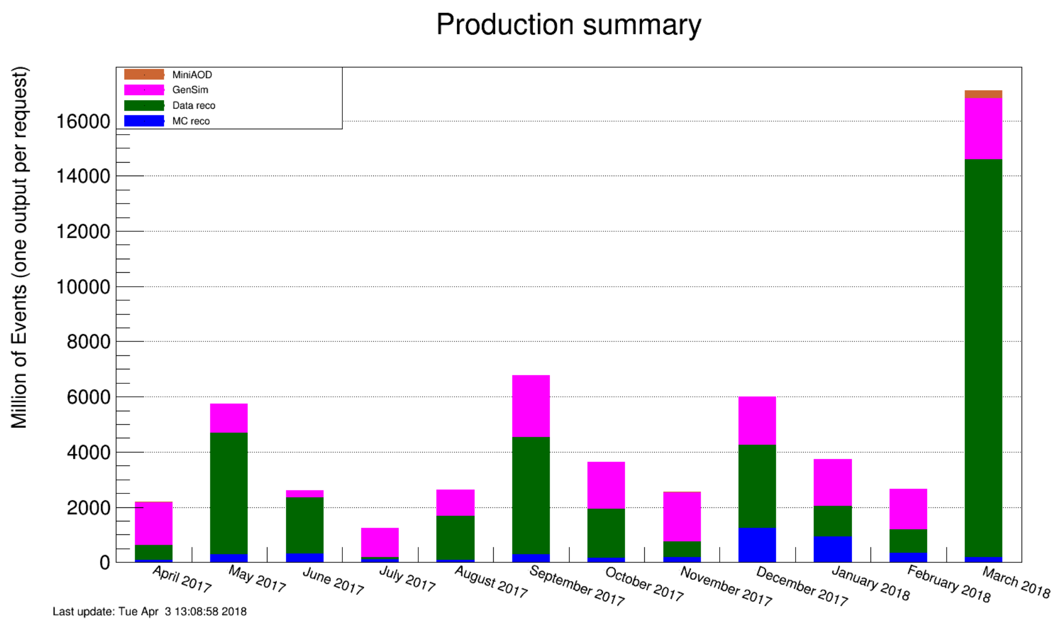


Figure 11: Summary of events produced during the last year. This picture does not include the new NANOAOD processing, which is very fast and would distort the overall picture due to the large number of events processed.

all data, 14.5 billion events, of an additional period, 2017-G, was received and quickly completed. Figure 11 shows the processing activity.

Generating and preparing Monte Carlo events for the 2017 data analyses was the second largest processing activity. About half of the 10 billion events requested have been released to the physics groups so far. Most of the events were simulated using the event pre-mixing method, and the classical pile-up event handling was used for only about half a billion events, leading to improved resource usage.

A small number of Monte Carlo events, 130 million, to prepare for the 2018 data taking were generated and processed in January. Additional HL-LHC upgrade Monte Carlo events, about 226 million, were generated and simulated during the quarter. Data from the 2017 Xenon-Xenon LHC run were also re-reconstructed and provided to the heavy-ion group by mid February. A few small, additional Monte Carlo samples were needed for the spring conferences and processed with high-priority.

The latest version of the NANOAOD data tier was generated for the 2016 and 2017 data, to allow physics groups to continue tuning this new data format and converting analyses to use it instead of the larger MINIAOD samples. Toward the end of the quarter a re-reconstruction request for the latest 2017 data taking period was received and processing started.

Overall, the CMS data and Monte Carlo processing used all of the available computing resources, about 160,000 cores, during the quarter. CMS switched to using Singularity to allow a per-job operating system selection. This is needed to support Scientific Linux 7-based data processing for 2018 data while still analyzing 2016 and 2017 data using SL6. The Singularity rollout is almost complete at the U.S. sites. Singularity provides also job isolation and thus replaces glexec at sites.

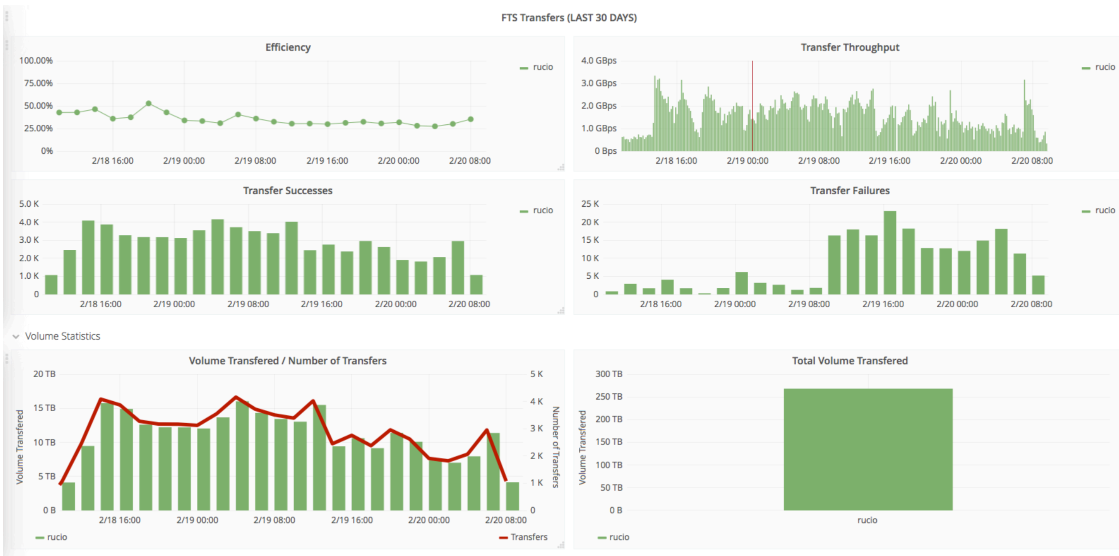


Figure 12: Transfer data for pre-mixed pileup samples being moved to NERSC.

