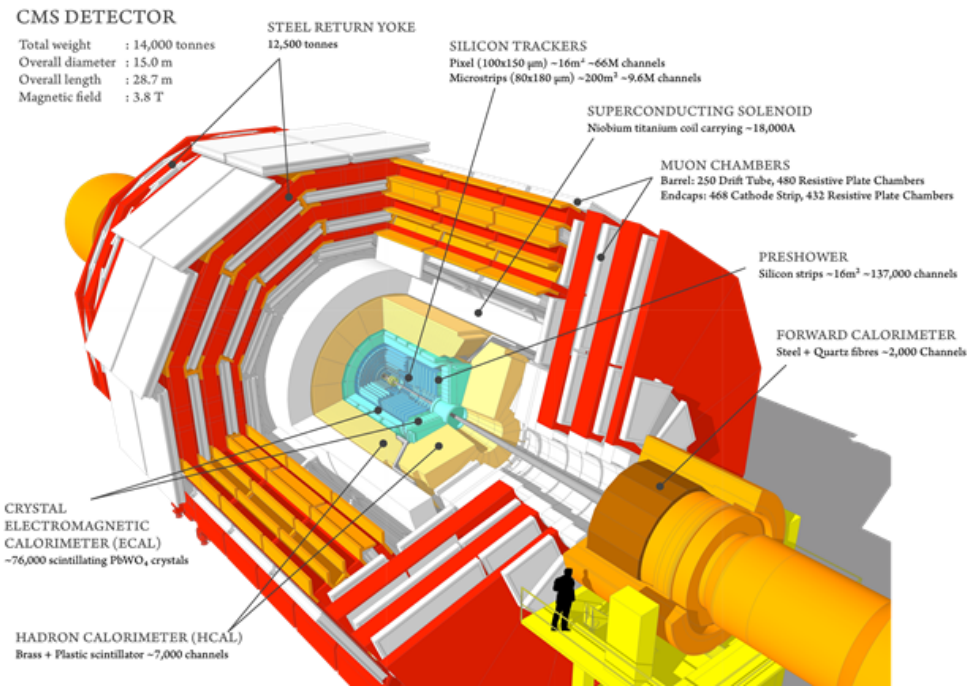
U.S. CMS Compact Muon Solenoid Operations Program Quarterly Report for the Period Ending March 31, 2015

U.S. CMS Operations Program



Program Manager's Summary

During the first quarter of 2015 the LHC Long Shutdown 1 (LS1) continued with an expectation of start of LHC beam operations in the next quarter. The LHC machine group continued the program of repairs of splices and other magnet components to allow the LHC to eventually reach its design energy of 14 TeV, with 13 TeV as this year's energy target.

CMS has been busy with a variety of activities during the shutdown that are described in the subsystem sections below. CMS worked to complete an extensive detector improvement program with a number of deliverables being installed and commissioned during this quarter, and continued a program of work in software and computing to prepare the startup of CMS data taking at the end of the coming quarter.

In January 2015 there have been changes in the management team for the U.S. CMS Operations Program (see Figure 1 for the updated Org Chart). The new Program Manager is Lothar Bauerdick from Fermilab. Dan Marlow of Princeton University continues as the Deputy Program Manager. Ken Bloom of U.Nebraska was appointed Software and Computing (S&C) Manager, and Liz Sexton-Kennedy of Fermilab was appointed deputy for S&C. The new Detector Operations Manager is Paul Padley of Rice U., replacing Vivian O'Dell (Fermilab) who was appointed to be U.S. CMS Phase-2 Upgrade Manager, and Max Chertok of UC Davis is overseeing the Phase-2 Upgrade R&D Area. There are two new positions in the Operations Program Management Team, with Aron Soha (Fermilab) being appointed Resource Manager and Greg Rakness (Fermilab) being the Liaison with CMS Run Coordination responsible for the day-by-day data taking and operations of the detector.

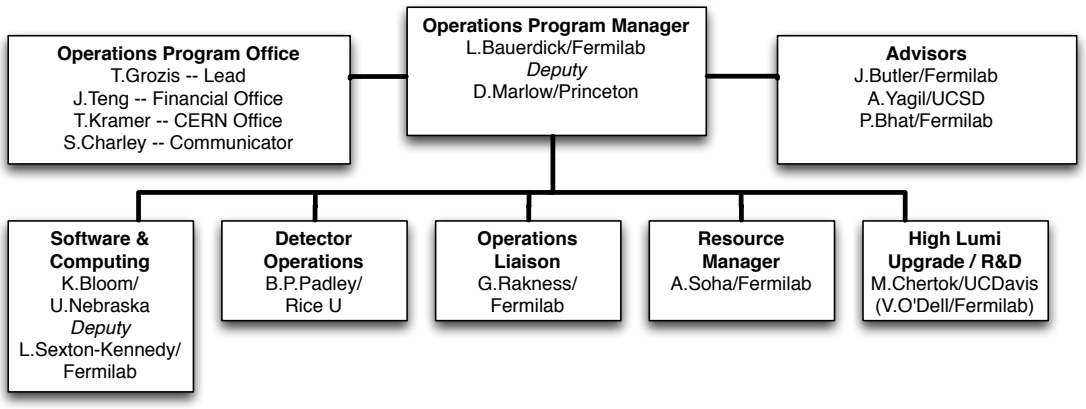


Figure 1: Updated Organization Chart for the U.S. CMS Operations Program.

Summary of CMS Activities During this Quarter

CMS is engaged in five major activities: preparation of improvements and repairs to the detector for the run starting this year; preparation of the detector, operations, computing, offline, data quality monitoring, trigger and physics simulations for the run starting in 2015; construction of the Phase 1 Upgrades; simulation studies, R&D and preparing a Technical Proposal for the Phase 2 Upgrades; and physics analysis of the data from the 2012 run. Each of these tasks has led to important activities and milestones during this quarter.

Regarding improvements and repairs to the detector, CMS completed its shutdown activities, and closed up the detector. A number of milestones and deliverables are listed below in this report.

The pixel luminosity telescope is now completely installed inside the CMS detector, and its functionality has been tested. The tracker profited from cosmic ray running with magnetic field on and off, and calibrations were performed for the Barrel and Forward Pixel detectors. All parts of ECAL are participating in global runs, following the migration to the new central DAQ and TCDS systems, and the recommissioning of the electron/photon trigger path is proceeding well. Significant HCAL development effort resulted in code for the HCAL local reconstruction for LHC operation with 25ns bunch spacing, including proper out-of-time pile-up subtraction, both for offline and the HLT. The Endcap Muon system participated smoothly in cosmic global runs throughout this period, and only a few remaining firmware and software issues were being worked on. The spatial resolution for each chamber type was evaluated using cosmics data and was found essentially unchanged from Run 1. The updated DAQ system, including the new Storage Manager Disk system and the new Trigger Control and Distribution System (TCDS) is ready for use in its basic functionality. Focus was on handling of edge cases, improving the monitoring and performance, and interfacing to the event display etc on the offline side. Work on the regional calorimeter trigger (RCT) and the endcap muon trigger continued with the system being ready for cosmic ray triggering, and significant progress was made timing-in the various elements of the triggers.

CMS got ready to begin data taking, starting with cosmic ray data to commission the experiment. In March this included running with the detector solenoid at 3.8 Tesla. At the end of the quarter the experiment was ready to continue commissioning with beams to prepare for physics running.

Computing Operations teams have been deeply involved in scale testing of processing at the Tier-0 facility and of data movements to Tier-1 facilities, along with processing of important Monte Carlo samples for both the coming run and the Phase 2 Upgrades studies. The U.S. computing facilities, at the Tier-1 and the Tier-2 centers, have deployed their full complement of computing resources – processing, disk and tape – by the April 1st start of the WLCG "Resource Year". All facilities have maintained high levels of availability and continued to evolve their systems to make use of new capabilities in areas such as multi-core job processing and wide-area network bandwidth expansions. The Software and Services team continued to deploy new features in support of both of analyzing existing data and for the upcoming running period. Important deliverables included the production release of the CRAB3 analysis job submission system, and efforts to make use of additional resources at DOE-ASCR high-performance computing facilities and from commercial computing cloud providers, as part of a strategy to add resources to the computing infrastructure more dynamically.

