IceCube Maintenance and Operations
Fiscal Year 2014 Mid-Year Report

October 1, 2013 – March 31, 2014

Submittal Date: March 31, 2014

University of Wisconsin–Madison

This report is submitted in accordance with the reporting requirements set forth in the IceCube Maintenance and Operations Cooperative Agreement, ANT-0937462.

Foreword

This FY2014 Mid-Year Report is submitted as required by the NSF Cooperative Agreement ANT-0937462. This report covers the six-month period beginning October 1, 2013 and concluding March 31, 2014. The status information provided in the report covers actual common fund contributions received through March 31, 2014 and the full 86-string IceCube detector (IC86) performance through March 1, 2014.

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Section I – Financial/Administrative Performance

The University of Wisconsin–Madison is maintaining three separate accounts with supporting charge numbers for collecting IceCube M&O funding and reporting related costs: 1) NSF M&O Core account, 2) U.S. Common Fund account, and 3) Non-U.S. Common Fund account.

The first FY2014 installment of $3,450,000 was released to UW–Madison to cover the costs of maintenance and operations during the first six months of FY2014. $470,925 was directed to the U.S. Common Fund account, and $2,979,075 was directed to the IceCube M&O Core account. The second FY2014 installment of $3,450,000 is planned to be released to cover the remaining six months of FY2014 (Figure 1).

FY2014	Funds Awarded to UW for Oct 1, 2013 – March 31, 2014	Funds to Be Awarded to UW for Apr 1, 2014 – Sept 30, 2014
IceCube M&O Core account	$2,979,075	$2,979,075
U.S. Common Fund account	$470,925	$470,925
TOTAL NSF Funds	**$3,450,000**	**$3,450,000**

Figure 1: NSF IceCube M&O Funds

Of the IceCube M&O FY2014 Core funds, $1,015,212 were committed to seven U.S. subawardee institutions. The institutions submit invoices to receive reimbursement against their actual IceCube M&O costs. Deliverable commitments made by each subawardee institution are monitored throughout the year. Figure 2 summarizes M&O responsibilities and total FY2014 funds for the seven subawardee institutions.

Institution	Major Responsibilities	Funds
Lawrence Berkeley National Laboratory	DAQ maintenance, computing infrastructure	$79,984
Pennsylvania State University	Computing and data management, simulation production	$40,878
University of California at Berkeley	Detector calibration, monitoring coordination	$92,973
University of Delaware, Bartol Institute	IceTop calibration, monitoring and maintenance	$206,796
University of Maryland at College Park	IceTray software framework, online filter, simulation software	$506,616
University of Alabama at Tuscaloosa	Detector calibration, reconstruction and analysis tools	$43,396
Georgia Institute of Technology	TFT coordination	$44,569
Total		**$1,015,212**

Figure 2: IceCube M&O Subawardee Institutions – FY2014 Major Responsibilities and Funding

IceCube NSF M&O Award Budget, Actual Cost and Forecast

The current IceCube NSF M&O 5-year award was established at the beginning of Federal Fiscal Year 2011, on October 1, 2010. The following table presents the financial status five months into FY2014, which is Year 4 of the award, and shows an estimated balance at the end of FY2014.

Total awarded funds to the University of Wisconsin (UW) for supporting IceCube M&O from the beginning of FY2011 through mid-year FY2014 are $24,344K. With the second FY2014 planned installment of $3,450K, the total FY2011-FY2014 budget is $27,794K. Total actual cost as of February 28, 2014 is $22,398K; open commitments are $2,791K. The current balance as of February 28, 2014 is $2,605K. With a projection of $2,357K for the remaining expenses during the final seven months of FY2014, the estimated unspent funds at the end of FY2014 are $248K, which is 3.6% of the FY2014 budget (Figure 3).

