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Open Science Grid

Annual Report

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Contents

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1. Executive Summary

Open Science Grid (OSG) is a large-scale collaboration that is advancing scientific knowledge through high performance computing and data analysis by operating and evolving a cross-domain, nationally distributed cyber-infrastructure (Figure 1). The OSG program consists of a Consortium of contributing communities (users, resource administrators, and software providers), a funded project, and satellite projects; this collaborative eco-system advances the science of Distributed High Throughput Computing (DHTC) for researchers in the US. In April 2012, the OSG project was extended until 2017 and is jointly funded by the Department of Energy and the National Science Foundation.

Figure 1:
Sites in the OSG Facility

The cutting edge computing and data demands of the scientific communities that OSG serves, in particular the Large Hadron Collider (LHC) experiments, have required OSG to actively drive the frontiers of Distributed High Throughput Computing and massively Distributed Computing and to develop a *production quality facility* that supports a broad variety of researchers; the OSG distributed facility, composed of computing centers at university campuses, national laboratories, and other community resources, has demonstrated that it is fully meeting the current and future needs of scientific computing at all scales. It provides a broad range of common services and support, a software platform, and a set of operational principles that organize and support scientific users who access DHTC resources that are accessible via the mechanisms of Virtual Organizations (VOs) and Campus Grids (CGs).

The US-based collaborators of the LHC experiments are major stakeholders in the OSG who rely on the OSG production fabric for a large fraction of their computing. The OSG continues to provide significant operational and software services in support of the LHC experiments and the Worldwide LHC Computing Grid (WLCG) project and serves as an anchor of collaboration across US ATLAS, US CMS and Alice US, providing means and mechanisms for joint activities and initiatives. The success of the globally distributed Grid computing facility has been acknowledged as an important factor contributing to the recent announcement of discovery of a new boson particle, *"...consistent with the Higgs boson"* from the LHC[1].

High Throughput Computing technology created and incorporated by the OSG and its contributing partners has now advanced to the point that scientific user communities (VOs) are simultaneously utilizing more geographically distributed HTC resources than ever before. Typical VOs now utilize ~20 resources with some routinely using as many as ~40 simultaneous resources. The overall usage of OSG has held steady during the last year at ~55M hours per month as shown in Figure 2.

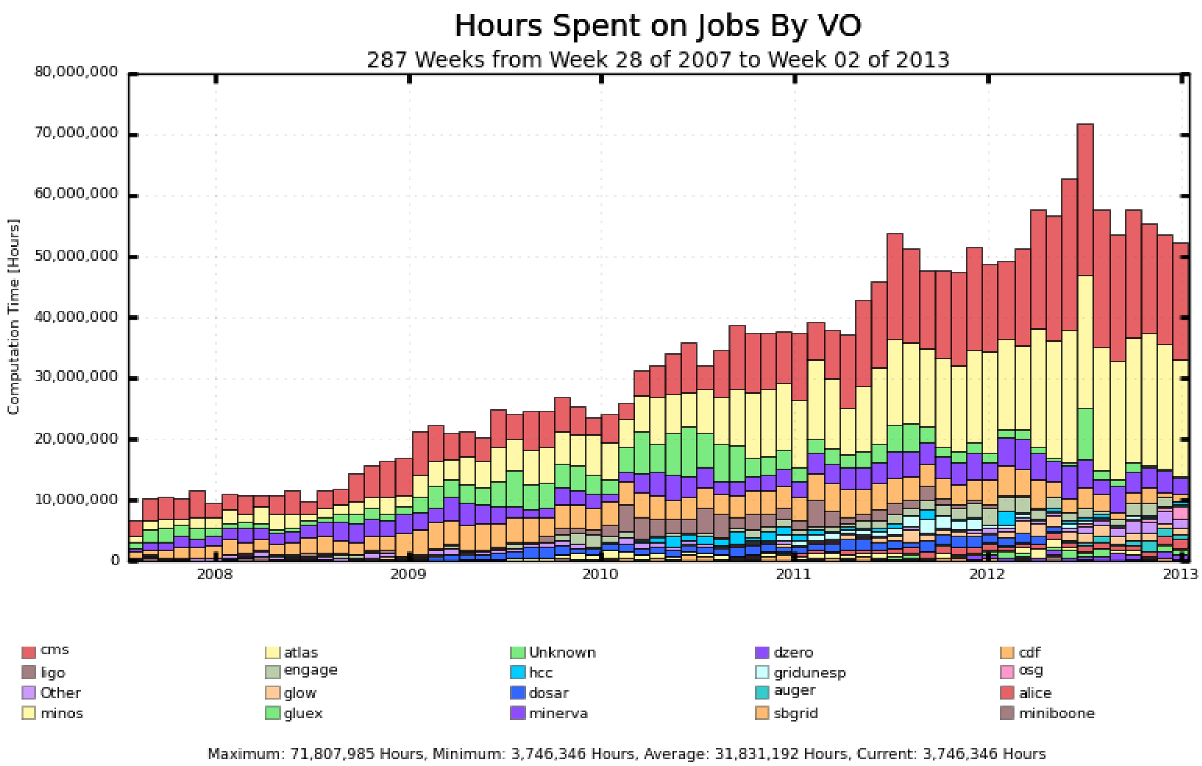

Figure 2:
OSG Usage (hours/month) from July 2007 to January 2013

Utilization by stakeholders varies depending on their needs during any particular interval. Overall use of the facility for the 12 month period ending January 2013 was 692M hours, compared to 562M hours for the previous 12 months period; detailed usage plots can be found in Appendix 1 entitled "Production on Open Science Grid." During stable, normal operations, OSG now provides ~1.8M CPU wall clock hours a day (~76,000 cores) with peaks occasionally exceeding 2.1M hours a day; approximately 25% of this capacity is available on a daily basis for resource sharing. Based on transfer accounting, we recorded ~320 Petabytes of data movement (both intra- and inter-site) during the last year; of this, we estimate 25% is GridFTP transfers between sites and the rest is via LAN protocols.

In the last year, non-HEP researchers accessed ~49M hours on an opportunistic basis (Figure 3); this usage was often greater than 1 million hours per week even during peak usage volumes of LHC activity.

[1] http://press.web.cern.ch/press/PressReleases/Releases2012/PR17.12E.html

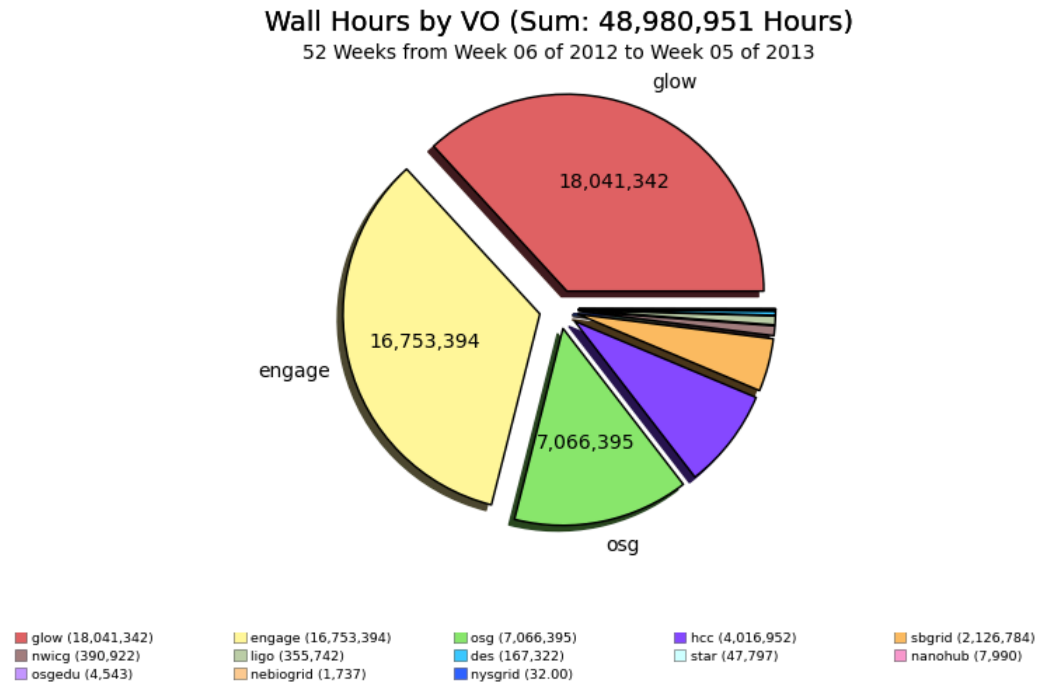

Figure 3:
OSG non-HEP usage from February 2012 to January 2013

In the last year, OSG has increased focus and resources toward bringing DHTC to researchers on campuses, via the Campus Grids program. OSG also joined the XD service provider forum to make OSG resources available to PIs through the XRAC allocation process, partnering with the XSEDE project. To enable individual researchers to extend their computing abilities using DHTC through OSG, a number of geographically distributed OSG partner institutions provided support through the "Campus Researchers Club" (section 2.2), mostly to non-HEP science domains. Through these novel approaches the OSG enabled the use of DHTC for the scientific endeavors of over 60 researchers, spanning 14 science domains, who are not associated with traditional OSG VOs.

Traditional OSG VOs continue to effectively leverage DHTC resources (see section 2.1) to produce science; these include CDF, Dzero, GlueX, Minerva, Minos, SBGrid, and others. By joining OSG they are able to magnify the value of their own computational resources via sharing. One such advantage is the ability to have "burst" mode access to many-fold greater resources than are owned and this can dramatically reduce the time-to-completion for complex computational workloads. This "burst" mode access in OSG was again demonstrated recently by the GlueX VO during December 2012; GlueX was able to use >2M CPU hours opportunistically during a 4 week period and thus complete a major simulation program in a timespan that would not have been possible if they only relied on their own resources.

One measure of the impact of OSG on science is the number of publications resulting from computations that leveraged OSG; the 2012 list of such publications is provided in Appendix 2 entitled "Science Publications Enabled by OSG" and summarized in Table 1 below:

Research Community	Number of Publications
ATLAS	131
CMS	123
CDF	66
Dzero	40
Minos	3
SBGrid	4
GridUNESP	17
GLOW	56
HCC	5
RENCI/Engage	3
UC3	9
UCSDGrid	7
User Support	3
Total	**467**

Table 1: Science Publications in 2012 Resulting from OSG Usage

In addition to serving science as described above, OSG is serving a broad community of scientists that learn about OSG largely via informal and/or scholarly channels. Our main avenue to track OSG impact in this case is via Citations of Reference. Two documents serve as key indicators; the first is the primary reference for OSG[2] itself and the second reference is for the GlideinWMS[3] system that provides the virtual overlay technology used to support almost all job submissions outside HEP on OSG. For these publications Google Scholar reports 117 and 30 citations, respectively, across more than a dozen different peer reviewed journals. Those include five different journals in computer science, three in biology, two in climate science, two in physics, and one each on Synchrotron Radiation, Crystallography, Psychophysiology, and the Proceedings of the National Academy of Science.

The OSG project continued to advance the state of DHTC; specifics of this are provided in section 3 and selected highlights are summarized below:

1. We are currently "beta testing" the OASIS service, based on the CERN CVMFS software, which will enable VOs to deposit their application software in one repository and have it be "automatically" propagated to multiple sites in OSG.

2. We are evaluating new technologies for the Compute Element, based on HTCondor and CREAM, to provide higher performance and improved service quality; this is in part driven by the recognition of the lifecycle of the Globus project.

[2] [Pordes2008] Pordes, R. et al. (2007). "The open science grid", J. Phys. Conf. Ser. 78, 012057. doi:10.1088/1742-6596/78/1/012057.

[3] [Sfiligoi2009] Sfiligoi, I., Bradley, D. C., Holzman, B., Mhashilkar, P., Padhi, S. and Wurthwein, F. (2009). "The Pilot Way to Grid Resources Using glideinWMS", 2009 WRI World Congress on Computer Science and Information Engineering, Vol. 2, pp. 428–432. doi:10.1109/CSIE.2009.950.

3. We have designed and deployed BOSCO v1.1 to enable campus researchers to "pool" multiple compute clusters at a single, easier to use, submit point; we have plans to evolve this to enable campus researcher to egress jobs from the campus to the national OSG production fabric.

4. With ESNet terminating the DOEGrids certificate authority and OSG taking over this service for the community, we have designed and implemented the OSG PKI service, which is based on a commercial certificate authority, DigiCert; this service has just achieved production deployment on January 28, 2013.

5. The OSG software packaging has completed the transition to native packaging; all software integrated and distributed by OSG for stakeholder installation is now available as RPMs. As of end-2012, more than 60% of OSG sites have successfully transitioned to this new software base.

6. We continue to improve the ease of use for researcher by adopting additional identity management systems; CILogon Basic is now accepted for all OSG IT services (e.g. OIM, twiki, etc.) and by a handful, but growing, number of sites for job execution.

7. We have started work on understanding how network transport awareness can be linked to job distribution in a DHTC environment; as a first step, we are creating a dashboard that provides overall network monitoring across the OSG fabric based on perfSONAR data from the sites.

8. We have enabled XSEDE users to access OSG opportunistic resources via deployment of a new interface; OSG is enabled as level 2 Service Provider in XSEDE where researchers can request HTC allocations via the standard XRAC process.

9. By leveraging the diversity of the OSG Consortium and project institutions, we are making DHTC resources available to an ever-increasing set of US campus researchers.

The OSG continues to grow its eco-system by collaboration with a broad set of satellite projects (section 4.3); these are independent projects that leverage and contribute to the advancement of DHTC and its use through OSG.

OSG has continued to grow the collaborative relationship with XSEDE as a member of the XD Service provider forum and as a level 2 service provider in the XSEDE confederation. We started collaborating with XSEDE staff on joint projects and plan work on a generalized CI interface between OSG and XSEDE for job execution, identity management, and integration across the separate accounting systems.

OSG is striving to make DHTC easier to use and more generally available to researchers in the US. Some facets that need further research and plans include:

1. Integration of cloud based resources,
2. Improved and easier to use Identity Management,
3. Better understanding of total available opportunistic capacity in the OSG production fabric,
4. Enabling campus researchers to adapt their computing to run "anywhere" in the national CI

We endeavor to strengthen the services provided to the HEP community and thus enable their work at ever increasing scales of data transport and computation. In addition, we are working to better understand the computation needs and challenges of researchers on campus and develop paths that enable improved access to DHTC in the national CI.

2. Science enabled by OSG

2.1 Virtual Organizations

2.1.1 ATLAS

The ATLAS collaboration, consisting of 174 institutes from 38 countries, completed construction of the ATLAS detector at the LHC, and began first colliding-beam data taking in late 2009. The 44 institutions of U.S. ATLAS made major and unique contributions to the construction of the ATLAS detector, provided critical support for the ATLAS computing and software program and detector operations, and contributed significantly to physics analysis, results, and papers published.

Experience gained during the first three years of ATLAS data taking gives us confidence that the grid-based computing model has sufficient flexibility to process, reprocess, distill, disseminate, and analyze ATLAS data in a way that utilizes both computing and manpower resources efficiently.

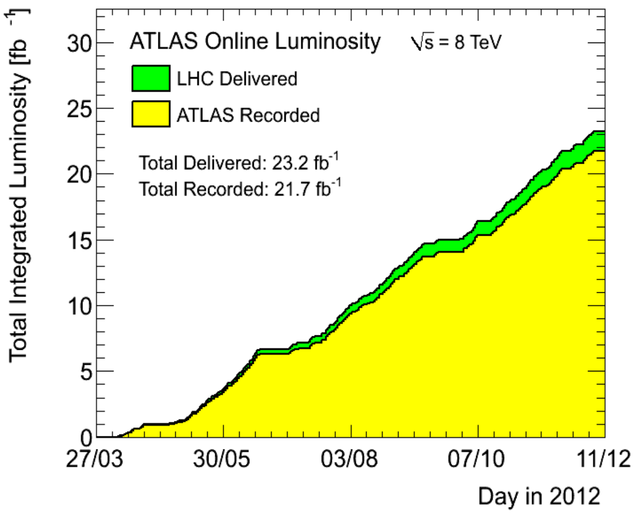

Figure 4:
Integrated Luminosity as delivered by the LHC machine vs. recorded by ATLAS

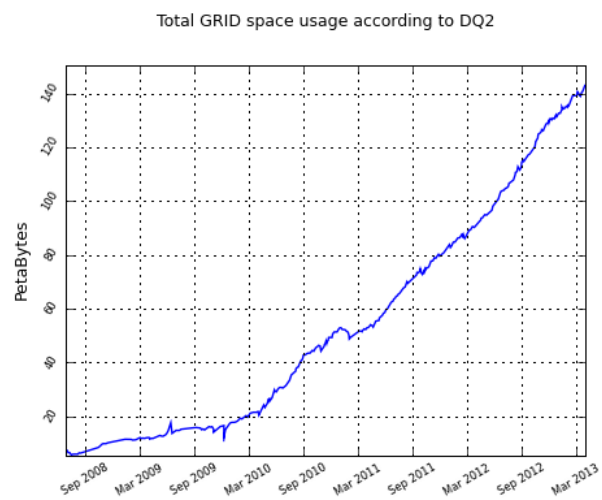

Figure 5:
ATLAS data volume on the Grid

The computing facilities in the U.S. are based on the Open Science Grid (OSG) middleware fabric of services and provide currently a total of 250k HEP-SPEC 2006 of processing power, 19 PB of disk space and 9 PB of magnetic tape archive. The Tier-1 center at Brookhaven National Laboratory and the 5 Tier-2 centers located at 9 Universities (Boston University, Harvard University, Indiana University, Michigan State University, University of Chicago, University of Illinois in Urbana Champaign, University of Michigan, University of Oklahoma and University of Texas at Arlington) and at SLAC have contributed to the worldwide computing effort at the expected level (23% of the total). Time critical reprocessing tasks were completed at the Tier-1 center within the foreseen time limits, while the Tier-2 centers were widely used for centrally managed production and user analysis.

A large fraction (~60%) of the available CPU resources available to the ATLAS collaboration at the Tier-1 and the Tier-2 centers is used for simulated event production. The ATLAS simulation requirements are completely driven by the physics community in terms of analysis needs and corresponding physics goals.

The current physics analyses are looking at real data samples of roughly 2B events taken in 2011 and 3B events taken in 2012, and ATLAS has roughly 3.5B MC events for 2011 data, and 2.5B MC events for 2012. Given the resource requirements to fully simulate an event using the GEANT 4 package, ATLAS can currently produce about 4 M events per day using the entire capacity available to production worldwide. ATLAS has close to 200 analyses in the stage of formal collaboration review, and the collaboration has published 199 papers in peer-reviewed journals and 400 public notes since first collisions about 3 years ago.

An example of the physics analysis work that has been enabled by OSG is shown in Figure 6 below. This is from the first publication announcing the discovery of a new Boson in ATLAS entitled: ***Observation of a New Particle in the Search for the Standard Model Higgs Boson with the ATLAS Detector at the LHC,*** which has been published in *Phys. Lett. B 716 (2012) 1-29*

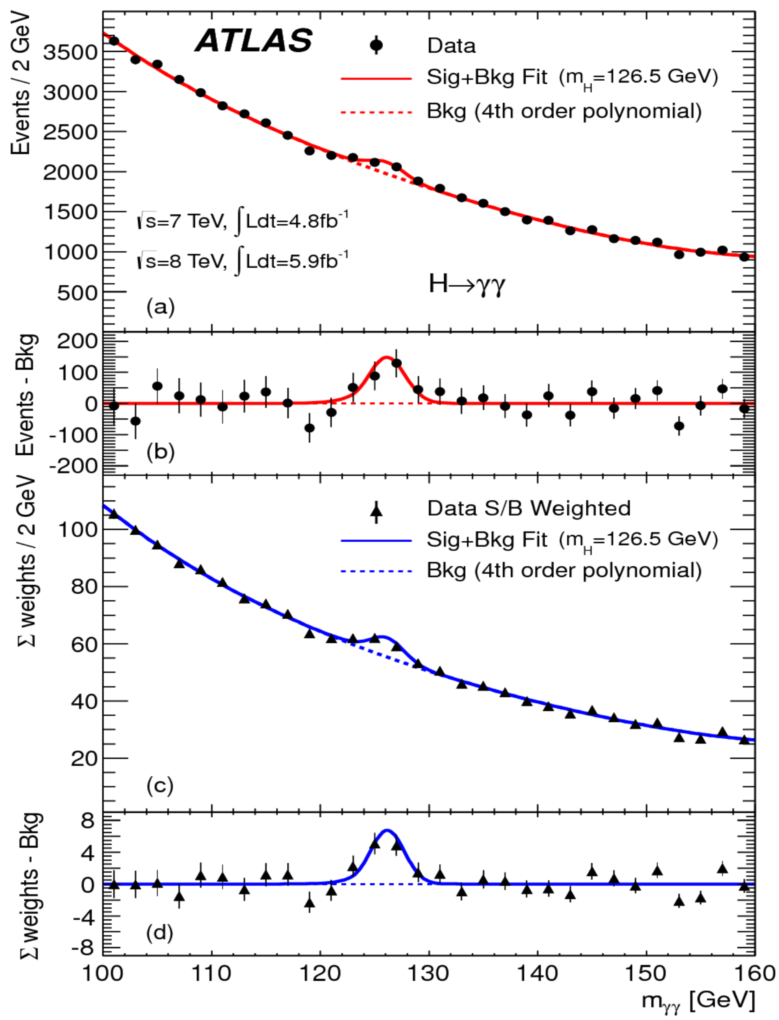

Figure 6:
Distribution of the invariant mass of diphoton candidates for the channel H → γγ in the ATLAS Higgs search

The distributions of the invariant mass of diphoton candidates after all selections for the combined 7 TeV and 8 TeV data sample. The inclusive sample is shown in a) and a weighted version of the same sample in c); the weights are explained in the publication. The result of a fit to the data of the sum of a signal component fixed to mH = 126.5GeV and a background component described by a fourth-order Bernstein polynomial is superimposed. The residuals of the data and weighted data with respect to the respective fitted background component are displayed in b) and d).

At the time forecasts for computing and storage resources were being prepared, before first collisions, much of the effort concentrated on searches, and only partial and not very sophisticated background samples were included. Today, roughly half of the analyses are careful measurements, most of which were not evaluated in detail prior to the arrival of data. These analyses are critical to our understanding of the Standard Model at 7 and 8 TeV, and are also key ingredients to tuning and validating the existing MC generators so that they can reliably be used for background estimates in search analyses. The search analyses rely on very large background samples, with higher equivalent luminosity than the data samples, with very precise modeling. Although data-driven techniques are used wherever possible, in the end, these techniques are most often used to normalize the MC background samples, but the shape determinations in multi-dimensional spaces require pure signal samples that don't exist in the data. The statistical precision of the background estimates needs to be significantly better than that of the data samples themselves, in order to take maximum advantage of the data. All of this adds up to a large need for high quality MC samples. There would have been a significant impact to physics if ATLAS would not have been able to take advantage of services and the amount of resources as they are provided through OSG in the US and sites in other regions contributing to ATLAS computing:

1) ATLAS would need to make difficult compromises. For example, ATLAS has carried out a fast reprocessing of the full 2012 data sample in preparation for the winter 2013 conferences, to take advantage of improved tracker and muon system alignments, and better calibrations of calorimeters. However, due to the 2012 run extension, and the fact that ATLAS has recorded 22 fb^{-1} of luminosity in 2012, ATLAS is also very busy extending many of the key MC samples in order to avoid compromising the quality of the analyses with lower luminosity in the MC samples than in the data samples. In 2012 ATLAS had barely the resources to carry out both of these operations – thanks to the resources provided by OSG and other regions ATLAS was able to avoid doing the processing sequentially, and thereby delaying the preparation of the final results on the 2012 data sample.

2) ATLAS decided to dedicate significant effort to using their best understanding of how Higgs, SUSY, and Exotics analyses have to be done today in order to predict how well ATLAS could do with 300 fb^{-1} of 14 TeV data, as well as 3000 fb^{-1} of data. These studies were a critical input to the European Strategy process started this summer, so ATLAS could provide a forecast of their physics reach for the High Luminosity Large Hadron Collider (HL-LHC) based on their best knowledge today. This work was done with very simple parameterized simulations of the detector response, tuned against the full simulation results. However, they required generating hundreds of millions of events at the generator level in order to properly estimate background levels in these searches in a new energy regime. Again, ATLAS barely managed to find the resources to do this work over the summer of 2012 without major impact on the ATLAS physics program. Also, this is important work that needs to continue in view of the design optimization of a HL-LHC detector upgrade.

To further improve efficient usage of resources, ATLAS is investing significant efforts in innovative approaches to simulation. One relies on large samples of "zero bias" data acquired during data taking in 2012, which can then be merged with precise simulations of high-PT physics signal events, to provide a very accurate and efficient simulation of the ATLAS performance at high levels of pileup. The other relies on an advanced framework (the Integrated Simulation Framework) which provides the ability to use different levels of accuracy in simulating different particles in a single event. For example, full GEANT simulation can be used for the critical simulation of the leptons in an event, while simpler models of the calorimeter response can be used to simulate the impact of pileup events. Both of these approaches will require considerable validation against the current 2011 and 2012 data samples, effectively generating large parallel samples of MC events using these new tools. Again, without the OSG fabric of services and resources at least at the present level, this key validation work would had to be reduced in priority compared to the more urgent analysis of the 2011/2012 data for publications.

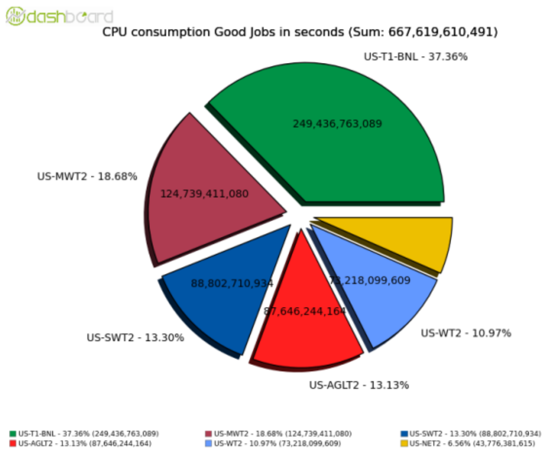

Figure 7:
CPU contribution of US ATLAS sites

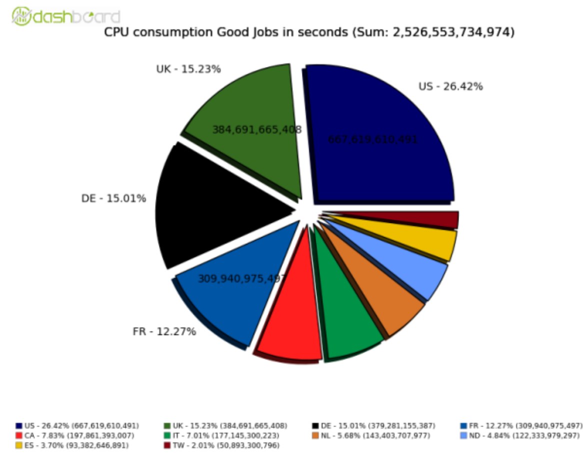

Figure 8:
US ATLAS CPU contribution vs. others

Moving from the computational side to data storage and data access U.S. ATLAS is in the process of adding direct access to data that is not available locally, meaning rather than requiring a process to wait until a programmatic replication of a dataset is completed the process is using a mechanism that allows to transparently discover the location of the needed data and access it over the Wide Area Network (WAN). US ATLAS is currently using xrootd at both the individual site level and the US ATLAS computing facility level. Tier 2 sites at SLAC and University of Texas at Arlington use xrootd as their baseline storage system, while the Tier-1 at BNL, University of Chicago and University of Michigan are using xrootd as an interface system on top of their dCache-managed storage to serve user analysis activities. The sites each have between 3 PB and 10 PB of usable disk storage installed and serve heavy user analysis activities.

U.S. ATLAS recently deployed a Federated ATLAS Xrootd system (FAX) aimed at providing direct data access over the WAN. The system allows users to access any data file in the federation via its global unique file name using the xroot protocol. FAX is implemented via a global xrootd redirector at BNL and some regional redirectors deployed at Tier-2 sites. In addition to Tier-1 and Tier-2 sites, Tier 3 sites are important members of this federation because quite often, "hot" user analysis data are initially produced at Tier 3 institutions.

ATLAS intends to implement and evaluate a still more fine grained approach to caching, below the file level. The approach takes advantage of a ROOT-based caching mechanism as well as recent efficiency gains in ROOT I/O implemented by the ROOT team that minimizes the number of transactions with storage during data read operations, which particularly over the WAN are very expensive in terms of latency. It also utilizes development work performed by CERN-IT on a custom xrootd server which operates on the client side to direct ROOT I/O requests to remote xrootd storage, transparently caching at the block level data that is retrieved over the WAN and passed on to the application. Subsequent local use of the data hits the cache rather than the WAN. This benefits not only the latency seen by a client utilizing cached data, but also the source site, freed from the need to serve already-delivered data. In addition caching obviously saves network capacities.

Deriving benefit from fine-grained caching depends upon re-use of the cache. As one approach to maximizing re-use, PanDA's (the ATLAS workload management system) existing mechanism for brokering jobs to worker nodes on the basis of data affinity will be applied to this case, such that jobs are preferentially brokered to sites which have run jobs utilizing the same input files.

Non-PanDA based applications using data at the cache site will also automatically benefit from the cache. The approach will integrate well with the federated xrootd system; it adds an automatic local caching capability to the federation. It may also be of interest in the context of serving data to applications running in commercial clouds, where the expense of data import and in-cloud storage could make fine-grained caching efficiencies valuable.

Once integrated into the OSG Distributed High Throughput Computing (DHTC) services, some or all above described capabilities will be available to the entire spectrum of scientific communities served by the OSG. This will be accomplished through the Virtual Data Toolkit (VDT) software infrastructure.