Transatlantic networking capabilities were transferred from U.S. LHCNet to the ESnet EEX service, and U.S. LCHnet officially ended its service in February. With the transition successfully completed at the beginning of the year, the U.S. LHCnet group's remaining activity was to decommission the

services and related hardware installation, and to transitioning to a development oriented configuration leveraging the existing Brocade, Pronto and Dell/Force10 switches for future R&D work outside of the LHC Operations Program.

With the Phase 1 Upgrade project having entered its construction phase, coordination between the Operations Program and the Upgrade Project management teams continued and it has been a priority in particular to coordinate resources between the Operations Program (including Phase 2 R&D) and the Phase 1 Upgrade Project. A detailed analysis of resources across the U.S. groups both for operations and for Phase 1 Upgrades was shown at the March review. No major issues were identified and small overlaps were corrected. The result is an excellent understanding of the personnel resource plans between Operations Program and Upgrade Project.

The R&D program for the CMS Phase 2 Upgrades was continuing during this quarter. The spending plan for R&D funds for 2015 amounts to about $3.5M. The plan is implemented such that $500k are left for later allocation, after the choice of technology for the endcap calorimeter upgrade, which is expected for the next quarter. This will allow to direct funds to additional R&D efforts for the chosen endcap calorimeter technology, once it is known. Strategic planning for the CMS Phase 2 Upgrades for high luminosity LHC operations was moving forward. U.S. groups worked towards completing the Technical Proposal for the Phase 2 upgrades in the coming quarter, to be reviewed by the LHCC in time for the fall RRB. A number of workshops and meetings were held in the U.S. to plan for the Phase 2 upgrades and to engage U.S. groups in the R&D required for the technical design and before start of construction of the upgrades.

The analysis of data taken in 2011 (5 fb^{-1} at 7 TeV) and 2012 (20 fb^{-1} at 8 TeV) continued during this quarter. By the end of the quarter, CMS had submitted some 375 papers for publication.

To summarize, during this quarter U.S. CMS made significant progress in all five fronts listed above. In the coming quarter we expect to finalize the commissioning of the CMS detector systems for the LHC startup in June 2015, complete the down-select process for the endcap calorimeter upgrades choice and submit the Phase 2 Upgrade technical proposal.

Resource Manager's Report

The funding provided by DOE and NSF to the U.S. CMS Operations Program for 2002 through 2015, as well as the funding guidance for 2016 through 2019, is shown in Figure 2.

Resources are distributed and tracked across the three areas of the program: 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 the current calendar year took place this past August and September. Through this process, U.S. CMS Management developed a detailed spending plan for 2015 and beyond. This plan was further refined through the March 2015 joint NSF/DOE Operations Program review.

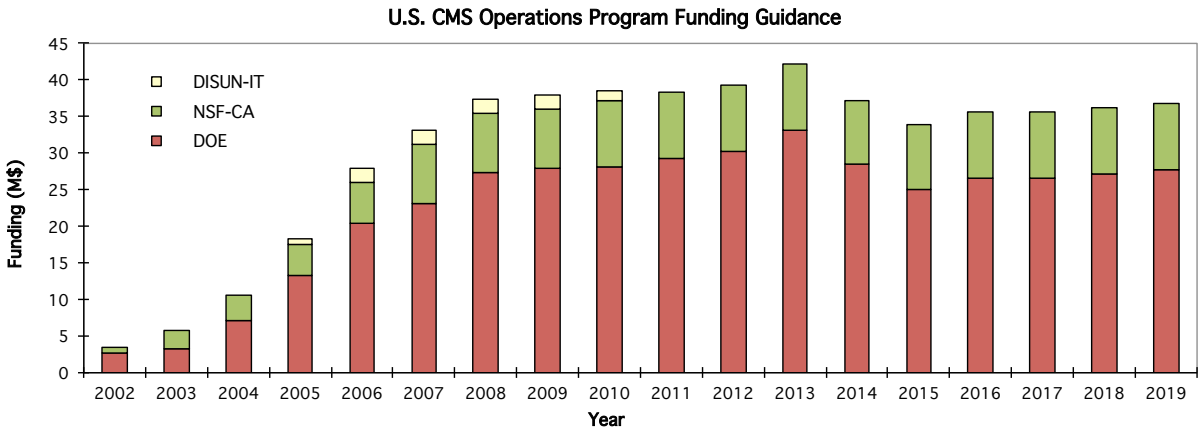


Figure 2: The annual U.S. CMS Operations Program funding provided by DOE and NSF. For 2002 through 2015 the chart shows the actual funding, while for 2016 onward the current funding guidance is shown.

Primarily during this 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 overseeing the program, and by representatives of the collaborating group and institution. Through March of 2015, a total of 86 SOWs (54 DOE and 32 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 1 shows the Spending Plan Change Log which captures revisions that were made prior to SOW approvals, as well as modifications implemented through Program Change Requests. The information is reported here down to the level-2 subsystem categories within DetOps, S&C, and ComOps.

The changes in the spending plan for Phase 2 Upgrade R&D during this quarter deserve a special note. The 2015 spending plan foresees to hold back $500k of funding eventually to be allocated to Phase 2 Upgrade R&D, the exact allocation to be decided upon after the CMS endcap calorimeter upgrade technology decision is made later this year. This is shown in the table as "Reduction, to be re-allocated after EC downselect". There was also an increase of $207,847 spread across several sub-areas of Phase 2 Upgrade R&D, involving eight institutions.

The spending plan is going over Calendar Years (CY), and for 2015 it is shown for DOE and NSF funds in Table 2. The plan will continue to evolve slightly as the remaining SOWs are being approved over the following quarter, and as Change Requests are executed. For the allocation of resources among the seven S&C WBS tasks indicated in both Table 1 and Table 2, small differences with respect to what was shown at the most recent Joint Oversight Group meeting are due to a more precise attribution of the travel, COLA, and M&S costs to each of the S&C WBS tasks.

Once funds have been committed, through purchase orders at Fermilab in the case of DOE, and

Table 1: Spending Plan Change Log for CY 2015 Q1

U.S. CMS Detector Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY15Q1 Plan**	**Change $**	**CY15Q2 Plan**
11	Endcap Muon	CR-021	UCSB: added funding for electronics labor and M&S	$1,805,557	$14,682	$1,820,239
12	Hardon Calorimeter	CR-025 & CR-026	UMinn CR-025: uTCA labor and M&S, FSU CR026: Maint&Repairs M&S, & presow adjustment	$1,558,683	$30,834	$1,589,517
13	Trigger	CR-024	Notre Dame TA COLA increase $3333 and Pre-SOW adjustments	$907,000	$12,475	$919,475
14	Data Acquisition		Pre-SOW COLA adjustments	$758,000	$22,208	$780,208
15	Electromagnetic Calorimeter		Pre-SOW adjustments	$851,000	($6,185)	$844,815
16/17	Tracker (Fpix&SiTrk)		Pre-SOW adjustments	$770,000	$5,461	$775,461
18	Detector Support			$209,473	$0	$209,473
19	BRIL		Pre-SOW COLA adjustments	$408,000	($19,820)	$388,180
30	Phase 2 Upgrade R&D		CR-030 and pre-SOW increases	$3,042,000	$207,847	$3,249,847
	Phase 2 Upgrade Endcap R&D		Reduction, to be re-allocated after EC down-select	$500,000	($500,000)	$0
11-18,30	**Detector Operations**			**$10,809,713**	**($232,498)**	**$10,577,215**

U.S. CMS Common Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY15Q1 Plan**	**Change $**	**CY15Q2 Plan**
21.2	Common Costs (M&OA, LS1, Loan)			$5,431,000	($178)	$5,430,822
21.3	RCMS			$519,000	($143)	$518,857
21.4	LHC Physics Center		Pre-SOW adjustments	$688,000	($54,171)	$633,829
21.5	Operations Support		Pre-SOW adjustments	$1,201,000	$156,534	$1,357,534
21.6	Program Office			$980,594	$0	$980,594
21.7	E&O			$286,000	$480	$286,480
21.8	Collaboration Support			$10,000	$0	$10,000
	Other		Moved from "Other" to LPC, Ops Support, & small adjustments	$162,000	($162,000)	$0
21	**Common Operations**			**$9,277,594**	**($59,477)**	**$9,218,117**

U.S. CMS Software and Computing Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY15Q1 Plan**	**Change $**	**CY15Q2 Plan**
22.1	Fermilab Facilities		Pre-SOW adjustments	$6,735,279	$3,000	$6,738,279
22.2	University Facilities			$4,117,582		$4,117,582
22.3	Computing Operations			$1,123,082		$1,123,082
22.4	Computing Infrastructure and Services			$2,095,189		$2,095,189
22.5	Software and Support			$1,938,046		$1,938,046
22.6	Technologies & Upgrade R&D			$902,380		$902,380
22.7	S&C Program Management & CMS Coordination		Pre-SOW adjustments	$710,772	($19,000)	$691,772
22	**Software and Computing**			**$17,622,331**	**($16,000)**	**$17,606,331**

U.S. CMS Operations Program Total	**$37,709,638**	**($307,976)**	**$37,401,663**

Table 2: Spending plan at the end of CY 2015 Q1, for funds from DOE, NSF, and the total.

