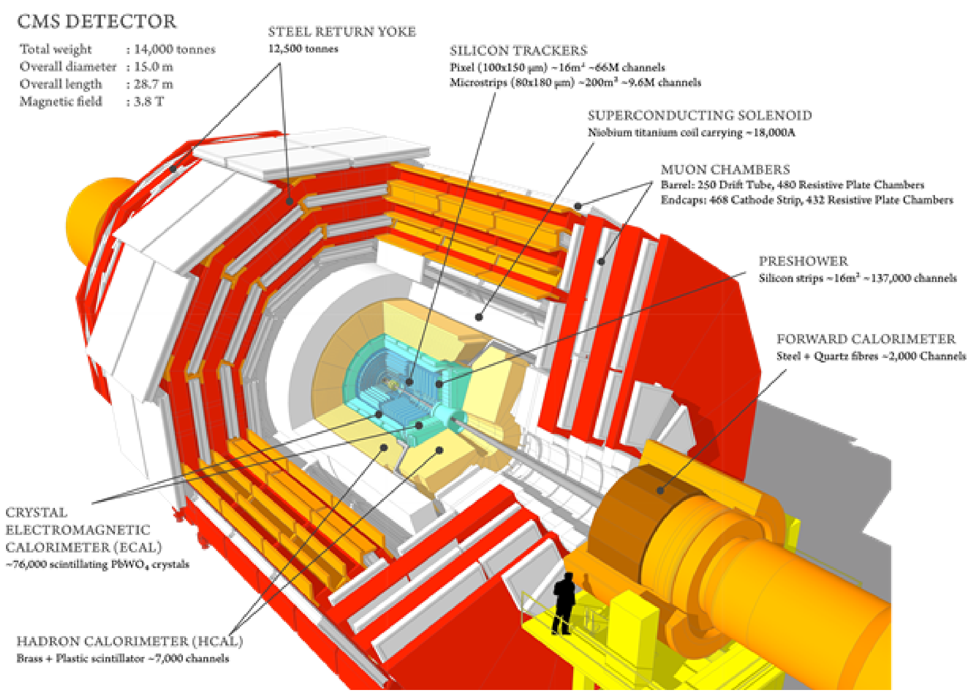
U.S. CMS Compact Muon Solenoid Operations Program Quarterly Report for the Period Ending June 30, 2015

U.S. CMS Operations Program



Program Manager's Summary

During the second quarter of calendar year 2015 (2015Q2) CMS operations transitioned from the end of the long shutdown (LS1) to the start of Run 2. After a series of commissioning runs, physics data taking began in June. Leading up to that, CMS had been busy with commissioning deliverables of the detector improvement program during LS1, getting the detector, readout and data processing ready to take high-quality data efficiently, and finishing a program of work in software and computing to prepare for the startup of CMS data taking.

The path to first LHC collisions was not entirely smooth, but ultimately successful. Repeated beam aborts in one sector (15R8) were traced to a "ULO" (Unidentified Lying Object) that is located within one specific magnet. The beam could be steered around it and the ULO location is stable enough that it does not significantly impact LHC operations. A number of other issues were resolved, including a magnet earth fault that was blasted away by running a high current. The LHC physics program then began with initially low luminosity and special runs, at 50 ns bunch crossing, proceeding to the intensity ramp up, before switching to 25 ns bunch crossing planned to start in the summer.

In this quarter CMS developed a serious problem with operating the magnet. In April for some time the magnet cryogenics team (the CERN CMS/TE group) has been struggling with clogging of filters in the refrigerating unit ("cold box") used to liquify helium to cool the superconducting CMS solenoid, supposedly caused by a larger-than-expected amount of as of yet unidentified pollutants in the system. There are indications that the contamination is Breox oil (which is used in the pumping system), traces of which were found in the turbine pre-filters. In addition carbon dust coming from a large absorber operating at a temperature of 80 Kelvin was found in the filters downstream of that absorber.

In April the decision was taken to warm up and open the cold box to replace the filters. This implied no cold box operation for weeks and thus no operation of the CMS magnet. This was the beginning of an extended series of studies of filter performance and a sequence of recycling operations. It led to having to start physics operations without the magnetic field on, and subsequently to periods of no field during LHC luminosity while the cold box needed to be recycled, with some impact on CMS' ability to fully participate in the initial running period at 50 ns bunch crossing.

Summary of CMS Activities During this Quarter

Regarding improvements and repairs to the detector, CMS completed its shutdown activities, and closed up the detector. A number of milestones achieved and deliverables finished are listed below in this report, showing that the LS1 detector improvement program was delivered successfully.

In the BRIL area, the pixel luminosity telescope (PLT) was successfully commissioned and is now being used as the primary luminosity monitor for the experiment. The Tracker Strip and Pixel detectors were calibrated, including bias and timing scans. ECAL is running smoothly and readout timing was checked and adjusted using beam splashes and first collision events. HCAL has participated fully in collisions with upgraded μTCA back-end in the HF, delivering good quality data. The endcap muon CSC systems were timed in and checked with collision data, and the timing calibration obtained in beam splash events and beam halo events etc. were found close to optimal. Installation of new DAQ including new HLT nodes was completed and routinely used in data taking with beam and cosmic runs. For the regional calorimeter and the endcap muon triggers, significant progress was made timing in the various elements using beam collisions.

Software and computing upgrades were also delivered on time for data taking, and the new and updated components are being used by the production teams and a large and increasing number of data analysis users. This includes the data management systems, the workflow management tools, the job scheduling environment, the analysis job submission, and the monitoring systems.

Thus, when LHC started to provide collision data at 13 TeV, CMS was ready to begin data taking at good efficiency, and efficiency was further improved steadily over the initial data taking period.

Regarding the preparations for the high-luminosity LHC upgrade (HL-LHC) during this quarter CMS submitted the Phase 2 Upgrade technical proposal, with strong U.S. contributions. Another important milestone was that CMS management decided on the choice of calorimeter technology for the endcap. The decision was taken against the Shashlik Calorimeter technology, and for the proposal of building a so-called "High Granularity Calorimeter" based on silicon readout with a scintillator-based backing hadron calorimeter. U.S. groups were strongly contributing to both proposals.