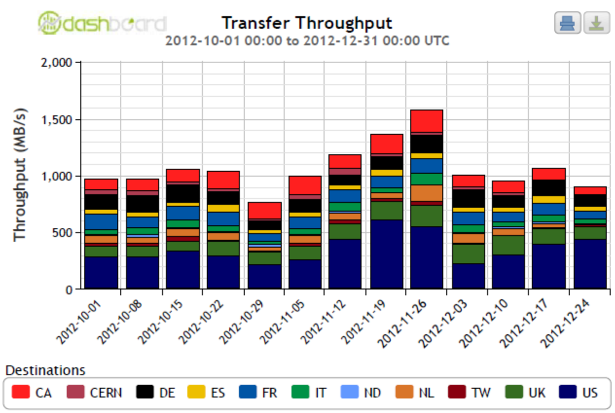

Figure 9:
Transfers from US sites to sites in other ATLAS Clouds

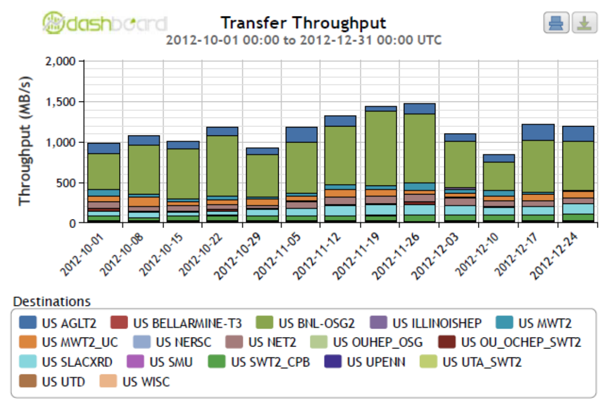

Figure 10:
Transfers from sites in other ATLAS Clouds to US Atlas sites

U.S. ATLAS (contributing to ATLAS as a whole) relies extensively on services and software provided by OSG, as well as on processes and support systems that have been developed and implemented by OSG. OSG is essential for the operation of the worldwide distributed ATLAS computing facility and the OSG efforts have aided the integration with WLCG partners in Europe and Asia. The derived components and procedures are the basis for support and operation covering the interoperation between OSG, EGI, and other grid sites relevant to ATLAS data analysis. OSG provides software components that are interoperable with European ATLAS grid sites, including selected components from the gLite middleware stack such as client utilities.

In addition to the services and operations mentioned above, U.S. ATLAS has also benefited from recent activities with OSG in the areas of Network monitoring, development of the next generation Computing Element, Grid Identity Mapping Service (GUMS), OSG Architecture, Native Packaging & Configuration Management.

U.S. ATLAS is also participating in the OSG Campus grids and inter-campus bridging efforts through the OSG Campus Infrastructures Community, and contributes to the pool of opportunistic resources in OSG in support of the GLOW, HCC, Engage, UCSD, UC3 and OSG virtual organizations, as well the larger community of users which access U.S. ATLAS resources via the OSG-XSEDE Glide-in service.

2.1.2 CMS

The CMS experiment at the CERN Large Hadron Collider is one of the largest and most exciting scientific endeavors. CMS is a world-wide collaboration of institutions that together have built, operate and analyze the data from the CMS detector. The U.S. is about a third of this effort with 48 U.S. institutions (universities and labs), with 678 scientific authors.

CMS has been recording 7 and 8 TeV proton-proton collisions since 2009, and the 2012 LHC physics run was the longest and was resulting in the largest amount of data and processing activity yet. The LHC has delivered around 1500 trillion collisions in the CMS detector that have been used to look for signals of new physics.

With the recent discovery of a new elementary particle that could well be the long-sought after Higgs boson, the LHC was in the news all around the world. Figure 11 shows the corrected invariant mass distribution for events that are candidates of Higgs decaying into two photons, reconstructed from their energy depositions in the CMS detector. There is a clear indication of a mass peak, giving evidence for a new particle.

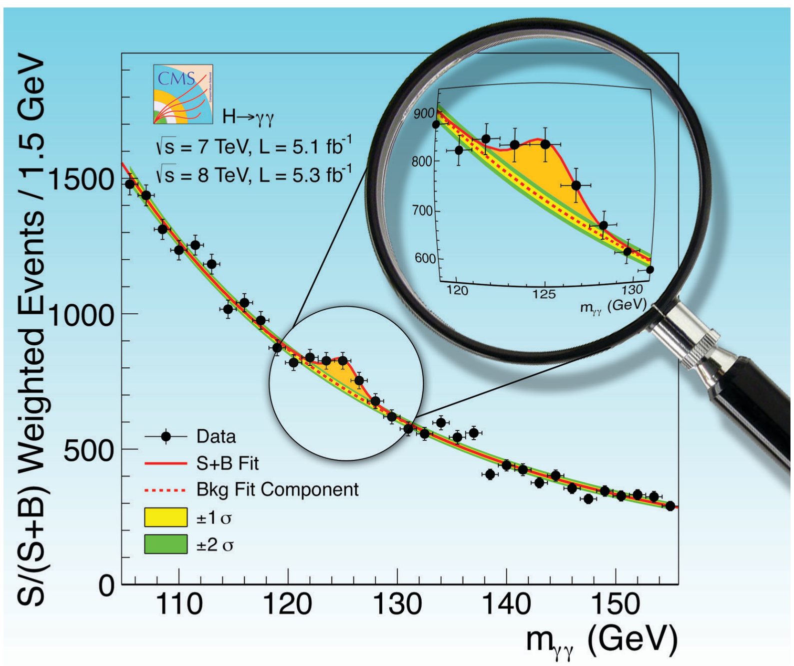

Figure 11: Invariant mass distribution of di-photons candidates for Higgs decaying into two photons, compared to simulation of a Standard Model Higgs at a mass of about 125 GeV

The properties of this new particle are consistent with that of a standard-model Higgs boson. This is one of the seminal achievements of particle physics in the past fifty years, and one that gives us a first glimpse of the mechanism of electroweak symmetry breaking. Detailed measurements of the boson, which will allow us to understand whether it is truly the Higgs particle, have now begun in earnest.

However, Higgs physics has been just one element of a very vibrant and broad physics program: during the year of 2012 the number of CMS papers that were published in scientific journals was 123 [ref CMS pub list]. Measurements of single- and double-boson (W, Z, γ) production have allowed for precise tests of the standard model at the highest energy scales ever observed. The LHC is a top-quark factory, and the

CMS measurement of the top-quark mass is already as precise as that of the Tevatron experiments. Searches for new phenomena have not led to the discovery of any new physics, but limits have been set on the mass scales for a wide variety of potential new particles and processes: heavy resonances, quark and lepton compositeness, fourth-generation and long-lived particles, and leptoquarks. Popular models like supersymmetry have been increasingly constrained by CMS measurements.

In order to distill the raw data read out of the CMS detector into statements about the fundamental constituents of matter, the forces of nature, and the evolution of the universe, an unprecedented volume of data of 1-2 PetaByte per month has been continuously processed and analyzed. The LHC experiments have put in place an infrastructure of Tier-1, Tier-2 and Tier-3 computing centers, worldwide. In the U.S. the CMS software and computing efforts are supported by DOE and NSF through several programs.

The Open Science Grid is a crucial part of this support providing the middleware fabric of services and operations support across participating institutions. This enables the collaboration to successfully use the computers and data storage systems distributed over many sites as an integrated high-throughput computing infrastructure.

The computing facilities and hardware infrastructure themselves are supported as part of the LHC operations program and currently provide a total of about 38,000 CPU cores of processing power, 28 PetaByte of disk space and 24 PetaByte of tape library space. The Tier-1 center at Fermilab and the Tier-2 centers located at 7 Universities (University of California San Diego, California Institute of Technology, University of Florida, Massachusetts Institute of Technology, University of Nebraska at Lincoln, Purdue University, University of Wisconsin at Madison) have contributed to the worldwide CMS computing effort at the expected level, effectively providing around 40% of the total CMS processing efforts. By virtue of being part of the OSG, these computing centers also are available to other OSG users "opportunistically".

The OSG resources support both the production efforts at Tier-1 and Tier-2 centers, producing massive amounts of simulated data and processing detector data for reconstruction and calibration, and the data analysis efforts of individual scientists and working groups. Figure 12 shows the total number of CPU hours used for the analysis efforts (left) and the MC production (right) at all CMS Tier-2 centers, where the OSG-based U.S. Tier-2s are labeled. This shows the impressive impact of OSG on the analysis and processing infrastructure of the experiment, providing about 40% of the total effort in these two categories, and showing the U.S. sites as amongst the top performers.

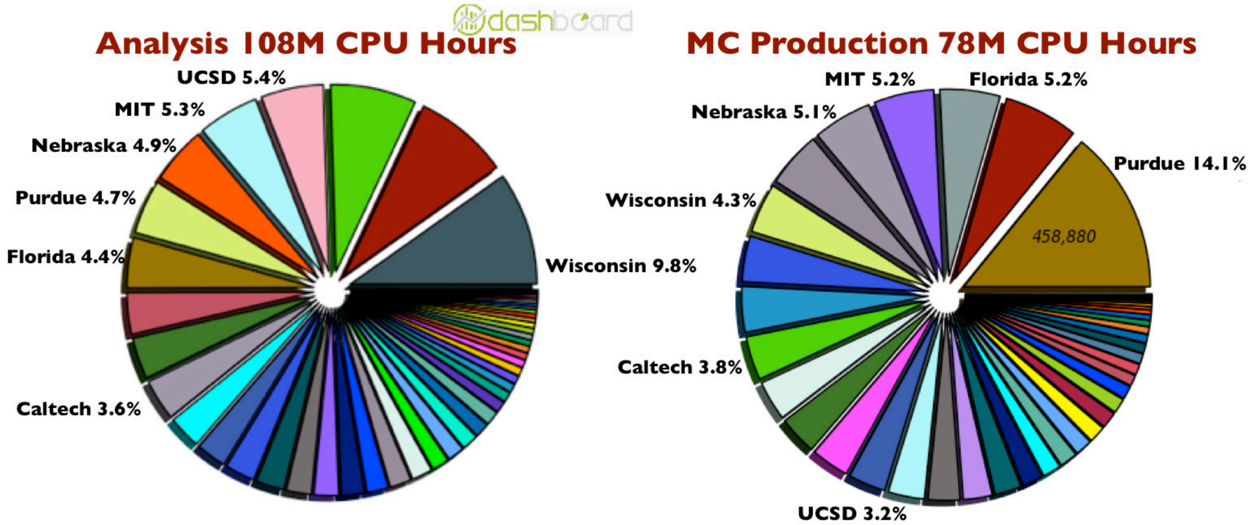

Figure 12: U.S. CMS Tier-2 sites contributing a ~40% fraction of CPU hours as part of the OSG for CMS data analysis and for CMS Monte-Carlo simulation.

CMS physics analysis is very data intensive. Processed datasets get transferred to Tier-1 and Tier-2 sites for analysis processing. A typical quarter has around 2 PetaByve of data being transferred to OSG data centers, at a maximum average of 80 TB per day. Results from MC production at Tier-2s get transferred to other sites, and a typical quarter has 1.5 PB of CMS data transferred from OSG data centers at a maximum rate of 70 TB per day. The OSG gives crucial supports to these efforts e.g. by helping CMS to deploy and operate a network monitoring infrastructure, based on nodes at each of the Tier-2 sites running perfSonar-based network monitoring.

Other projects supported and provided by OSG continue to be essential for CMS. There is support for basic functionality like accounting services through the Gratia project, identity management services through the PKI project, or support for middleware components like Bestman, software packaging, testing and deployment etc. OSG support also includes a number of important forward-looking technology projects. Examples are the Parrot and CVMFS system to support software and configuration setup at non-CMS sites that was successfully used for a pilot test of including Amazon EC2 resources into the OSG system. The AAA project has the goal to provide data access to any CMS data on disk, from anywhere with an network connection, at any time. The project collaborates with OSG and CMS and other projects in the OSG eco-system like the core Root development team at CERN, and xrootd developers in the U.S. and Europe to achieve its ambitious goals. The AAA xrootd infrastructure is continuing to increase in usage as seen by our accounting and monitoring. The dominant user in terms of gigabytes transferred remains the “overflow” activity, but we have started seeing new users. This technology allows individual university computing installation full access to CMS data samples. One highlight is the Notre Dame University Tier-3, which is experimenting with using the remote streaming capabilities to utilize otherwise idle CPUs at their site.

For the coming years, as the LHC heads towards its first long shutdown in order to upgrade to full energy and higher intensity, the software and computing communities of these experiments are confronted with the challenge of handling an order of magnitude more data rate when the machine resumes collisions in 2015, with no significant increase in funding. CMS relies on a close collaboration with the OSG to confront those challenges.

2.1.3 CDF

With 18 months having passed since the Tevatron shut down operations, a vibrant physics program at CDF continues to produce valuable results, with OSG resources and infrastructure playing a pivotal role in providing the experiment with the computing power it needs. In 2012, 51 CDF papers were accepted for publication, while 39 more were submitted. Recent physics highlights at CDF include: the world's most precise measurement of the W mass; a measurement of the forward-backward top-pair production asymmetry displaying a 3-standard-deviation difference with Standard Model predictions; first evidence for CP-violation in the charm sector; and, in combination with D0, a near-3-standard-deviation light Higgs boson signal (Figure 13).

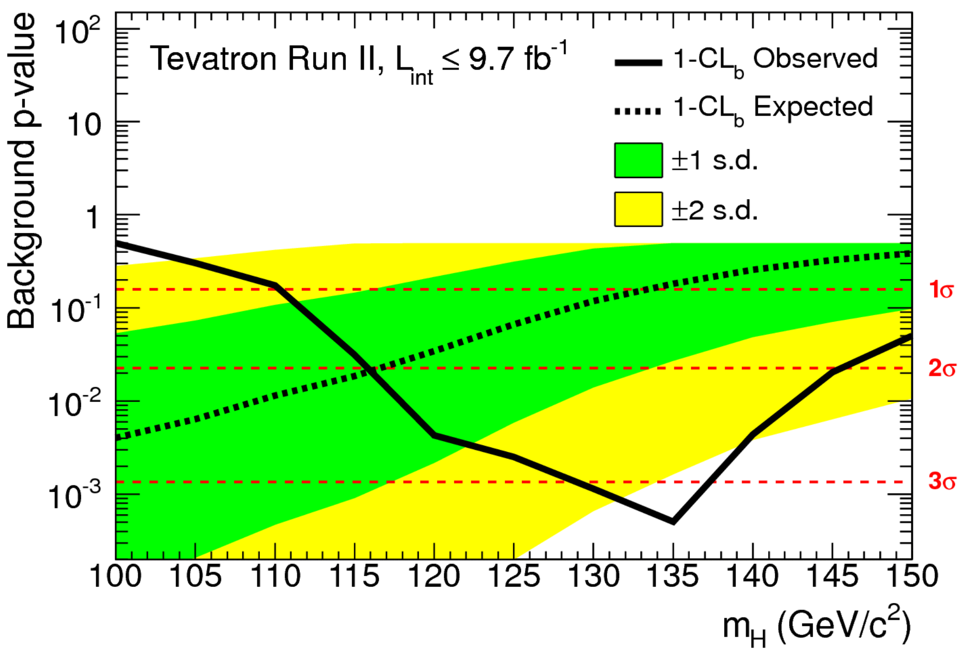

Figure 13:
Upper limit plot of combined CDF and D0 search for the Standard Model Higgs as of the summer of 2012, showing a near 3-standard deviation signal.

OSG resources support the analysis work for the collaboration and were crucial in the processing of the CDF dataset -- both for reconstruction of raw data events (also referred to as "production") and creation of analysis ntuples from the reconstructed data. The Higgs boson search result, for instance, consumed several million CPU hours between the shutdown of the Tevatron and the summer of 2012 when the result was released. This intensive processing was necessary to produce the MC data samples, calculate the sophisticated discriminants and limits in the CDF and the Tevatron combined result. Without the means to efficiently access these resources that is enabled by the OSG infrastructure, producing these results on such a short time scale would not have been possible.

While the main raw data reconstruction processing ended in fall 2011, OSG resources and infrastructure continues to be heavily used in order to update ntuples of production-level data and create Monte Carlo (MC) events. Major processing projects included a complete re-ntupling of the dataset in the spring of 2012 to a format useful for flavor physics, and an extensive and on-going effort to produce MC for top physics analyses. Despite the Tevatron shutdown, processing has remained active during the past year.

The OSG resources available to CDF include those accessed via the CDFGrid portal and the North American Grid portal (NAmGrid). Additionally, LCG grids in Europe have been available for CDF projects for almost two years under the EuroGrid portal, which utilizes the glide-in factory run on OSG resources at UCSD. CDFGrid, consisting of several thousand virtual machines (VMs) running on almost four hundred Fermilab-based nodes, is the most heavily used grid resource on the CDF experiment, providing access to CDF software packages and data handling capability on every node. At any given time, a large fraction of these VMs are typically in use with many jobs waiting to run. NAmGrid, consisting of opportunistically-accessible nodes at CDF, CMS, D0 and general purpose (GP) nodes at Fermilab, as well as nodes at MIT and KISTI (Korea Institute of Science and Technology Information), do not possess the CDF software and data handling capabilities of CDFGrid nodes. Nonetheless the VMs provided by NAmGrid are highly useful for projects such as the creation of MC events, which have no need of these resources. NAmGrid remained actively used throughout most of the past year. Plans currently exist to use NamGrid to produce large amounts of MC data that will be useful for flavor physics analysis. EuroGrid continues to host additional activity

During this past year, CDF has produced numerous important physics results, all of which rely on the invaluable OSG resources and infrastructure at its disposal. While fewer FTEs are expected to be dedicated to the experiment over the coming years, OSG computing will continue to play the same critical role in future CDF results.

2.1.4 D0

Since the Tevatron collider is no longer in operation, the primary use of OSG by the D0 experiment is in generating Monte Carlo simulation for use in physics analysis. D0 is currently using 19 different OSG sites, which has provided an average of ~20 million MC events/week over the past year.

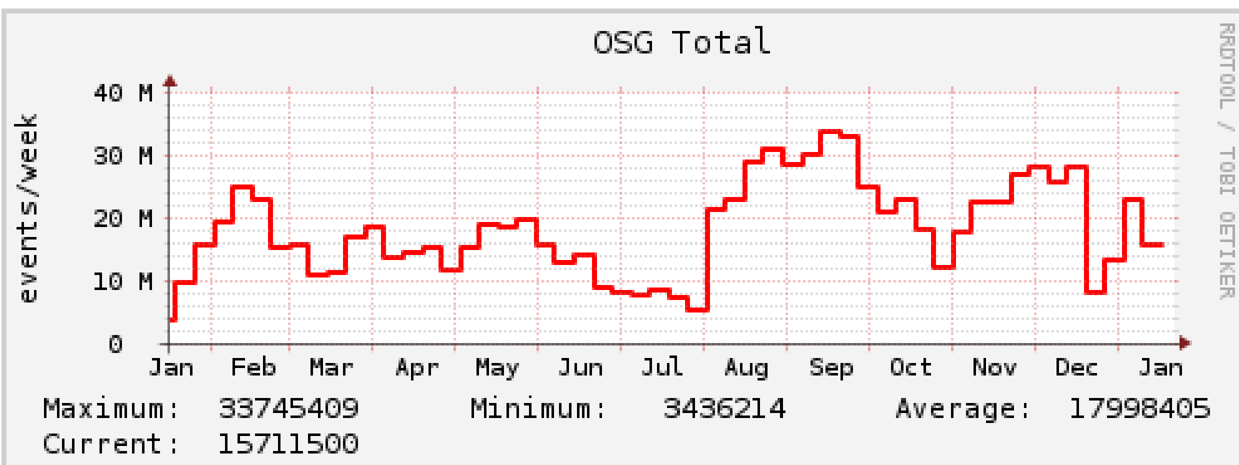

Figure 14:
Number of Monte Carlo events produced each week in 2012 for D0 using OSG resources

The ability of OSG to generate MC for D0 continues to improve. In fact, a record week was achieved in September, where 34 million MC events were generated.

D0 has been using OSG for many years and during the past year OSG has passed the 3 billion event mark for the total number of generated MC events for D0.

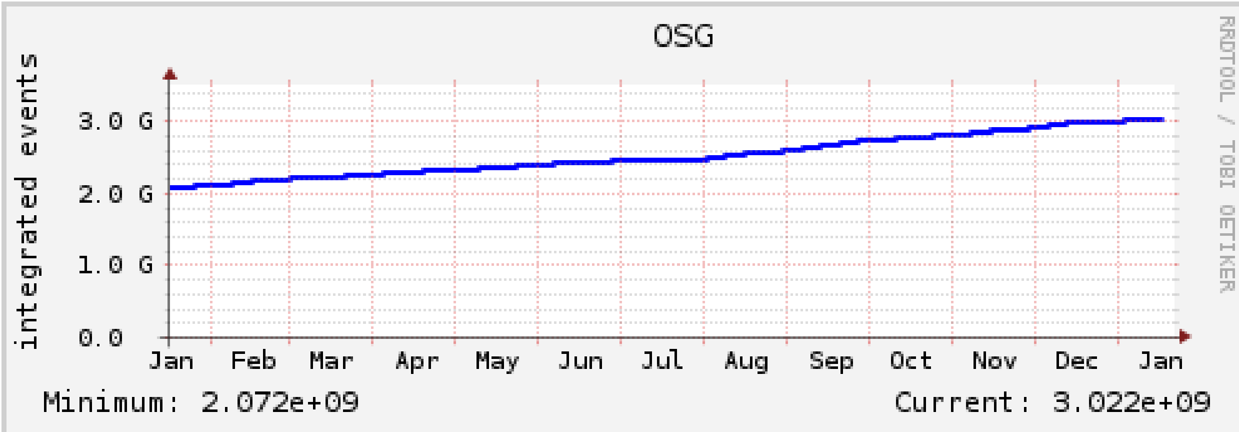

Figure 15:
Total number of Monte Carlo events generated for D0 using OSG resources.

This shows the reliability and robustness of OSG resources that D0 has been able to enjoy over the years. Most physics analyses rely heavily on MC in order to publish results. OSG resources produce ~37% of all MC events for D0 (Figure 16), so OSG has been critical in D0's ability to publish results in a timely manner.

Figure 16:
Fraction of D0 Monte events for 2012 generated by different computer resources.

During the past year, 40 papers have been published on topics relating to the top quark, b quark, Z/W boson, QCD and the Higgs Boson, including a combined CDF/D0 result on evidence of a particle consistent with the Standard Model Higgs Boson.

2.1.5 GlueX

The physics goals of Glue-X are to discover the spectrum of exotic mesons in the mass range 1.5 – 2.5 GeV (exotic resonance region predicted by LQCD). In 2010 the experiment entered the construction phase, and plans to begin physics data taking (CD4) in 2015. The Glue-X contributed resources at the University of Connecticut as part of the distributed OSG facility.

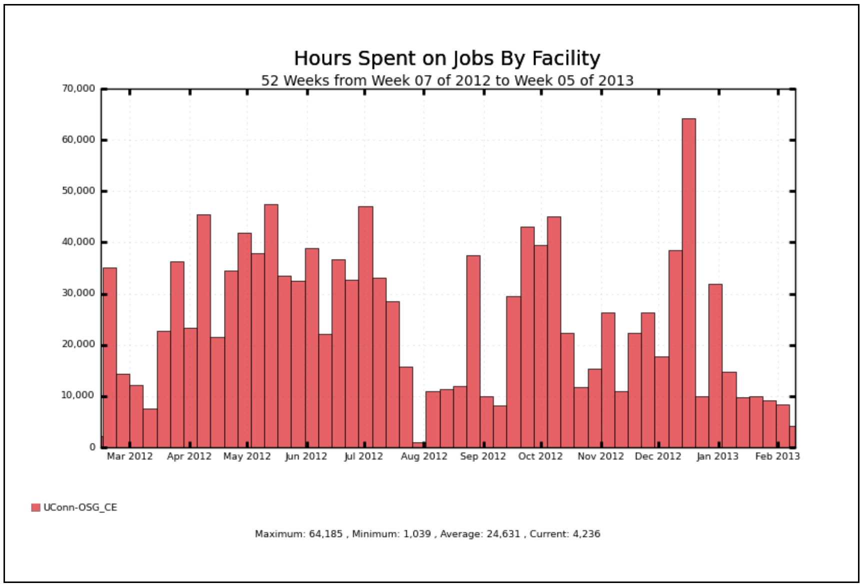

Figure 17:
U Connecticut Facility Contributions in 2012

The experiment plans a series of process and data challenges that will ramp up to the final system of 5.4 thousand cores of CPU and 2.5 Petabytes /year of storage. Results from using OSG have been published in a PhD thesis in August 2012.

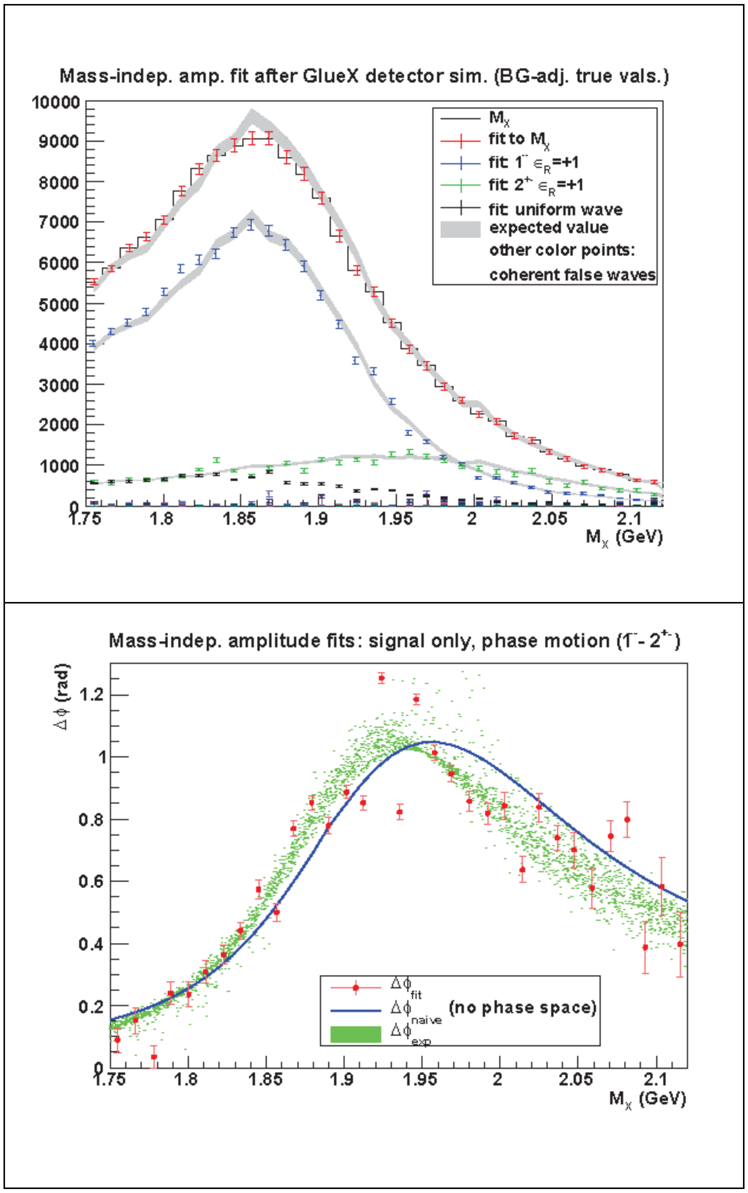

Figure 18:
Results from Physics Analysis of initial Glue-X data from Ph.D thesis of Igor Senderovich

In December 2012 Glue-X requested a significant production run on OSG and was able to quickly ramp up to a significantly greater sustained usage for a few weeks.

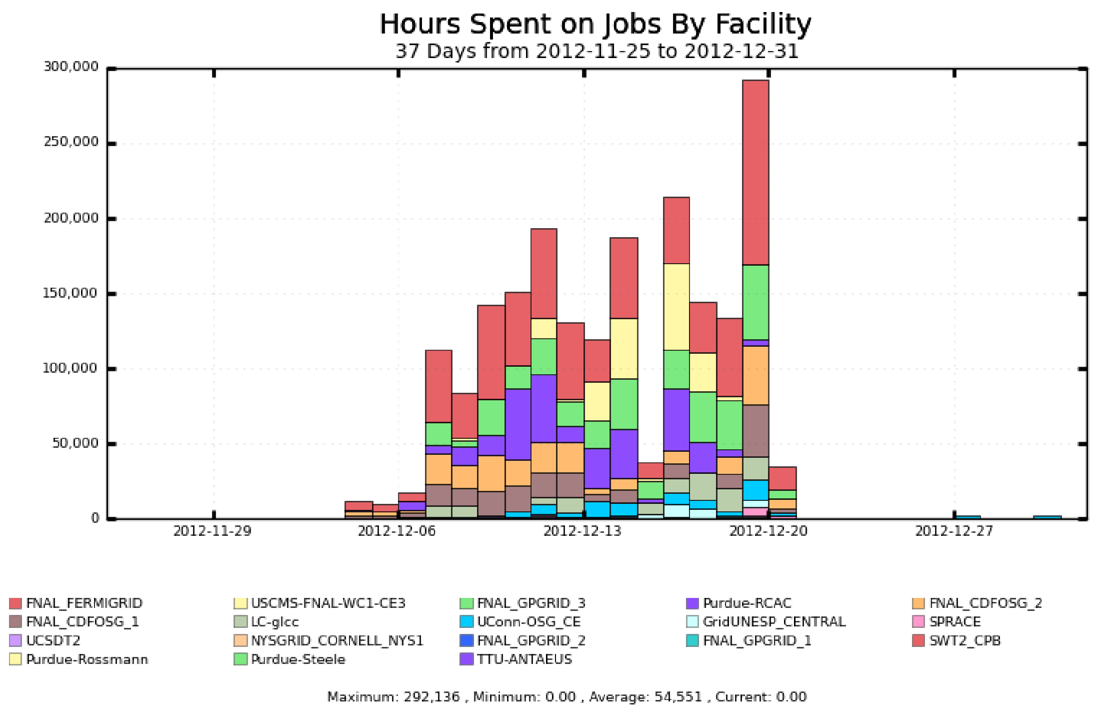

Figure 19:
Glue-X Production Simulation, December 2012

2.1.6 Minerva

The MINERvA experiment is designed to perform detailed studies of neutrino and anti-neutrino interactions with nuclei and perform precise measurements of interaction cross sections. This work will provide important inputs to neutrino oscillation experiments, contribute to the understanding of neutrino interactions within the nuclear medium, and open a unique window into nucleon structure. In April of 2012, the experiment concluded a 3-year period of data taking using both neutrino and anti-neutrino beams. MINERvA is in the process of analyzing the data from this first phase of data taking and expects to publish the first results during 2013. The experiment has presented a number of preliminary results based upon the first 25% of the dataset, including preliminary measurements of the anti-neutrino charged-current quasi-elastic cross section as a function of the momentum transfer (Figure 20), kinematic distributions for neutrino charged-current inclusive interactions (Figure 21), ratios of neutrino cross sections in lead, iron, and carbon to that in scintillator, and kinematic distributions of pion production in neutrino-nucleus interactions, among others.