Computing Infrastructure and Services

Several improvements were made to the workflow management systems during this quarter. The Tier0 was fully converted from the CERN Agile Infrastructure to using native HTCondor for job submission. WMAgent, the production workflow system, was modified to improve the throughput of high priority workflows and to improve the availability of job log files for debugging. The internal agent monitoring was also improved. The WMArchive project is now regarded to be in production and is in maintenance mode. Further work in this area is to better utilize this data from the CERN-provided monitoring infrastructure.

Low-level production use of NERSC continued while we investigated improved options to integrate the HEPCloud/NERSC resources into the CMS computing infrastructure; planning is ongoing for ramp-up of these resources. This will allow us to increase the use of NERSC for CMS production.

We began commissioning of the PSC/Bridges and TACC/Stampede2 HPC resources through HEPCloud and an OSG-supported University of Chicago Hosted-CE shared with ATLAS.

The evaluation of Rucio as a future data management system is proceeding very well. All technical issues have been solved or have understood solutions. A small fraction of global CMS data is now visible in Rucio and test transfers, including to and from tape, are occurring regularly. Rucio was used to transfer the 670 TB premixed pileup dataset to NERSC for production processing there. Figure 12 shows a portion of this transfer with rates up to 3 GB/s. By a modification of the rules in Dynamo, the CMS dynamic data management system, a full copy of the MINIAOD data tier has been stored on U.S. CMS disk resources as of February 2018.

The XRootD caching proxy infrastructure ("XCache") at UCSD has been augmented with additional servers at Caltech, set to go into production in the next quarter. The UCSD team continues to monitor the usage patterns and working set sizes, as well as following discussions for possible implementations of a write-through disk cache. The latter is an important optimization in any future cache-based storage site. Finally, the collaboration with UCSC in the analysis of CMS access patterns has resulted in a design of a new algorithm for optimizing the data stored in a cache.

Software and Support

In the first quarter of 2018, the CMS software teams integrated releases for legacy processing passes for 2017 data, and prepared the releases for commissioning and startup of data taken in 2018. We reached a major milestone in adding the ability to process multiple LuminosityBlocks concurrently with CMSSW to further increase the multi-threading efficiency at very high core counts, which is important for running on KNL and similar architectures. We measured the performance to fully understand how this new feature can be used, as well as modified code that was preventing good performance.

The milestone to test and incorporate the bulk I/O API developed in collaboration with the NSF DIANA project into ROOT has been delayed to the second quarter of 2018 because of DIANA effort availability. We switched ROOT to use the LZ4 compression providing a higher compression factor while reducing CPU consumption. In the context of community projects, CMS started on the path to migrate our geometry description in the software, important both for simulation and reconstruction, to the DD4HEP community package.

Our R&D projects are progressing well. For instance, the vectorized Kalman filter package mkFit was further optimized and achieved a x10 speed up compared to the non-vectorized production tracking software implementation. We are also continuing to investigate vectorized tracking on GPUs, which so far has not yielded encouraging results. This work was reported at the ”connecting the dots” conference. The machine learning benchmark suite to guide resource estimates for various applications is progressing well and has first implementations of different benchmarks.

In the next major version of ROOT, called ROOT 7, GUI and drawing components will be updated to use web technologies that are used in in-browser drawing. This has consequences for the underlying library called EvE using for FireWorks, the CMS event display. We started evaluating client-server implementations to update EvE and the event display.

Other activities

The U.S. CMS Blueprint activity continued to organize project discussions around the future directions of CMS software and computing research and development. The overarching goal of facilitating discussion of how to ensure that U.S. CMS continues a coherent R&D plan towards HL-LHC. Topics during this quarter included:

- how to evolve the resource models given improvements in workflows, changes to the CMS analysis model and new monitoring information that helps to better follow how CMS uses its current resources
- the CMS usage and future needs of the transatlantic network bandwidth. We organized a follow-up discussion that included U.S. ATLAS and ESnet
- how to balance resources devoted to CMS (eg, T1/T2) facilities with dynamic and opportunistic sites (eg, HPC).
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During the last quarter, the U.S. CMS security team completed the following activities. The team collected and updated the site security contact information. This was done as part of an effort to improve incident response and traceability capabilities. Members of the team attended and presented a talk at OSG All-Hands Meeting about the site admins security responsibilities. The team finished the first draft of the CMS job traceability document. The main goal of this document is to evaluate the current computing infrastructure and make it more secure and responsive to attacks. The document will cover the entire lifespan of a job and discuss how we can trace it, and what tools and capabilities are available for this. Team members also attended the WLCG security workshops and regular meetings to represent CMS, and are regularly attending WLCG Authz Calls.