This was decided by CMS management (spokesperson and deputies, upgrade and technical coordinator) with input from a report by a down-select committee that had been charged to carefully study the proposals, and that presented its findings and comments in April. The committee was charged to evaluate a number of criteria, in particular the calorimetric performance and benefit to physics analysis, technical feasibility, integration into CMS, operations issues, the scale of effort for R&D and construction, and validity of cost estimates of either proposal.

The report proposed a list of major criteria to be considered in the selection of one design and included an evaluation of the technical and schedule risks. CMS management decided to select the HGCal proposal, and that decision was endorsed by the CMS Collaboration Board in May.

Although the Shashlik Calorimeter proposal is not moving ahead, CMS encouraged the groups involved — including a number of U.S. institutions — to continue an effort within the next year to carry out a targeted and limited continuation of the R&D that includes additional:

- measurements needed to certify radiation hardness of the key optical components,
- engineering studies to certify the usage of capillaries,
- R&D to define Quality Assurance/Quality Control necessary to construct such a device.

The goal is to capture those aspects of the R&D that might be useful for future experiments and can be accomplished with the limited resources available. U.S. CMS Operations Program Management asked the U.S. groups involved in Shashlik Calorimeter R&D to provide a plan for this limited continuation of R&D to close out those efforts.

Closing out the analysis of Run 1 data taken in 2011 (5 fb^{-1} at 7 TeV) and 2012 (20 fb^{-1} at 8 TeV) proceeded and by the end of the quarter CMS had submitted some 375 papers for publication. One of these marked a particularly visible milestone with the publication of the joint article between CMS and LHCb, on the *Observation of the rare* $B_s^0 \to \mu^+\mu^-$ *decay from the combined analysis of CMS and LHCb data* in Nature.

In summary, during this quarter U.S. CMS made significant progress in physics analysis and publications of existing data, in detector operations, in upgrades and R&D. CMS was successfully commissioned and ready for the start of LHC Run 2, and physics data taking started.

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 1.

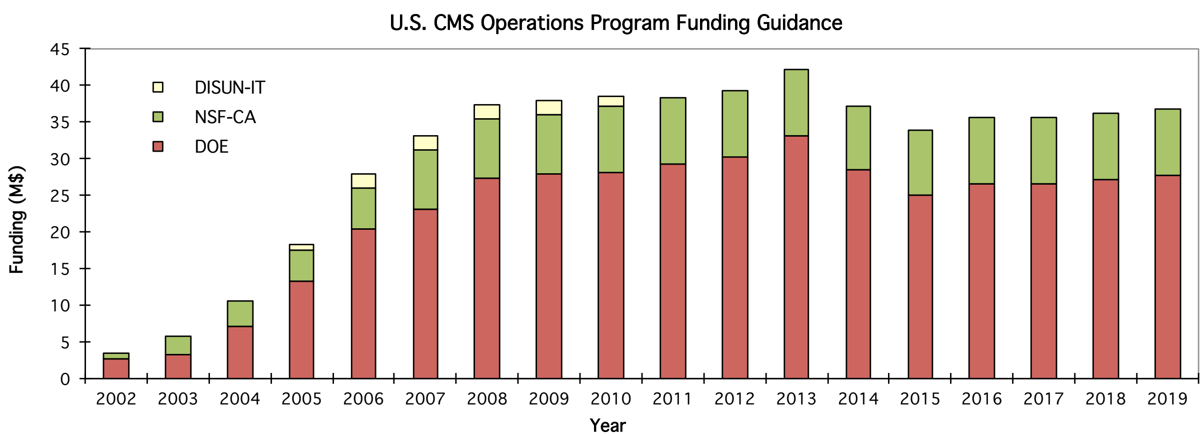


Figure 1: The annual U.S. CMS Operations Program funding provided by DOE and NSF. For 2002 through 2015 the chart shows the actual funding, while for 2016 onward the current funding guidance is shown.

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 the current calendar year took place this past August and September. Through this process, U.S. CMS Management developed a detailed spending plan. This plan was further refined through the March joint NSF/DOE Operations Program review.

Primarily during the first quarter of the calendar year, Statement of Work (SOW) agreements were established with each institution that is providing a deliverable in exchange for Operations Program funding. The SOWs specify the tasks to be carried out, as well as any portions of salaries, materials and services (M&S), travel funding, or cost of living adjustments (COLA) to be paid from the Operations Program budget. The SOWs must be approved by U.S. CMS Operations Program management, by the Fermilab Director Designee, and by representatives of the collaborating group and institution. Through June of 2015, a total of 106 SOWs (68 DOE and 38 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 Change Requests. The information is reported here down to the level-2 subsystem categories within DetOps, S&C, and ComOps. The calender year 2015 (CY15) spending plan, as of the end of Q2, is shown for DOE and NSF funds in Table 2. The plan will continue to evolve slightly as Change Requests are executed.

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 2 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, while spending at Fermilab has historically been budgeted according to the fiscal year. Of special note is that this year we have transitioned to reporting based on calendar year rather than based on fiscal year. There are two features of Figure 2 related to this transition. First, obligations for DOE spending at Fermilab in the last three months of calendar year 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 3 shows the total obligations and the spending plan, for NSF funds. Of the $9M in NSF funding, $2.7M in subawards went out this quarter, in addition to spending directly at Princeton.

Resources deployed at CERN, and paid directly in Swiss francs, account for approximately 28% 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 in CY15 Q2 averaged 0.94 CHF/USD. Figure 4 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 4 does not include the last 823K CHF of the Upgrade Common Fund payments and the 3,827K CHF M&O-A payments, as these are each made through multiple payments to a separate Team Account.