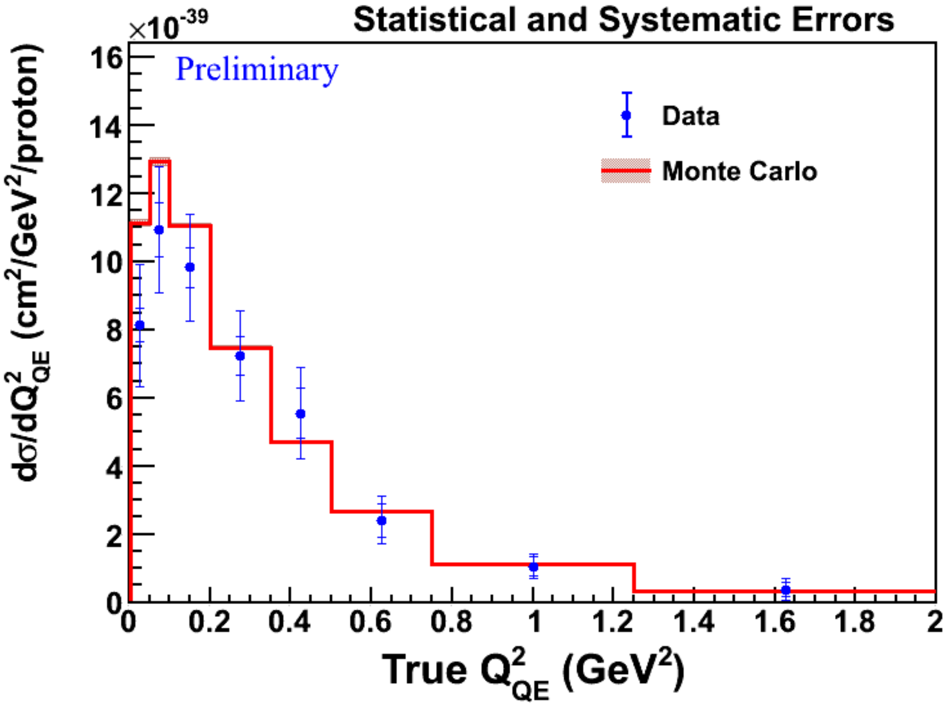

Figure 20:
Preliminary measurement of the anti-neutrino charged-current quasi-elastic cross section vs. Q2 compared to a GENIE MC prediction. The inner error bars represent statistical uncertainties, while the outer represent systematic uncertainties.

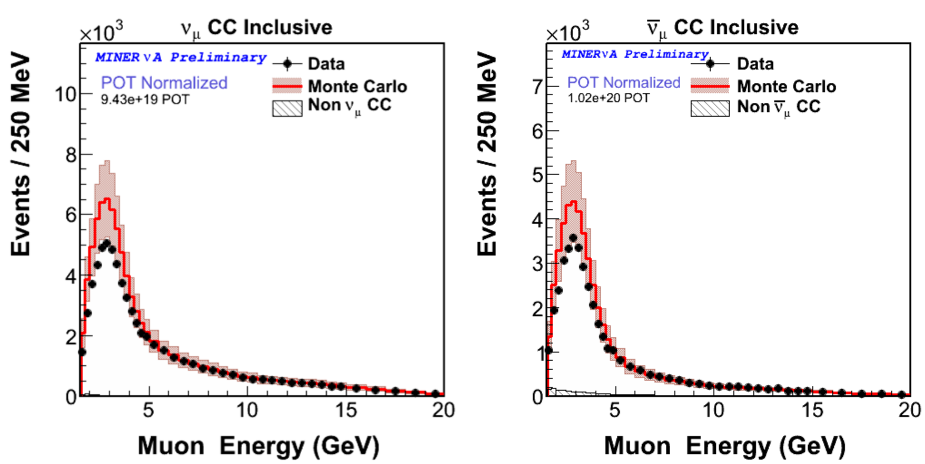

Figure 21:
Preliminary measurement of the reconstructed muon energy in inclusive charged-current neutrino (left) and anti-neutrino (right) interactions compared to a GENIE MC prediction. The distributions are normalized to the number of protons on target (POT).

All of the large scale computing performed by MINERvA is managed using OSG infrastructure and is run on OSG resources at Fermilab. Over the past year, MINERvA jobs have consumed over 3.4 million core-hours on these resources. Analysis computing by individual physicists accounted for approximately 60% of this usage, with centralized Monte Carlo generation, simulation and reconstruction using about 30%, and centralized raw data reconstruction the remaining 10%. The level of CPU utilization across the year was highly non-uniform and at times approached seven times the CPU nominally allocated to MINERvA. Use of opportunistic cycles across OSG resources at Fermilab allowed the experiment to access the CPU needed during these periods of peak demand, while keeping procurements targeted to meet the average demand.

MINERvA is in the process of integrating grid-compliant data handling services into their processing model and completing the transition to fully grid-compliant jobs. This step will allow for improved and more flexible resource management, which will become increasingly important as the experiment moves into the next phase of data taking during the second quarter of 2013. Data rates at that time are expected to increase by a factor of about six for the remainder of the experiment, with concomitant increases in computing demand. OSG infrastructure and resources will continue to provide the primary means for meeting this demand.

2.1.7 Minos

MINOS data analysis use of OSG at Fermilab continued through CY 2012, increasing to 6.9 million core hours in 1.9 Million submitted jobs, with 4 million managed file transfers. This computing resource, combined with 240 TB of dedicated BlueArc NFS file storage, has allowed MINOS to move ahead with traditional and advanced analysis techniques. Minos uses collaborating universities' OSG and Teragrid resources for all Monte Carlo generation.

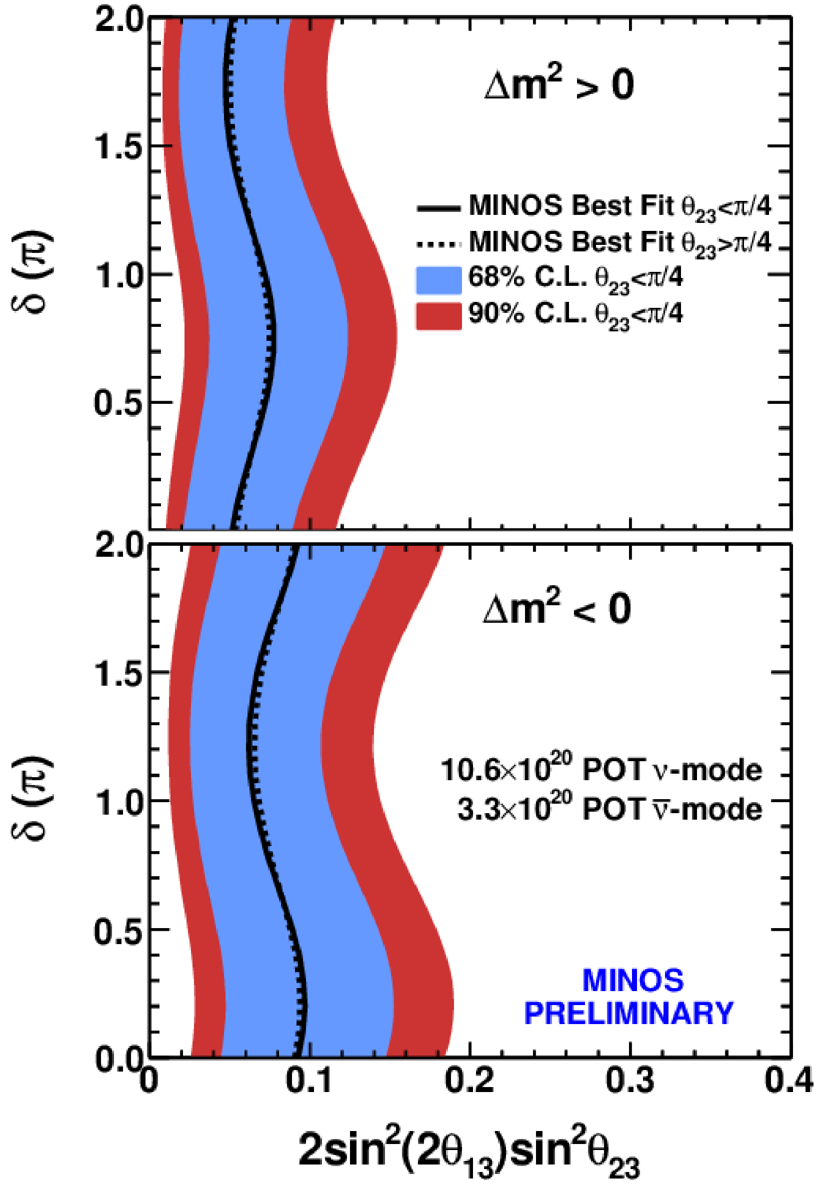

Figure 22:
MINOS has produced the most precise measure of the neutrino and anti-neutrino mass splitting

These computing resources are critical as the experiment continues to pursue challenging analyses, and to prepare for new Minos+ data coming in 2013. Minos presented important neutrino Time Of Flight results at the Neutrino 2012 conference.

2.1.8 SBGrid

SBGrid Consortium (http://sbgrid.org) provides comprehensive research computing software support to 230 structural biology laboratories globally. In 2012 more than 2000 scientists had access to the SBGrid compilation of approximately 300 scientific applications and member labs published 240 scientific papers. While the majority of SBGrid-supported applications are installed on workstations and computing clusters in members' laboratories, a handful of computationally demanding workflows require more extensive resources. To support these needs SBGrid operates a computing portal[4] that connects to computational resources of the Open Science Grid. In 2012 the portal supported two specific workflows: a) a WSMR workflow[5] (Stokes-Rees and Sliz, 2010a) used to determine structures of novel macromolecules by molecular replacement, and b) DEN refinement[6] (O'Donovan et al., 2012), which was used to refine structures of macromolecules at low resolution. In 2012 we completed 144 WSMR searches and 89 DEN jobs. WSMR and DEN workflows were broken down into 998,253 individual grid jobs and consumed 2,218,321 computational hours in total.

We have also used the WSMR portal to further explore WSMR search parameters. In 2011 we had established that LLG scores can be used to identify correct molecular replacement solutions for proteins and that LLG are more sensitive than translation function scores. More recently we have extended this validation to structures of nucleic acids.

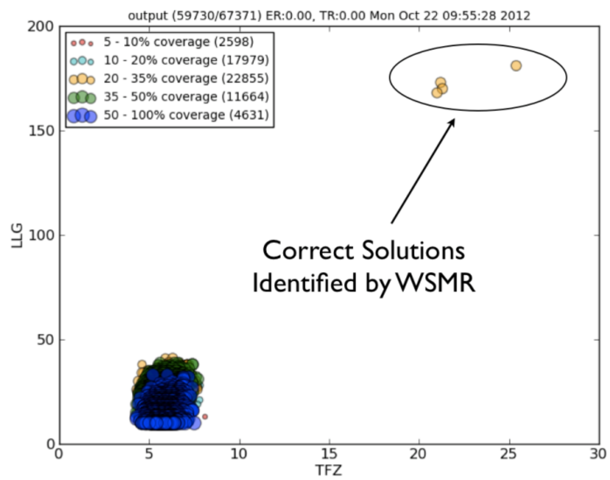

Figure 23:
An example of a successful WSMR run completed using OSG resources in 2012

Four structures identified by the search (high LLG and TFZ scores) can be used to complete structure determination of a novel macromolecular complex. WSMR is the only sequence independent method that can be used to determine structures of difficult datasets.

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[4] Stokes-Rees, I., and Sliz, P. (2010b). Compute and data management strategies for grid deployment of high throughput protein structure studies. Many-Task Computing on Grids and Supercomputers (MTAGS), 2010 IEEE Workshop on 1–6.

[5] Stokes-Rees, I., and Sliz, P. (2010a). Protein structure determination by exhaustive search of Protein Data Bank derived databases. Proc. Natl. Acad. Sci. U.S.a. *107*, 21476–21481.

[6] O'Donovan, D.J., Stokes-Rees, I., Nam, Y., Blacklow, S.C., Schröder, G.F., Brunger, A.T., and Sliz, P. (2012). A grid-enabled web service for low-resolution crystal structure refinement. Acta Crystallogr. D Biol. Crystallogr. *68*, 261–267.

2.1.9 NEES

Earthquake engineering researchers use resources through NEEShub batchsubmit facility that allows users to use Open Science Grid resources to run OpenSees; this is enabled under the NEES VO. OpenSees is an open source simulation package that is used to simulate the response of structural and geotechnical systems to seismic events. OpenSees is widely used in the earthquake engineering community, and is supported by NEEScomm.

2.1.10 GridUNESP

The São Paulo State University (UNESP) has built a distributed computational infrastructure that is considered one of the largest multi-campus Grid initiatives in Latin America, with computing resources distributed on distinct campuses throughout the state. GridUNESP, as the project is known, is a statewide, multipurpose Grid infrastructure that is providing reliable and high-performing computational power to distinct research groups from several areas of science and engineering, allowing them to access state-of-art data processing and storage systems. GridUNESP is a long term project that intends to leverage the scientific research at UNESP [7].

The project, deployed with the important support of US Open Science Grid, contains a central cluster located in São Paulo city and seven secondary clusters at different UNESP campuses. The central cluster is most appropriate for running tightly coupled parallel applications using MPI and proprietary parallel libraries, whereas the secondary clusters are more suitable for running loosely coupled applications or near embarrassingly parallel computations. The eight sites are interconnected through the KyaTera network, an R&E experimental optical network provided by FAPESP in association with Telefonica Brazil, a subsidiary of the Spanish company that provides fixed-line telecommunications services in the state of São Paulo.

A formal partnership between UNESP and the Open Science Grid Consortium was signed in 2009[8] [2], which enabled GridUNESP to use the OSG middleware stack to integrate its computational resources and share them with other R&E institutions worldwide. The GridUNESP VO was created in December 2009 as the first Virtual Organization outside U.S. It is a multipurpose VO, including projects from different research fields, including Biology and Biophysics, Chemistry, Computer Science, Geosciences, Materials Science, Meteorology, and Physics.

In three years of operation, GridUNESP resources have processed 4.5 million jobs, accounting for almost 40 millions of CPU hours (Figure 24).

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[7] R. L. Iope, N. Lemke, G. A. von Winckler, "GridUNESP: a multi-campus Grid infrastructure for Scientific Computing", in Proc. of the 3rd Latin American Conference on High Performance Computing (CLCAR 2010), 25-28 August 2010, Gramado, Brazil, pp. 76-84.

[8] OSG Document 827-v1: GridUNESP and OSG Agreement. Available at http://osg-docdb.opensciencegrid.org/cgi-bin/ShowDocument?docid=827

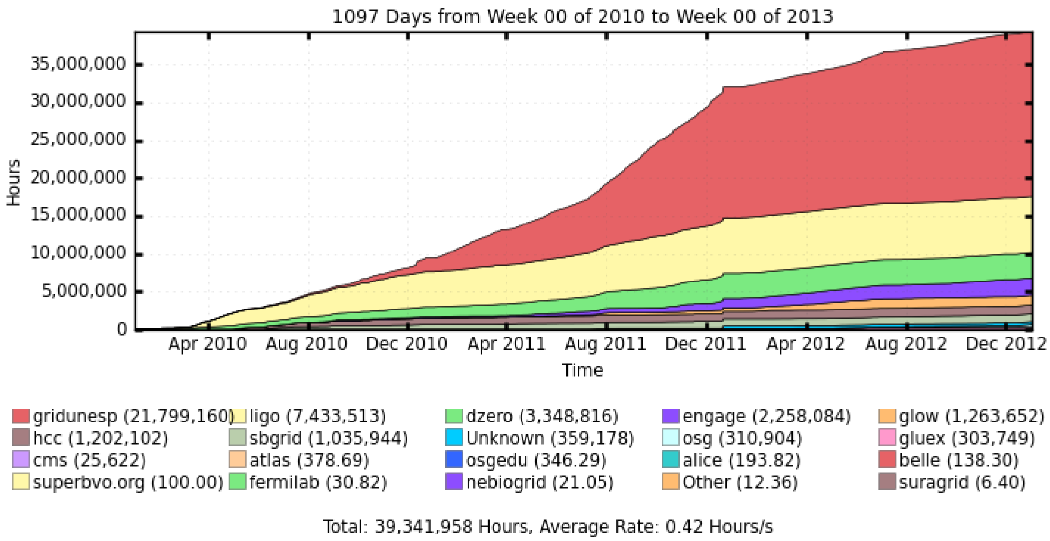

Figure 24:
GridUNESP - cumulative hours by VO

The project supports more than 40 research groups, with over two hundreds registered users (Figure 25) working on different areas (Figure 26).

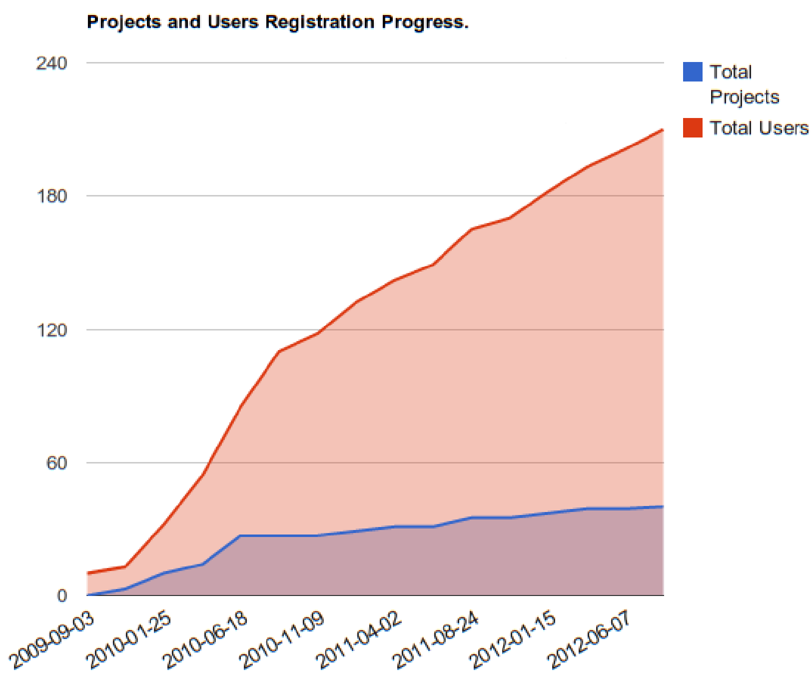

Figure 25:
Registered projects and users

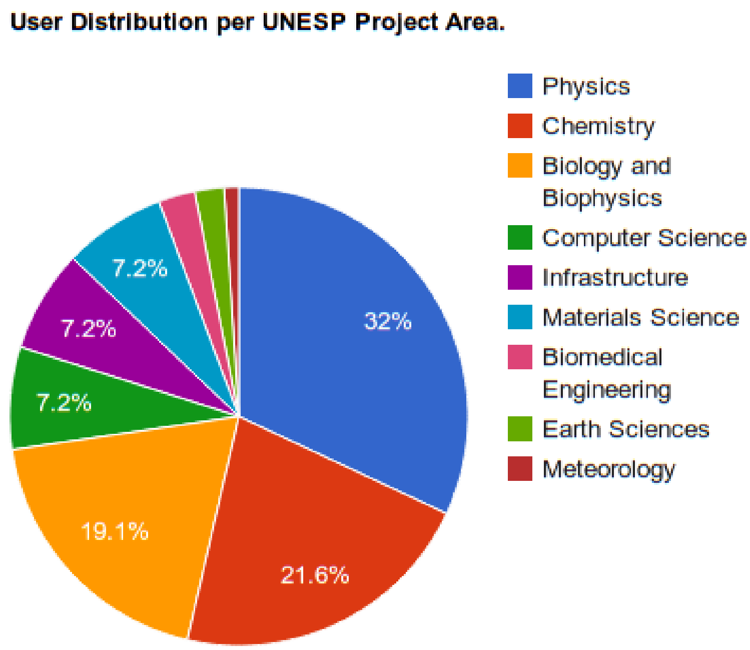

Figure 26:
User distribution per research field

The technical support efforts have been focused on adapting HPC software to grid-friendly workflows, and nowadays GridUNESP successfully runs scientific applications like Crystal, Dirac, GAMESS, Gaussian, Gromacs, and POY with MrBayes parallel (MPI-like) support. Due to those efforts, the number of researchers interested in using the infrastructure has been growing systematically since the system became operational in January of 2010. There is a real demand for high-end computational resources and for qualified technical support inside UNESP. The utilization of resources by the users of the GridUNESP VO, represented by the mean occupancy of computing resources along the year, evolved from 19% in 2010 to 53% in 2011 and achieved 74% in 2012.

2.2 Campus Researchers

The OSG project leverages its geographic and institutional diversity to bring DHTC computing to a broad and growing cross-section of US researchers, both as individuals and groups. Typically these researchers do not bring computing resources to connect to OSG and are motivated to accomplish their scientific computing in the most efficient and timely manner. The OSG team assists these researchers in adapting their applications to run in the DHTC environment, helps them get access to OSG for submitting their jobs, and supports them in completing their research computation.

In the last year, these teams enabled DHTC use of the OSG for over 60 researchers, spanning 14 science domains, and utilizing over 24M hours of computing.

Table 2

Science	Sub-Category	Researchers	Affiliation	Project Title (and URL, if available)	Usage (Hours)	OSG Team
Astronomy	Extrasolar planet astronomy	Ewa Deelman, Bruce Berriman	USC ISI / NASA IPAC	Atlas of Periodicities present in the time-series data sets released by the Kepler satellite	355,382	OSG-XSEDE
Astrophysics	Cosmology	Chang Feng	UCSD	Gravitational lensing of CMB	452,948	UCSDGrid
Astrophysics	Cosmology and Extragalactic Astrophysics (astro-ph.CO)	K. T. Story, et al.	Kavli Institute, University of Chicago	Measurement of CMB using the South Pole Telescope, http://pole.uchicago.edu	6,500	UC3
Astrophysics	Cosmology and Extragalactic Astrophysics (astro-ph.CO)	Z. Hou, et al.	University of California, Davis	Measurement of CMB using the South Pole Telescope, http://pole.uchicago.edu	6,500	UC3
Biochemistry	Protein Folding	Yifan Song and Huang Possu	Baker Lab, University of Washington	Prediction and Design of Protein Structures and Protein-protein Interactions, http://www.bakerlab.org	377,292	UCSDGrid
Biochemistry	Protein Structure	Craig Patricio	UCSD	Center for Theoretical Biological Physics	18,392	UCSDGrid
Biology	Biochemistry	Alan Attie	University of Wisconsin at Madison	Multiple genetic studies of metabolic diseases	23,700	GLOW
Biology	Bioinformatics, Computational Biology	Victor Ruotti, Ron Stewart, James Thomson, Jeff Nie	Morgridge Institute for Research	Computational tools for gene network building, the Stem Cell Knowledgebase, and integration of the Galaxy bioinformatics framework with HTCondor/CHTC resources	13,403	GLOW
Biology	Cell Biology	Paul Wolberg	University of Michigan	Multi-scale Computational Models to study the Human Immune Response to infection with M.	2,836	OSG-XSEDE

				tuberculosis		
Biology	Conservation Biology, Sustainability	Volker Radeloff	University of Wisconsin at Madison	Conservation and sustainability analyses of urban- and suburban-wildlife interfaces	1,968	GLOW
Biology	Genomics and Ecology	Rohita Sinha	Department of Food Science and Technology, University of Nebraska	Functional Annotation of Metagenomic Assemblies	448,389	HCC
Biology	Integrative Biology and Neuroscience	Don Krieger	University of Pittsburgh	Very high resolution functional brain mapping	1,107,068	OSG-XSEDE
Biology	Molecular and Synthetic Genomics	David Schwartz	University of Wisconsin at Madison	Laboratory for Molecular and Computational Genomics (LMCG), http://www.lmcg.wisc.edu/	163,308	GLOW
Biology	Molecular Biology	Yongna Xing	University of Wisconsin at Madison	Targeting PP2A activation for developing therapeutics	3,218	GLOW
Biology	Pharmacology	Douglas Myers-Turnbull	UCSD	The role of symmetry of tertiary structure in protein evolution	6,164	UCSDGrid
Biology	Plant and Livestock Genetics	Shawn Kaeppler, Natalia de Leon, Daniel Gianola, Guilherme Rosa	University of Wisconsin at Madison	Multiple projects in maize and livestock genetics	22,736	GLOW
Biology	Population Genetics	Mark Berres	University of Wisconsin at Madison	Spatially-explicit models of population genetic structure in avian species	14,778	GLOW
Biology	Proteomics/Microbiology	Shi-Jian Ding	Department of Pathology/Microbiology, University of Nebraska Medical Center	Systematic Identification of Post-translational Modifications from Complex Proteome Mixtures	183,261	HCC
Biology	Statistical Genetics	Cecile Ane	University of Wisconsin at Madison	Genealogical discordance and whole genome duplication	948,455	GLOW
Biology	Statistical Genetics	Karl Broman	University of Wisconsin at Madison	Statistical methods and software for QTL mapping	194,903	GLOW
Biology	Structural Biology, Biophysics	John Markley, Eldon Ulrich, Miron Livny	University of Wisconsin at Madison	Biological Magnetic Resonance Bank (BMRB), http://www.bmrb.wisc.edu/	4,412,976	GLOW

Chemistry	Computational Chemistry, Biophysics	Qiang Cui	University of Wisconsin at Madison	Multiple biomolecular simulation projects involving QM/MM	39,499	GLOW
Chemistry	Computational Chemistry, Polymer Physics	Arun Yethiraj	University of Wisconsin at Madison	Computer simulations of complex fluids	3,138	GLOW
Chemistry	Geochemistry, Biomaterials Engineering	Nita Sahai	The University of Akron (previously UW-Madison)	Bio-mineral interactions and engineering	2,298	GLOW
Chemistry	Materials Chemistry	JR Schmidt	University of Wisconsin at Madison	Modeling gas adsorption in nano-porous materials	54,903	GLOW
Chemistry	Molecular Thermodynamics, Statistical Mechanics	Juan DePablo	University of Chicago (previously UW-Madison)	Course grain simulations of DNA biophysics	857,926	GLOW
Chemistry	NMR Spectroscopy, Structural Biology	Robert Powers	Department of Chemistry, University of Nebraska	Comparison of Protein Active Site Structures (CPASS) http://cpass.unl.edu	2,580,337	HCC
Chemistry	Statistical Mechanics (cond-mat.stat-mech)	Glen M. Hocky, David R. Reichman	Columbia University	A small subset of normal modes mimics the properties of dynamical heterogeneity in a model supercooled liquid, http://www.columbia.edu/cu/chemistry/groups/reichman/people/glen.html	36,000	UC3
Climate Science	Cloud formation	Johannes Muelmenstaedt	Scrips Institute of Oceanography	Cloud Properties over the North Slope of Alaska	100,220	UCSDGrid
Climate Science	Modeling and decision systems	Joshua Eliot	University of Chicago	Center for Robust Decision Making on Climate and Energy Policy, http://www.rdcep.org/	540,000	UC3
Computer Sciences	Algorithm Development, Optimization	Michael Ferris	University of Wisconsin at Madison	Optimization and optimization algorithm development	581,807	GLOW
Computer Sciences	High Throughput Computing	Miron Livny, Brooklin Gore, HTCondor Team	University of Wisconsin at Madison	UW Center for High Throughput Computing, http://chtc.cs.wisc.edu/; HTCondor, http://research.cs.wisc.edu/htcondor/	390,912	GLOW
Computer Sciences	Optimization, Geology	Chris Ré	University of Wisconsin at Madison	Deep linguistic processing: bringing dark data to light	337,921	GLOW

Earth and Atmospheric Sciences	Meteorology	Cody Opperman, Noah Lock	Dept. of Earth and Atmospheric Sciences, Severe Storms Research Group, University of Nebraska	Thunderstorm Observation by Radar (ThOR) algorithm	20,074	HCC
Engineering	Civil & Earthquake Engineering	Andre Barbosa, Patricia Clayton	Oregon State University, University of Washington	Simulation of structures' responses to earthquakes, http://nees.org/	3,410	User-Support
Engineering	Education	James Herold	UCRiverside	Segmenting pen strokes using pen speed	11,142	UCSDGrid
Engineering	Electrical/Computer Engineering	Thomas Jahns, Robert Lorenz	University of Wisconsin at Madison	Wisconsin Electric Machines and Power Electronics Consortium (WEMPEC), http://www.wempec.wisc.edu/	1,560	GLOW
Mathematics	Combinatorics	Alexander Arlange	Rochester Institute of Technology	Ramsey Numbers R(C4,Km)	140,121	User-Support
Medicine	Biomedical Imaging	Martin Purschke	Brookhaven National Lab	Positron Emission Tomography (PET) at BNL, http://www.bnl.gov/pet/	1,628	User-Support
Medicine	Biomedical Optics	Paul Campagnola	University of Wisconsin at Madison	Analysis of optical properties in ovarian cancer using Monte Carlo simulations	866,730	GLOW
Medicine	Chemical Genomics and Drug Discovery	Samy Meroueh	Indiana University School of Medicine	Structural Protein-Ligand Interactome (SPLINTER) - http://www.biodrugscreen.org/	36,473	CSIU
Medicine	Hearing Science	Ruth Litovsky, Tyler Churchill	University of Wisconsin at Madison	Waisman Binaural Hearing & Speech Lab (BHSLab): Auditory nerve model analyses, http://www.waisman.wisc.edu/bhl/	408,090	GLOW
Medicine	Metagenomics/ Virology	David O'Connor	University of Wisconsin at Madison	Novel pathogen discovery in African non-human primates, http://labs.pathology.wisc.edu/oconnor/	112,052	GLOW
Medicine	Neuroscience, Behavioral Genetics	Ned Kalin	University of Wisconsin at Madison	Understanding the neurobiology of anxiety during childhood	175,101	GLOW
Medicine	Statistical Signal Processing	Barry Van Veen	University of Wisconsin at Madison	Dynamic models of brain networks from electroencephalographic or magnetoencephalographic data	358,218	GLOW

Physics	Accelerator Modeling	Armando Fella	SuperB experiment; CNRS–Orsay	Test jobs in preparation for designing SuperB accelerator, http://superb.infn.it/home	23,239	User-Support
Physics	Accelerator Modeling	Tobias Toll	Brookhaven National Lab	Electron Ion Collider (EIC) at BNL, https://wiki.bnl.gov/eic/index.php/Main_Page	612,896	User-Support
Physics	Astronomy	Don Petravick, Brian Yanny	NCSA & FNAL	Basic processing of DES exposures, https://cosmology.illinois.edu	129,308	User-Support
Physics	Astronomy	John Peterson	Purdue	Software development for LSST telescope, http://www.lsst.org/lsst/	393,597	User-Support
Physics	Biophysics	Carol Hirschmugl	University of Wisconsin at Madison	Sychrotron Radiation Center (SRC), http://src.wisc.edu/	20,204	GLOW
Physics	Condensed Matter Physics	Susan Coppersmith, Mark Friesen	University of Wisconsin at Madison	Projects in theoretical condensed matter physics and quantum information theory, http://uw.physics.wisc.edu/~coppersmith/	230,128	GLOW
Physics	High Energy Physics	Duncan Carlsmith, Sridhara Dasu, Matthew Herndon, Wesley Smith	University of Wisconsin at Madison	CMS, http://www.hep.wisc.edu/cms/	371,723	GLOW
Physics	Magnetospheric Physics	Robert McIntosh	University of Texas at Dallas	Global Distribution of Characteristics of Auroral Particles	49,684	OSG-XSEDE
Physics	Particle Physics	SauLan Wu	University of Wisconsin at Madison	ATLAS	859,202	GLOW
Physics	Phenomenology	Stefan Hoeche	SLAC	Validation and use of software for particle physics phenomenology, http://www.freacafe.de/physics/index.php	199,536	User-Support
Physics	Theoretical Condensed Matter Physics	Natalia Perkins, Craig Price	University of Wisconsin at Madison	Finite temperature phase diagram of the classical Kitaev-Heisenberg model: Application to iridates	3,086,002	GLOW
Physics	Theoretical Physics	Pran Nath	Northeastern University	Search for Beyond the Standard Model Physics at the LHC	103,679	OSG-XSEDE
Social Sciences	Economics	Amit Gandhi	University of Wisconsin at Madison	Industrial organization and econometric analyses	512,998	GLOW
Social Sciences	Economics	Kenichi Fukushima	University of Wisconsin at	History dependent labor income taxation	377,568	GLOW

			Madison			
Social Sciences	Economics	Nicolas Roys	University of Wisconsin at Madison	Multiple optimization projects for labor economics and macroeconomics	72,712	GLOW
Statistics	Biostatistics	Kam-Wah Tsui, Sijian Wang	University of Wisconsin at Madison	A robust high dimensional smoothing spline predictor	508,987	GLOW
Statistics	Biostatistics	Grace Wahba, Sijian Wang	University of Wisconsin at Madison	New/improved methods for statistical data analysis	439,260	GLOW
Statistics	Clinical statistics	Jun Shao	University of Wisconsin at Madison	Statistical methods in clinical research	30,238	GLOW

The major regional OSG teams that enabled access to DHTC computing for US researchers in this reporting period are described immediately below.