WBS	Subsystem	DOE Funds	NSF Funds	Total
11	Endcap Muon	$1,485,519	$334,720	$1,820,239
12	Hadron Calorimeter	$1,516,106	$73,411	$1,589,517
13	Trigger	$771,665	$147,810	$919,475
14	Data Acquisition	$780,208	$0	$780,208
15	Electromagnetic Calorimeter	$844,815	$0	$844,815
16/17	Tracker (Fpix-SiTrk)	$735,924	$39,537	$775,461
18	Detector Support	$209,473	$0	$209,473
19	BRIL	$134,100	$254,080	$388,180
30	Phase 2 Upgrade R&D	$2,647,904	$601,942	$3,249,847
11-19,30	**Detector Operations**	**$9,125,714**	**$1,451,500**	**$10,577,215**
21.2	Common Costs (M&OA,LS1,UpgrdLoan)	$4,341,559	$1,089,263	$5,430,822
21.3	Run Coordination and Monintoring	$518,857	$0	$518,857
21.4	LHC Physics Center	$633,829	$0	$633,829
21.5	Operations Support	$1,229,704	$127,830	$1,357,534
21.6	Program Office	$863,044	$117,550	$980,594
21.7	Education and Outreach	$170,000	$116,480	$286,480
21.8	Collaboration Support	$10,000	$0	$10,000
21	**Common Operations**	**$7,766,994**	**$1,451,123**	**$9,218,117**
22.1	Fermilab Facilities	$6,752,842	$0	$6,752,842
22.2	University Facilities	$110,737	$3,988,418	$4,099,156
22.3	Computing Operations	$710,490	$412,240	$1,122,730
22.4	Software and Support	$1,670,757	$428,176	$2,098,933
22.5	Computing Infrastucture and Services	$1,687,530	$255,791	$1,943,321
22.6	Technologies & Upgrade R&D	$205,518	$691,966	$897,484
22.7	S&C Program Management and CMS Coordination	$462,014	$229,852	$691,866
22	**Software and Computing**	**$11,599,888**	**$6,006,443**	**$17,606,331**
U.S. CMS Operations Program Total		**$29,259,289**	**$8,750,758**	**$37,401,662**

through university sub-awards at Princeton in the case of NSF, they are considered obligated for the purpose of this report. Figure 3 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, to facilitate the graphic representation of expected spending over the year. In reality, by intention, this is not the case due to equipment purchases and the larger funding transfers to CERN-based Team Accounts, the latter of which are usually made when exchange rates are favorable.

Spending through Universities and CERN Team Accounts is allocated and tracked according to the calendar year following the yearly spending plans that are based on calendar years of performance, while spending at Fermilab is budgeted according to the fiscal year. Of special note is that with this quarterly report we transition to reporting based on calendar year to align reporting with the annual spending plans as reviewed by the funding agencies, which are done in calendar year (CY).

There are two features of Figure 3 related to this transition. First, obligations for DOE spending at Fermilab in the last three months of CY 2014 have been included in the plotted obligations for 2015. Second, to accommodate the three month offset between fiscal year and calendar year, a buffer of $3M has been allocated this year, drawing from carry over from previous years. This is indicated by the difference between the solid and dashed blue lines. Figure 4 shows the total obligations and the spending plan, for NSF funds. Of the $9M in NSF funding, a first installment of $6M arrived during this quarter. In addition to spending at Princeton, which hosts the NSF cooperative agreement, only one subaward went out this quarter. Obligations of NSF funds will increase substantially in the next quarter as the bulk of the subawards are issued.

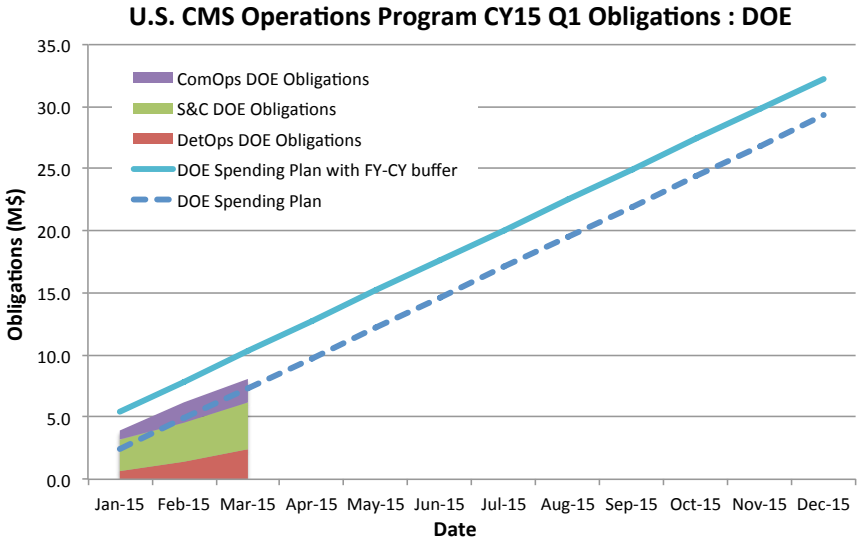


Figure 3: Obligations and spending plan for DOE funds. The spending plan is indicated with the assumption of equal monthly increments to give a rough guide. The lines show the spending plan with (solid) and without (dashed) a required buffer to bridge the difference between fiscal year and calendar year for funds spent at Fermilab, as described in the text.

Resources deployed at CERN, and paid directly in Swiss francs, account for approximately 28%

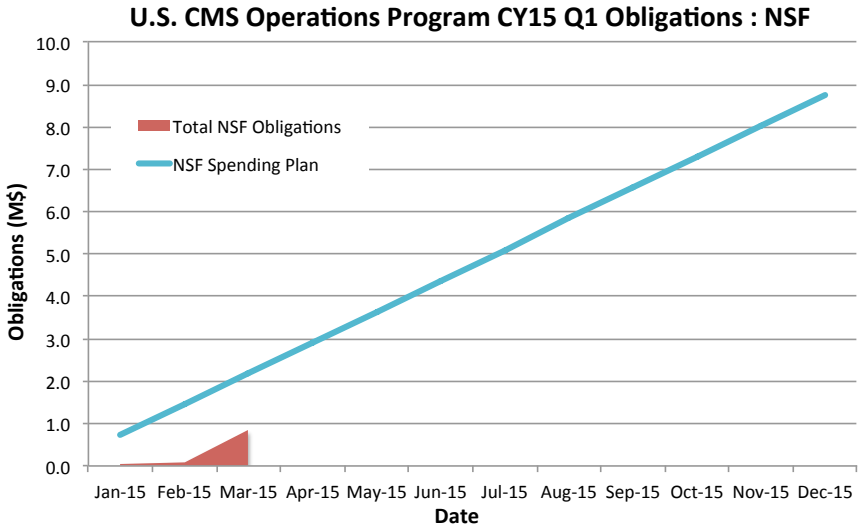


Figure 4: Obligations and spending plan for NSF funds. The spending plan is indicated with the assumption of equal monthly increments to give a rough guide. Only one subaward was issued during this quarter. The majority of subawards will be issued during the next quarter.

of the 2015 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 this quarter averaged at 0.95 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 last 615K CHF of the Upgrade Common Fund payments (paid in February) and the M&O-A payments (3,827K CHF, to be paid in three installments later this year), as these are discrete payments to a separate Team Account.