Table 1: Spending Plan Change Log for CY15 Q2

WBS	Subsystem	Change Request Number	Description of Change	CY15Q2 Plan	Change $	CY15Q3 Plan
U.S. CMS Detector Operations Change Control Activity						
11	Endcap Muon	CR-022 & CR-023	UCSB CR-022: ME11 Electronics Labor correction, Team Account CR-023: Software/DAQ personnel	$1,820,239	$15,801	$1,836,040
12	Hardon Calorimeter	CR-027 & CR-028	Pre-sow adjust of software personnel, new UMinn SOW for electronics personnel, Iowa CR-027: HF improvements & HCAL sourcing, Brown & KSU CR-028: COLA and Travel	$1,589,517	$8,646	$1,598,163
13	Trigger			$919,475	$0	$919,475
14	Data Acquisition			$780,208	$0	$780,208
15	Electromagnetic Calorimeter		Adjustments	$844,815	($3,000)	$841,815
16/17	Tracker (Fpix&SiTrk)		Pre-sow adjustments	$775,461	($42,663)	$732,798
18	Detector Support	CR-016 & CR-017	Fermilab CR-016: CTPPS front-end board design labor, Fermilab CR-017: 2nd CTPPS module labor and M&S, CERN team account SOW adjustment	$209,473	$48,789	$258,262
19	BRIL			$388,180	$0	$388,180
30	Phase 2 Upgrade R&D	CR-030 & CR-017		$3,249,847	$107,409	$3,357,256
11-18,30 Detector Operations				**$10,577,215**	**$134,982**	**$10,712,197**
U.S. CMS Common Operations Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY15Q2 Plan**	**Change $**	**CY15Q3 Plan**
21.2	Common Costs (M&OA, LS1, Loan)		LS1 Common Fund overhead reduction	$5,430,822	($15,000)	$5,415,822
21.3	RCMS		Developer contract	$518,857	$35,556	$554,413
21.4	LHC Physics Center			$633,829	$1,808	$635,637
21.5	Operations Support		BU CR-077: Trigger coordinator and convener support	$1,357,534	$98,057	$1,455,591
21.6	Program Office		Travel for Upgrade Planning and other M&S adjust	$980,594	$48,800	$1,029,394
21.7	E&O			$286,480	$0	$286,480
21.8	Collaboration Support			$10,000	$0	$10,000
21	**Common Operations**			**$9,218,117**	**$169,220**	**$9,387,337**
U.S. CMS Software and Computing Change Control Activity						
WBS	**Subsystem**	**Change Request Number**	**Description of Change**	**CY15Q2 Plan**	**Change $**	**CY15Q3 Plan**
22.1	Fermilab Facilities		Changes are a combination of pre-sow adjustments ($41K personnel increase, $8K travel increase), change request CR-008 of $35K for Amazon Cloud Pilot, and reduction of $211K due to a favorable price on LPC Computing Analysis Facility disk purcahse	$6,738,279	($182,010)	$6,556,269
22.2	University Facilities			$4,117,582	$24,926	$4,142,508
22.3	Computing Operations			$1,123,082	$5,949	$1,129,031
22.4	Computing Infrastructure and Services			$2,095,189	$11,742	$2,106,931
22.5	Software and Support			$1,938,046	$13,040	$1,951,086
22.6	Technologies & Upgrade R&D			$902,380	($3,050)	$899,330
22.7	S&C Program Management & CMS Coordination			$691,772	$2,504	$694,276
22	**Software and Computing**			**$17,606,331**	**($126,900)**	**$17,479,431**
U.S. CMS Operations Program Total				**$37,401,663**	**$177,302**	**$37,578,965**

Table 2: Spending plan at the end of CY15 Q2, for funds from DOE, NSF, and the total.

WBS	Subsystem	DOE Funds	NSF Funds	Total
11	Endcap Muon	$1,501,320	$334,720	$1,836,040
12	Hadron Calorimeter	$1,524,752	$73,411	$1,598,163
13	Trigger	$771,665	$147,810	$919,475
14	Data Acquisition	$780,208	$0	$780,208
15	Electromagnetic Calorimeter	$841,815	$0	$841,815
16/17	Tracker (Fpix-SiTrk)	$703,520	$29,278	$732,798
18	Detector Support	$258,262	$0	$258,262
19	BRIL	$134,100	$254,080	$388,180
30	Phase 2 Upgrade R&D	$2,719,814	$637,442	$3,357,256
11-19,30	**Detector Operations**	**$9,235,456**	**$1,476,741**	**$10,712,197**
21.2	Common Costs (M&OA,LS1,UpgrdLoan)	$4,326,559	$1,089,263	$5,415,822
21.3	Run Coordination and Monintoring	$554,413	$0	$554,413
21.4	LHC Physics Center	$635,637	$0	$635,637
21.5	Operations Support	$1,327,761	$127,830	$1,455,591
21.6	Program Office	$911,844	$117,550	$1,029,394
21.7	Education and Outreach	$170,000	$116,480	$286,480
21.8	Collaboration Support	$10,000	$0	$10,000
21	**Common Operations**	**$7,936,214**	**$1,451,123**	**$9,387,337**
22.1	Fermilab Facilities	$6,556,269	$0	$6,556,269
22.2	University Facilities	$111,217	$4,031,291	$4,142,508
22.3	Computing Operations	$713,568	$415,463	$1,129,031
22.4	Software and Support	$1,677,995	$428,936	$2,106,931
22.5	Computing Infrastucture and Services	$1,694,841	$256,245	$1,951,086
22.6	Technologies & Upgrade R&D	$206,191	$693,139	$899,330
22.7	S&C Program Management and CMS Coordination	$464,016	$230,260	$694,276
22	**Software and Computing**	**$11,424,097**	**$6,055,334**	**$17,479,431**
U.S. CMS Operations Program Total		**$28,595,767**	**$8,983,198**	**$37,578,965**

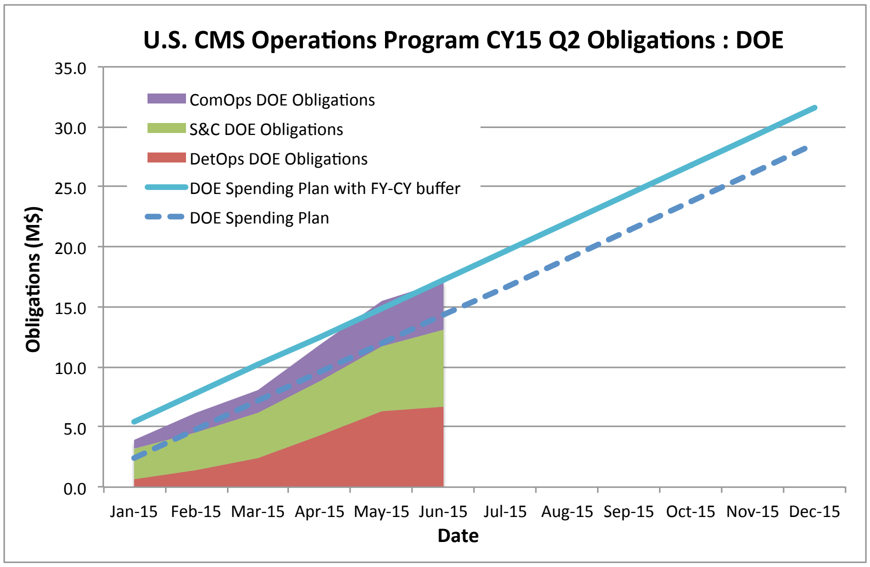


Figure 2: Obligations and spending plan for DOE funds. The spending plan is indicated with the assumption of equal monthly increments just as a rough guide. The lines show the spending plan with (solid) and without (dashed) a required buffer to bridge the difference between fiscal year and calendar year for funds spent at Fermilab, as described in the text.