2.2.1 GLOW

Established in 2006, the Center for High Throughput Computing (CHTC) at the University of Wisconsin at Madison (UW-Madison) provides numerous resources to support the computational needs of campus researchers. UW-Madison maintains multiple on-campus clusters for distributed high-throughput computing. These campus resources provided roughly 67 million CPU hours during the 2012 calendar year. As an active member of the Open Science Grid (OSG), the CHTC provided an additional 17 million CPU hours to campus researchers via the OSG in 2012. To support software testing in a diverse environment with multiple platforms, researchers also have access to the UW Build and Test Lab (BaTLab). All of the above computing resources are managed with the HTCondor resource scheduling system, which is actively developed at UW-Madison by the HTCondor team. Together, CHTC and HTCondor staff provide support to other on-campus cluster administrators. Over the next year, the CHTC will be supplementing its on-campus resources to provide high performance computing (HPC) capabilities in addition to the numerous high throughput computing (HTC) resources already available. In order to aid researchers in utilizing all of these resources, the CHTC employs a team of Research Computing Facilitators who provide consulting, matchmaking, and support. All of the above services are provided to UW-Madison researchers and collaborators at no charge. The CHTC, located in the Department of Computer Sciences, is funded by grants from the National Science Foundation (NSF) and Department of Energy (DOE), and various UW-Madison funding efforts.

2.2.2 HCC

The Holland Computing Center (HCC) of the University of Nebraska (NU) began to use the OSG to support its researchers during 2010 and usage is continuing and growing. HCC's mission is to meet the computational needs of local scientists, and does so by offering a variety of resources. In the past year, the OSG has served as one of the resources available to their scientists, leveraging the expertise from the OSG personnel and running the CMS Tier2 center at the site. Support for running jobs on the OSG is provided by our general-purpose applications specialists. To distribute jobs, we primarily utilize the Condor-based GlideinWMS system originally developed by CDF and CMS; this provides a user experience very similar to using a local Condor batch system, greatly lowering the barrier of entry for users.

2.2.3 RENCI/Engage

In April 2008, PI McGee, at RENCI, was awarded an OSG Satellite Project (Embedded Immersive Engagement for Cyberinfrastructure – EIE4CI) from the CI-TEAM program to establish the Engage VO, engagement program, and with co-pi Goasguen, explore the use of OSG techniques for catalyzing campus grids. Although this project is no longer a funded activity, RENCI continues to partner and support the new researchers in the regions. The EIE4CI team has been successful in engaging a significant and diverse group of researchers across scientific domains and universities. The infrastructure and expertise that we have employed has enabled rapid uptake of the OSG national CI by researchers with a need for scientific computing that fits the model of national scale distributed HTC.

Engage-VO users during this reporting period come from a number of science domains including: Biochemistry (Zhao), theoretical physics (Bass, Peterson, Bhattacharya, Coleman-Smith, Qin), Mechanical Engineering (Ratnaswamy), Earthquake Engineering (Espinosa, Barbosa), RCSB Protein Data Bank (Prlic), and Oceanography (Thayre). Also during this reporting period, RENCI has made available two clusters to the Engage community including opportunistic access to the 11TFlop BlueRidge system, including GPGPU nodes being used by an EIE4CI molecular dynamics user, and some experimental large memory nodes (two nodes of 32 cores and 1TB of system memory).

2.2.4 UC3

In January of 2012 we launched a new project aimed at facilitating sharing of computing resources within the Computation and Enrico Fermi Institutes as well as across the UChicago campus, and, as appropriate, opportunistic computing resources from the Open Science Grid. The project, UC3, aims to facilitate distributed high-throughput computing by joining diverse resources on campus, including the ATLAS Midwest Tier 2 center, so that idle cycles from one group can be put to good use by another. A 540 job slot cluster, funded by the University and dedicated to UC3, was deployed to “seed” application groups with high-throughput styled application workloads. Additionally a 50 TB storage system with an HDFS filesystem and a Globus Online endpoint, integrated with CiLogon and the University of Chicago identity management system, was deployed to host staged datasets for processing. Participation in the project so far has come from technical teams supporting different science disciplines at UC, including particle astrophysics, medical imaging, high energy physics, and computer science including the Globus Online team at Argonne. Additional staff from the central IT services and research networking staff of the University have assisted with the integrated identity management solution, for both processing and data resources, and provided a quick registration service as well as other centrally hosted services that support the project. An important goal of UC3 is to serve as a testbed for OSG Campus Grid Services and to contribute to and provide feedback to the OSG Campus Infrastructures Community program. For this purpose UC3 was used for testing early releases of the BOSCO (for job management) and Skeleton Key (for data access) software packages. Contributed support comes from leveraged contributions from the University of Chicago, the U.S. ATLAS Tier 2 program (where we re-used deployment and configuration management systems, and for software deployment using CVMFS), UChicago IT Services, and from the OSG in the context of developing models for campus grids.

2.2.5 UCSDGrid

The UCSD CMS Tier-2 team provides a login interface for regional researchers and CMS colleagues. In 2010, one of the particle theorists in the department came by asking for help with a large computing problem. The team gave him access to the login interface, and taught him how to use condor to submit jobs to the grid via glideinWMS. Over time, and word of mouth, other researchers were recruited around campus. At this point, the login interface for "UCSDGrid" is operated on hardware from the Center for Theoretical Biological Physics. The UCSDGrid is a group inside the

Engage VO of OSG. As a result, this team operates no extra services other than the login interface and a connection into glideinWMS job submission system. Operations is essentially zero maintenance, and they have provided about a Million CPU hours in 2012 as well as 15TB disk space for scientists studying Biochemistry, Cosmology, Climate Science, Engineering and Pharmacology. In 2012 this "outreach activity" has led to publications in the Journals Climate and PRD.

2.2.6 User Support Team

As part of the funded effort in the OSG project, the User Support team provides a consulting and assistance framework that accelerates the time-to-production of new science communities. Often, we embed a member of the User Support team with each new community for up to few months to accelerate the ramp-up to production; we provide direct contributions to customization and integration of the researcher's software to enable use of DHTC computing. This team is responsible for integrating and operating the systems that enable OSG as a service provider for XSEDE users. The job submission host that is deployed for OSG-XSEDE is also reused for other research communities who directly approach OSG for access to DHTC computing resources. The User Support team is presently comprised of staff from USC-ISI, FNAL, and BNL and enables DHTC access for XSEDE users of OSG as well as other research groups that want to use OSG.

3. The OSG Fabric of Services

3.1 Production on the OSG Facility

The OSG facility provides the platform that enables production by the science stakeholders; this includes operational capabilities, security, software, integration, testing, packaging and documentation as well as VO and User support. Scientists who use the OSG demand stability more than anything else and we are continuing our operational focus on providing stable and dependable production level capabilities, especially as the usage of the OSG facility continues to increase.

The stakeholders continued to perform record amounts of data processing. The two largest experiments, ATLAS and CMS continued their simulation and analysis in preparation for the accelerator shutdown in early 2013. During this time, while new data from the detectors will not be collected, analysis is projected to continue at the same levels. The OSG infrastructure has demonstrated that it is up to meeting the needs of its largest stakeholders. Over the previous year just short of one petabyte of data was transferred between OSG resources each day - up 23% from the previous annual report; this is accompanied by nearly 1.9M million CPU hours per day.

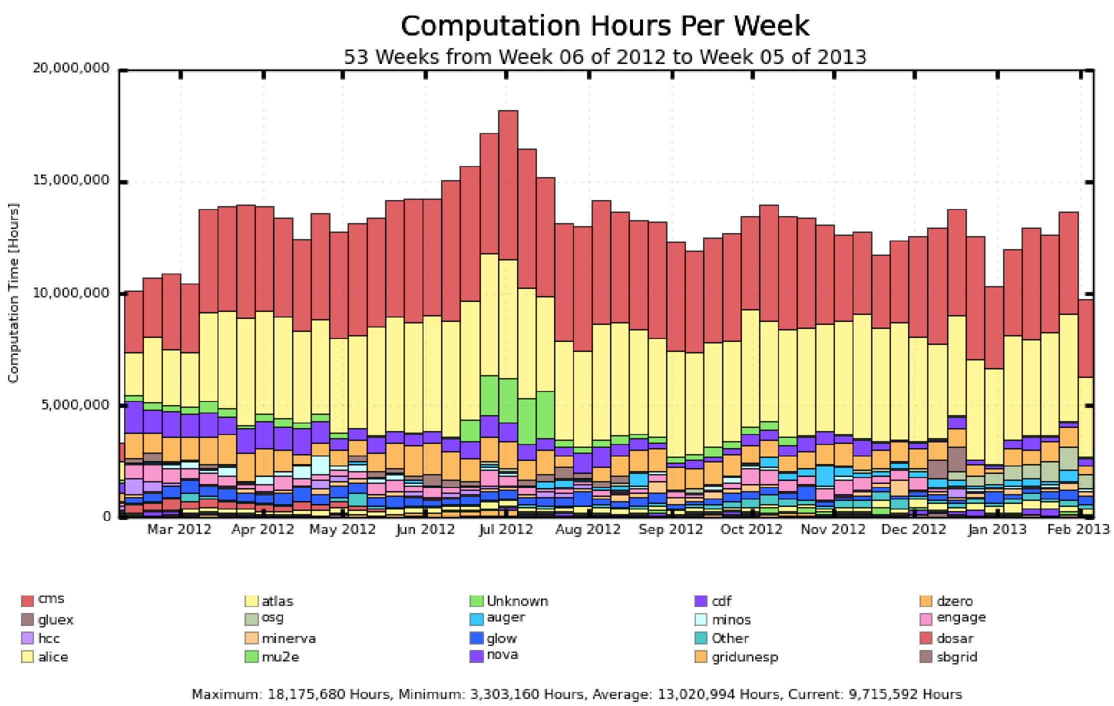

Figure 27:
OSG facility usage vs. time for the past year, broken down by VO

During the last year OSG provided VO users over 13M hours per week reaching a peak of ~18M hours during the summer of 2012. OSG provides an infrastructure that supports a broad scope of scientific research activities, including the major physics collaborations, biological sciences, nanoscience, applied mathematics, engineering, medicine, and computer science. Most of the current usage continues to be in the area of physics but non-physics use of OSG is an important area with usage of nearly 50M hours over the previous year.

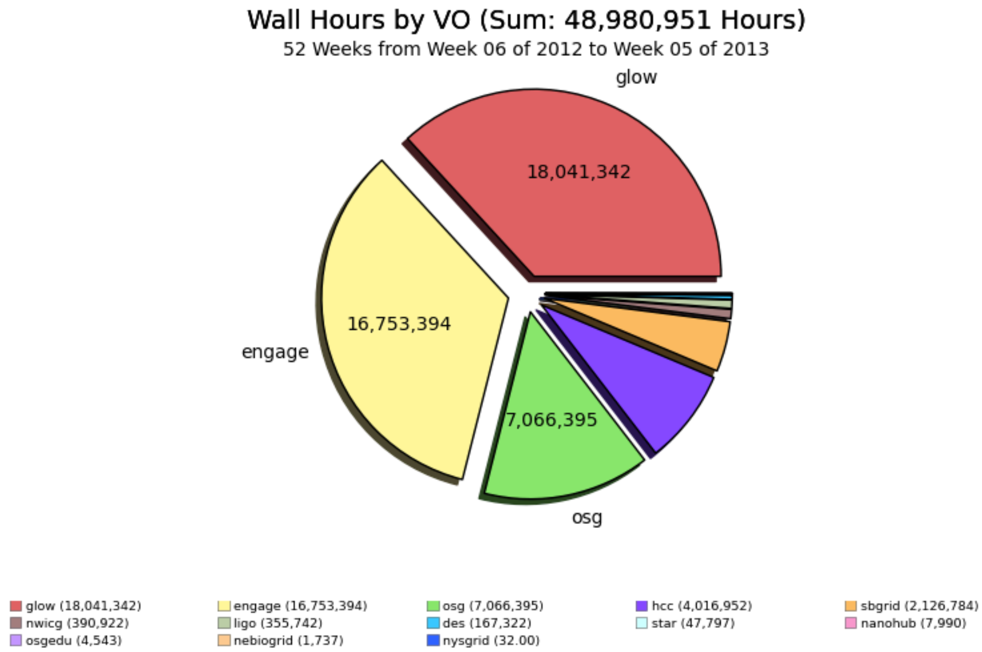

Figure 28:
OSG non-HEP hours of usage by VO

With 115 sites, the production provided on OSG resources continues to grow; the usage varies depending on the needs of the stakeholders. And OSG's investment in Campus Infrastructure Communities is paying off with many scientists using local submission nodes to "flock" to the OSG facility. Campus communities at the University of Nebraska, University of Wisconsin, University of California San Diego, Indiana University, and University of Chicago are utilizing local and national resources with HTC resources provided by OSG.

OSG actively supports it stakeholders in the broad deployment of a flexible set of software tools and services for efficient, scalable and secure distribution of workload among OSG sites. The glideinWMS technology pioneered during the previous years is now the major technology for submitting jobs seamlessly to multiple OSG locations.

As evidenced by increase in volume, scope and diversity of the workload handled globally by the OSG supported Workload Management Systems this program continues to be extremely important for the science community. The OSG continues to draw new entrants from diverse areas of research who receive significant benefit by leveraging stable and proven environment for access to resources, job submission and monitoring tools created and maintained by OSG.

OSG faces a major operational change with the distribution of user and service credentials, previously provided by the DOE, now being maintained by the OSG in association with the commercial credential provider DigiCert. This change will force most OSG users and resources to update their authentication mechanisms. While this process will provide a minor inconvenience to users as the update to the new credentials, it also allows OSG to decouple its procedures from the backend certificate issuing service. Future changes of this nature will not affect the user, as the frontend that was developed is independent of the backend certificate issuer. The OSG Security, Operations, and Technology teams provided significant effort to assure a smooth transition.

This year also saw a push for OSG resources to update the installed software packages from the custom packaging tool *Pacman* to the more generic Redhat Package Manager (RPM) to simplify installation for the resource providers and release management for the OSG Software Team. At this point the majority of the resources on OSG have updated to this new packaging with a final push for all sites to update by early summer of 2013.

2012 saw increased reliance on the Gratia software for recording and understanding a the usage patterns across the production sites and resources. At the end of the year OSG participated in the management review of the project and, as an important stakeholder in the software, expects to be increasingly active in using and contributing to improved reporting and analytics capabilities.

In summary, OSG has demonstrated that it is meeting the needs of US CMS and US ATLAS stakeholders at all levels of operation. OSG is successfully managing the uptick in cycles and data movement as the LHC data taking continues into 2013. OSG continues to actively support and meet the needs of a growing community of non-LHC science and campus level researchers that are increasing their reliance on OSG. And OSG shows the willingness and skill to adapt to the new technologies that allow our stakeholders to complete their research.

3.2 Technology

The OSG Technology Area provides the OSG with a mechanism for medium to long-term technology planning. This is accomplished via two sub-groups, the Blueprint and Investigations groups.

<u>Blueprint</u>: The blueprint sub-group records the conceptual principles of the OSG and focuses on the long-term evolution of the OSG. This group has been meeting approximately three times a year and updates the “Blueprint Document” to reflect our understandings of the basic principles of the OSG. The primary topics discussed at the blueprint meetings this year include improved monitoring for data servers, bridging to other cyber-infrastructures, information system futures, campus grid plans, the intersection of cloud computing with OSG, and federated identity plans.

<u>Investigations</u>: To manage the influx of new external technologies - while keeping to the OSG principles - this sub-group does investigations to understand the concepts, functionality, and impact of external technologies. The goal is to identify technologies that are potentially disruptive in the medium-term of 12-24 months and give the OSG recommendations on whether and how to adopt them. Based on the recommendations of this and the Blueprint group, a temporary team may be formed from OSG staff to adopt the technology to the OSG. We consider the following work “highlights” of the past year:

- <u>OASIS</u>: The OSG Application Software Installation Service has progressed from the “Technology investigation” phase toward a production deployment. The OSG Technology team has worked with Operations to deploy an instance of CVMFS at GOC and integrate it with OIM. This instance has progressed to a “beta” status; we encourage sites to install the clients and have invited several VOs to try using it. This appears to fulfill the promise of “install once, run everywhere “we were looking for in last year’s technology investigation.

- <u>HTCondor-CE</u>: Last year’s investigation on potential “next-generation CEs” resulted in the selection of focusing on HTCondor as a potential replacement for the Globus GRAM software. We’ve worked with the HTCondor team to define a series of improvements necessary for this use case. The Technology team has helped integrate, package, and document the resulting configuration. One of the achieved design goals of the HTCondor-CE is a special configuration of HTCondor that contains no additional piece of software for OSG to support. By using

HTCondor for the CE, we align the technology used in the OSG Production Grid with the Campus Grid's BOSCO effort. Further, the underlying "blahp" software for HTCondor to communicate with the LSF, SGE, PBS, and SLURM batch schedulers is shared across HTCondor-CE, BOSCO, and INFN's CREAM CE.

- User isolation: For pilot-based batch jobs, it is important to provide a level of separation between the payload and pilot jobs. These provide work from two distinct users with two distinct privilege levels. It is important that the payload is unable to access the pilot's files or control its processes. Toward this end, OSG has shipped a program, glexec, which allows the pilot to launch a process as a different Unix user based on the payload's grid proxy. The existing configuration requires the payload user to already be registered with the site; we have a prototype improvement that no longer requires the payload user to be registered at the site as long as the glexec request is from a known pilot and presents a valid certificate. This should allow opportunistic VOs run payloads from within an OSG pilot without registering at a site, allowing us to demolish one of the most difficult barriers for new VOs.

Other technical work in this area includes improvements to the Gratia software probes and collectors for Campus Grids and the OSG-XSEDE portal, continuing the use of iRODS for OSG public storage (with the User Support Area), and starting to integrate OSG with cloud technologies such as OpenStack.

Communications: The OSG Technology team participates in several working groups of the WLCG, including:

- The WLCG Grid Deployment Board (GDB).
- The storage interfaces and federated storage working group.
- The WLCG interoperability group.

These working groups allow us to disseminate our findings to the wider grid ecosystem and help guide the evolution of the WLCG. All investigation results are also uploaded to the OSG document repository (osg-docdb.opensciencegrid.org). To further engage and inform the wider community, we maintain a blog chronicling our activities (http://osgtech.blogspot.com).

Upcoming Challenges: The Technology team plans to make improvements in the following areas in the next year:

- Software Simplicity: Based on the findings of the last two years, we believe we can reduce OSG's dependency on the BDII software and simplify the information services interfaces that the OSG supports. Continuing the adoption of the HTCondor-CE will also reduce the number of unique components on the OSG CE. We believe these eliminations will decrease the total investment for a site to participate in the OSG production grid.
- Opportunistic Usage: The Technology area would like to focus on decreasing barriers to entry for new users. The OSG cannot predict what opportunistic resources are available at Production Grid sites; we would like to improve this via improved glideinWMS monitoring and actively probing sites for available CPU capacity. OSG Technology is also working on the Cross-CE, which aims to decrease the number of sites that need to authorize a certain VO before it starts running on the OSG.

3.3 Campus Grids

The Campus Infrastructure initiative is focused on the development of Distributed HTC (DHTC) infrastructures in campus environments. The DHTC principles (diverse resources, dependability, autonomy, and mutual trust) that OSG advances and implements at a national level apply equally well to a campus environments. The goal of the Campus DHTC infrastructure activity is to continue and translate this natural fit into a wide local deployment of high throughput computing capabilities at the nation's campuses, bringing locally operated DHTC services to production in support of faculty and students as well as enabling integration with XSEDE, the OSG, and other cyber infrastructures. Deploying DHTC capabilities onto campuses carries a strong value proposition for both the campus and the OSG. Intra-campus sharing of computing resources enhances scientific competitiveness and when interfaced to the OSG production infrastructure increases the national computational throughput.

To accomplish this we are executing the following approach that is aiming to eliminate key barriers to the adoption of HTC technologies by small research groups on our Nation's campuses.

1. Support for local campus identity management services removes the need for the researchers to fetch and maintain additional security credentials such as grid certificates.
2. An integrated software package that moves beyond current cookbook models that require campus IT teams to download and integrate multiple software components. This package does not require root privileges and thus can be easily installed by a campus researcher.
3. A campus job submission point capable of routing jobs to multiple heterogeneous batch scheduling systems (e.g. Condor, LSF, PBS etc.). Previously existing campus DHTC models required that all resources are managed by the same scheduler.
4. Coordinated education, training and documentation activities and materials that cover the potential, best practices and technical details of DHTC technologies.

The job submission interfaces presented to campus faculty and students are identical to those already in use today on the OSG production infrastructure. Hence this provides a seamless mechanism for extending their work onto the OSG. This forms a natural seedbed of a new generation of computational scientists who can expand their local computing environment into the national CI.

For the first three items above we have begun the development of Bosco. Bosco is an integrated software package that provides the easiest way for a user to submit HTC jobs to clusters available on the campus or directly from their laptop or desktop computers. The Bosco team has released several early releases of Bosco for user testing that include a full set of documentation and the creation of the Bosco website for users (http://bosco.opensciencegrid.org). We are currently working primarily on making the interface seamless between the users system and one or more remote clusters. This is a very challenging problem and the team is engaged in fixing a steady stream of issues encountered by a handful of test users.

OSG has had a number of activities related to DHTC outreach, education, and training that pertain, in some fashion, to the context of using or building campus grid infrastructures. These have either been in the form of summer school events[9], site administrator workshops[10], or in the case of Grid Colombia a full-scale "build-a-grid" curriculum which comprised two weeks from Unix how-to all the way to deploying production services[11]. The style of each was designed to fit the target audience: the OSG summer schools for example have focused on researchers and students, not infrastructure. The site administrator workshops focused on infrastructure and core OSG and network services, not users or science workloads. In context of the Campus Grids activity the challenges are different as they involve both science use (from the research domain engagement goal) and the necessary core infrastructure and

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[9] The 2012 OSG Summer School, https://opensciencegrid.org/bin/view/Education/OSGUserSchool2012

[10] OSG Site Administrator Workshops, https://www.opensciencegrid.org/bin/view/SiteCoordination/WebHome

[11] Grid Colombia Workshop, https://twiki.grid.iu.edu/bin/view/ReleaseDocumentation/GridColombiaWorkshop2010

services to effectively use resources on and off-campus. To date the focus has been development of tools to access compute cycles, but over the course of OSG Next Five Years program this will necessarily involve data (and other advanced services) in more integral ways. Therefore in 2012 the *OSG Campus Infrastructures Community* (CIC) Initiative was launched which aims to provide a forum for sharing tools, applications and best practices for creating such environments through webinars and in-person meetings. The CIC area has held two seminars and a face-to-face workshop.

3.4 Operations

The OSG Operations team provides the central point for operational support for the Open Science Grid and provides the coordination for various distributed OSG services. OSG Operations publishes real time monitoring information about OSG resources, supports users, developers and system administrators, maintains critical grid infrastructure services, provides incident response, and acts as a communication hub. The goals of the OSG Operations group are: supporting and strengthening the autonomous OSG resources, building operational relationships with peer grids, providing reliable grid infrastructure services, ensuring timely action and tracking of operational issues, and assuring quick response to security incidents. During the last year, OSG Operations continued to provide the OSG with a reliable facility infrastructure and community support while at the same time improving services to offer more robust tools to the OSG stakeholders.

OSG Operations actively supports US LHC and will continue to refine and improve our capabilities for these stakeholders. As OSG Operations supports the LHC data-taking phase, we continue to meet the high expectations for service reliability and stability of existing and new services.

With the increased support for campus and other community users, Operations is extending its services to meet new usage patterns and needs.

A major change to user identification management procedures has heavily impacted operations effort during the past year. As OSG moves from credentials being provided by DOEGrids to DigiCert the OSG Operations Team has been responsible for developing the interfaces, updating procedures and documentation, and tracking each credential request.

During the last year, the OSG Operations continued to provide and improve tools and services for the OSG, these include:

- Developed and implemented the new OSG Public Key Infrastructure (PKI) Front End service allowing users to request certificates via the OSG Information Management (OIM) service. Developed an administrative interface to issue and track all certificate related activities. Worked with the OSG Security Team to document the changes to the Certificate Authority (CA) processes.

- Exceeded expectations for service availability and reliability as defined by Service Level Agreements.

- Operated the BDII service, critical to the LHC community, at an availability of 99.94% during the reporting year. Figure 29 shows the downtime fraction for critical Operations services; downtime fraction is defined as (1-Availability) and shown here is the average for the two instances of each service. Actual aggregated availability is higher than indicated by this plot - from a user perspective these services are unavailable only if both instances are unavailable.

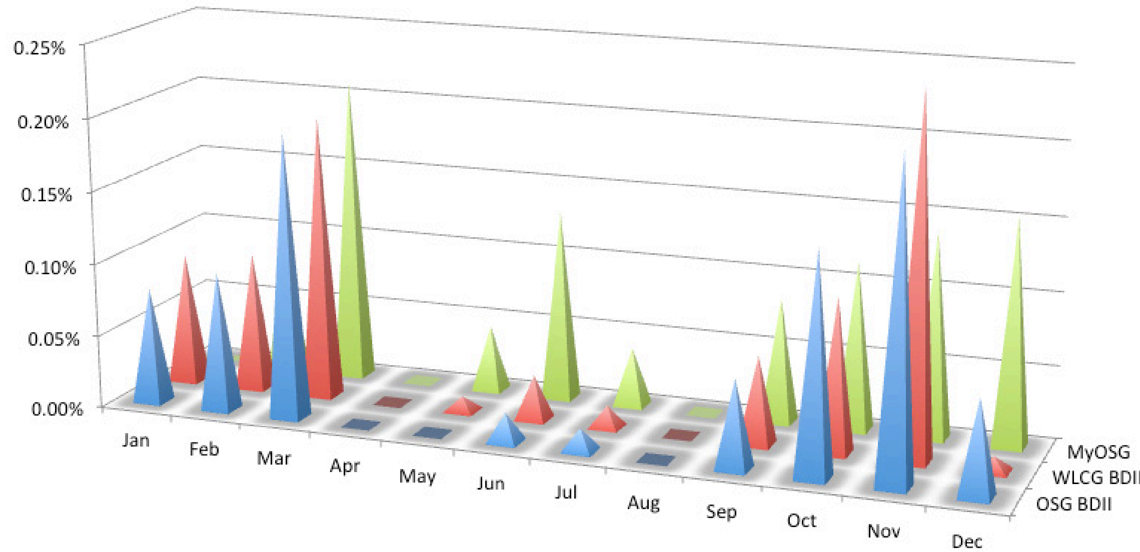

Figure 29:
The downtime fraction for critical Operations services.

- Operations Support experienced a 20% increase in opened tickets. This is partially due to the influx of certificate requests associated with the CA transitioning from DOEGrids to DigiCert. Ticket response quality with the increased load was maintained at the same levels as before.

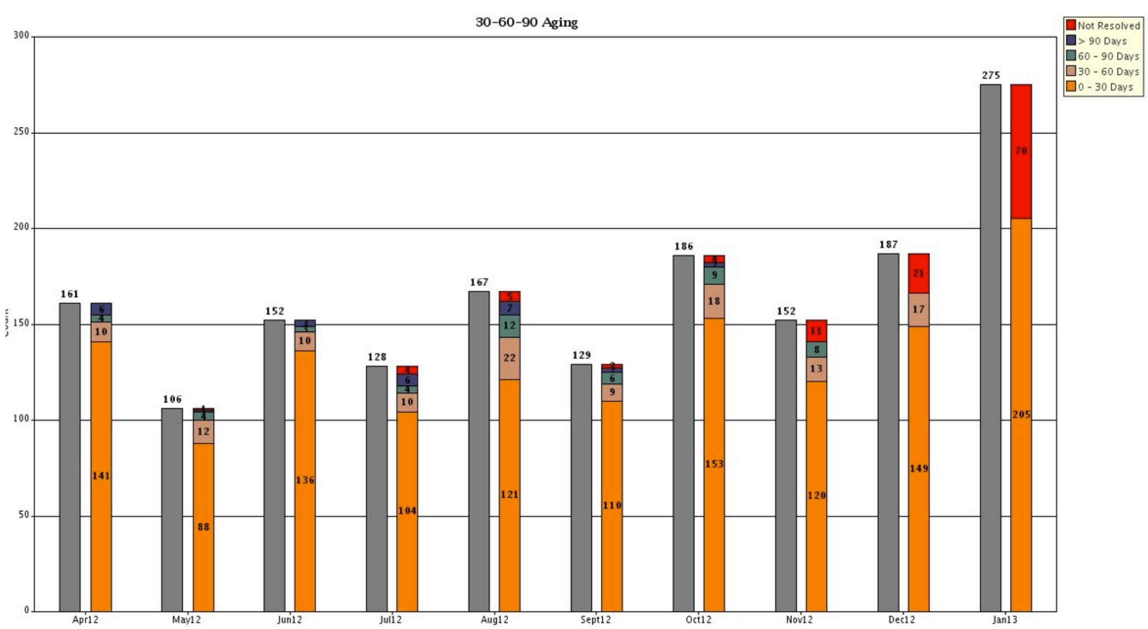

Figure 30:
Monthly Ticketing Activity April, 2012 to January, 2013. The gray bars are opened tickets, the orange bars are resolved tickets, and red bars are tickets not resolved.