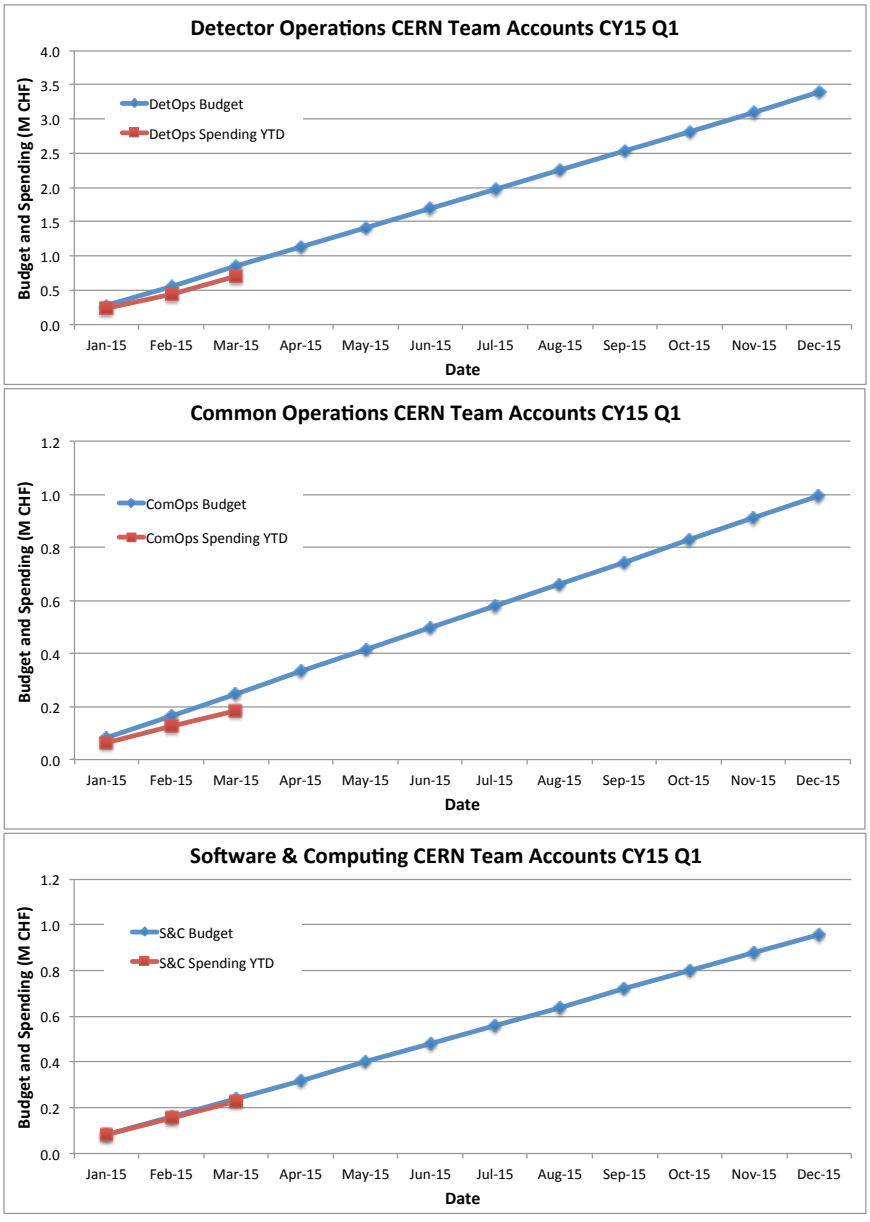


Figure 5: Budget plan and year-to-date spending, in Swiss francs, through DetOps (top), ComOps (middle), and S&C (bottom) Team Accounts.

Education and Outreach

In the fall of 2014, we received reports from the summer 2014 US CMS Education and Outreach (E&O) mini-grants. They were:

- Iowa U.: Supporting High School teachers to do HCAL research.
- Rochester U.: Supporting girl's High School physics summer classes.
- Brown U.: Develop materials and supplies to staff the Waterfire festival (a Providence-wide, fall-long event with high public traffic).
- Brown U.: Develop algorithm and coding to run Tier-3 CMS analysis on the Grid.
- Boston U.: Develop a mini CMS Center, suitable for Quarknet and master classes.
- Iowa U.: Design and build models of CMS using 3D printing technology.

Most grants achieved their goals completely. Two achieved significant progress, but fell short of their final goal. The Brown U. grant to staff the Waterfire festival managed to do all preparations, but was not selected to participate in the festival. Instead, the presentations occurred on the Brown University campus. The PI intends to apply again for the festival in 2015. In addition the Iowa proposal to build models of CMS was successful, however their stretch goal, which was to instrument these models with cosmic ray detection instrumentation has not yet completed. However, the group has been able to make models of the CMS detector using 3D printing technology. We have decided to build models of the detector to be sent to all participating U.S. CMS institutions, plus a few to funding agencies so they can show a model of CMS to people in the national science funding community.

In the spring of 2015, we put out a call for proposals for the summer 2015 U.S. CMS E&O mini-grants. The successful proposals were

- Florida: Support an effort to adapt the Oculus Rift 3D viewer to three dimensional representations of CMS event displays.
- Iowa: Supporting HS teachers to do calorimetry research.
- Maryland: Support a chemistry teacher to write lesson plans and units of how chemistry plays a big role in HEP detector technology.
- Rochester: Supporting girls HS physics summer classes,
- Sienna College/Cornell: Support undergraduates to build a cloud chamber using Peltier coolers, rather than dry ice. One unit will be given to the Quarknet program for evaluation and the grant was predicated on an article being submitted to a journal and a presentation at national conference.
- Notre Dame: Support two summer high school teachers to work on -shlik technology and to help build the optical decoding units for - HCAL upgrade.

- Waubonsee/Fermilab: To support a summer seminar program to teach local area high school teachers about particle physics.

The U.S. CMS video program is going strong. During the fall, we created videos on The Big Bang Theory, Quantum Foam, Cosmic Inflation and Superstrings. In addition, we made a parody of the hugely successful video "#Hashtag" by Jimmy Fallon and Justin Timberlake. In the spring, we made videos on "GUTs and TOEs", the LHC accelerator, the LHC experiments and complex (i.e. self-interacting) dark matter.

Our "Got a Minute?" video series is going well. These videos are one or two minutes in duration and are presented by young physicists. The goal of this program is multi-fold. We train the young physicists to appear more natural on camera. The videos are suitable for Quarknet and master classes, as well as being useful for reporters who need a short explanation of a physics topic. Finally, these videos are useful for physics faculty to show their department and are also suitable for department web pages.

In anticipation of the resumption of operations of the LHC, we contacted the alumni magazines of all U.S. CMS institutions and pitched stories that would highlight the impact of the respective university's faculty. Caltech has requested a story, but the faculty declined to cooperate. For UCLA, U.S. CMS Education and Outreach coordinator wrote an article for their summer 2015 issue of UCLA magazine.

We continue to try to place stories in visible national magazines about the LHC. We have been in contact with NBC, Newsweek, Scientific American and NOVA about the LHC reboot. Projects with all of these media outlets are ongoing. In January, NOVA showed an episode that highlights the LHC.

Detector Operations

By the end of this quarter, Long Shutdown 1 of the LHC had come to an end. CMS completed its shutdown activities, closed up the detector, and took cosmic ray data to commission the experiment. In March this included running with the detector solenoid at 3.8 Tesla. At this time the experiment is ready to continue commissioning with beams to prepare for physics running.

Milestones and Metrics

US CMS has developed a set of milestones and metrics for 2015 to measure performance. At the present time the detector is still being commissioned and so we do not report metrics. Milestone progress is reported for each subsystem individually below.

BRIL

The main emphasis of the US-CMS effort as part of the BRIL sub-detector group is the pixel luminosity telescope (PLT). The detector is now completely installed inside the CMS detector and its functionality has been tested. It is ready to take "splash" events that are planned during the first/second week of April. Monitoring and online error diagnostics tools are prepared and deployed to enable regular shift operations. The relative luminosity measurements during VdM scans are in preparation and on track for the first scans.