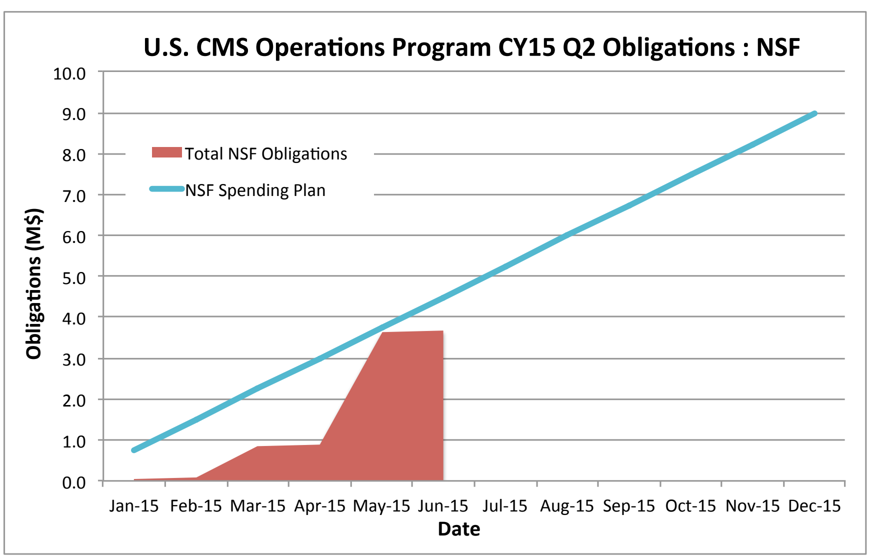


Figure 3: Obligations and spending plan for NSF funds. The spending plan is indicated with the assumption of equal monthly increments as a rough guide.

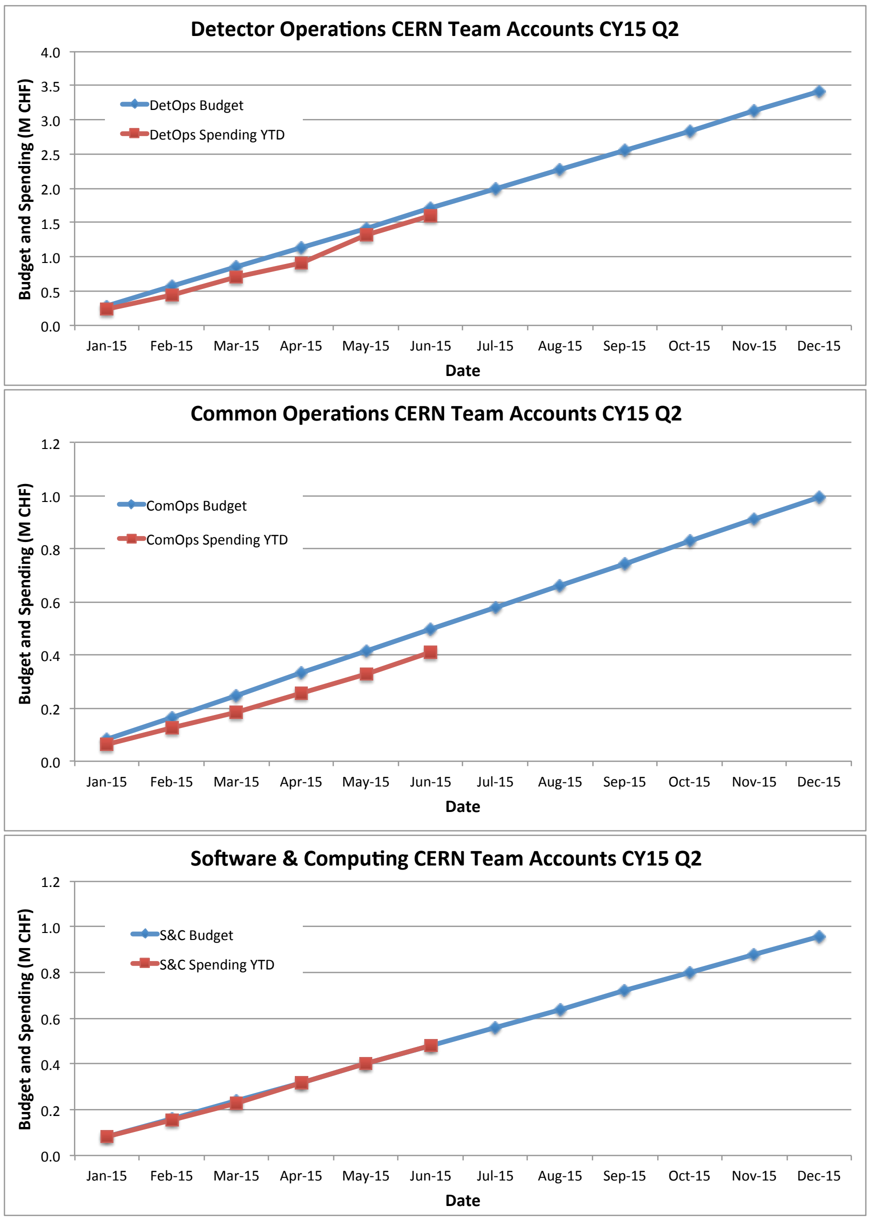


Figure 4: Budget plan and year-to-date spending, in Swiss francs, through DetOps (top), ComOps (middle), and S&C (bottom) Team Accounts.