- Continued our partnership with Worldwide LHC Computing Grid and European Grid Initiative operations groups. This included working on change management for our shared services (Ticketing, Monitoring, and Accounting) and attendance and presentations at major peering partner events.

- Worked with OSG Technology Team to install, test, and release a beta version of the OSG Application Software Installation Service (OASIS). This work continues on plan for a March 2013 release.

- Worked on developing a realtime event monitoring service which displays a variety of Operational service activities as they occur. This has been released in a test environment.

- Continued efforts to improve service availability via the completion of several hardware and service upgrades:

    - Moved most services to the state of the art Data Center located on the University of Indiana campus. Previously services were located on multiple IU campus.
    - Procured and installed new hardware to host the OASIS service.
    - Added networked storage to provide storage for all OSG Operation Center services.
    - Updated operating systems to latest RHEL versions to assure consistency of service environment.
    - Moved most services to utilize Linux Virtual Server (LVS) to improve efficiency of providing high availability services.
    - Continued to maintain high availability for the OSG-XSEDE submission node.

3.5 Network Monitoring

Networks are fundamental to the use and operation of grid systems, yet, to-date, they have been treated as an external "black box" with no awareness of the network state and no possibility to manage or prioritize traffic to optimize the performance and efficiency of the overall grid system. This year OSG began a new effort to integrate "networking" into OSG (in much the same way as storage systems and clusters have been) to deliver an ensemble-system capable of robustly serving scientists.

The long-term goal of this OSG network activity is to define a set of services and functionality which transform the current best effort networks into a managed component of the OSG. Over time we intend to augment the OSG software stack with a monitored, managed network component, building upon the tools and framework already existing or planned in OSG wherever appropriate and extending capabilities as required.

The initial work for this first year focused on the required network monitoring needed to be able to understand the network's behavior and impact within OSG, as well as the needed planning and coordination to prepare for the longer term goal.   The year 1 primary goals are listed and discussed below:

1) Enabling a network monitoring activity under OSG

    a. Guiding the definition and deployment of perfSONAR-PS for OSG sites

    b. Leading the development and deployment of OSG infrastructure needed to monitor the OSG deployed perfSONAR-PS instances.

c. Helping OSG end-sites and users maintain the deployed infrastructure and access the related higher-level monitoring

d. Documenting the deployed infrastructure

2) Coordinating network related efforts within OSG to ensure network-related developments are properly considered as OSG progresses

a. This includes planning for the incorporation of evolving methods for controlling networks end-to-end (both internal and external to the OSG footprint).

b. Raising awareness within OSG about networking to make sure relevant stakeholders are positioned to take advantage of networking capabilities as they are available.

c. Helping to organize new efforts to develop, prototype and deploy networking capabilities within OSG as deemed useful by OSG management.

In conjunction with the WLCG, we are pushing to instrument all WLCG (including OSG sites) with perfSONAR-PS installations to provide the needed network metrics and diagnostic capabilities. For goal 1a above, OSG sites can refer to the Wiki[12] for deployment details. In addition OSG has supplemented OIM with the ability to track perfSONAR-PS installations and detailed instructions are in the OSG Wiki[13]. Regarding 1b**,** OSG Networking and Operations have been working together to test and define the eventual network services that Operations will support. Initial tests of the Modular Dashboard (goal 1c) have begun. The Modular Dashboard was started at BNL as a way to gather, summarize and display perfSONAR-PS network metrics (for an example showing the OSG US-ATLAS Tier-2 sites[14]). This project was successfully moved into a new public GitHub area[15] and over 32,000 lines of code are in place. Documentation (goal 1d) about OSG Networking is being developed and is available on the OSG Wiki[16].

Goal 2 is being reached by a combination of activities. The OSG Area Coordinators meeting keeps all the other OSG areas informed about Network-area progress (topics are rotated through each week). In addition OSG activities are advertised at relevant meetings (ESnet/Internet2 Joint Techs, LHCONE/LHCOPN meetings and similar venues) and useful information is fed back to OSG. Likewise, efforts from various Network-research projects (DYNES, ANSE, PANDA Big-Data, etc.) are being used to preview possible future technologies relevant for OSG and guide our planning and deployment goals.

Many of the tools and technologies we wish to deploy "in production" for OSG are still under active development. This creates a challenge to deploy the software in a timely way. For the deployment at all OSG sites, we are targeting the perfSONAR-PS Toolkit. We are currently working closely with the Toolkit developers to ensure that it is simple to deploy and maintain. The next version of the Toolkit will contains many improvements in configuration, ease-of-use and resiliency. In addition to the toolkit deployments at sites, we are working with the OSG Grid Operations Center to commission a central OSG "Dashboard" that aggregates and displays network measurement results.

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[12] http://twiki.cern.ch/twiki/bin/view/LCG/PerfsonarDeployment
[13] https://www.opensciencegrid.org/bin/view/Documentation/RegisterPSinOIM
[14] http://perfsonar.racf.bnl.gov:8080/exda/?page=25&cloudName=USATLAS
[15] https://github.com/PerfModDash
[16] https://www.opensciencegrid.org/bin/view/Documentation/NetworkingInOSG

In summary, currently the focus is on 1) producing an OSG perfSONAR-PS Toolkit installation once v3.3 is released and 2) creating a new OSG Network Dashboard once the GitHub project provides sufficient functionality to be useful.

3.6 Software

The OSG Software team produces a software distribution to allow site administrators to add a local compute cluster to the OSG and to give individual researchers access to OSG computing resources. To achieve this goal, the team also develops a few software tools to fill "gaps" between available components. The OSG Software distribution consists mainly of middleware that builds upon a base operating system to support end-user applications. The focus of OSG is on software that is *not* part of standard repositories or is especially difficult to install and configure manually. Ultimately, the mission of the Software team is to minimize the effort needed to manage the software that underlies distributed high-throughput computing. To fulfill its mission, the team works closely with the OSG Technology, Production, Operations, and Security teams, plus key stakeholders in the scientific user community.

This year, a key accomplishment of the Software team was to finish work on a major transition in focus and in means of deployment. Historically, the OSG Software stack was built around a packaging tool called *Pacman*. Although it served well for many years, we wanted to improve user experiences by switching to a toolset that is more widely used in our community. Further, many key software components existed already in standard software repositories and users wanted us to take advantage of them, allowing the Software team to concentrate on components that are specialized for our environment. So starting in June 2011, the team began creating RPM packages distributed in Yum repositories. The initial conversion lasted through 2011, then a second round of conversions, improvements, and broadening of support filled the first half of 2012. During the transition, the team maintained both production distributions, Pacman and RPM, so that sites could operate without loss of support.

In the time covered by this report, the main transition challenges were to fix bugs introduced by the new packaging, especially due to a concomitant major version upgrade to a central component (Globus), and to address issues (packaging, documentation, etc.) that arose with initial production deployments. With over 300 packages in our system and many more required from other distributions, the real complexity lies in the interactions among components.

As of September 2012, the new OSG Software 3 distribution was complete, in that it contained no defects that blocked production deployment. All needed software packages were converted to RPMs, Enterprise Linux versions 5 and 6 (32- and 64-bit) were fully supported, and many packages were dropped from the OSG distribution for ones already in standard distributions. At this milestone, the OSG Production team advised sites to upgrade to the new distribution and, in February 2013, over 60% of sites had upgraded at least their central service node. In November 2012, the Pacman-based software distribution was deprecated, with an End-Of-Life of May 2013. With the transition nearly complete, the team can focus on adding and updating software for ever-changing needs and on making the software easier to deploy.

A recent project highlights the contributions of the OSG Software team. Much of the OSG security fabric relies on Public Key Infrastructure (PKI) technology. At its heart are X.509 certificates, which are used to cryptographically sign, encode, and decode private data over an unsecured public network. There are concerns about the strength of a widely used X.509 cryptography algorithm (SHA-1), so the broader PKI community is urging a move to a newer, more robust algorithm (SHA-2). Unfortunately, not all software that uses X.509 certificates is known to handle SHA-2 signed certificates yet. This year, the Software team was able to test all of its software that depends on PKI for SHA-2 compliance and, for the few components that were not ready, develop patches to bring the software into compliance. Full deployment of SHA-2 certificates may yield new issues, but for now this project is complete well ahead of the August 2013 target for initial deployment.

More generally, since April 2012 the Software team has released 15 versions of the RPM distribution and 3 maintenance versions of the older Pacman distribution. Many new software components have been added, including CernVMFS, new OSG PKI tools, Pakiti, and a CA certificate update tool written in-house. We have updated or fixed several components, including significant work on the Globus Toolkit (esp. GRAM), BeStMan (for SHA-2 compliance), GUMS, HTCondor, and many Java security updates.

Throughout the year, the OSG Software team has deepened its commitment to and involvement in several communities; these include OSG site administrators, science end users, distributed high-throughput computing users, and providers and other packagers of grid middleware software. The benefits of deeper engagement flow both ways. For example, the team has contributed many enhancements and bug fixes back to the Globus Toolkit software project, which is distributed broadly via the *Extra Packages for Enterprise Linux* (EPEL) repository. Going the other way, the CernVMFS software was already available in RPM format, thereby requiring few changes and hence relatively low effort for inclusion in the OSG distribution. When the team updated the jGlobus software, another team used the changes to improve the dCache distributed storage software. And in May 2012, many of the team's experiences and findings were presented at the Computing in High Energy and Nuclear Physics (CHEP) 2012 conference.

In the coming year, the Software team continues to face a variety of challenges. Large among them is completing the transition from Pacman to RPM distribution of software. As remaining sites upgrade, new issues will be found and handled. For example, we already know that many sites have yet to convert their job-execution resources because they rely on specific properties of Pacman packages. Thus, the Software team has undertaken a project to provide those sites with the tools that they need to upgrade smoothly.

More generally, the team will continue to deal with specific challenges that arise as a result of continual change in the distributed high-throughput computing landscape:

- Incorporating new technologies, including support for SLURM-based compute clusters and the forthcoming HTCondor-CE site front-end;
- Updating existing software, for reasons such as better SHA-2 support, changes to the Java environment that underlies many components, security improvements, and general bug fixes and enhancements;
- Expanding coverage of automated testing to improve the quality of the integrated software stack; and
- Continuing to simplify and make more robust the installation and configuration processes.

3.7 Security

The Security team leads the OSG effort to provide operational security, identity management, security policies, adopting useful security software, and disseminating security knowledge and awareness within the OSG. The work can broadly be classified into two main areas: 1) maintaining operational security; and 2) improving the identity management capabilities for OSG stakeholders.

In the operational security area, we conducted the following key activities.

1. In July 2012, OSG CMS Tier2 resources participated into a WLCG-wide security challenge. The EGI security team prepared the initial challenge planning and the technical infrastructure. The OSG security team coordinated the operational aspects of the challenge for eight US-CMS Tier2 sites. Overall, the challenge went really well and all OSG resources successfully passed the test.

2. The OSG security team joined the XSEDE operational security team as part of OSG becoming a resource provider and started collaborating with the XSEDE incident response process. The new tie between the two teams strengthened our previously informal information sharing practice, which now became part of our operational life-cycle.

3. During the year there was one security incident that affected a grid site. The attack vector was not related to grid services and there were no targeted attacks against grid resources or users. This incident only affected one VO's pilot jobs and ~10 users who directly submitted jobs to the affected machines. The main damage was loss of time of the grid administrators to clean up and re-instantiate the compromised machines.

4. In the past year, we identified and learned of a number of software vulnerabilities with potential of high level compromise; these important vulnerabilities could have affected VOMS Admin, HTCondor, Tomcat, MySQL, Java, glibc, sudo. The security team evaluated the vulnerabilities, recommended solutions, and monitored our sites' progress in following the security recommendations. Thus, no attacks materialized to exploit these vulnerabilities, mainly due to the prompt work performed by our site admins in implementing preventive measures.

5. To help our sites monitor their services against known vulnerabilities, the OSG security team integrated an existing software package, Pakiti, into the OSG Software stack. With this new software, which can be locally set up and run by sites, a site manager can more easily monitor the vulnerabilities on his/her entire cluster of machines and services.

In the Identity Management area, the security team started a key initiative of increasing the acceptance of campus-based identities in OSG; specifically, enable CILogon Basic identities in OSG. Since CILogon Basic CA lacks IGTF[17] accreditation, the OSG team provided risk assessment to candidate sites, helped them conduct their internal risk assessment, and provided technical support to enable these identities at their sites. So far, five major sites (among the top-ten producing sites in OSG) have moved to accept these identities. In addition, OSG Central IT services run by GOC and Fermilab (such as twiki, docdb, and myosg) now accept these identities for access. The security team's ongoing goal is to continue working with OSG sites to increase the recognition and adoption of campus identities.

The security team conducted a survey of how OSG sites consume identity information. This survey sought to understand: what type of identity information is valuable and relevant to OSG sites; why the information is important; and how the sites make use of the information. Five top-producing OSG sites were interviewed and the results of the survey was shared with the OSG management and also presented at the MAGIC meeting[18]. This work received a positive response from MAGIC attendees and OSG was asked to present again when we make further progress in this area.

Finally, this team coordinated the OSG response to an important change in the hash algorithms used to sign X.509 certificates. Due to the vulnerability of SHA-1 hashing algorithm against collision attacks, the IGTF has asked all Certificate Authorities to switch to SHA-2 hashing algorithm. Thus, the OSG project undertook significant work to check compatibility of the OSG software stack and fix identified issues. The security team provided security guidance and consultation to the software team which drove the project.

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[17] International Grid Trust Federation http://www.igtf.net/

[18] Middleware and Grid Interagency Coordination http://www.nitrd.gov/nitrdgroups/images/d/d8/12%2C04%2C12MAGIC_Minutes.pdf

3.8 User Support

The goal of the User Support area is to enable science and research communities from their initial introduction to the OSG to effective use of the DHTC services and to provide ongoing support for existing communities' evolving needs. The work of this team covers the creation of new capabilities for users, and enabling new communities in joining OSG and leveraging the HTC computation resources.

In the area of new capabilities, the User Support team has worked on two major initiatives. The first was to enable OSG as a "level 2" service provider in XSEDE; this capability has been operational since April 1, 2012 and is described further in section 3.9 below. In addition, we continued to address aspects of the large data placement in OSG; in a distributed system where computation tasks can "land" on any of over 100 sites, we face the challenge of making large data sets accessible "anywhere" for those analysis jobs. For smaller VOs there continues to be the need to coordinate data placement with job execution; we evaluated and integrated iRODS with OSG software to provide a limited "public storage" facility for VOs. This capability allows users to stage their data at one node and have it moved to various OSG sites where jobs can read this data; jobs can then produce output data that is handed over to the system for subsequent processing on the grid or moved back to the user's submit host easy retrieval. This capability has been successfully tested with 3 communities (SLAC Phenomenology, EIC @ BNL, and SAGA) and now awaits large scale testing.

We have continued to actively support various new communities in adopting and leveraging the OSG DHTC fabric; these include

1. NEES - Provided support for the integration of the NEESHub portal (Purdue) with OSG resources. Supporting simulation jobs of researchers (e.g. Andre' Barbosa at UCSD) who ran finite element calculations on the response of building structures to simulated earthquakes traces and produced 12 TB of data, running 17,000 jobs for 500,000 CPU hours.
2. DES – Supported Brian Yanny of DES at FNAL in porting DES data management pipelines to run on FermiGrid using OSG interfaces. We demonstrated the ability to process 100 images in 15 hours working toward the target production process that can handle 300 images within 24 hours; as part of this we are addressing the challenge of staging in and out 5.4 TB per day.
3. Electron Ion Collider - Supported Thomas Ullrich and Tobias Toll from the Nuclear Physics community at BNL in the design of a new collider. They calculated momentum amplitudes for 4 different ions for the simulation of collision processes in the new accelerator; they produced 3 TB of data, running 160,000 jobs for 600,000 CPU hours
4. SLAC - Started a focused activity with SLAC management, IT personnel, and scientific communities to improve the integration of their resources with the OSG. We supported Stefan Hoeche of the SLAC Phenomenology group to complete the proof-of-principle phase for multi-particle quantum chromodynamics calculations using Monte Carlo methods for the searches for new physics; this computation produced 2 TB of data on OSG, running 9,000 jobs for 100,000 CPU hours. In addition, we supported Steffen Luitz and Armando Fella of the SuperB VO in their simulation production in September 2012 at SLAC, Caltech, Ohio Supercomputing Center and, opportunistically, at Fermilab.
5. SAGA – Assisted the SAGA team at Rutgers (Shantenu Jha et. al.) with integrating the "back-end" of their science portal with OSG job submission and data movement technologies.

We are in early stages of work with a group at BNL (Martin L. Purschke, et. al.) in simulating the technology for MRI-compatible PET detectors using OSG. We have also started work with iPlant collaborators at TACC (Rion Dooley et. al.) to enable the "back end" of their science portal to submit jobs into OSG.

In the last year, we have assisted various teams in connecting their resources to OSG as new sites associated with specific VOs; these include: 1) PNNL (for the Belle & Belle-2 experiment), 2) Oregon State (NEES), 3) Ohio Supercomputing Center (Belle-2); and 4) UMD-IGS. In addition, we continue to provide tutorial and outreach to communities interested in leveraging OSG; this included a tutorial on use of HTC resources at the XSEDE-12 conference.

3.9 OSG as an XSEDE Service Provider

During the period for this report, OSG implemented an interface for OSG to be an XSEDE service provider. The effort started in November 2011 when the interface was designed and presented to the OSG and XSEDE teams as a new resource. The system was integrated and fully tested before entering production on April 1, 2012.

The OSG-XSEDE resource is implemented as a virtual cluster that forms an abstraction layer to access the distributed OSG production fabric. This interface allows XSEDE users to view the OSG as a single cluster where they manage their jobs, provide the inputs and retrieve the outputs. XSEDE users access the OSG via the OSG-XSEDE login host which appears as one of the resources in the XSEDE infrastructure. For the OSG-XSEDE effort, a set number of service units (SUs, in OSG 1 SU = 1 CPU hour) is made available for allocation to XSEDE users, currently 2M hours/quarter, which are then drawn from the opportunistic cycles available on OSG. Usage is recorded on both the OSG and the XSEDE side. When a job completes, a usage record is sent to the OSG central usage database (GRATIA). Periodically, a tool queries GRATIA, summarizes the usage, and sends a summary usage record to the XSEDE central database (XCDB). The system is designed to send summary records because the XCDB is not setup for high throughput computing, and could be overwhelmed if millions of job records were submitted. These summary records from OSG debit users' XSEDE allocations.

The OSG-XSEDE host was mostly integrated from existing software, but some development was required to tie the existing software pieces together. OSG's and XSEDE's software stacks were similar enough that the basic grid services were installed from the OSG software stack. From XSEDE's point of view, the OSG-XSEDE host appears as running slightly different software versions than other XSEDE sites. These differences are small enough to not be noticeable by most users. One facet were these differences have been noticeable has been in the XSEDE and OSG site monitoring. For example, the OSG certificate authority bundle does not fully pass the XSEDE tests and, conversely, the XSEDE certificate bundle does not pass the OSG test; the solution to this particular problem was to create a merged bundle. Another area where some development work was necessary was the tie-in with the XSEDE allocations and accounting system. The XSEDE distributed database tool AMIE was integrated with an existing resource and project management system named Gold. From Gold, custom tools were developed to maintain local user accounts and allocations mappings; this Gold interface also handles the previously mentioned summary usage records from GRATIA which are then sent back to XCDB via AMIE.

This implementation provides access to the OSG resources using the DHTC overlay methods leveraging GlideinWMS and Condor. For failover, GlideinWMS is set up to bring in resources from two GlideinWMS factories, one at UCSD, and one at Indiana University. User communities with larger workloads are allowed to set up local submit hosts and use Condor flocking to connect their submit host with the OSG-XSEDE "gateway" to the OSG production fabric. The current flocking sites are VT

Bioinformatics, the SAGA group at Rutgers, iPlant at TACC (in the process of getting set up), and USC Information Science Institute (for testing purposes).

The allocations and usage of the OSG-XSEDE host ramped-up slowly at first; recently the usage has increased significantly as seen in Figure 31.

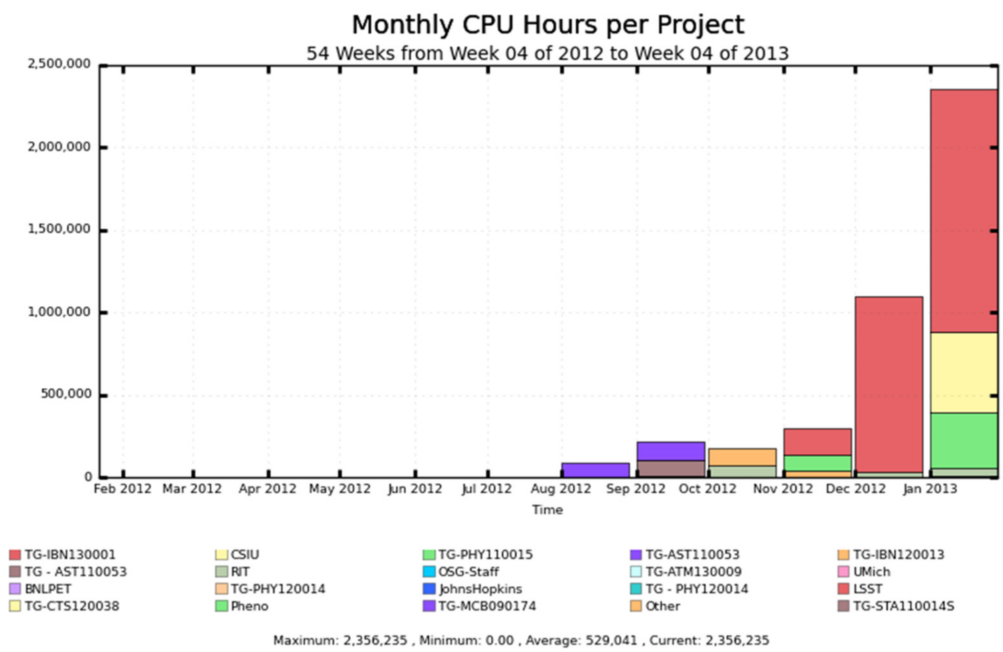

Figure 31:
Usage history for jobs originating on the OSG-XSEDE interface

There are a few data points emerging that suggest that the current 2M SUs/quarter may not meet future demand from DHTC users via XSEDE. In January 2013, we observed usage exceeding 2M SUs; and it appears that allocation requests against OSG at the March 2013 XRAC will be in the range of 10-20M hours. Moving forward, a major challenge will be handing the increase in demand of new and existing XSEDE users and balancing that against the expectations of existing OSG VOs who provided the computing resources that are accessed via this interface. Another issue is the lack of proven methods for predicting the actual unused capacity, opportunistic cycles, in OSG available in the future. We are investigating several ideas including one where an XSEDE user would get a base allocation, but could burst and use additional hours if they are available. During the next year, we will continue to work on this problem within OSG and work with the XSEDE allocations team to effectively serve as many users as possible.

3.10 OSG PKI CA

A key identity management component of OSG's technical fabric is a public key infrastructure (PKI) to allow for authentication of users and services, namely the DOE Grids PKI operated by ESnet. In early 2012, ESnet informed OSG that the DOE Grids PKI is scheduled to be shut down in March 2013. The OSG PKI Transition Project was formed to address this change and has been working over the course of 2012 and into 2013 to establish the new OSG PKI as a replacement to the DOE Grids PKI. The project is a collaboration between OSG staff, ESnet, and numerous OSG VO communities whose work is coordinated via a weekly call and the OSG twiki. Funding for the project came from the DOE ASCR (via the OSG Project) and the USATLAS and USCMS experiments. The Indiana University Center for Applied Cybersecurity Research provided management for the project under a subcontract from the OSG.

The project started by performing an analysis of possible options[19] for replacing the ESnet CA and selected the option of contracting with a commercial certificate authority (CA) operator, DigiCert, and building the necessary infrastructure around their CA offering. A pilot was undertaken to validate this choice[20], then the project was split into the following phases: Planning[21], Development[22], Transition[23], and finally Operations.

Highlights of this project included:

- Weekly phone calls to include OSG VOs and other stakeholders into the project decision processes.
- Undertaking a contingency analysis[24] to understand the impacts and mitigations should DigiCert suddenly be unable to provide service.
- Frequent communications, in coordination with ESnet, to inform VOs on how the transition impacts them and provide guidance in transitioning their users.
- Enacting a contract with DigiCert, on behalf of OSG, ATLAS and CMS, and implementing a policy framework for the PKI.
- Developing PKI services, client software, training, and documentation.

At the time of this report, the Transition phase is completing and the new PKI is operational, issuing certificates to the OSG community. OSG and ESnet are in process of transitioning users prior to ESnet shutting down the DOE Grids PKI on March 23rd. The OSG PKI is serving not only the OSG community of VOs, but other DOE Grids PKI communities previously outside of OSG, including the Oak Ridge and Argonne National Laboratories, and the National Fusion Collaboratory who plan on using the new OSG PKI.

Final activities to be completed by May, 2013 include reporting on lessons learned at the OSG All-hands Meeting, finishing support for certificate renewal, and finalizing transferring ownership of the PKI to the OSG Operations and Software teams.

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[19] James Basney, Mine Altunay and Von Welch. Options and Recommendation for Replacement of the DOE Grids CA in the OSG PKI. OSG-doc-1077, 2011. http://osg-docdb.opensciencegrid.org/cgi-bin/ShowDocument?docid=1077

[20] Mine Altunay, Jim Basney, Jeremy Fischer, Chander Sehgal and Von Welch. *OSG DigiCert Pilot Report*. OSG-doc-1097, March 2012. http://osg-docdb.opensciencegrid.org/cgi-bin/ShowDocument?docid=1097

[21] Von Welch (ed). OSG PKI Planning Phase Report. June 11, 2012. http://osg-docdb.opensciencegrid.org/cgi-bin/ShowDocument?docid=1120

[22] Von Welch (ed). OSG PKI Development Phase Report. September 12, 2012. http://osg-docdb.opensciencegrid.org/cgi-bin/ShowDocument?docid=1136

[23] Von Welch (ed). OSG PKI Deployment and Development Phase Report. November 8, 2012. https://osg-docdb.opensciencegrid.org:440/cgi-bin/ShowDocument?docid=1145

[24] Mine Altunay and Von Welch. Open Science Grid Recovery Plans from Public Key Infrastructure Failures. August 10, 2012. https://osg-docdb.opensciencegrid.org:440/cgi-bin/ShowDocument?docid=1121

4. Project, Consortium, and Partners

4.1 Project Institutions

The OSG Project is jointly enabled by the following institutions:

Table 3

Institution	Key Functions
University of Wisconsin - Madison	PI, Software, Campus Grids
BNL	Co-PI, Technology Investigation, Software
FNAL	Co-PI, Executive Director, Security, Software, User Support, Project Management
Indiana University	Operations, Communications
Morgridge Institute	Campus Grids, Network Monitoring
UCSD	Co-PI, Operations (gWMS Factory), Software
University of Chicago	Production, Campus Grids, Software
University of Illinois & NCSA	Security
University of Michigan	Network Monitoring
University of Nebraska - Lincoln	Technology Investigation, Software, User Support
USC-ISI	User Support

4.2 OSG Council & Consortium

The Consortium consists of all organizations that participate in and/or contribute to the OSG. The Council is the governing body of the Consortium, overseeing the work of the project and ensuring that effective bi-directional communication occurs between the stakeholders and the groups providing the OSG fabric of services. Our goal this year is to make progress in ensuring the Council adequately represents the diversity of the engaged community. We are also working on developing recommendations from three sub-committees to help in our future: The Council structure, OSG 's Relations with Industry, and "Sustaining the OSG". Drafts of these reports will be discussed at the upcoming All Hands Meeting in March 2013.

4.3 Satellite Projects

The OSG coordinates with and leverages the work of many other projects that collaborate with OSG in different ways. Projects are classified as satellites if they expect to collaborate closely with OSG and impact members of the OSG Consortium. These projects are Satellite Projects if they meet the following pre-requisites:

1. OSG was involved in the planning process and there was communication and coordination between the proposal's PI and OSG Executive Team before submission to agencies.

2. OSG commits support for the proposal and/or future collaborative action within the OSG project.

3. The project agrees to be considered an OSG Satellite project.

Satellite project are independent projects with their own project management, reporting, and accountability to their program sponsors; the OSG core project does not provide oversight for the execution of the satellite project's work program. Current and recent OSG satellite projects where there is significant interaction are enumerated below.

1. ExTENCI – Extending Science Through Enhanced National Cyberinfrastructure (OSG interface – Ruth Pordes, Miron Livny) The ExTENCI project has worked with members of OSG and TeraGRid/XSEDE to enable applications to run across the 2 infrastructures, as well as extend the development of new cross-CI capabilities such as wide-area Lustre

2. iSGTW Sustaining and Strengthening the US Desk for International Science Grid This Week. (OSG Interface: Ruth Pordes, Rob Quick) During the past year OSG has successfully transitioned this activity from being internally staffed to an independent partner in order to sustain its broad approach and mission and put this well respected and internationally backed publishing vehicle for the science enabled by distributed computing. OSG is well represented on the editorial and governing board. The new ISGTW editor, Amber Harmon, is co-located with the OSG communications staff at Indiana University, and the connector is through the project office Communications group.

3. AAA - Any Data, Anytime, Anywhere. (OSG Interface: Ken Bloom) This project has been working closely with the CMS and ATLAS OSG VOs as well as other OSG staff members to enable dynamic access to existing world-wide data caches and provide the capabilities for applications on any laptop, server, or cluster, to access data seamlessly from wherever it is stored.

4. dV/DT - Accelerating the Rate of Progress towards Extreme Scale Collaborative Science. (OSG Interface: Brian Bockelman) The dV/DT project is ramping up with staffing and a plan for the research to be done. The research will be focused on issues of resource management within a collaboration, supporting the "submit locally and compute globally" paradigm. In close collaboration with the OSG community, the goal will be to advance the state-of-the-art in the areas of: trust, planning for resource provisioning and workload, computer, data, and network resource management.