Table 3: BRIL Milestones

Subsystem	Description	Scheduled	Achieved
BRIL	Hardware installed	Jan	Jan
BRIL	Ready to deliver Lum	March	March
BRIL	Ready to deliver bkg nums	May	

Tracker

Since closing of CMS the tracker (Strips and Pixel) have operated well at the lower temperatures (see Milestone table). Unlike the conditions during Run 1, the lower humidity conditions have been maintained even during full magnetic field. This is a good success for the tracker humidity campaign. Detailed, post insertion, calibrations were performed for both the Barrel (BPiX) and Forward (FPiX) Pixel detectors, and the whole CMS tracker was able to profit from cosmic ray running with magnetic field on and off. With the field on, it was found that a sector, about 3%, of the BPiX will trip if all the modules in that sector are turned on. Debugging of the BPiX sector, and optimizing the number of powered modules in sector will continue when the CMS magnetic field is turned back on.

Table 4: Tracker Milestones

Subsystem	Description	Scheduled	Achieved
Tracker	Installation and checkout		Achieved
Tracker	Tracker operate -15C		Achieved
Tracker	Pixel operate -10C		Achieved
Tracker	Ready for proton beams	March	March

ECAL

A two-day detailed review of ECAL online and offline readiness for Run 2 was held on 2nd/3rd February 2015. This covered the current commissioning status, the near-term goals and the plans for commissioning and calibration with the first LHC beams. Significant progress was observed in all areas and the detector is in good shape for Run 2. All parts of ECAL (EB/EE/ES) are participating in global runs, following the migration to the new central DAQ and TCDS systems. The immediate goals involve the recommissioning of the electron/photon trigger path and the validation of the

ECAL links to the legacy and upgrade calorimeter trigger systems (with new components installed during LS1). The timing synchronization of the ECAL trigger and readout is being validated and will be further tested during the beam commissioning period (including the use of beam splash events). Laser calibration data is being recorded at 3.8T to monitor the recovery of crystal transparency during LS 1. A successful test of the cold operation of the ECAL preshower, which will operate at -8^0C during Run 2, has been performed.

Table 5: ECAL Milestones

Subsystem	Description	Scheduled	Achieved
ECAL	Finish HV Install	Feb	delayed
ECAL	Baseline levels zero suppression	March	March
ECAL	Complete install HV calib system	April	
ECAL	Selective readout	June	
ECAL	Trigger thresholds	June	
ECAL	Zero suppression thresholds	June	

Regarding the delayed milestone, 3 of the 6 CAEN HV mainframes have been installed. Final one is scheduled to be installed on May 12th. This is behind the original schedule but it is not a problem because the existing mainframes are fully operational so we are swapping them out progressively. The delay was caused by when we received them from CAEN.

HCAL

Since the previous report, the HCAL has completed its Long Shutdown 1 (LS1) activities and is currently finalizing its Run 2 preparations, which include the completion of the first milestone of the Phase-1 upgrade of installing the HF μTCA back-end electronics. Significant effort was invested into the development of the HCAL local reconstruction code for LHC operation with 25ns bunch spacing, including proper out-of-time pile up subtraction. The code was provided for Offline while its faster version for use in the High-Level Trigger (HLT) is presently undergoing tests.

Table 6: HCAL Milestones

Subsystem	Description	Scheduled	Achieved
HCAL	Fully functional HCAL in CRAFT runs	March	March
HCAL	prepared to do HF Phase scan and ϕ symmetry calibration analysis	May	
HCAL	New HBHE backend operating in parallel with legacy system	July	

EMU

The CSC system participated in cosmic global runs throughout this period, including extended runs in the closed configuration at zero magnetic field (CRUZET) and runs with the solenoid ramped

up to full field of 3.8 T (CRAFT). The operation of the CSC were generally smooth, with a few remaining firmware/software issues being worked on. The CSCValidation program was revived to present prompt diagnostic information from the CRUZET and CRAFT runs. The web interface was updated and features were added to compare data from different runs in real time. The spatial resolution for each chamber type was evaluated from the 2015 CRAFT cosmic ray data. It was found to be essentially unchanged with respect to the November 2014 data, when the magnet was last powered.

Table 7: EMU Milestones

Subsystem	Description	Scheduled	Achieved
EMU	CSC ready for collisions	May	
EMU	Calibration for HLT and Offline included in DB	July	
EMU	Fine timing adjustments with collision data completed	July	

DAQ

The DAQ2 system, including new Storage Manager Disk system and the new Trigger Control and Distribution System (TCDS) that was read out through the SLinkExpress fiber link of the FEROL module system was successfully used in global data taking through out the first quarter of FY 2015 in its basic functionality. The focus during this quarter was on commissioning the DAQ2 system to handle edge cases, improving it's the monitoring and performance.

Table 8: DAQ Milestones

Subsystem	Description	Scheduled	Achieved
DAQ	Hardware Installation of DAQ2 with new HLT nodes complete	April	
DAQ	Complete DAQ2 is operational for collisions	July	
DAQ	μTCA DAQ link commissioned for new trigger and HCAL FEDs	July	
DAQ	DAQ2 with Run I design performance	September	

Trigger

During this quarter the US groups continued their work on the regional calorimeter trigger (RCT) and the endcap muon trigger. In both significant progress was made timing in the various elements of the triggers.
This work will continue with the arrival of beams which, being synchronous, simplify the task. During the cosmic ray running the system was successfully used to trigger the events.

Table 9: Trigger Milestones

Subsystem	Description	Scheduled	Achieved
TRIG	Legacy RCT ready for physics	June	
TRIG	MPC ready for physics	June	
TRIG	CSCTF Ready for physics	June	
TRIG	Stage-1 Layer-1 calorimeter trigger ready for physics	September	

Software and Computing

The first quarter of 2015 has seen all of CMS prepare for the start of the 13 TeV collisions of Run 2, and U.S. CMS Software and Computing has been helping the collaboration be ready for this important moment in the history of the LHC. The U.S. facilities, both Tier-1 and Tier-2, have deployed their full complement of computing resources – processing, disk and tape – by the April 1 start of the WLCG resource year. All facilities have maintained high levels of availability and continued to evolve their systems to make use of new capabilities in areas such as multi-core job processing and wide-area network bandwidth expansions. The team supporting Tier-3 facilities has also prepared for the start of the run via direct site support and the development of services such as CMS Connect. Operations teams have been deeply involved in scale testing of processing at the Tier-0 facility and data movement at Tier-1 facilities, along with processing of important Monte Carlo samples for both the coming run and Phase 2 upgrades. The Software and Services team continued to deploy new features in support of both of those running periods. Efforts in the Computing Infrastructure and Services area included improving the functionality, stability and scalability of the grid and cloud based job submission infrastructure, enabling the use of opportunistic resources, and improving the availability of CMS data through more dynamic and flexible storage strategies. Particularly interesting features included the production release of the CRAB3 analysis job submission system, and efforts to make use of ASCR facilities and commercial clouds as part of a strategy to add resources to the computing infrastructure more dynamically.

Fermilab Facilities

This was a productive quarter for the Fermilab Tier-1 facility, as we continued to prepare for the start of LHC Run 2. In anticipation of the run, U.S. CMS has pledged to provide 120 kHS06 in CPU, 10,800 TB in disk, and 29,400 TB in tape resources at the Fermilab Tier-1 center. All of these capabilities were successfully deployed and available to CMS in time for the April 1, 2015 deadline.

During this quarter FNAL facilities were available over 99% of the time, with site readiness metrics passing 94% of the time, as shown in Figure 6. The site readiness metrics for a Tier-1 are expected to be above 98% averaged over the year during LHC running time.

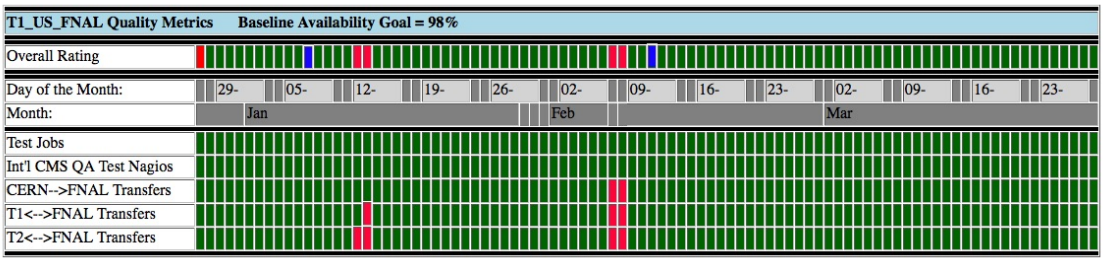


Figure 6: Overall hourly availability of U.S. CMS Tier-1 at Fermilab.