(a)	(b)	(c)	(d)= a - b - c	(e)	(f) = d – e
YEARS 1-4 Budget Oct.'10-Sep.'14	**Actual Cost To Date** through Feb. 28, 2014	**Open Commitments** on Feb. 28, 2014	**Current Balance** on Feb. 28, 2014	**Remaining Projected Expenses** through Sept. 2014	**End of FY2014 Forecast Balance** on Sept. 30, 2014
$27,794K	**$22,398K**	**$2,791K**	**$2,605K**	**$2,357K**	**$248K**

Figure 3: IceCube NSF M&O Award Budget, Actual Cost and Forecast

The current forecasted balance at the end of the third year of the five-year M&O award (FY2014) is expected to be less than the allowed 10% annual carryover, according to the M&O Cooperative Agreement.

IceCube M&O Common Fund Contributions

The IceCube M&O Common Fund was established to enable collaborating institutions to contribute to the costs of maintaining the computing hardware and software required to manage experimental data prior to processing for analysis.

Each institution contributed to the Common Fund, based on the total number of the institution's Ph.D. authors, at the established rate of $13,650 per Ph.D. author. The Collaboration updates the Ph.D. author count twice a year before each collaboration meeting in conjunction with the update to the IceCube Memorandum of Understanding for M&O.

The M&O activities identified as appropriate for support from the Common Fund are those core activities that are agreed to be of common necessity for reliable operation of the IceCube detector and computing infrastructure and are listed in the Maintenance & Operations Plan.

Figure 4 summarizes the planned and actual Common Fund contributions for the period of April 1, 2013–March 31, 2014, based on v14.0 of the IceCube Institutional Memorandum of Understanding, from April 2013. Actual Common Fund contributions are currently $21k less than planned. It is anticipated that all the final contributions will be fulfilled.

	Ph.D. Authors	Planned Contribution	Actual Received
Total Common Funds	**124**	**$1,692,600**	**$1,671,395**
U.S. Contribution	67	$941,850	$941,850
Non-U.S. Contribution	55	$750,750	$729,545

Figure 4: Planned and Actual CF Contributions for the period of April 1, 2013–March 31, 2014

Section II – Maintenance and Operations Status and Performance

Detector Operations and Maintenance

Detector Performance **–** During the period from September 1, 2013, to March 1, 2014, the full 86-string detector configuration (IC86) operated in standard physics mode 94.8% of the time. Figure 5 shows the cumulative detector time usage over the reporting period. Maintenance, commissioning, and verification required 0.3% of detector time. Careful planning of the hardware upgrades during the polar season limited the partial configuration uptime to 4.4% of the total. The unexpected downtime due to failures of 0.5% is comparable to previous periods and reflects the stability of the detector operation.