5. CC-NIE Integration: Bringing Distributed High Throughput Computing to the Network with Lark. (OSG Interface: Brian Bockelman) The Lark project is ramping up in terms of staffing and the program of work. Initial connections between UNL and UW are being tested.

6. CorralWMS - Integrated Resource Provisioning Across the National Cyberinfrastructure in Support of Scientific Workloads (OSG interface: Tim Cartwright) CorralWMS is now in the last phase of its development. The project has delivered new capabilities to the released versions of GlideWMS in the OSG Virtual Data Toolkit. The pilot factories and frontends operated within OSG have benefited from the developments of this team. Also, the functionality is interfaced as part of the Pegasus workflow system used on XSEDE site.

7. DASPOS - Data and Software Preservation for Open Science (OSG Interface – Michael Ernst) The DASPOS project is working with several OSG communities and in the international context of the

Data Preservation for High Energy Physics (DPHEP) initiative to define a roadmap for preservation of physics data and deploy prototype end to end systems for testing.

5. Education & Communications

5.1 Education

The OSG Education area provides a variety of training opportunities for existing staff and for domain science users. In the latter case, training events are also a type of outreach activity, in that they reach out to the science community, helping to engage new students, faculty, and researchers in the OSG infrastructure with the aim of transforming their research through the use of High Throughput Computing.

During the last year, OSG sponsored, organized, and delivered training events as follows:

Table 4

Workshop	Length	Location	Month
OSG User School	4 days	Madison, WI	June, 2012
Grid School in Ghana	3 days	Kumasi, Ghana	August, 2012

The 2012 OSG User School was the third annual offering of our training program (formerly called the OSG Summer School) for domain science students. The goal of the School is to help students learn to use distributed high-throughput computing, locally or across the grid, as a tool for doing their research. This year, we hosted 31 students from 21 institutions and diverse fields, including physics, chemistry, biology, engineering, economics, and animal sciences. Through lecture, many hands-on exercises, and even a live-action role-play, students learned how to run science applications on distributed resources (locally and on OSG), build complex workflows, manage large and distributed data, and turn scientific computing challenges into appropriately sized and scaled workflows that are ready for real-world use. Five OSG staff served as the instructors, and as a special and highly motivating event, four UW–Madison researchers came and talked about how using high-throughput computing has transformed their own research. Again this year, students rated the School very highly, and they seemed eager to apply what they learned to their own research; we will be following up with them throughout the year to see how it goes and to support them as we can.

The Grid School in Ghana was part of the second biennial African School of Fundamental Physics and its Applications (ASP) held in Kwame Nkrunah University of Science and Technology (KNUST) in Kumasi, Ghana. The overarching program goal is to build capacity in sub-Saharan African countries to participate in high-energy physics research and to use advanced detector and accelerator technologies beyond fundamental physics. Further, the 2012 School focused on information technology, and to that end included extra days for the Grid School. A total of 56 students from 17 African countries learned to use High Throughput Computing and grid technologies to support their research in a curriculum modeled after a condensed version of the 2012 OSG User School. The Grid School portion of the program was very well received, with over 97% of the students indicating that the computing program be offered as a regular program in future ASP offerings. Three OSG staff helped develop the curriculum, then traveled to Ghana to lead the Grid School and work directly with students.

5.2 Communications

Communications that speaks to the different audiences, is clear and concise and that also can help to explain, encourage and motivate activities remains a challenge. We rely on members of OSG to communicate locally with their organizations and scientific communities.

More OSG specific activities include: a) a monthly newsletter; b) several blogs used by the technical and product contributors and staff; c) contributions to and membership in the editorial board of the International Science Grid this Week; d) webinars such as the Campus Infrastructure Community (CIC); and e) oversight of the information published through the collaborative workspace. We publish a monthly OSG newsletter which is sent to a broad list and whose focus is communication to the members of the Consortium. The newsletters are archived at https://twiki.grid.iu.edu/bin/view/Management/NewsLetters The OSG Planet Blog has a few committed contributors. The BOSCO product manager blog is reaching a much broader audience and teaching us some new and different ways to communicate. iSGTW is not only publishing the weekly newsletter but increasingly accessed through social media such as Facebook and Twitter.

5.3 Research Highlights

As researchers accomplish Science using OSG, we work with them to document and share their work and computational use of OSG via Research Highlights. Sarah Engel and Greg Moore -- both from the IT Communications Office at Indiana University -- joined OSG Communications in summer 2012. The IU team has since contributed four highlights on science and research benefiting from OSG services:

1. Sept. 2012: Tyler Churchill (Waisman Center, University of Wisconsin at Madison)
2. Oct. 2012: Andreas Prlic (Research Collaboratory for Structural Bioinformatics at the University of California, San Diego)
3. Nov. 2012: Tricia Clayton (Network for Earthquake Engineering Simulation)
4. Dec. 2012: Don Krieger (Brain Trauma Research Center at the University of Pittsburgh)

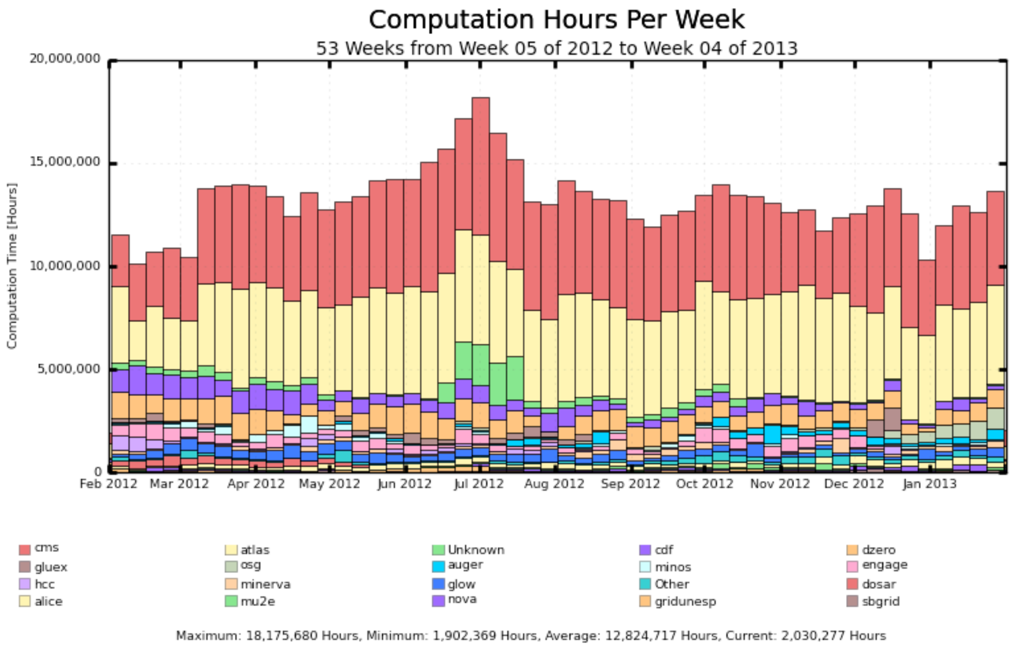
The team has taken particular care to feature diverse topics and organizations to further show that OSG use extends well beyond high energy physics. Lead generation for these highlights has been a challenge, but OSG leadership is stepping in to help fill the pipeline with enough material to keep the process running smoothly. OSG research highlights are archived at https://www.opensciencegrid.org/bin/view/Management/OSGResearchHighlights .

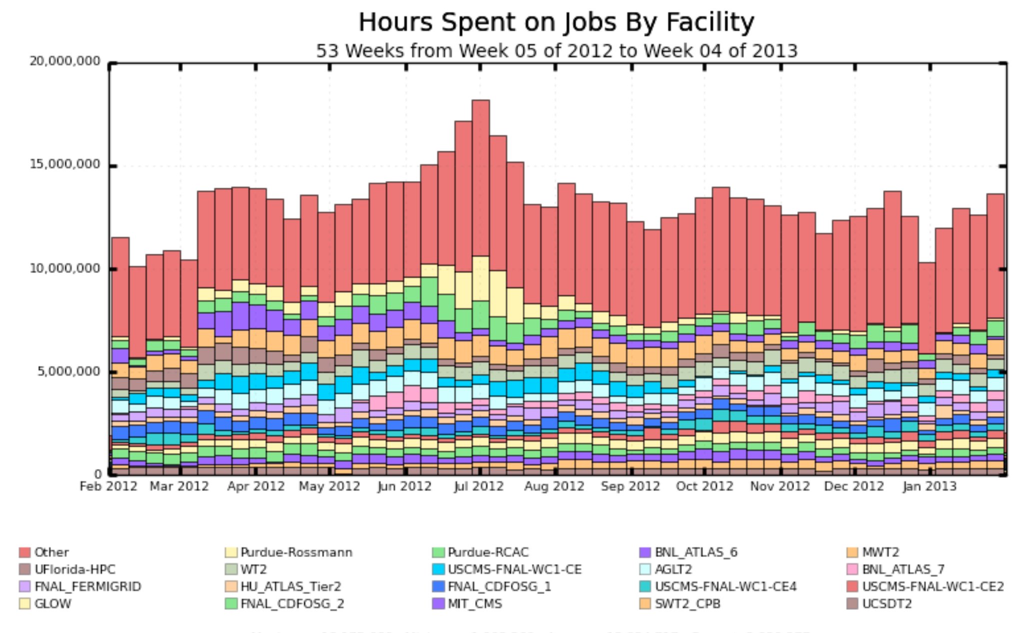
In addition to producing research highlights, IU has assisted with editing OSG background materials such as new user documentation. Their fresh perspectives have helped the extended OSG communications team target broader audiences, both through OSG channels and through IU's involvement in other initiatives such as XSEDE and iSGTW.

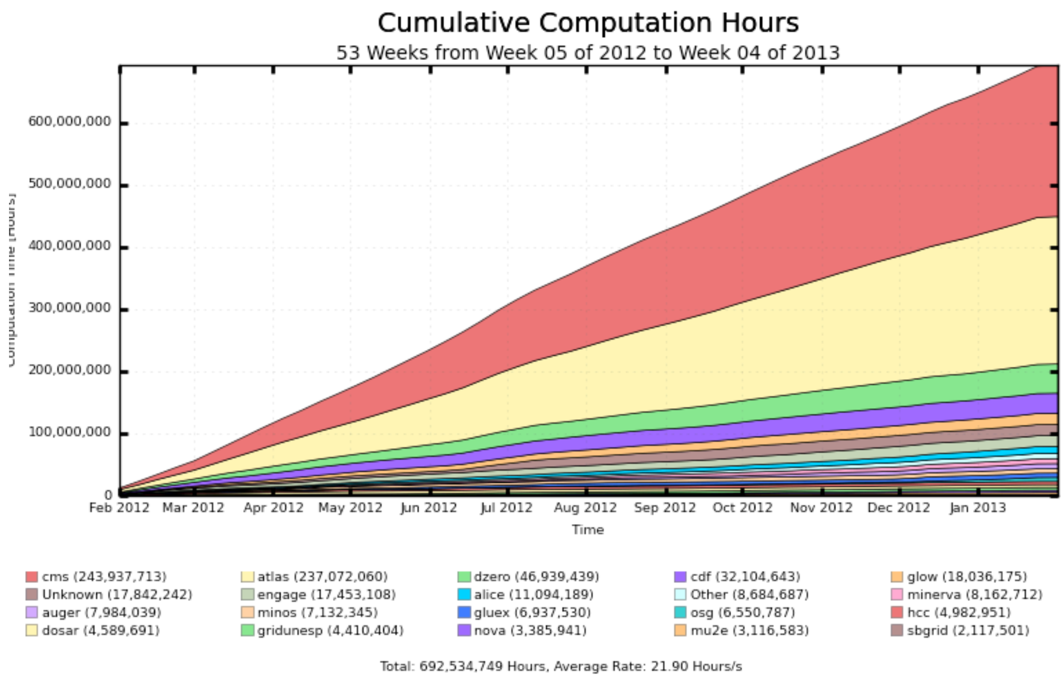
Production on Open Science Grid

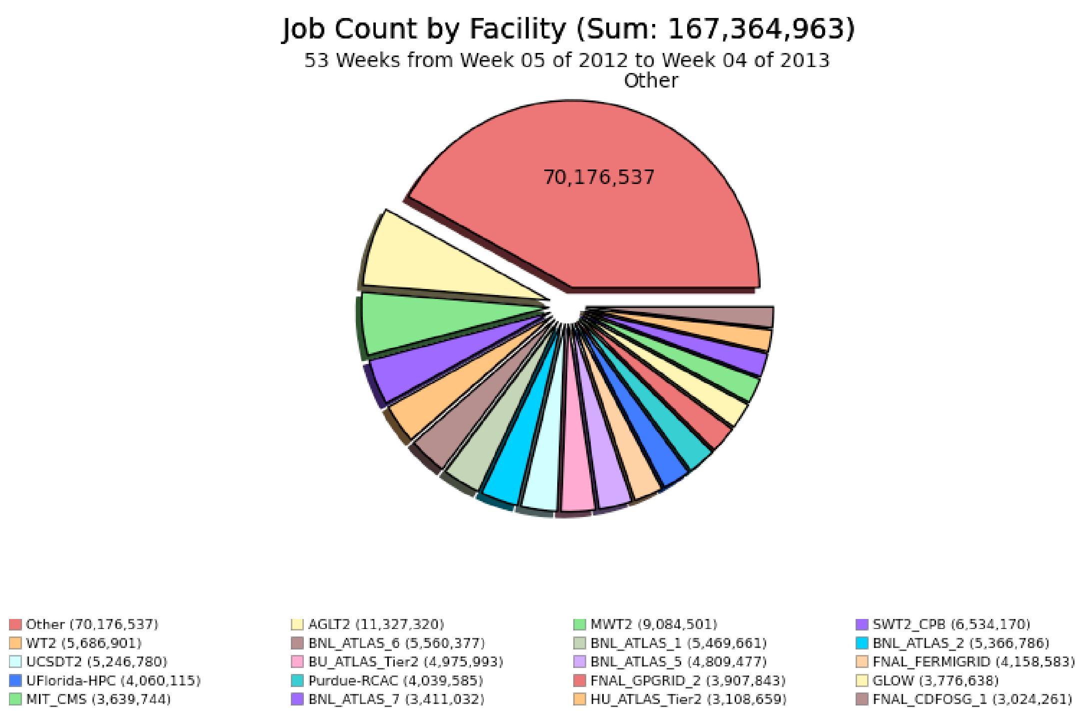
February 2012 – January 2013

1. Overall OSG Facility Summary

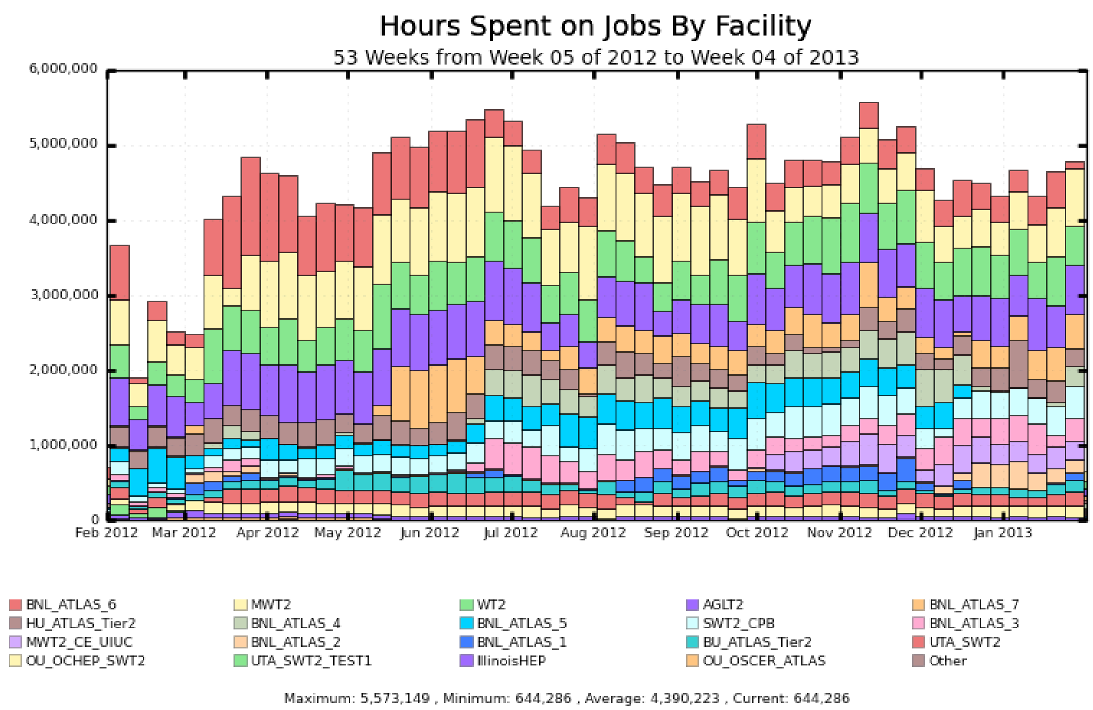


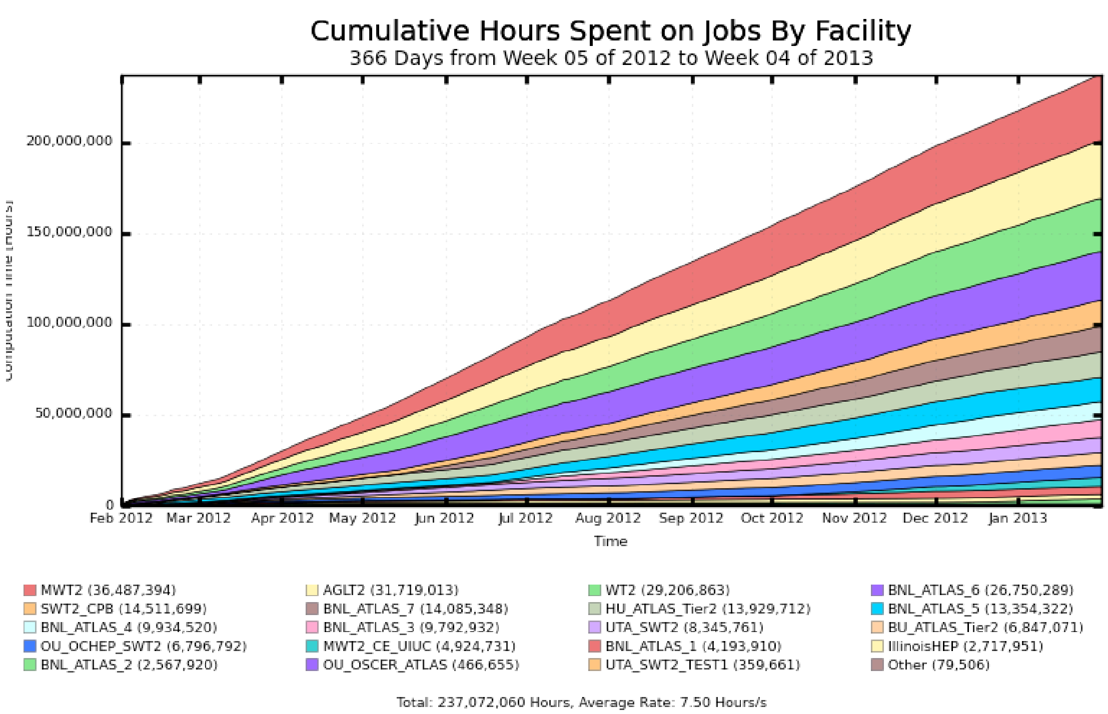



Cumulative Computation Hours
53 Weeks from Week 05 of 2012 to Week 04 of 2013
600,000,000
500,000,000
400,000,000
300,000,000
200,000,000
100,000,000
0
Feb 2012
Mar 2012
Apr 2012
May 2012
Jun 2012
Jul 2012
Aug 2012
Sep 2012
Oct 2012
Nov 2012
Dec 2012
Jan 2013
Time
cms (243,937,713)
atlas (237,072,060)
dzero (46,939,439)
cdf (32,104,643)
glow (18,036,175)
Unknown (17,842,242)
engage (17,453,108)
alice (11,094,189)
Other (8,684,687)
minerva (8,162,712)
auger (7,984,039)
minos (7,132,345)
gluex (6,937,530)
osg (6,550,787)
hcc (4,982,951)
dosar (4,589,691)
gridunesp (4,410,404)
nova (3,385,941)
mu2e (3,116,583)
sbgrid (2,117,501)
Total: 692,534,749 Hours, Average Rate: 21.90 Hours/s

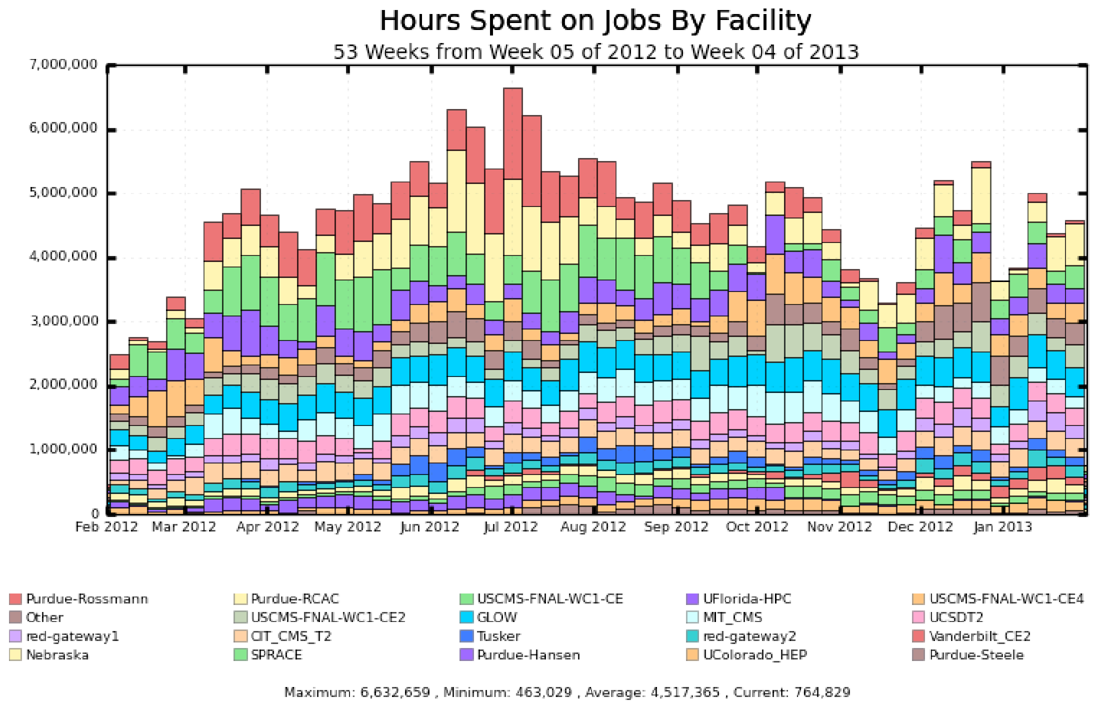

Job Count by Facility (Sum: 167,364,963)
53 Weeks from Week 05 of 2012 to Week 04 of 2013
Other
70,176,537
Other (70,176,537)
AGLT2 (11,327,320)
MWT2 (9,084,501)
SWT2_CPB (6,534,170)
WT2 (5,686,901)
BNL_ATLAS_6 (5,560,377)
BNL_ATLAS_1 (5,469,661)
BNL_ATLAS_2 (5,366,786)
UCSDT2 (5,246,780)
BU_ATLAS_Tier2 (4,975,993)
BNL_ATLAS_5 (4,809,477)
FNAL_FERMIGRID (4,158,583)
UFlorida-HPC (4,060,115)
Purdue-RCAC (4,039,585)
FNAL_GPGRID_2 (3,907,843)
GLOW (3,776,638)
MIT_CMS (3,639,744)
BNL_ATLAS_7 (3,411,032)
HU_ATLAS_Tier2 (3,108,659)
FNAL_CDFOSG_1 (3,024,261)