Detector Operations

At the beginning of the quarter, CMS had a successful cosmic ray run with the magnet at 3.8 Tesla in preparation for beam. This was followed by LHC running with single beams for commission which allowed CMS to use beam halo and splash events to further its commission efforts. During this period it became apparent that there was contamination in the liquid helium of the CMS magnet. The decision was taken to turn off the magnet and investigate the source of contamination and replace filters as necessary.

The investigation of the issues with the magnet's helium supply continued through the quarter. At the present time the source of the contamination is not well understood however a detailed analysis showed that it was unlikely that the contamination could reach the magnet itself. The decision was taken at the end of the quarter to ramp up the magnet and periodically replace filters as necessary. By July 6 the magnet was again operating at 3.8 Tesla.

CMS is presently collecting data with LHC collisions at $\sqrt{s} = 13$ TeV. Physics data is being collected and commissioning ongoing while they increase the number of bunches in the beam step-by-step.

Milestones and Metrics

U.S. 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 U.S. CMS effort as part of the BRIL sub-detector group is the pixel luminosity telescope (PLT). The detector is installed inside the CMS detector close to the beam pipe, about 170 cm away from the interaction point on either side of it. On each side there are 8 three-layer silicon pixel detectors. The detector is kept at a temperature of -15 degrees Celsius. The rate of triple coincidences is used to provide luminosity measurements for each bunch crossing. The framework is in place to continuously publish this information to the LHC and to CMS, and this has been done over the last two months.

Furthermore, the PLT also monitors the beamspot online using full pixel detector information that is sampled at a lower rate. Luminosity is also calculated from this hit information and using tracking algorithms. The PLT has participated in the very first short Van der Meer scan and a first calibration of the published luminosity numbers has been done. Online monitoring for all the BRIL sub-systems is in place and is being developed further. The offline analysis code is ready and systematic studies started.

One out of 16 telescopes developed a fault after the temperature was raised and reduced for the barrel pixel detector several times. The cause for this is thought to be that contact problems might have been introduced during installation, that then developed further due to the temperature changes. This is not expected to significantly reduce the luminosity precision and for consistent reporting the affected telescope is presently taken out.

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	May

Tracker – Strips

Using pp collisions with no magnetic field in the detector, the strips have completed primary timing and bias scans, and identified and found coping mechanisms for problems. We have found that pneumatic control lines in the cooling system can become clogged with ice. The mitigation mechanism is to include a bleed valve that continually flushes the lines. Currently, the correct flow rate for the bleed is being determined. This is important as a loss of cooling in part of the strip detector will affect running. Most of our other operations have been concerned with detector maintenance and learning to operate with the new VME controllers, the new timing system and the upgraded DAQ.

Tracker – Pixels

Pixels also took advantage of collisions with no field to perform the primary bias and timing scans. The pixels will do a follow-up timing scan with the B field on (the B field effects the cluster size). There have been several issues for pixels with the new DAQ and timing system, and as with the strips, these have been understood and fixed. There is a problem in the Barrel Pixel detector (not an U.S. responsibility) that effects one sector (about 1.6% of the system). Only part of that sector can hold power when the B field is present. We have tried to include as many modules as possible in the inner barrel layer and all the modules in the outer layer. More testing will be done on the Barrel Pixel with the B field expected to be on again in July.

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

ECAL is running smoothly with first collisions following the consolidation and development work performed during LS1. Commissioning with beam commenced in April with beam splash events, for which ECAL provided the reference trigger signal. The readout timing of EB, EE and ES was checked and adjusted using beam splashes and first collisions events. These data were also used to and adjust the timing alignment of the EB and EE trigger primitives and to commission the electron/photon Level-1 trigger path.

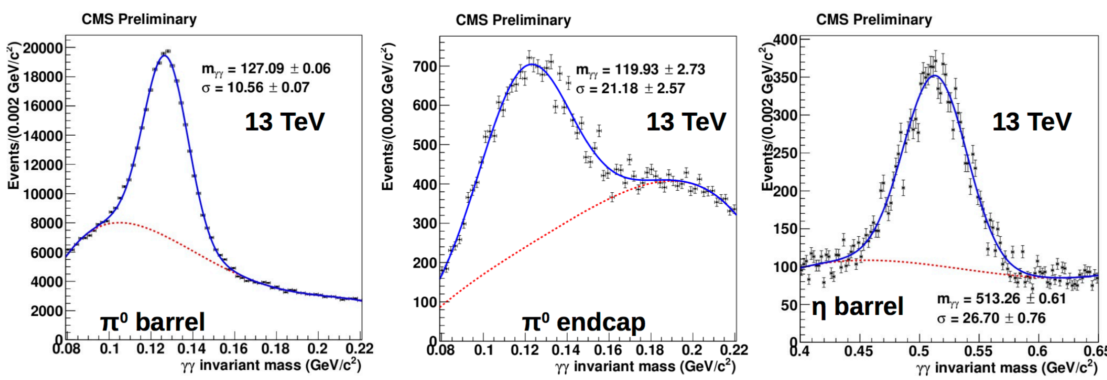


Figure 5: Reconstructed π^0 and η peaks from 13 TeV pp collisions.

We have successfully exercised the π^0/η reconstruction code for calibration using first 13 TeV collisions data obtained from the minimum bias dataset. Figure 5 shows clear π^0 and η peaks observed in both the barrel and the endcaps. These data are being used for first signal intercalibration and will also be used to verify the timing intercalibration constants.

The upgrade of the barrel ECAL high voltage system has now been completed. The mainframes have been replaced with more efficient CAEN models. A new calibration system has been installed. The HV system supplies the avalanche photodiode detectors used to readout the crystals. The gain is very sensitive to the HV and hence the calibration is important. The new system will enable an improved calibration to be performed in 24 hours versus the previous 2 weeks that were required.

Table 5: ECAL Milestones

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

The milestones that were due in June have been slightly delayed by the reported problems with the magnet. All these features have been tuned as far as possible without the magnetic field and will be finalized with magnetic field data.

HCAL

The HF has participated fully in collisions so far with the upgraded μTCA backend (installed in late 2104) delivering good quality data. The objective of high reliability physics running for HF has been basically achieved. HF Trigger Primitives to were delivered to the Regional Calorimeter Trigger (RCT). The Look-Up-Tables (LUTs) were updated for the new PMT gains. The remaining single split crate with VME legacy electronics has been a useful tool in verifying the functionality of the new backend. The work done on the HF backend proved extremely useful in getting the μTCA backend for HBHE up and running in record time during this current LHC technical stop.