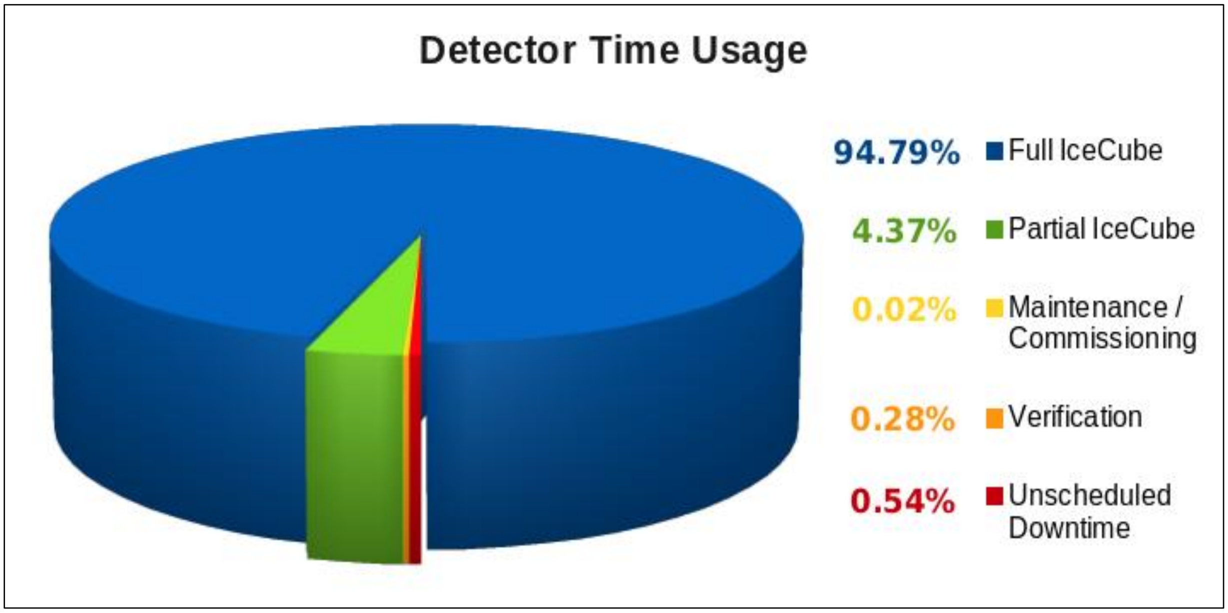

Figure 5: Cumulative IceCube Detector Time Usage, September 1, 2013 – March 1, 2014

Over the reporting period of September 1, 2013, to March 1, 2014, an average detector uptime of 98.7% was achieved, comparable to previous years, as shown in Figure 6. Of the total uptime, 83.4% of the time the runs were successful, meaning the DAQ did not fail within the set 8-hour run duration and used the full 86-string detector. This run failure rate is higher than normal and reflects some instability after the upgrades this pole season (see discussion below).

However, we have now implemented the ability to track portions of failed runs as good, allowing the recovery of data from all but the last few minutes of multi-hour runs that fail. This recently-added feature has provided us a gain of 10.3% in clean uptime, bringing the average for this reporting period to 93.8% for standard analysis-ready, full-detector data, as shown in Figure 6. Further improvement of clean uptime is expected: the clean uptime since the feature was first enabled (March 1, 2013) is approximately 96%.