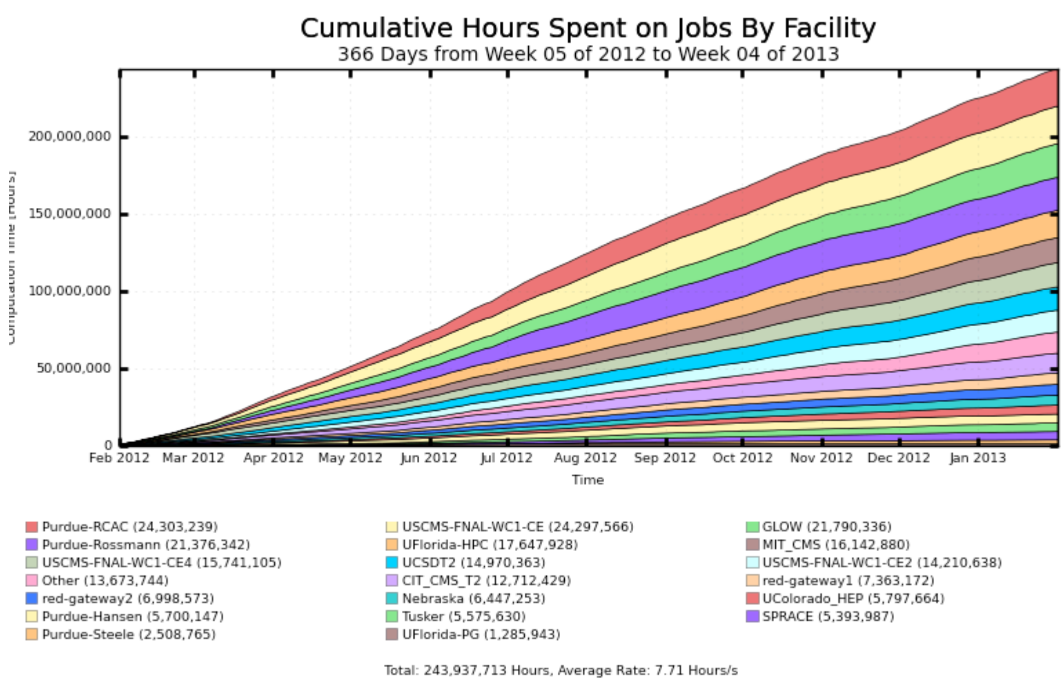
2. ATLAS on the OSG



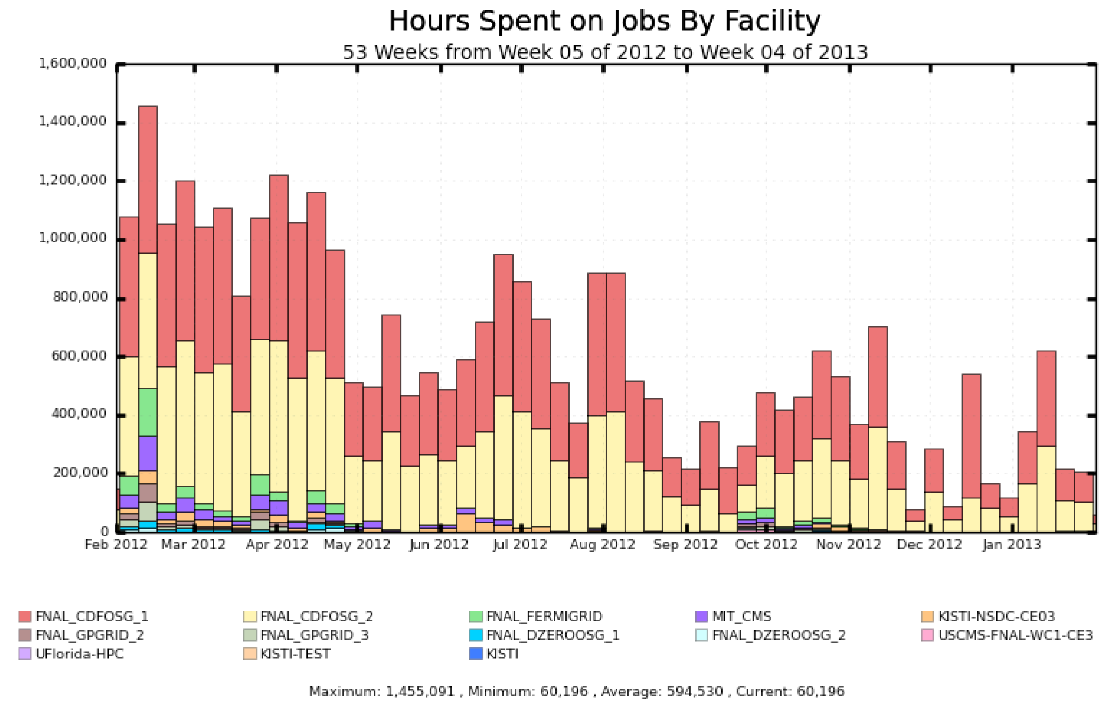


3. CMS on the OSG

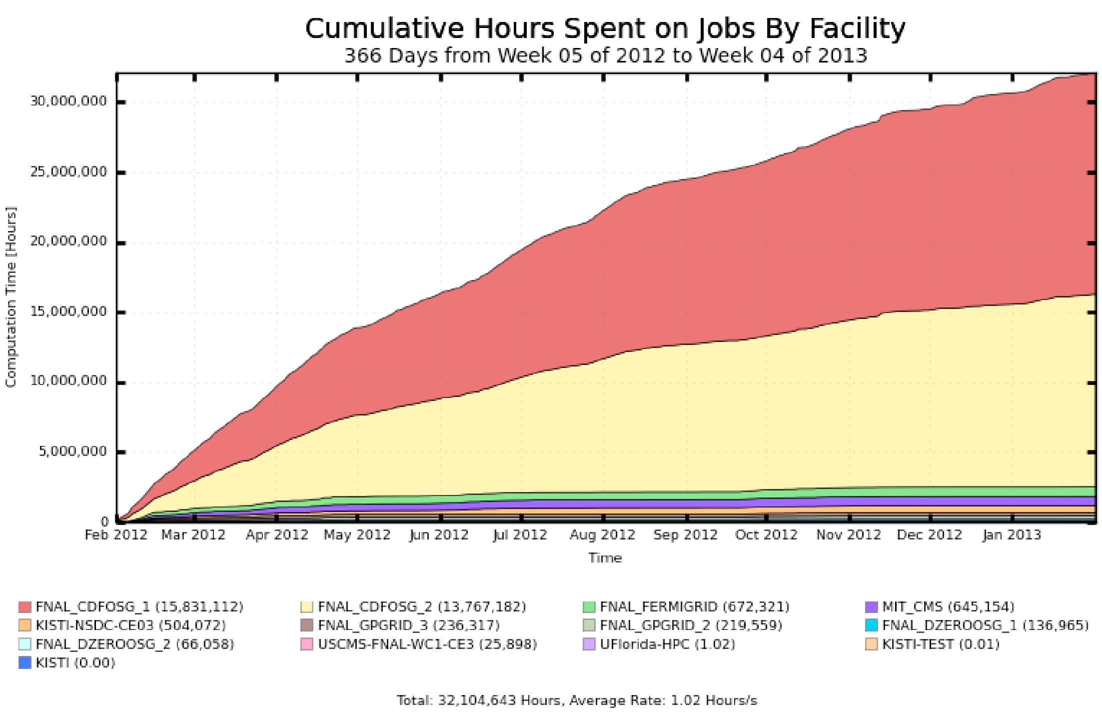




4. CDF Usage

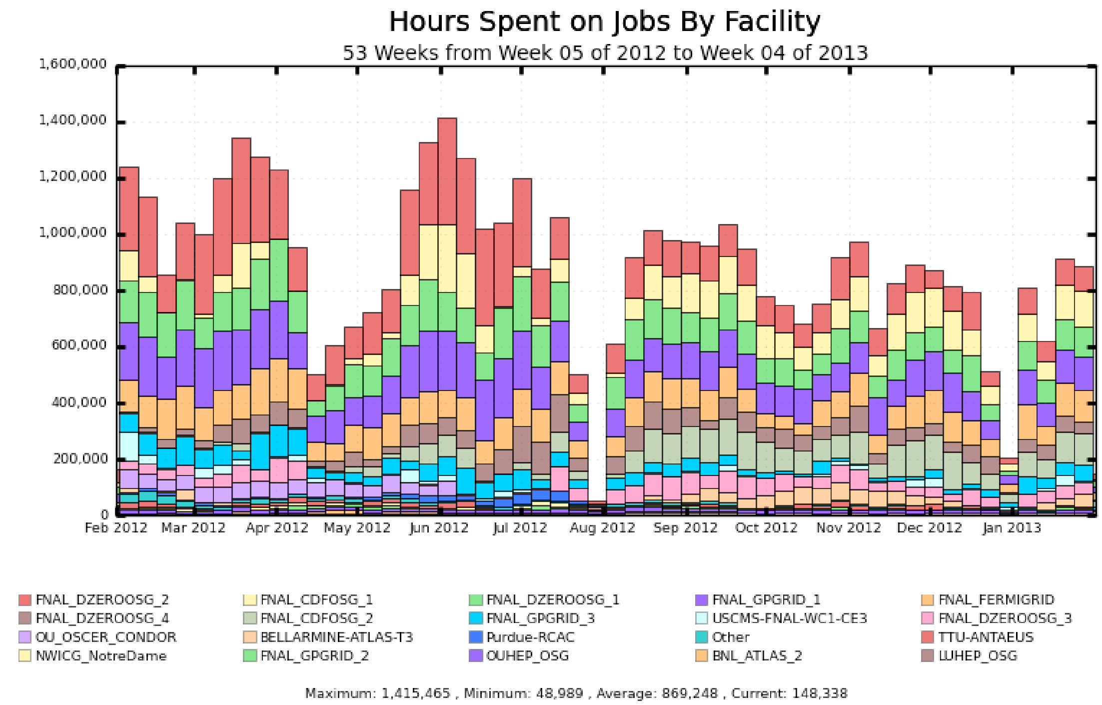


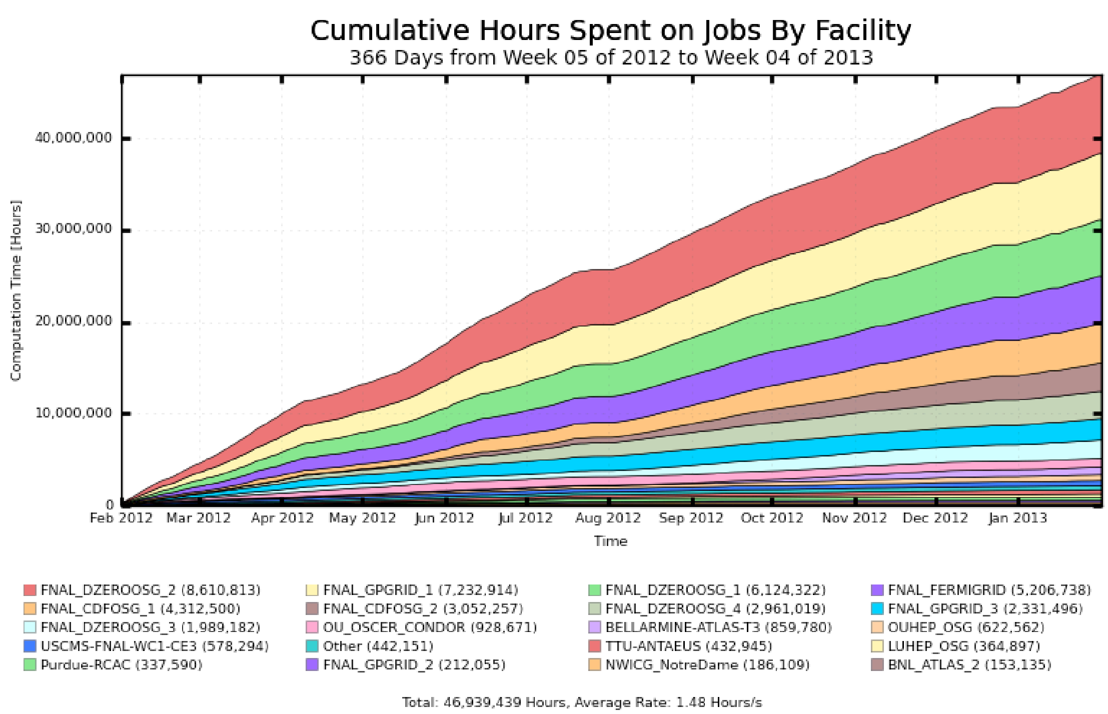
Hours Spent on Jobs By Facility
53 Weeks from Week 05 of 2012 to Week 04 of 2013
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Feb 2012 Mar 2012 Apr 2012 May 2012 Jun 2012 Jul 2012 Aug 2012 Sep 2012 Oct 2012 Nov 2012 Dec 2012 Jan 2013
FNAL_CDFOSG_1
FNAL_CDFOSG_2
FNAL_FERMIGRID
MIT_CMS
KISTI-NSDC-CE03
FNAL_GPGRID_2
FNAL_GPGRID_3
FNAL_DZEROOSG_1
FNAL_DZEROOSG_2
USCMS-FNAL-WC1-CE3
UFlorida-HPC
KISTI-TEST
KISTI
Maximum: 1,455,091 , Minimum: 60,196 , Average: 594,530 , Current: 60,196



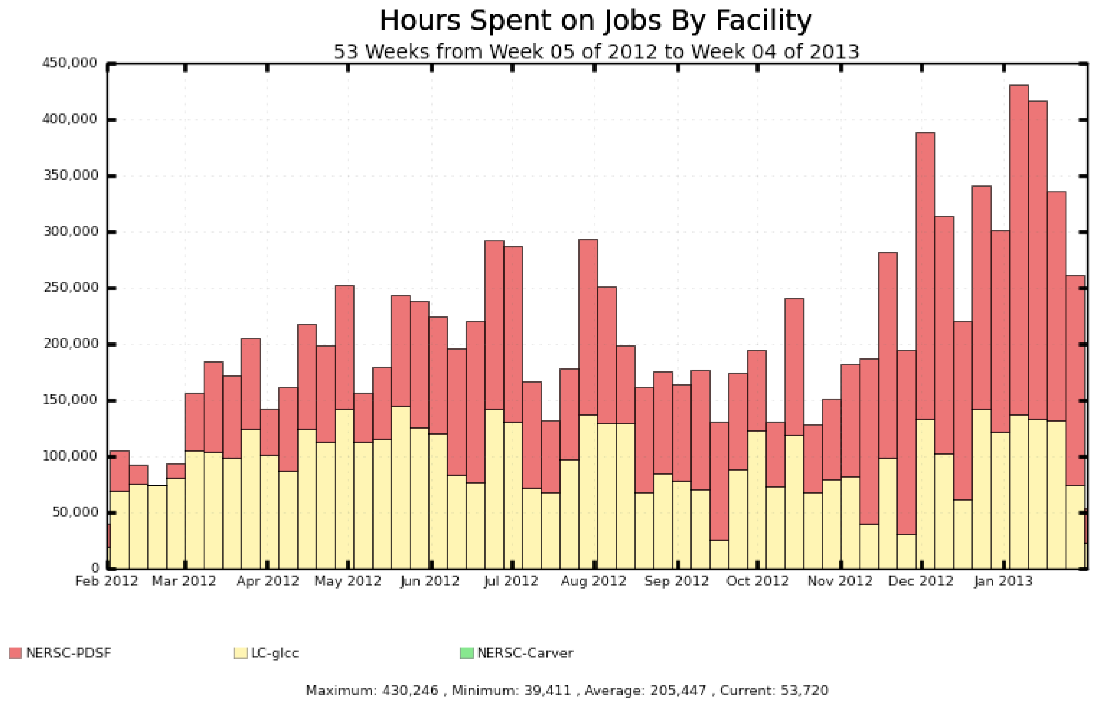
Cumulative Hours Spent on Jobs By Facility
366 Days from Week 05 of 2012 to Week 04 of 2013
Computation Time [Hours]
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
Feb 2012 Mar 2012 Apr 2012 May 2012 Jun 2012 Jul 2012 Aug 2012 Sep 2012 Oct 2012 Nov 2012 Dec 2012 Jan 2013
Time
FNAL_CDFOSG_1 (15,831,112)
FNAL_CDFOSG_2 (13,767,182)
FNAL_FERMIGRID (672,321)
MIT_CMS (645,154)
KISTI-NSDC-CE03 (504,072)
FNAL_GPGRID_3 (236,317)
FNAL_GPGRID_2 (219,559)
FNAL_DZEROOSG_1 (136,965)
FNAL_DZEROOSG_2 (66,058)
USCMS-FNAL-WC1-CE3 (25,898)
UFlorida-HPC (1.02)
KISTI-TEST (0.01)
KISTI (0.00)
Total: 32,104,643 Hours, Average Rate: 1.02 Hours/s

5. DZERO Usage

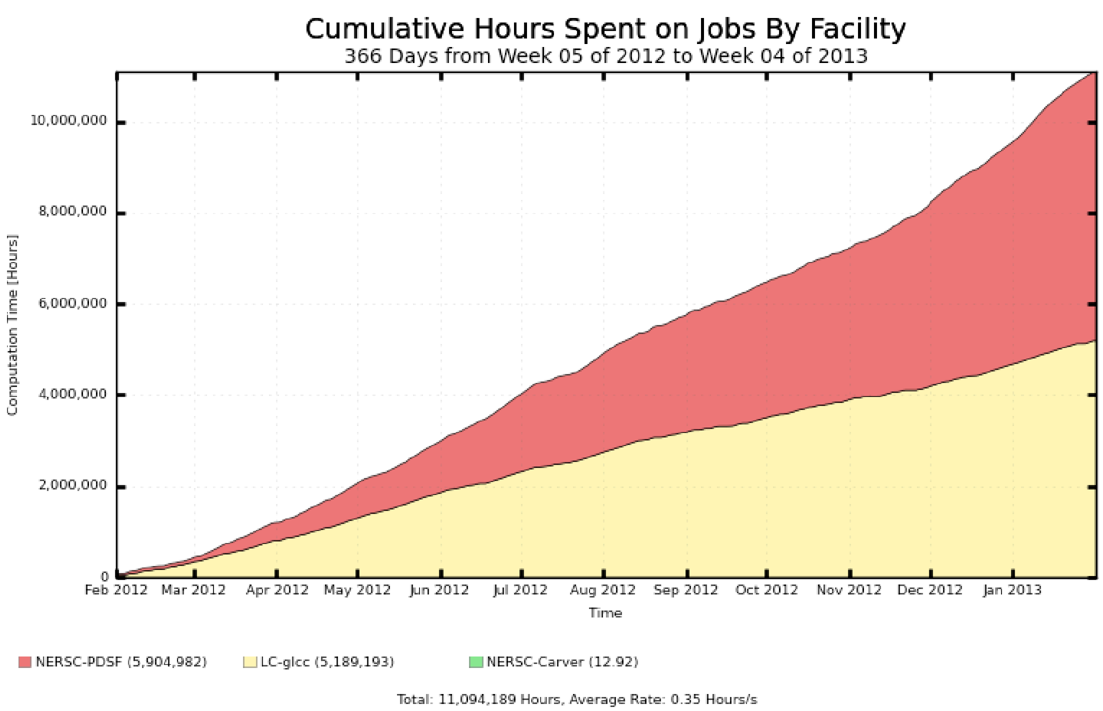




6. ALICE

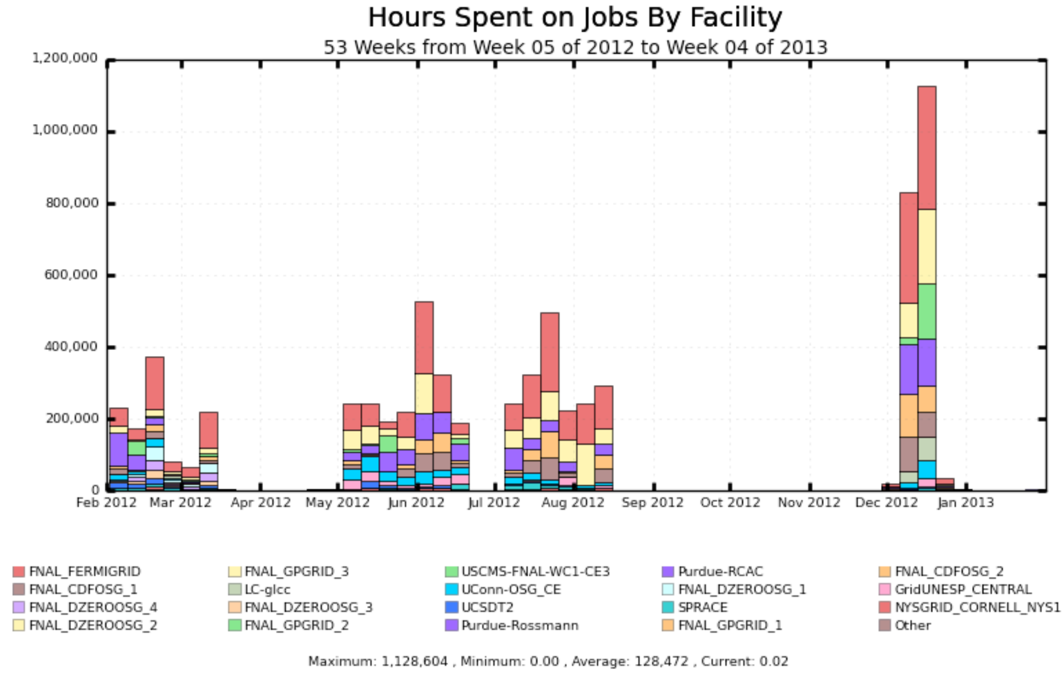


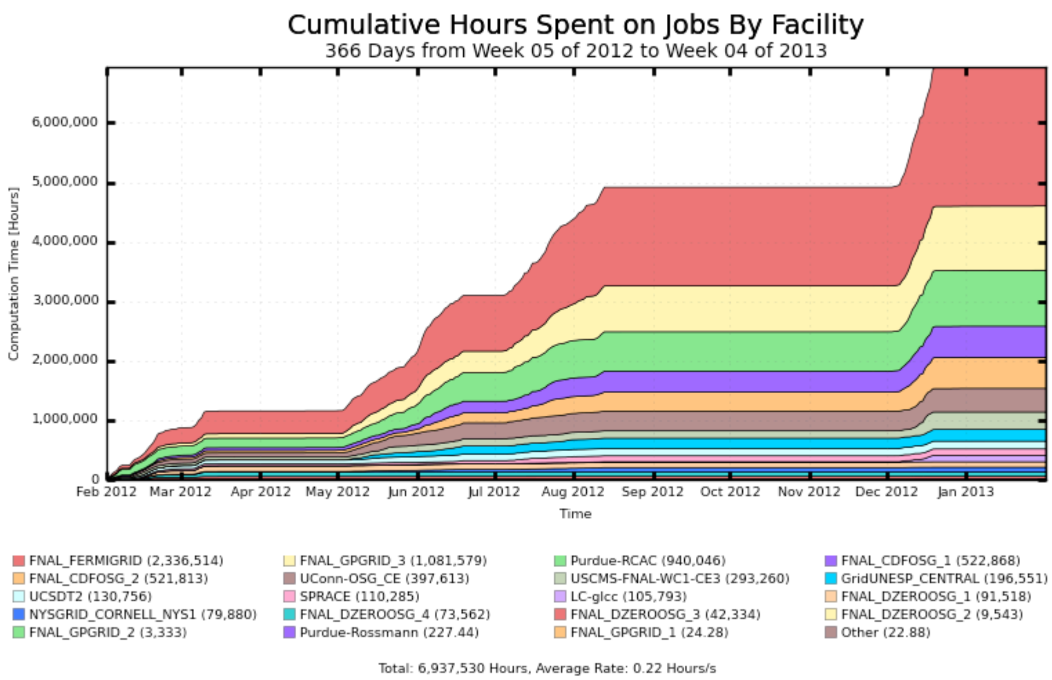
Hours Spent on Jobs By Facility
53 Weeks from Week 05 of 2012 to Week 04 of 2013
NERSC-PDSF
LC-glcc
NERSC-Carver
Maximum: 430,246 , Minimum: 39,411 , Average: 205,447 , Current: 53,720



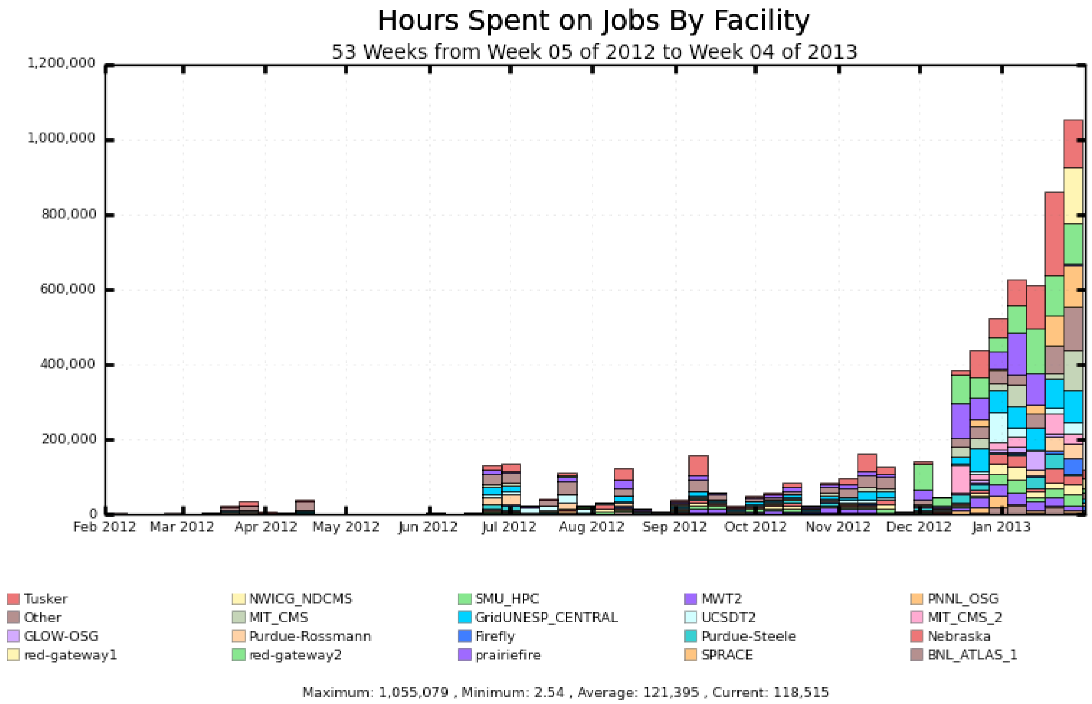
Cumulative Hours Spent on Jobs By Facility
366 Days from Week 05 of 2012 to Week 04 of 2013
Computation Time [Hours]
Time
NERSC-PDSF (5,904,982)
LC-glcc (5,189,193)
NERSC-Carver (12.92)
Total: 11,094,189 Hours, Average Rate: 0.35 Hours/s

7. Gluex

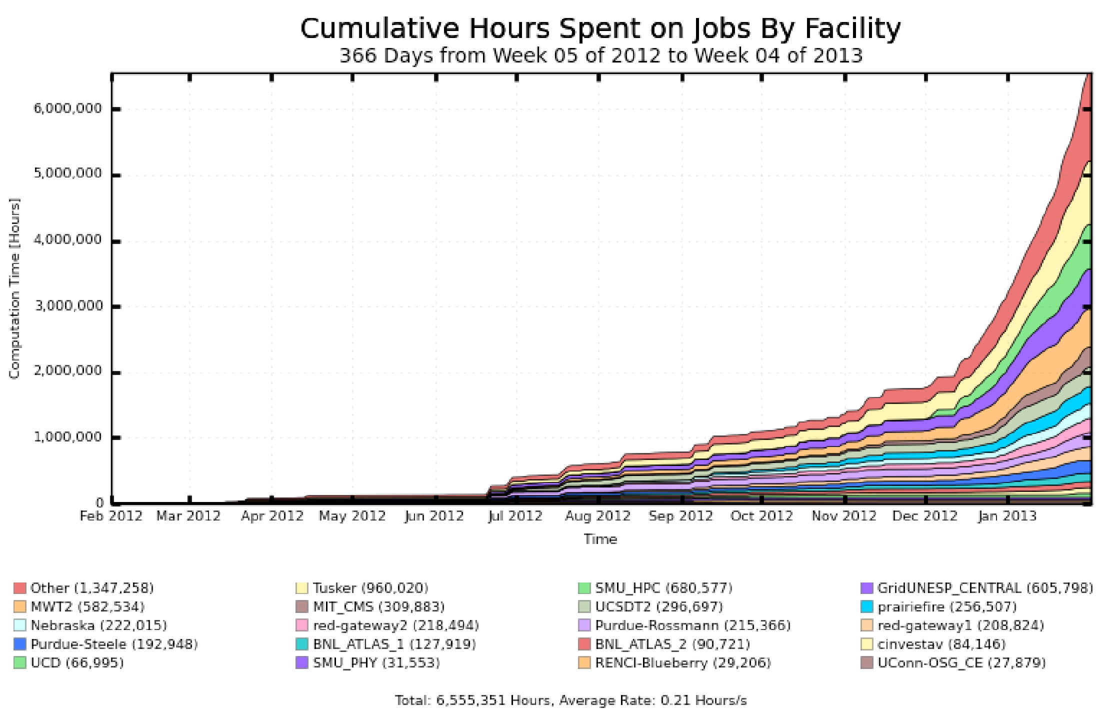

Hours Spent on Jobs By Facility
53 Weeks from Week 05 of 2012 to Week 04 of 2013
FNAL_FERMIGRID
FNAL_GPGRID_3
USCMS-FNAL-WC1-CE3
Purdue-RCAC
FNAL_CDFOSG_2
FNAL_CDFOSG_1
LC-glcc
UConn-OSG_CE
FNAL_DZEROOSG_1
GridUNESP_CENTRAL
FNAL_DZEROOSG_4
FNAL_DZEROOSG_3
UCSDT2
SPRACE
NYSGRID_CORNELL_NYS1
FNAL_DZEROOSG_2
FNAL_GPGRID_2
Purdue-Rossmann
FNAL_GPGRID_1
Other
Maximum: 1,128,604 , Minimum: 0.00 , Average: 128,472 , Current: 0.02


Cumulative Hours Spent on Jobs By Facility
366 Days from Week 05 of 2012 to Week 04 of 2013
Computation Time [Hours]
Time
FNAL_FERMIGRID (2,336,514)
FNAL_GPGRID_3 (1,081,579)
Purdue-RCAC (940,046)
FNAL_CDFOSG_1 (522,868)
FNAL_CDFOSG_2 (521,813)
UConn-OSG_CE (397,613)
USCMS-FNAL-WC1-CE3 (293,260)
GridUNESP_CENTRAL (196,551)
UCSDT2 (130,756)
SPRACE (110,285)
LC-glcc (105,793)
FNAL_DZEROOSG_1 (91,518)
NYSGRID_CORNELL_NYS1 (79,880)
FNAL_DZEROOSG_4 (73,562)
FNAL_DZEROOSG_3 (42,334)
FNAL_DZEROOSG_2 (9,543)
FNAL_GPGRID_2 (3,333)
Purdue-Rossmann (227.44)
FNAL_GPGRID_1 (24.28)
Other (22.88)
Total: 6,937,530 Hours, Average Rate: 0.22 Hours/s

8. OSG

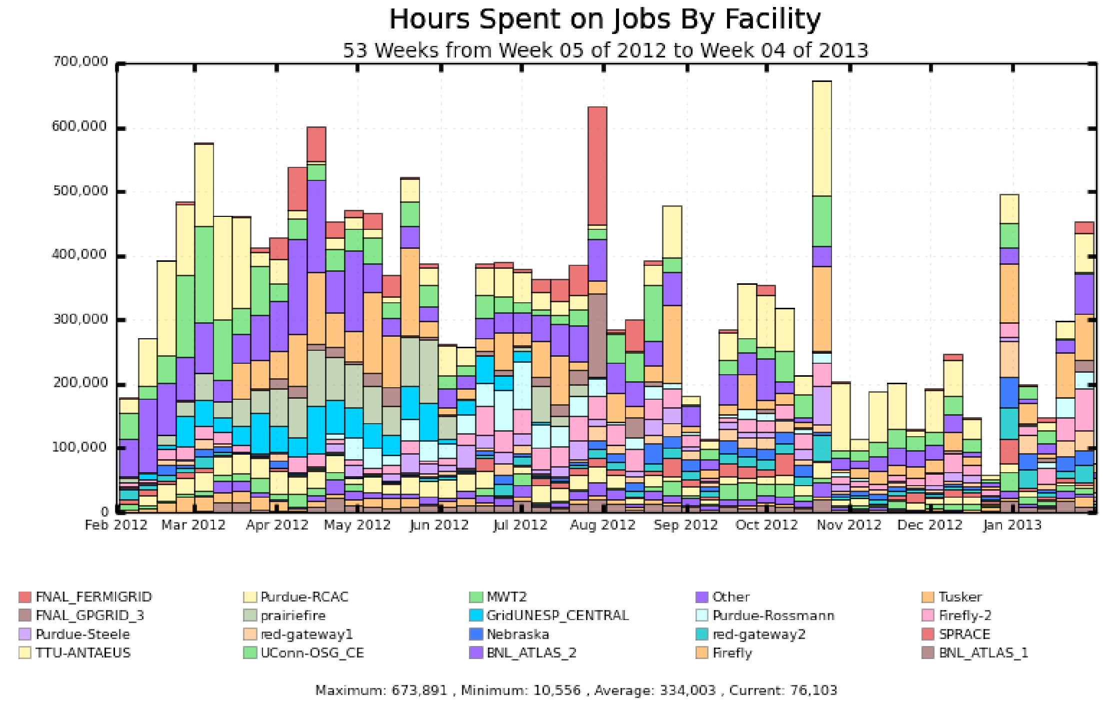


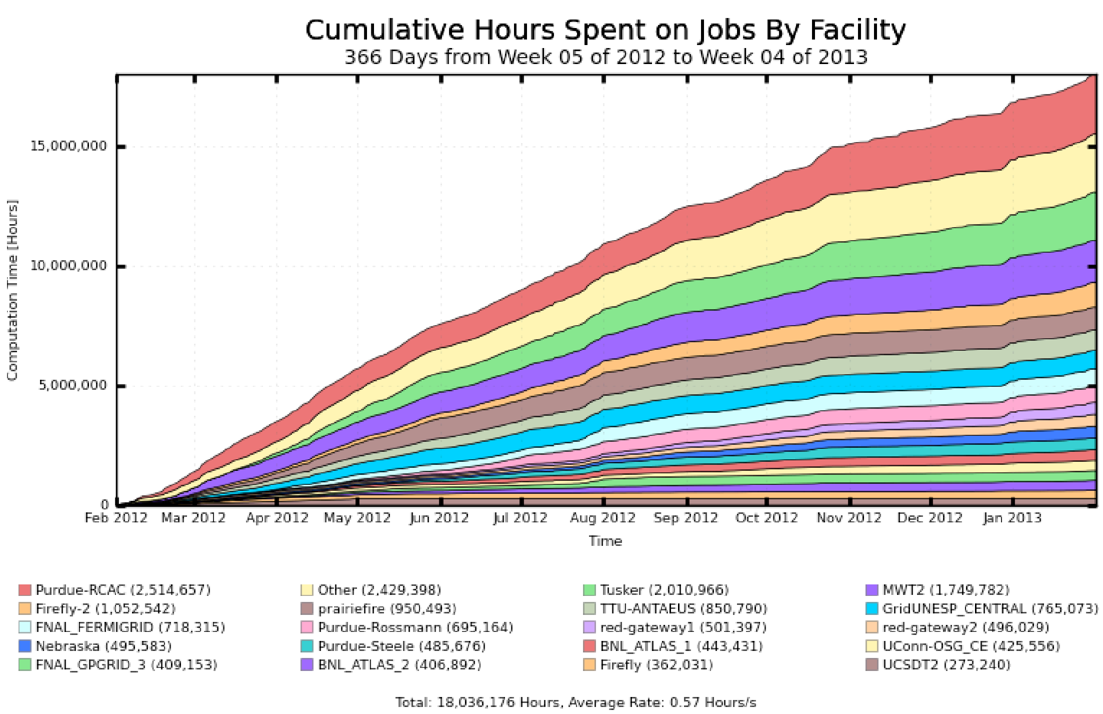
Hours Spent on Jobs By Facility
53 Weeks from Week 05 of 2012 to Week 04 of 2013
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Feb 2012 Mar 2012 Apr 2012 May 2012 Jun 2012 Jul 2012 Aug 2012 Sep 2012 Oct 2012 Nov 2012 Dec 2012 Jan 2013
Tusker
Other
GLOW-OSG
red-gateway1
NWICG_NDCMS
MIT_CMS
Purdue-Rossmann
red-gateway2
SMU_HPC
GridUNESP_CENTRAL
Firefly
prairiefire
MWT2
UCSDT2
Purdue-Steele
SPRACE
PNNL_OSG
MIT_CMS_2
Nebraska
BNL_ATLAS_1
Maximum: 1,055,079 , Minimum: 2.54 , Average: 121,395 , Current: 118,515