Beyond increasing the quantity of computing to CMS this year, the Tier-1 facility improved the capability of those resources. As luminosity increases in the upcoming run, CMS is expected to require its CPU resources be able to be used in a multi-core mode, with tasks utilizing multiple CPU cores simultaneously. In early February, the FNAL Tier-1 became the first of the CMS Tier-1s to provide all its CPU as partitionable multi-core slots, allowing jobs to run any configuration from 1 to 8 simultaneous cores, as needed. Early in March CMS began first tests of Tier-0 workflows which successfully used this capability.

This quarter we also aggressively tested data transfer capabilities from CERN, which also tested the new ESnet transatlantic link. CMS expects to be able to transfer data at rates peaking at 600MB/s to FNAL disk only storage, and 400 MB/s to tape storage. In February FNAL underwent a week-long test demonstrating 1.3 MB/s aggregate transfers from CERN. In addition to the CMS requirements we also added simultaneous staging of 400 TB of data, and initiating a deletion of about 1 PB of test data to further strain the dCache storage servers. These tests were successful in hitting needed rates and identifying potential bottlenecks in the software driving data transfers.

University Facilities

Tier-2 facilities

The first quarter of 2015 saw continued light usage of the U.S. CMS Tier-2 facilities. Most data analyses from the previous LHC run have been completed, and the demand for simulation samples for Run 2 has not picked up yet.

The seven U.S. sites have continued in their preparations for the coming data run through a program of technical improvements and the deployment of necessary hardware resources. Important improvements to networking in particular have been made in the past quarter. All seven sites have ~100Gbps WAN capability now. Also, ESnet is starting to connect Tier-2 sites to their LHCONE VPN. All sites have deployed the HTCondor-CE computing element, and have either retired or are planning to retire their GRAM CEs. CMS is also testing the running of very high-IO data reconstruction at the U.S. Tier-2 sites, instead of only at Tier-1 sites.

All sites have operated successfully this quarter. On our two official performance metrics based on

CMS test jobs, all sites were at least 88% "available" and 94% "ready", see Figure 7. The CMS goal for each of these metrics is 80%. The U.S. Tier-2 centers hosted 39% of all CMS user analysis jobs (goal is 25%).

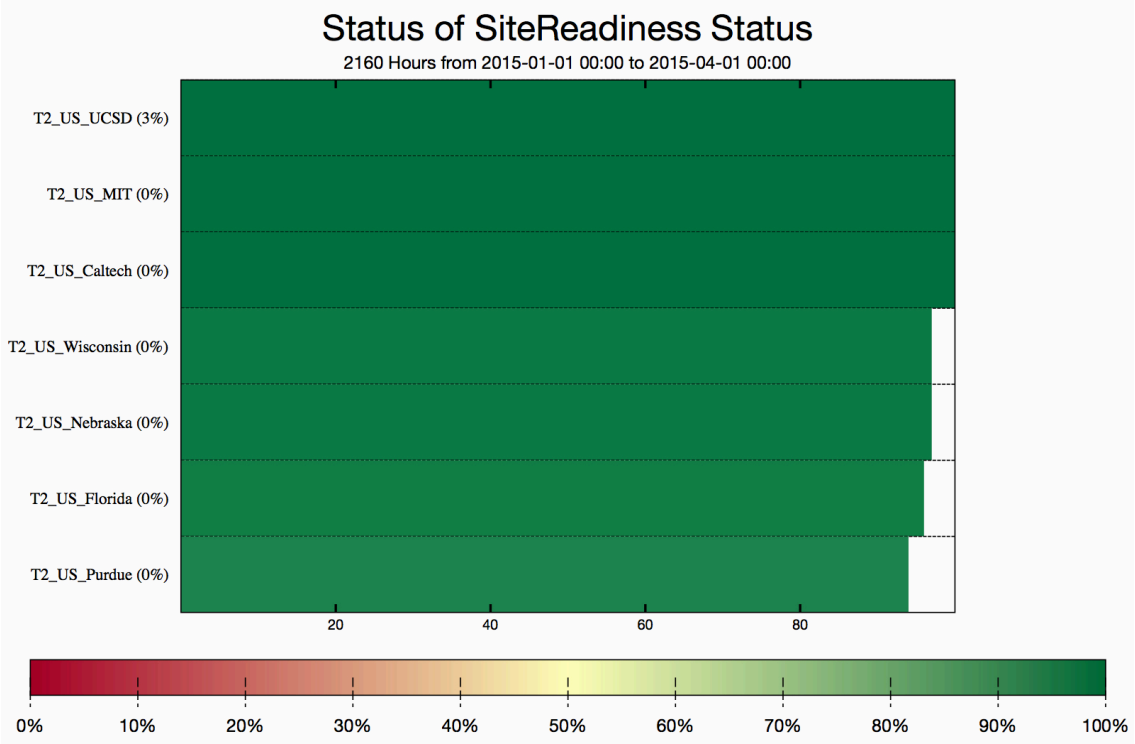


Figure 7: The site readiness metric for the U.S. CMS Tier-2 sites during this quarter. All sites were above 94%; the CMS goal for Tier-2 sites is > 80%.

Tier-3 support

Fourteen Tier-3 sites required assistance from the Tier-3 support team this past quarter. These support activities include helping sites complete the transition from OSG 3.1 to 3.2 and assisting several sites in rebuilding their site in preparation for Run 2. In addition, we migrated the centrally operated PhEDEx server for Tier-3 sites from SL5 to SL6 and the latest version of PhEDEx. A majority of the issues concerned the following packages/tools: GUMS, HTCondor-CE, SUM tests, XRootD, Hadoop, CVMFS, glexec, PhEDEx, certificates, GlideInWMS, and squids. In addition, we also helped resolve problems with Rocks, GIP/BDII, OIM, SSL, RSV tests, and lcg-tools.

The Tier-3 support team has undertaken an effort to refresh the documentation for Tier-3 configuration and administration. This effort will continue into the next quarter. We are also investigating options for making installation and administration of Tier-3 sites easier for sites by making use of modern cluster configuration and provisioning systems like Puppet and Foreman. A survey was initiated to collect information on how site coordinators currently manage their sites. This activity is ongoing.

CMS Connect

The U.S. CMS software and computing project took the first concrete steps towards standing up a new service, CMS Connect, based on the CI-Connect platform developed for OSG. The CI-Connect platform is also used to implement the OSG Connect and ATLAS Connect services. Working with the OSG team from the University of Chicago, we have configured the login server and configures the service to send jobs to the CMS GlideInWMS factory operated at UCSD. We have demonstrated the ability to submit and run jobs through the CMS Connect service, and are in the process of preparing documentation in anticipation of opening the system to the first beta testers in the next quarter.

Computing Operations

In this quarter the Tier-0 was operating in data taking mode to support recording of cosmic ray events without and with magnet field on. A sufficient number of cosmic ray events were collected to align the detector for the startup of LHC Run 2. In parallel, scale testing of the Tier-0 infrastructure directly using the OpenStack cloud at CERN was continuing, identifying several bottlenecks that were solved together with CERN-IT. Importantly for the Tier-0, CMS completed establishing the glideinWMS global pool, combining all previously separate analysis and production pools and allowing for more flexible provisioning and optimization of resources. The Tier-0 was the last system to be migrated. CMS decided to have a separate Tier-0 glideinWMS pool to guarantee undisturbed data taking, but with the ability to flock jobs to the global pool to run prompt reconstruction at all Tier-1 sites. Each Tier-1 site is now able to run multi-core pilot jobs using 4-8 cores, running the CMS reconstruction application multi-threaded across multiple cores, for data taking and re-reconstruction of data, at the Tier-0 and all Tier-1 sites. The global pool itself reached more than 110k parallel jobs and now is the largest HTCondor-based glideinWMS pool in the world.