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	May
HCAL	New HBHE backend operating in parallel with legacy system	July	

EMU

The CSC system participated all of the start-up and tuning runs, including beam splash, beam halo, 900 GeV collisions, and finally stable collisions at 13 TeV. The beam runs were used to first check the timing of the CSC trigger and data paths. The initial timing settings for the new and refurbished chambers were derived earlier this year from cosmic ray running. They were found to be close to optimal. The first runs with collisions were reconstructed and examined in detail. Generally the CSC data looked very good with much lower fraction of missing channels than in Run 1.

Table 7: EMU Milestones

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

DAQ

Installation of new DAQ including new HLT nodes was completed and routinely used in data taking with Beam and Cosmic runs. Hardware to read Trigger and HCAL μTCA feds were installed and SLinkExpress (fiber data links that connect the μTCA feds to DAQ readout modules) are operating at 4 Gbps. Trigger and HCAL sub-systems are using them using central DAQ and MiniDAQ.

Using emulated data, the Event Building performance has already reached the Run 1 design performance (100 kHz L1 accept rate for 1 MB Events) with full DAQ chain - event building, high level trigger (HLT) processing (actually emulated as sleep) and collecting HLT selected event in to single streams ready to be send to the Tier-0 computing center, in emulation runs. This needs to be confirmed with real detector data with full the HLT menu but for that we need to wait for the LHC luminosity to increase.

Table 8: DAQ Milestones

Subsystem	Description	Scheduled	Achieved
DAQ	Hardware Installation of DAQ2 with new HLT nodes complete	April	April
DAQ	Complete DAQ2 is operational for collisions	July	May
DAQ	μTCA DAQ link commissioned for new trigger and HCAL FEDs	July	June
DAQ	DAQ2 with Run 1 design performance	September	

Trigger

During this quarter the US groups continued their work on the regional calorimeter (RCT) and the endcap muon triggers. In both areas significant progress was made timing-in the various elements of the triggers using beam collisions.

Regional Calorimeter Trigger

During the last three months, the configuration and monitoring of the RCT with the optical RCT Summary Card was done with the Trigger Supervisor. Several iterations of the sequence were necessary to insure link stability before the Global Calorimeter Trigger main crate configuration, and now it is very reliable. The RCT with oRSCs participated in the first collisions of LHC Run 2, and the oRSCs have operated without issues since then.

Endcap Muon Trigger

The Endcap Muon Trigger was successfully used to trigger on the first stable beam collisions at 13 TeV. The system was successfully timed-in for halo muons and for first collisions. The DT/CSC data exchange is also timed-in for the most part, but possible fine-tuning of the DT data from the outer wheels may be required once we collect data with the CMS magnet on.

Table 9: Trigger Milestones

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

HL-LHC Upgrade R&D

During this quarter, the HL-LHC High-Luminosity LHC ("Phase 2") endcap calorimetry downselect decision was made by the CMS collaboration. To cover the pseudorapidity region from 1.5 to 3.0, the high granularity electromagnetic (HGCal) plus the hadronic (FH and BH) calorimeter system was selected. As outlined in the CMS Technical Proposal (LHCC-P-008[1]) the HGCal incorporates a silicon/tungsten sampling electromagnetic section followed by two hadronic sections: a front one, FH, with silicon sensors and a back one, BH, using plastic scintillator, each with brass absorber. For the endcap region, this design should provide excellent calorimetry in a very challenging environment of high pileup and substantial radiation exposure. The U.S. groups play strong roles in this R&D and will contribute key facets of the construction. As a result of the decision, the operations program subsequently provided additional R&D funds to the principal US groups, UCSB, Minnesota, FNAL, and Maryland, and to the CERN Team Account, for the remainder of 2015.

The other electromagnetic calorimetry technology previously under consideration, the Shashlik design, will not be considered further for the HL-LHC upgrade. Nevertheless, at the time of the downselect, the collaboration strongly endorsed an appropriate close out of Shashlik R&D so that key elements of the design could be evaluated and the results published. After discussing the close out plan with the Shashlik leaders, the U.S. CMS Operations Program provides some additional funding for this effort to the four main groups involved, Notre Dame, Virginia, CalTech, and Iowa.

Also during this period, the Project Manager for U.S. CMS HL-LHC project, Vivian O'Dell (Fermilab), appointed Level-2 managers. For the large tracker project, including the forward pixels, outer tracker, and track trigger, Karl Ecklund (Rice U.) and Chris Hill (OSU) will serve as joint Level-2 managers. Jeremy Mans (U.Minnesota) is the Level-2 manager for endcap calorimetry, Colin Jessop (Notre Dame U.) is Level-2 manager for barrel calorimetry, along with Alexei Safonov (Texas A&M U.) for the muon systems, and Jeff Berryhill (Fermilab) for the trigger system. The Level-2 manager for DAQ is yet to be named. Anders Ryd (Cornell U.) serves as deputy project manager for the HL-LHC upgrade.

[1] CMS Technical Proposal available at https://cds.cern.ch/record/2020886

Software and Computing Overview

The second quarter of calendar year 2015 saw the transition from the end of the long shutdown to the start of LHC operations for Run 2, and activities in Software and Computing reflected that. Both Tier-1 and Tier-2 facilities saw an increase in activity correlated with the start of the run and increased processing activity from both individual users and centrally-coordinated activities. Site availability remained high throughout the quarter. New capabilities developed during the shutdown were put to good use across the facilities in the service of faster and more robust operation. The production software release for the start of Run 2 was successfully deployed and is being used by physicists. The Tier-0 has been running effectively during the startup phase, and sample processing and production and data management are operating ever-more smoothly. As experience has been gained under running conditions, the many components of computing infrastructure and services have been improved as necessary for better functionality and scalability. More forward-looking efforts continue, such as preparations to incorporate commercial cloud resources elastically into existing facilities, and research and development efforts that point towards future technologies and capabilities expected for the HL-LHC.