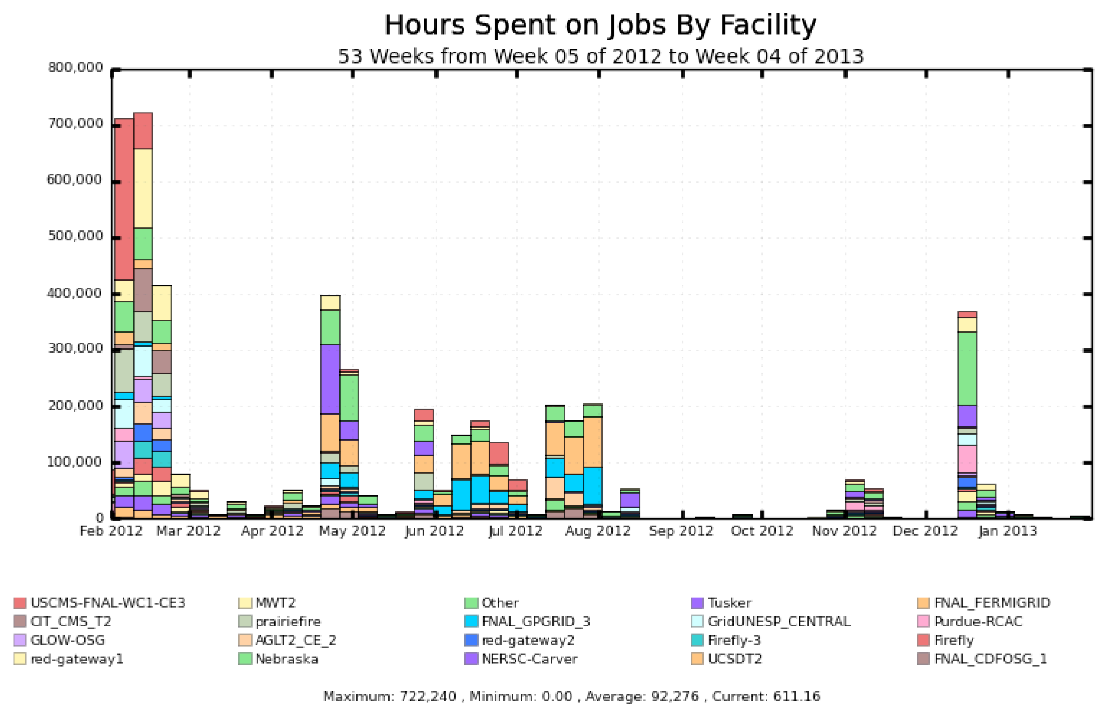
Cumulative Hours Spent on Jobs By Facility
366 Days from Week 05 of 2012 to Week 04 of 2013
Computation Time [Hours]
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
Feb 2012 Mar 2012 Apr 2012 May 2012 Jun 2012 Jul 2012 Aug 2012 Sep 2012 Oct 2012 Nov 2012 Dec 2012 Jan 2013
Time
Other (1,347,258)
MWT2 (582,534)
Nebraska (222,015)
Purdue-Steele (192,948)
UCD (66,995)
Tusker (960,020)
MIT_CMS (309,883)
red-gateway2 (218,494)
BNL_ATLAS_1 (127,919)
SMU_PHY (31,553)
SMU_HPC (680,577)
UCSDT2 (296,697)
Purdue-Rossmann (215,366)
BNL_ATLAS_2 (90,721)
RENCI-Blueberry (29,206)
GridUNESP_CENTRAL (605,798)
prairiefire (256,507)
red-gateway1 (208,824)
cinvestav (84,146)
UConn-OSG_CE (27,879)
Total: 6,555,351 Hours, Average Rate: 0.21 Hours/s

9. GLOW Usage

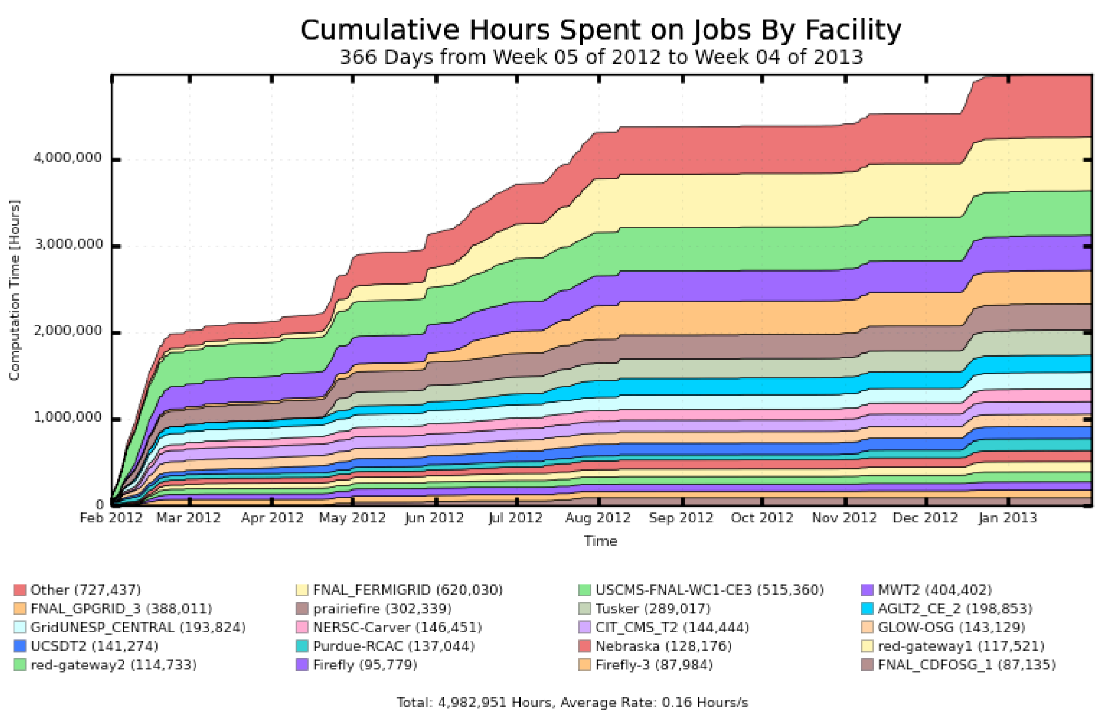

Hours Spent on Jobs By Facility
53 Weeks from Week 05 of 2012 to Week 04 of 2013
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Feb 2012
Mar 2012
Apr 2012
May 2012
Jun 2012
Jul 2012
Aug 2012
Sep 2012
Oct 2012
Nov 2012
Dec 2012
Jan 2013
FNAL_FERMIGRID
Purdue-RCAC
MWT2
Other
Tusker
FNAL_GPGRID_3
prairiefire
GridUNESP_CENTRAL
Purdue-Rossmann
Firefly-2
Purdue-Steele
red-gateway1
Nebraska
red-gateway2
SPRACE
TTU-ANTAEUS
UConn-OSG_CE
BNL_ATLAS_2
Firefly
BNL_ATLAS_1
Maximum: 673,891 , Minimum: 10,556 , Average: 334,003 , Current: 76,103


Cumulative Hours Spent on Jobs By Facility
366 Days from Week 05 of 2012 to Week 04 of 2013
Computation Time [Hours]
15,000,000
10,000,000
5,000,000
0
Feb 2012
Mar 2012
Apr 2012
May 2012
Jun 2012
Jul 2012
Aug 2012
Sep 2012
Oct 2012
Nov 2012
Dec 2012
Jan 2013
Time
Purdue-RCAC (2,514,657)
Other (2,429,398)
Tusker (2,010,966)
MWT2 (1,749,782)
Firefly-2 (1,052,542)
prairiefire (950,493)
TTU-ANTAEUS (850,790)
GridUNESP_CENTRAL (765,073)
FNAL_FERMIGRID (718,315)
Purdue-Rossmann (695,164)
red-gateway1 (501,397)
red-gateway2 (496,029)
Nebraska (495,583)
Purdue-Steele (485,676)
BNL_ATLAS_1 (443,431)
UConn-OSG_CE (425,556)
FNAL_GPGRID_3 (409,153)
BNL_ATLAS_2 (406,892)
Firefly (362,031)
UCSDT2 (273,240)
Total: 18,036,176 Hours, Average Rate: 0.57 Hours/s

10. HCC Usage

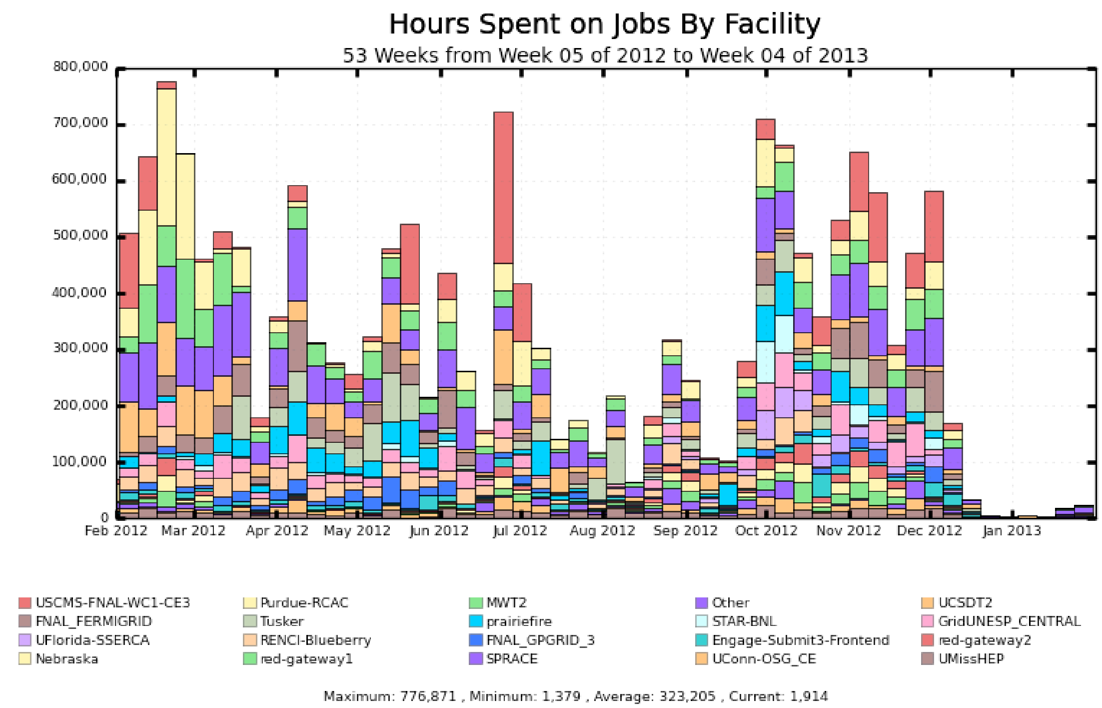


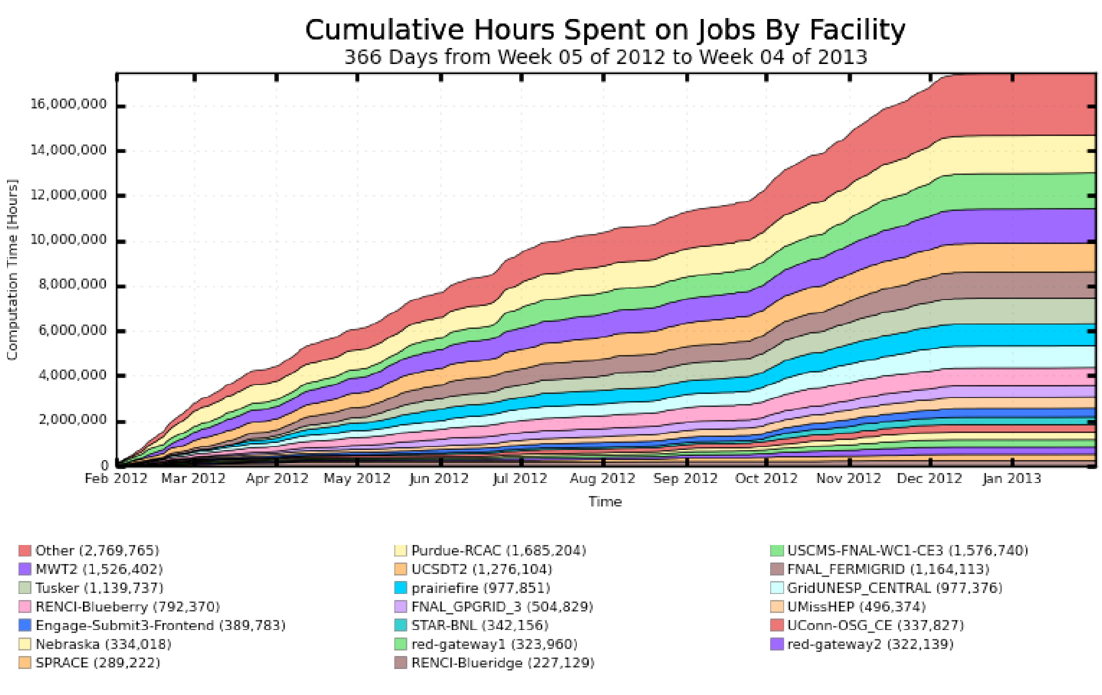
Hours Spent on Jobs By Facility
53 Weeks from Week 05 of 2012 to Week 04 of 2013
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Feb 2012
Mar 2012
Apr 2012
May 2012
Jun 2012
Jul 2012
Aug 2012
Sep 2012
Oct 2012
Nov 2012
Dec 2012
Jan 2013
USCMS-FNAL-WC1-CE3
MWT2
Other
Tusker
FNAL_FERMIGRID
CIT_CMS_T2
prairiefire
FNAL_GPGRID_3
GridUNESP_CENTRAL
Purdue-RCAC
GLOW-OSG
AGLT2_CE_2
red-gateway2
Firefly-3
Firefly
red-gateway1
Nebraska
NERSC-Carver
UCSDT2
FNAL_CDFOSG_1
Maximum: 722,240 , Minimum: 0.00 , Average: 92,276 , Current: 611.16



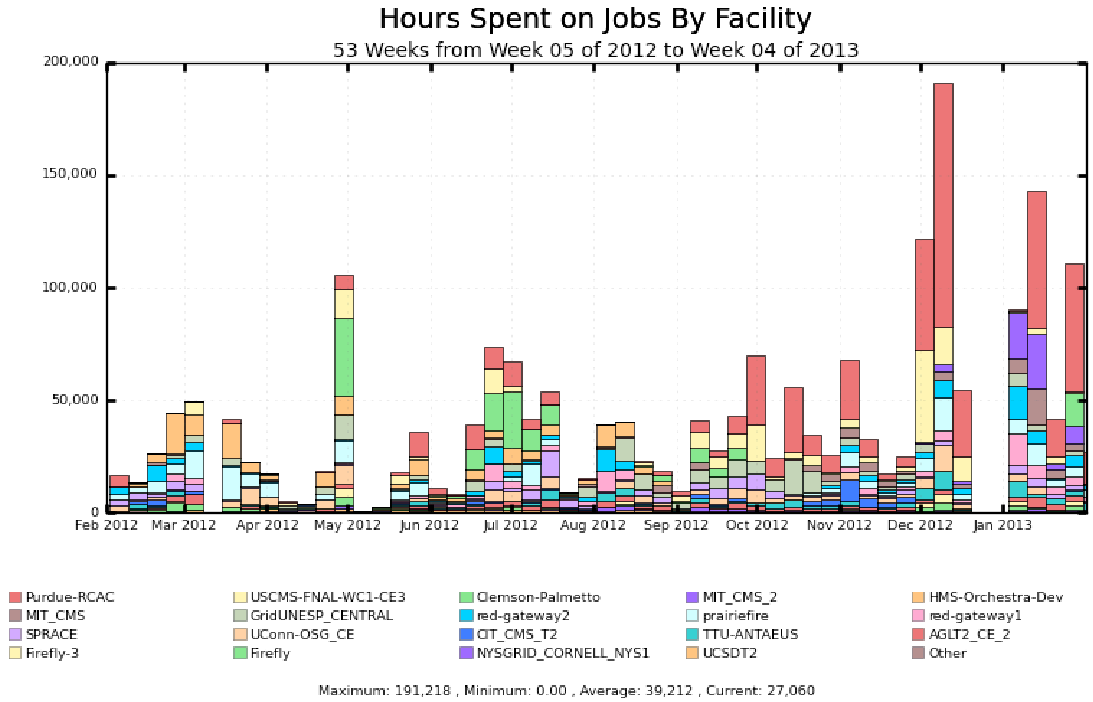
Cumulative Hours Spent on Jobs By Facility
366 Days from Week 05 of 2012 to Week 04 of 2013
Computation Time [Hours]
4,000,000
3,000,000
2,000,000
1,000,000
0
Feb 2012
Mar 2012
Apr 2012
May 2012
Jun 2012
Jul 2012
Aug 2012
Sep 2012
Oct 2012
Nov 2012
Dec 2012
Jan 2013
Time
Other (727,437)
FNAL_FERMIGRID (620,030)
USCMS-FNAL-WC1-CE3 (515,360)
MWT2 (404,402)
FNAL_GPGRID_3 (388,011)
prairiefire (302,339)
Tusker (289,017)
AGLT2_CE_2 (198,853)
GridUNESP_CENTRAL (193,824)
NERSC-Carver (146,451)
CIT_CMS_T2 (144,444)
GLOW-OSG (143,129)
UCSDT2 (141,274)
Purdue-RCAC (137,044)
Nebraska (128,176)
red-gateway1 (117,521)
red-gateway2 (114,733)
Firefly (95,779)
Firefly-3 (87,984)
FNAL_CDFOSG_1 (87,135)
Total: 4,982,951 Hours, Average Rate: 0.16 Hours/s

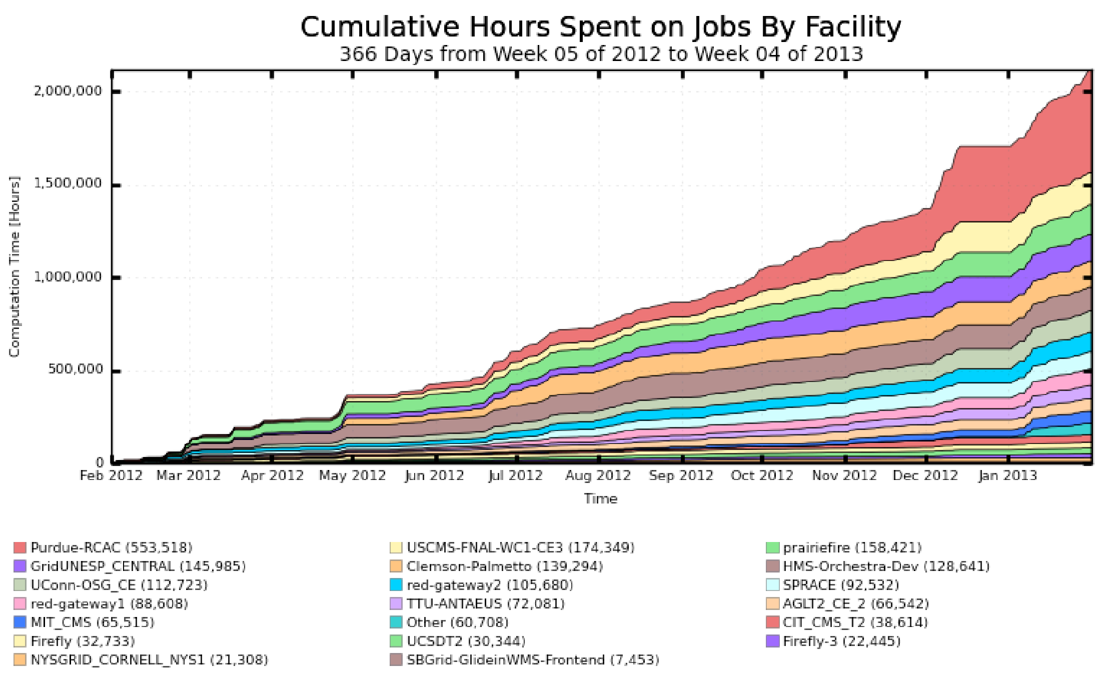
11. ENGAGE Usage



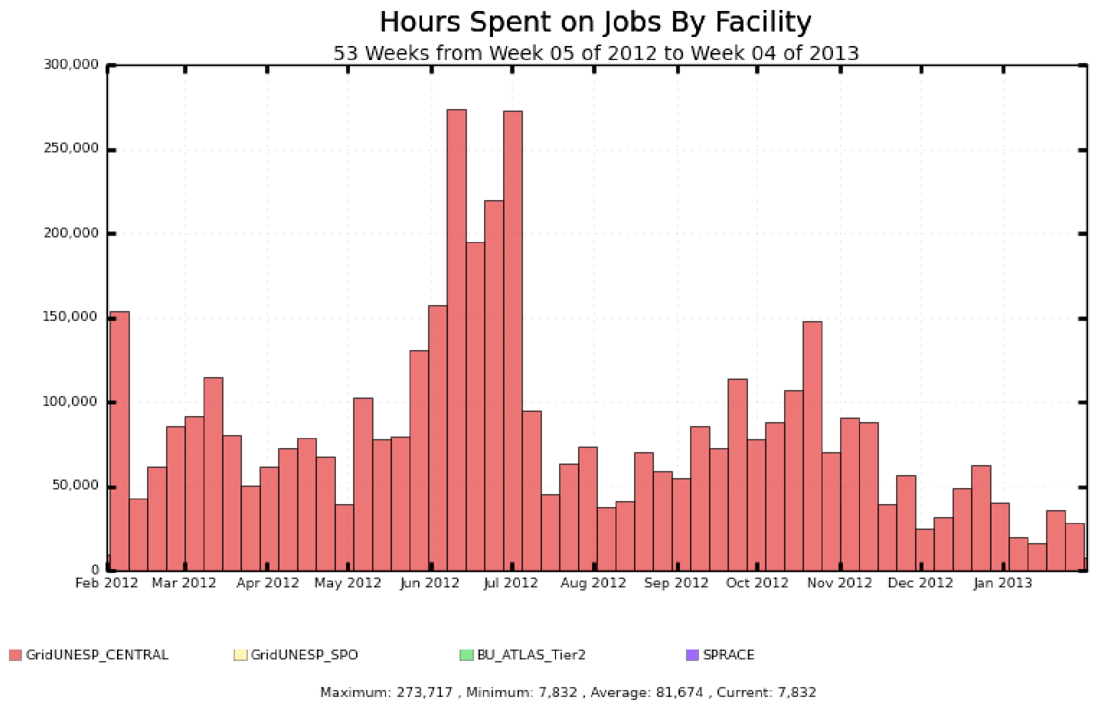


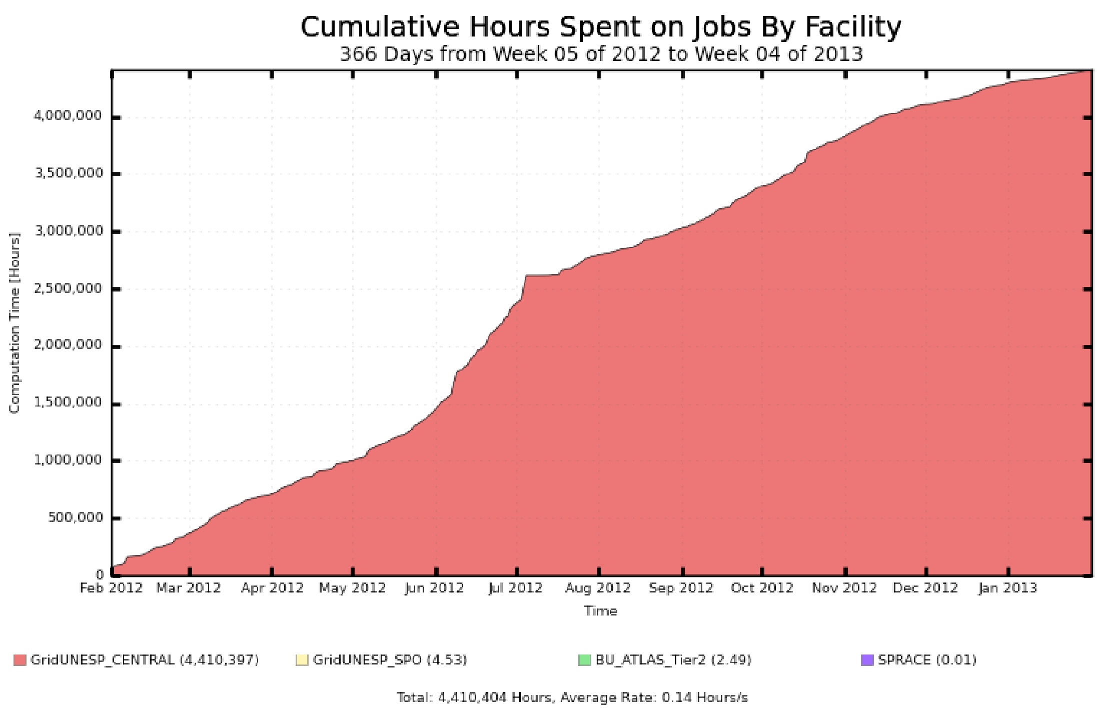
12. SBGrid Usage





13. GridUNESP





Appendix 2

Science Publications enabled by OSG

2012

Contents

ATLAS

1) Search for resonances decaying into top-quark pairs using fully hadronic decays in pp collisions with ATLAS at $\sqrt{s}=7$ TeV By ATLAS Collaboration (Georges Aad et al.). arXiv:1211.2202 [hep-ex]. 10.1007/JHEP01(2013)116. JHEP 1301 (2013) 116.

2) Search for contact interactions and large extra dimensions in dilepton events from pp collisions at $\sqrt{s}=7$ TeV with the ATLAS detector. By ATLAS Collaboration (Georges Aad et al.). arXiv:1211.1150 [hep-ex]. Phys.Rev. D87 (2013) 015010.

3) Search for pair production of heavy top-like quarks decaying to a high-pT W boson and a b quark in the lepton plus jets final state at $\sqrt{s}=7$ TeV with the ATLAS detector By ATLAS Collaboration (Georges Aad et al.) arXiv:1210.5468 [hep-ex]. 10.1016/j.physletb.2012.11.071. Phys.Lett. B718 (2013) 1284-1302.

4) Search for doubly-charged Higgs bosons in like-sign dilepton final states at $\sqrt{s}=7$ TeV with the ATLAS detector By ATLAS Collaboration (Georges Aad et al.). arXiv:1210.5070 [hep-ex]. 10.1140/epjc/s10052-012-2244-2. Eur.Phys.J. C72 (2012) 2244.

5) Search for pair production of massive particles decaying into three quarks with the ATLAS detector in $\sqrt{s}=7$ TeV pp collisions at the LHC By ATLAS Collaboration (Georges Aad et al.). arXiv:1210.4813 [hep-ex]. 10.1007/JHEP12(2012)086. JHEP 1212 (2012) 086.

6) Search for anomalous production of prompt like-sign lepton pairs at $\sqrt{s}=7$ TeV with the ATLAS detector By ATLAS Collaboration (Georges Aad et al.). arXiv:1210.4538 [hep-ex]. 10.1007/JHEP12(2012)007. JHEP 1212 (2012) 007.

7) Search for R-parity-violating supersymmetry in events with four or more leptons in $\sqrt{s}=7$ TeV pp collisions with the ATLAS detector. By ATLAS Collaboration (Georges Aad et al.). arXiv:1210.4457 [hep-ex]. 10.1007/JHEP12(2012)124. JHEP 1212 (2012) 124.

8) ATLAS search for new phenomena in dijet mass and angular distributions using pp collisions at $\sqrt{s}=7$ TeV By ATLAS Collaboration (Georges Aad et al.). arXiv:1210.1718 [hep-ex]. 10.1007/JHEP01(2013)029. JHEP 1301 (2013) 029.

9) Search for Supersymmetry in Events with Large Missing Transverse Momentum, Jets, and at Least One Tau Lepton in 7 TeV Proton-Proton Collision Data with the ATLAS Detector By ATLAS Collaboration (Georges Aad et al.). arXiv:1210.1314 [hep-ex]. 10.1140/epjc/s10052-012-2215-7. Eur.Phys.J. C72 (2012) 2215.

10) Search for resonant top plus jet production in $t\bar{t}$ + jets events with the ATLAS detector in pp collisions at $\sqrt{s}=7$ TeV By ATLAS Collaboration (Georges Aad et al.). arXiv:1209.6593 [hep-ex]. 10.1103/PhysRevD.86.091103. Phys.Rev. D86 (2012) 091103.

11) ATLAS search for a heavy gauge boson decaying to a charged lepton and a neutrino in pp collisions at $\sqrt{s}=7$ TeV By ATLAS Collaboration (Georges Aad et al.). arXiv:1209.4446 [hep-ex]. 10.1140/epjc/s10052-012-2241-5. Eur.Phys.J. C72 (2012) 2241.

12) Search for a heavy top-quark partner in final states with two leptons with the ATLAS detector at the LHC By ATLAS Collaboration (Georges Aad et al.). arXiv:1209.4186 [hep-ex]. 10.1007/JHEP11(2012)094. JHEP 1211 (2012) 094.

13) Search for high-mass resonances decaying to dilepton final states in pp collisions at s**(1/2) = 7-TeV with the ATLAS detector. By ATLAS Collaboration (Georges Aad et al.). arXiv:1209.2535 [hep-ex]. 10.1007/JHEP11(2012)138. JHEP 1211 (2012) 138.

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2) Limits on anomalous trilinear gauge boson complings from WW, WZ and Wγproduction in pp collisions at √s=1.96 TeV; Published 11/20/12: Phys. Lett. B 718, 451 (2012) arXiv:1208.5458 plots 8.6 fb^{-1}

3) Measurement of angular correlations of jets at √s=1.96 TeV and determinationof the strong coupling at high momentum transfers ; Published 11/15/12: Phys. Lett. B 718, 56 (2012) arXiv:1207.4957 plots 0.7 fb^{-1}

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5) Combination of the Top-Quark Mass Measurements from the Tevatron Collider Published 11/08/12: Phys. Rev. D 86, 092003 (2012), arXiv:1207.1069 plots 5.8 fb^{-1}

6) Measurement of the Semileptonic Charge Asymmetry using B^0 meson mixing with the D0 detector
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11) Combined search for the standard model Higgs boson decaying to bb using the D0 Run II data Published 9/20/12: Phys. Rev. Lett. 109, 121802 (2012), arXiv:1207.6631 plots 9.5−9.7 fb^{-1} PRL Editors' Suggestion

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Published 8/13/12: Phys. Rev. D 86, 032005 (2012), arXiv:1203.1082 plots 5.3 fb^{-1}

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30) Search for Charged Massive Long-Lived Particles
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Published 3/20/12: Phys. Rev. D 85, 052006 (2012), arXiv:1110.3771 plots 0.7 fb^{-1}

32) Search for Pair Production of the Scalar Top Quark in Muon+Tau Final States
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