On the data management side, all Tier-1s placed about 50% of their disk resources under dynamic data management. The remaining 50% of the disk space will be managed by operations to pre-stage input samples for processing and to keep freshly recorded data permanently on disk to allow for rapid re-reconstruction if the need arises in LHC Run 2. All Tier-1 sites ran tape staging scale tests and fulfilled the requirements for LHC Run 2.

On the processing side, a large number of high-priority Monte Carlo production campaigns were run particularly for the Phase 2 Upgrade efforts. The number of events produced is shown in Figure 8. In addition, a re-digitization/re-reconstruction campaign of the data samples produced for the 2014 computing, software and analysis challenge (CSA14) was finished in this quarter. All these activities were delayed from their original schedule due to continuing issues with availability of validated CMSSW software releases, but computing operations did their best to make up for delays by increasing turn-around times for production, using the HLT farm when available, and through other measures. The Phase 2 Upgrade workflows put a particularly high stress on the systems due to their increased memory needs and high I/O rates from the mixing of very large number of pileup events. MC simulation ran in parallel producing the requested number of MC events.

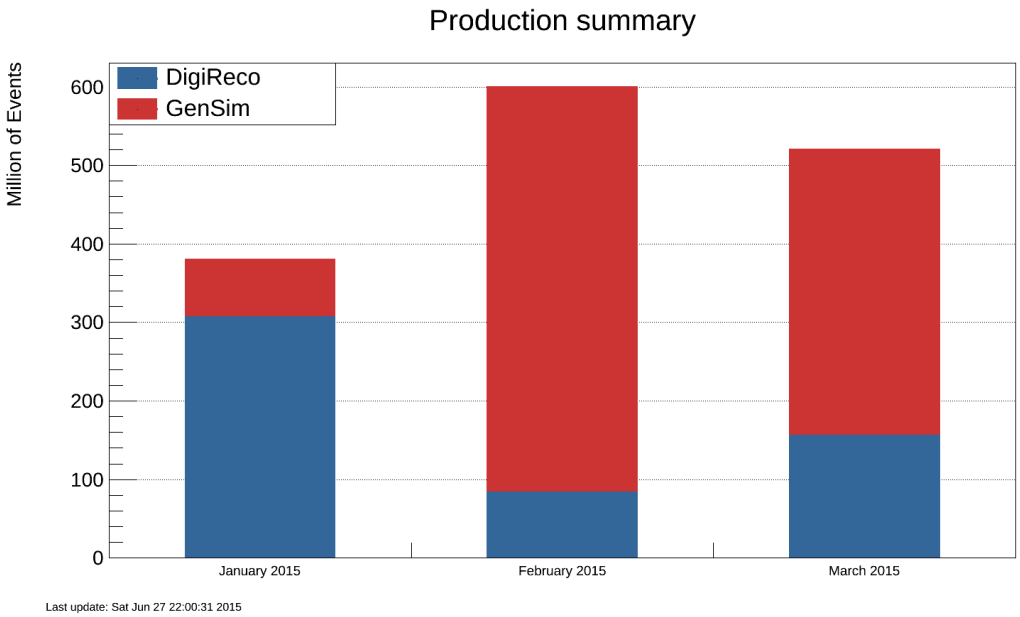


Figure 8: Quantities of Monte Carlo events produced during the months of this quarter.

Computing Infrastructure and Services

During the LS1 period the work within U.S. CMS Computing Infrastructure and Services centered around infrastructure improvements needed to be fully ready for the next LHC run in 2015. Work in this area includes improving the functionality, stability and scalability of the grid and cloud based job submission infrastructure, enabling the use of opportunistic resources, and improving the availability of CMS data through more dynamic and flexible storage strategies.

During the quarter, work on the WMAgent concentrated on minor improvements needed for the impending Run 2. This entailed continued refinement and improved monitoring for multi-core workflows and progress towards abstracting how processing and storage locations are referenced to insulate the agents from internal changes at sites. The WMAgent team completed the migration to CouchDB 1.6 and made substantial progress towards replacing the request management system. For the next quarter we aim to release this system as well as to begin preparations for WMArchive, a new database which will store performance information about each job.

The Tier-0 system was successfully operated through several test runs as well as through both the CRUZET (0 T) and CRAFT (3.8 T) cosmic-ray runs used for calibration. The system was scaled up to 9,000 cores (compared to the 14,000 cores expected for the final system). The ability to run multithreaded prompt reco on the Tier-1 systems was successfully tested. With development effectively finished for the Tier-0, the aim for the next quarter and beyond is to reliably operate the system during Run 2 data taking.

The reporting period saw a major milestone on the analysis system as CRAB3 was declared to be in production and the preferred system for CMS analysis-job submission. The user base continued to expand, see Figure 9, as improvements to end-user conveniences were put in place, including an option to predict the optimal job configuration parameters based on an automated test run. Work

commenced on enabling CRAB jobs to be submitted to the FNAL LPC analysis facility, LPC-CAF. This capability is on track to be delivered late next or the following quarter.

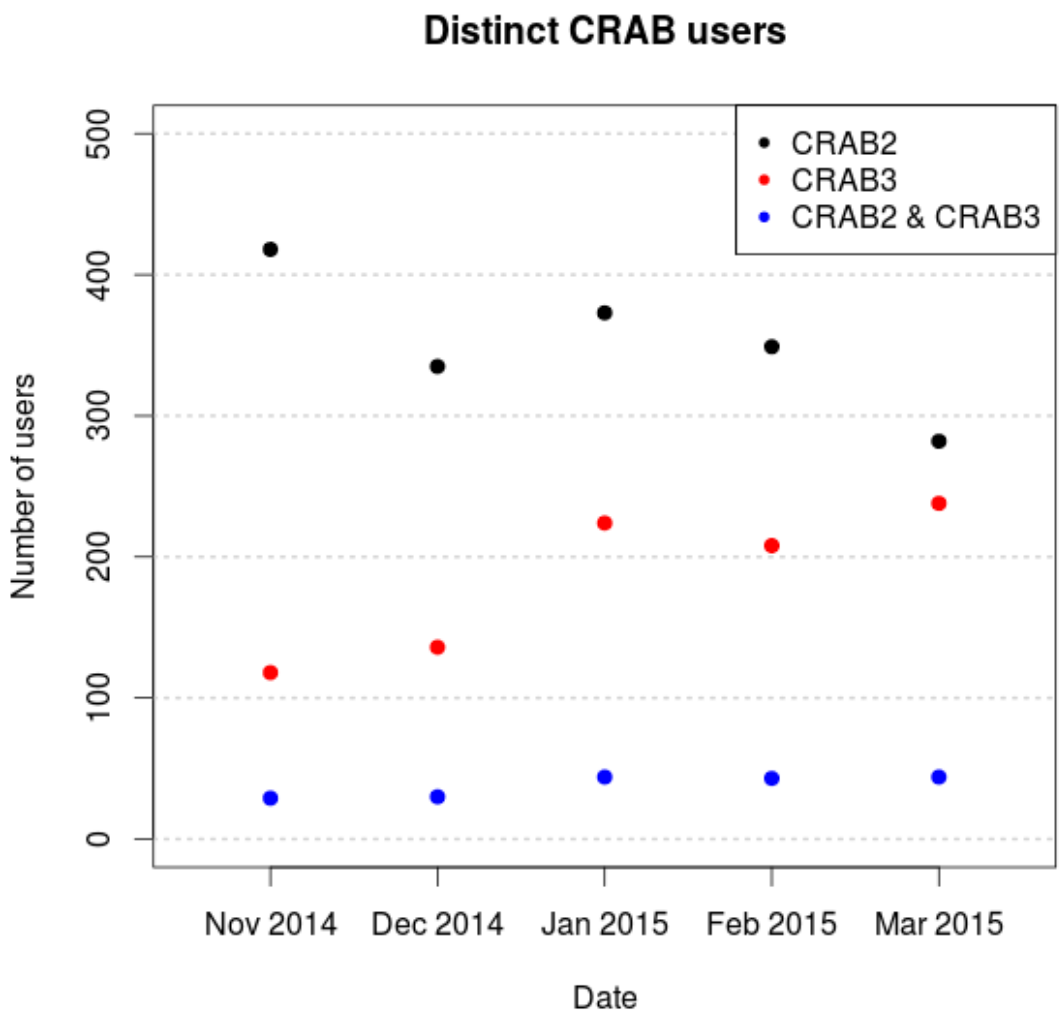


Figure 9: Number of unique users of CRAB2 and CRAB3, showing the increased adoption of the new CRAB version.