Major milestones achieved this quarter

Date	Milestone
April 2015	Tier-1 and Tier-2 resources pledged to WLCG for 2015 deployed
April 2015	Release of CMSSW_7_4_0 for all aspects of Run 2 processing
April 2015	Improve WMAgent and dashboard to properly account for jobs with different # of cores
May 2015	Demonstrate and document full capability of multi-core processing in production at Tier-0 and Tier-1 centers
May 2015	CMS submits a proposal for a AWS grant
June 2015	HTCondor overflow enabling in the U.S. region in the global pool
June 2015	Site configurable glideins to prioritize local users

Fermilab Facilities

This quarter marked the transition from LHC Run 2 preparation to stable operations with first physics collisions in June. The Fermilab Tier-1 facility continued to test data transfers from CERN and utilization increased over past months as Monte Carlo simulation for Run 2 proceeded in earnest. During this quarter Fermilab facilities were available 98% of the time, with site readiness metrics passing 94% of the time. The site readiness metrics for a Tier-1 are expected to be above 98% averaged over the year during LHC running time. Metrics for the Fermilab facility showed 100% readiness during the latter half of the quarter, including the beginning of physics data-taking.

During this quarter a mis-configuration in one of the newly deployed disk servers at the Tier-1 led to the loss of 670 simulated data files, of which 400 had no replica. To put this number in perspective, the Fermilab disk storage typically houses around 4 million files at any given time. Fermilab took this incident very seriously, filing a Service Incident Report[2] with the WLCG outlining the time line of the incident, and steps taken to prevent a similar loss from occurring in the future. It was found that a validation step was missed in configuring one storage node, corrupting data written to it for a brief period. Procedures have been significantly improved, to reduce the possibility of such mis-configurations from happening. An additional burn-in period for new storage servers is also now required to catch similar problems before precious data may be written to new nodes.

The 2015 Tier-1 equipment procurement process began during this quarter for storage and CPU resource needs to meet the 2016 CMS computing resource requests and to replace retiring hardware. For 2016 the Fermilab facility is to increase CPU capabilities by 33%. Disk storage is to increase by a similar fraction, requiring the addition of 3.2 PB storage space. Early indications are that we will be able to take advantage of improvements in market prices over the estimates provided at the beginning of this year.

University Facilities

Tier-2 Facilities

This quarter saw an increase in the usage of the U.S. CMS Tier-2 facilities as the LHC Run II began, especially during May and June 2015, as seen in Figure 1. This increase was largely due to the new possibility of running the data reconstruction at the U.S. Tier-2 sites. These workflows place a heavy strain on the internal networking capabilities of the sites, and our sites were all able to handle the increased load.

The seven U.S. sites have completed their preparations for the coming data run through a program of technical improvements and the deployment of necessary hardware resources. Important improvements to networking have been made in the past quarter, in particular the connection of the Tier-2 sites to the LHCONE VPN by ESNet, which should be completed next quarter. All sites have deployed the HTCondor-CE computing element, and have either retired or are planning to retire their GRAM CEs very soon.

All of the U.S. CMS Tier-2 sites have operated successfully this quarter. On our two official performance metrics based on CMS test jobs, all sites were at least 88% "available" (a 4% improvement over the first quarter 2015) and 94% "ready", the same as last quarter. The CMS goal for each of these metrics is 80%. The U.S. Tier-2 centers hosted 35% of all CMS user analysis jobs (the goal is at least 25%).

Tier-3 Facilities and Activities

Thirteen Tier-3 sites required assistance from the Tier-3 support team this quarter. These support activities include helping sites complete the transition from OSG software version 3.1 to 3.2 and assisting several sites in rebuilding their site in preparation for Run 2. Special projects included assisting the Princeton Tier-3 site with a cluster whose worker nodes have an ARM architecture, the first of its kind in the U.S., and implementing a modern cluster configuration and provisioning

[2] The Service Incident Report can be found at https://twiki.cern.ch/twiki/pub/LCG/WLCGServiceIncidents/uscmsT1_SIR_042015.pdf

system at the University of Maryland. Both can serve as prototypes for future Tier-3 sites. Efforts continue to refresh documentation for site configuration and administration, and to set up a ticketing system within the context of the existing Global Grid User Support (GGUS) system.

Progress on the CMS Connect service continues. Now that the basic functionality has been established, the effort is focused on testing the service at scale and writing documentation appropriate for the intended use cases. Beta testing with users beyond the Tier-3 support team should commence once the documentation and examples have reached a more mature state.

Operations

In this quarter, the Tier-0 was operating in data taking mode to process data from global data taking. Due to the limited amount of data taken the operation ran as smoothly as one can expect for the start of data taking. After some discussion it was decided that well-defined prompt skims and MINIAODs will be produced in the Tier-0.

The processing of Monte Carlo was one of the most active areas in the last quarter. The tools for DIGI-RECO processing were automated to allow for efficient use of the Tier-2 centers around the globe instead of using only the Tier-1 centers. The automated system was able to allow our team to efficiently operate the much extended system with a similar effort. The automation of the system has substantially reduced the time to complete requests. Generally requests now take about a week once they are available to the operations team and the tails have substantially decreased. It is also noted that the requests available to the operations team did not put a lot of pressure on the production system such that resources were typically used to only about 50%. We have completed about 2.6 billion DIGI-RECO events and about 1.7 billion GEN-SIM events. The commissioning of the global queue in regular operations has progressed but some sluggishness in the system has been identified and is being worked on actively with the developers. During this quarter some more tests of the HLT farm were performed but interference with the ongoing data taking prevented extensive usage. The main problems seem to be addressed and we should be able to make use of the HLT in more substantial way.

In the area of data transfers and data management substantial progress has been made. The AAA operations has been integrated into the the operational tasks of our team and the first line responses are now handled by the operations team. There are still a number of issues coming up that need active support from the developers is very important but we are working towards resolving these issues together. The Dynamic Data Management is smoothly operating for the official datasets for CMS users for a while now, and in this quarter we have laid the foundations to employ a similar scheme for all datasets used by the production team, which we hope to commission during the next quarter. In the sites and services area business was mostly as usual; we have performed a full review of the storage quotas of Tier-1 and Tier-2 sites which have now been updated.

Computing Infrastructure and Services

During this quarter the LS1 shutdown period ended and CMS computing transitioned to Run 2 data taking. The work within U.S. CMS Computing Infrastructure and Services centered around last-minute infrastructure improvements needed to be fully ready for Run 2. 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. We also began laying the groundwork for future improvements to come during and after Run 2.