DBS, DAS, and PhEDEx are U.S. data management products and are all in stable condition for the start of Run 2. Each has seen minor tweaks to adapt to new operating conditions. Furthermore, in this quarter CMS conducted a review aimed at improving data management and movement for end users; this review resulted in a number of recommendations which will be turned into work packages over the next year or so. This will impact all of the data management products, but is only a moderate amount of effort.

There was no glideinWMS release during the quarter. However, significant progress was made towards next quarter's goals: a master-slave high-availability mode for the VO frontend and a sep-

aration of the user collector from the collection broker. This will enable the infrastructure to scale more than 150,000 jobs in a pool.

Xrootd related activities in this quarter revolved around the xrootd-4.2 release, especially consolidations of the caching proxy code. We added support for using the xrootd built-in volume manager, allowing caching proxy to use several mount-points for data storage. We also implemented and tested a configuration for a cluster of caching proxies. As this is a rather novel usage, some minor changes needed to be implemented within xrootd itself. Following these two extensions we also consolidated the caching proxy configuration syntax. The hdfs healing code was rewritten in a more robust manner and packaged for inclusion into OSG software stack to make it more easily available to all CMS sites operating hdfs. At the end of January we helped organize a very successful XRootd workshop at UCSD, which brought together the XRootd developers with members of ALICE, ATLAS, CMS and OSG.

In addition to the global pool transition already mentioned above, we commissioned workflows on DOE (NERSC Carver) and NSF (SDSC Gordon) supercomputers, and submitted an Amazon Web Services (AWS) proposal that was accepted. The latter is a two-year pilot project for which AWS covers 90% of the cost. The goal of the proposal is to establish our capability to elastically grow resources to meet deadlines. In year one of the project, this elastic scaling is proposed to reach 50% increase in resources for CMS globally, sustained for 1 month. The proposal is a joint venture with Fermilab and OSG, and is thus driven by the U.S. both intellectually as well as regarding effort to execute the project. All of these activities are part of a larger objective towards more agile operations across traditional as well as less traditional types of resources in the future.

Software and Support

The software group continues to produce improved software releases to support the development of the major fronts of CMS. The two areas of primary development are Run 2 and Phase 2 upgrades, where the reconstruction software for both continues to evolve. To be ready for the new challenges of Run 2, both the physics performance, particularly in preparation for 25 ns LHC operations, and the technical performance of this software has continued to improve. Recent accomplishments include the adoption of ROOT6 and continued adoption of the multi-threaded framework within the simulation and reconstruction areas. The software release for data taking is currently in its final preparation phase.

The CMSSW release cycle for SLHC upgrade studies, CMSSW_6_2_X_SLHC, continues to be the basis of simulation studies to support the preparation of the Technical Proposal for the CMS Phase 2 upgrade for the HL-LHC. This release supports both Phase 1 and Phase 2 detector studies. The Phase 2 simulation configurations for the Technical Proposal are now finalized, including recent work on the forward calorimetric systems, forward region shielding and support materials. There is a continued focus on the challenges of developing robust reconstruction algorithms despite the very high pileup conditions, which include up to an average pileup of 200 interactions per bunch crossing. Production campaigns of large Monte Carlo sample generations have continued as the software has been evolving. Significant improvements in both the operational and reconstruction

quality of these very challenging applications have been achieved over the past three months.

U.S. LHCNet Decommissioning

This quarter's main activity was to finalize the transition of the transatlantic production network services to ESnet EEX and to decommission U.S. LHCNet. This section provides an update on the equipment decommissioning process at the various points of presence and the migration of services for the future collaboration and projects.

During December 2014, the U.S. LHCNet team worked with ESnet and the CERN network operations center (NOC) for the circuit migration and fail-over testing of the LHCOPN circuits between CERN and Fermilab, and CERN and BNL. This process involved shutting down the transatlantic circuits one by one within the US LHCNet domain and shifting the services over to the ESnet network. The testing process went smoothly, with no apparent issues or outages. On December 8th, all the paths carrying LHC traffic were switched over to ESnet. The LHCONE service between Internet2 and CERN through Amsterdam was decommissioned close to the end of December.

The U.S. LHCNet team was then involved in the process of coordinating, decommissioning and shipping the equipment installed at various remote Co-location sites.

The Amsterdam PoP has been cleared and all the equipment is in the process of being shipped to Caltech. The equipment from New York and Chicago will be shipped back to Caltech as per the schedule. The rack locations in remaining two PoPs will be cleared to avoid any further charges.

As outlined in the statement of work, during the 4-month period of service migration, the US LHCNet group at Caltech is working on the following deliverables and efforts delivered to the Operations Programs:

1. Transition completion from US LHCNet to ESnet EEX production services, including teardown of the final circuit on January 22nd.

2. Meeting the contractual obligations with Level3 followed with plans to decommission the US LHCNet optical multiplexers and other equipment that is no longer needed at the CERN, Amsterdam, New York and Chicago points of presence, shipping or storing the equipment as needed.

3. Transitioning to a development oriented configuration leveraging the Brocade, Pronto and Dell/Force10 switches at these PoPs as well as Caltech. The team will perform the reconfiguration of the equipment and network routes for the follow-on phase of the Caltech network team working together with ESnet, other R&E networks, university teams and lab teams at Fermilab and Brookhaven. The latter is to support future ongoing technical developments of software-defined networking, dynamic circuits, and state of the art high throughput data transfer methods in partnership with ESnet.

This decommissioning work is closing out the U.S. LHCNet project and there is no further cost to the Operations Programs related to U.S. LHCNet transatlantic production services past April 30, 2015.

The Caltech team and ESnet are continuing joint research projects in the context of ANSE (Advanced Network Services for Experiments) and LHCONE, as well as new initiatives on the future Internet architectures in the context of future evolution of the LHC Computing Models. In association with the foreseen program, arrangements are underway for a modest allocation of continued rack space for servers and software defined network switches at CERN, and Starlight in Chicago. We are also discussing an allocation in Amsterdam and the SURFnet/SARA PoP. In all cases, there will be no co-location costs. We will of course use the equipment and 100 Gbps link at Caltech, funded by the NSF CHOPIN project together with support from the California regional network CENIC.

Several of the following areas of work will be closely coordinated with ESnet to ensure a smooth transition, and to define the joint development program from May 1 2015 onward, together with the LHC experiments, and Fermilab, CERN and BNL in particular.

- Continuing the work on the use of dynamic circuits, monitoring and software-defined network control. This includes, in the near term, bringing the use of PhEDEx with OSCARS dynamic circuits into pre-production use among a limited set of sites, and adapting the use of the circuit mechanisms and some of the code in PhEDEx to PanDA for ATLAS.
- The application-side (PhEDEx, PANDA) work for this is supported mostly by the NSF ANSE project, but the network configuration, operation and testing work will be done in the context of the Caltech Network Development program.
- Continued work to develop point-to-point circuits in the context of LHCONE. This will build on the PhEDEx and PanDA, in order to provide improved data transfer performance, and more predictable time to completion for dataset transfers.
- Continued software-defined network development in the context of Open Daylight. This is targeted at the selection of optimal paths across the complex networks used by the LHC experiments for sets of flows, taking into account other traffic in progress and other pending requests. This will result in better load balancing, especially during periods of intensive network use.
- Another aspect of this is to couple these control mechanisms with comprehensive monitoring, to moderate the aggregate use by the LHC experiments, so as not to saturate the available network infrastructure or overly impede other network traffic.

Several of these research items have been demonstrated successfully at the Supercomputing 2014 conference last November. and the work areas will serve to bring these to a pre-production state this year, followed by the development of production services on an increasing scale during LHC Run 2.

A complementary line of ongoing development is focused on state of the art systems for high throughput data transfers at moderate cost, adapting to the rapid progress in both networks and network interfaces, as well as server architectures matched to the current generation of 100 Gbit/sec links.

Further specification and definition of the work areas and deliverables will be provided as part of the Caltech network development plan, in close coordination with ESNet and the LHC experiments.