During the quarter, work on the WMAgent concentrated on enhancements to smooth operations during Run 2. A new facility was added (LogDB) to track problems with workflows, including operator comments and the ability to auto-subscribe newly produced data was added. The WMAgent team also released the next version of the CMS request management system; during the next quarter we aim to put this system into production. A new effort, WMArchive, a database which will store performance information about each job, moved towards the prototype phase and took on new importance as we need robust performance monitoring for running on Amazon Web Services (discussed below). WMAgent and all computing projects began a campaign to modernize their Python code as we prepare for upcoming transitions.

The Tier-0 system was successfully operated through commissioning beam splashes and first collisions at 13 TeV from the LHC. The Tier-0 is now deployed on its final infrastructure hardware, including a migration of the (P5 to Meyrin) transfer infrastructure from CASTOR to EOS. 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 another major milestone for the CRAB3 analysis system as the number of users of CRAB3 surpassed those of the older CRAB2 system. This transition is completely driven by choices of the users themselves. A couple of user conveniences were added: the ability to locally test a CRAB job and to automatically steer jobs away from problem sites as defined by the CMS Site Status Board. Work continued on enabling CRAB jobs to be submitted to the Fermilab LPC analysis facility, which is on track to be delivered in the next quarter. The ability to "grab" jobs for local users of grid-enabled sites was provided during this quarter.

DBS, DAS, and PhEDEx are our 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. In particular, DAS was modified to enable horizontal scaling, necessary because it is the primary user-facing conduit of metadata information. A space monitoring component related to PhEDEx has made significant strides and is now in operation, allowing us to see details of how disk space at Tier-1 and Tier-2 centers is being used.

There was a significant GlideinWMS release during the quarter delivering on our goals: a master-slave high-availability mode for the VO Frontend and a separation of the user collector from the collection broker. These improvements enable the infrastructure to scale more than 150,000 jobs in a pool. For the next quarter, GlideinWMS will fix monitoring issues related to completed multicore glideins. They will also, coupled with the AWS pilot project, add native configuration support for EC2 spot pricing and availability zones in the Glidein factory.

Minor operational improvements continue to be made for the global data federations infrastructure built on the "Any Data, Anytime, Anywhere" (AAA) infrastructure. This includes the creation of a transitional federation including sites that are not yet deemed sufficiently stable and/or performant in their support of AAA. The logic here is that the XRootd redirector should not redirect to sites of dubious quality unless no other options exist. At present, all Tier-3 sites are being added to this transitional federation. In addition, this quarter saw a major release update to XRootd (4.2.0). This is the biggest update since November 2014 (4.1.0), and included a number of contributions from U.S. CMS project as well as AAA.

We submitted an Amazon Web Services (AWS) proposal which was accepted. This is a two-year pilot project for which amazon.com covers 90% of the cost. The goal of the proposal is to establish our capability to elastically grow resources, to provide additional processing capacity on demand e.g. in front of conferences or other deadlines. The proposal foresees towards the end of 2015 the elastic scaling capability to reach a 50% resources increase for CMS globally, for a period of up to one month. The proposal is a joint venture with Fermilab and OSG, and thus is 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. In addition, we continued to support operations at NERSC (Carver) and SDSC (Gordon), enabling new workflows as needed.

Software and Support

A major milestone was achieved when CMSSW_7_4_0 was released on April 2nd, in the beginning of this quarter. It is now fully deployed in both online and offline areas including DIGI-RECO MC production, HLT, and prompt reconstruction in the Tier-0 facility. This version completes essentially all of major goals for the long shutdown including the migration to ROOT6, deployment of the MINIAOD format as an output of the prompt reconstruction, and the development of a highly efficient multi-threaded simulation and reconstruction application.

CMSSW_7_5_X was the development release for most of this quarter. Work was done to further optimize the physics performance of the reconstruction with 25 ns bunch spacing accelerator conditions, particularly for local HCAL reconstruction. The changes in the HCAL code had many effects downstream that needed to be understood and fed into the software. There is still a possibility that CMS will move to this release when 25 ns data taking starts in August. In that case MC samples that have been produced so far will be reprocessed with this newer release.

Upgrade work continues in the releases for the HL-LHC Technical Proposal and for the Scope Document. We have achieved major gains towards running with a pile-up of 200 events. Grid production is now enabled and will be an important piece of the July production for the Scope Document. The exponential increase in the needed CPU per event implies that these events require significant resources and the proposed samples for the Scope Document require the entire Tier-1 resources of CMS for a month or more.

Technologies and Upgrade R&D Planning

The CHEP 2015 conference, held in April in Okinawa, provided a venue for several presentations on technologies and R&D projects being pursued by U.S. CMS Software and Computing. These presentations allowed us to document the achievements of our ongoing research efforts.

For instance, a simple time-slice driven discrete simulation tool for computing models in the HL-LHC era was presented[3]. It seeks to exploit the reliability and capacity of wide-area networks for data management, whose robustness was underestimated in Run 1. The simulation can be used to model all elements of a distributed computing system.

The status of a project to evaluate both the computational performance and the power use of different processors and systems, using HEP standard benchmarks and methods, was presented in two

[3] see paper at http://arxiv.org/abs/1507.07430

other CHEP 2015 presentations. Our testing now includes not only Intel Xeon Sandy Bridge and Xeon Phi, but also Haswell and a recent Atom processor on loan from Intel. We continued the work with the ARMv7/ARMv8 processors and added also a Power8 processor. A related ongoing project will demonstrate the use of low-power processors (in particular heterogeneous use of non-Intel architectures such as ARMv8). A complete chain of submission was demonstrated through an x86 head node to an ARMv8 worker node (an Applied Micro XGene-1 ARMv8 development board) and in this quarter work progressed with Redhat and HP on configuring a production HP Moonshot system (with six m400 server cartridges, each with 8 cores and 64GB), in particular resolving OS and firmware issues.

Progress on the demonstrator project on tracking reconstruction on the Intel Xeon Phi was also presented at CHEP 2015[4]. Previous work had shown parallelized and vectorized track fitting with a simplified geometry and setup. In this period preliminary work was done to demonstrate a simplified track building, again with the simplified geometry. A full project will be spawned from this prototyping work thanks to an NSF PIF award ("Collaborative Research: Particle Tracking at High Luminosity on Heterogeneous, Parallel Processor Architectures", PHY-1521042, PHY-1520942 and PHY-1520969).

[4] see paper at http://arxiv.org/abs/1505.04540