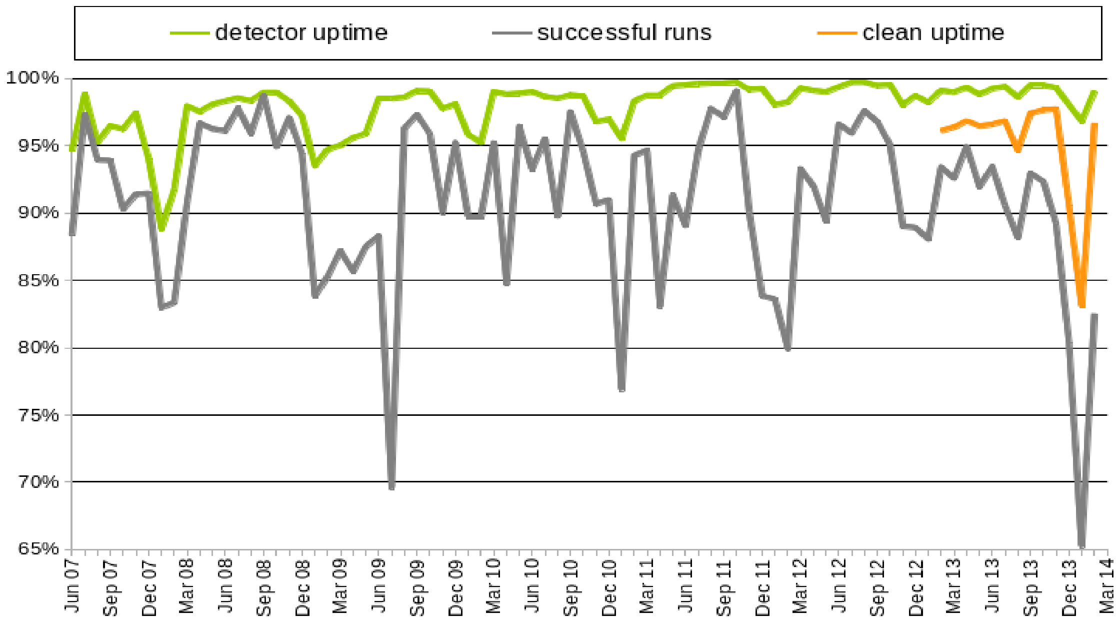

Figure 6: Total IceCube Detector Uptime and Clean Uptime

About 3% of the loss in clean uptime is due to the failed portions of runs that are not usable for analysis and runs less than 10 minutes long. About 2% of the loss in clean uptime is due to runs not using the full-detector configuration. This occurs when certain components of the detector are excluded from the run configuration during required repairs and maintenance. This South Pole season was an exception and saw around 4% loss of clean uptime due to partial-detector runs while hardware components were upgraded. Additionally, the experiment control system and DAQ are moving towards a non-stop run configuration. This will eliminate the approximately 90–120 seconds of downtime between run transitions, gaining roughly 0.5% of uptime.

The IceCube Run Monitoring system, I3Moni, provides a comprehensive set of tools for assessing and reporting data quality. IceCube collaborators participate in performing daily monitoring shift duties by reviewing information presented on the web pages and evaluating and reporting the data quality for each run. The original monolithic monitoring system processes data from various SPS subsystems, packages them together in ROOT files for transfer to the Northern Hemisphere, and reprocesses them in the north for displaying on the monitoring web pages. In a new monitoring system under development (I3Moni 2.0), all detector subsystems will report their data directly to IceCube Live via a ZeroMQ messaging system. Major advantages of this new approach include: higher quality of the monitoring alerts; simplicity and easier maintenance; flexibility, modularity, and scalability; faster data presentation to the end user; and a significant improvement in the overall longevity of the system implementation over the lifetime of the experiment.

The infrastructure for collecting the monitoring data is in place at SPS, and we are now focusing on generation and delivery of the monitoring quantities from various data acquisition and data processing subsystems. During a workshop in November 2013, we documented the monitoring quantities in detail to allow contributors to work in parallel on quantity delivery. Development of the statistical methods to detect data-quality issues is nearing completion. A staged rollout of the monitoring system, initially in parallel with the existing system, will begin in 2014.

IceCube Live v2.3 was released and deployed in January 2014. This release resolved 71 issues and requested features, including a new paging alert that detects rare cases in which multiple DAQ runs fail in a short time but still have produced some physics events, as well as better tracking of the usage of the low-latency ITS Iridium link. The uptime for the I3Live experiment control system during the reporting period was 99.999% (down two minutes for a hardware upgrade in December).

Structured data transmitted to I3Live are now inserted automatically into MongoDB and available for views which will be implemented for the I3Moni 2.0 system. Preparatory work for I3Moni 2.0 has also involved extensive cleanup and streamlining of existing database tables and code for the Web site.

Planned work for the next year includes significant efficiency improvements to the low-latency ITS Iridium messaging system. Also planned is the implementation of a data path whereby supernova alarms triggered in the external SNEWS network are transmitted into I3Live, paging the winterovers and causing DAQ HitSpool data to be saved for detailed analysis. Visualization upgrades are also planned, including a revamp of the graphing in IceCube Live using the Highcharts plotting library. Migration of legacy scripts for IceTop monitoring to provide long-term input directly into IceCube Live is still underway.

The IceCube Data Acquisition System (DAQ) has reached a stable state, and consequently the frequency of software releases has slowed to the rate of 1–2 per year. Nevertheless, the DAQ group continues to develop new features and patch bugs. During the reporting period of October 2013–March 2014, the following accomplishments are noted:

- Delivery of a new release ("Furthermore") of DAQ on November 1, 2013, that includes performance enhancements in the IceCube trigger system by spreading the multiple trigger algorithms across many execution threads, thus benefiting from the multicore architectures used in the DAQ computing platforms. This release also includes a data-replay feature that allows end-to-end testing of the "stopless runs" feature on the northern test system. This feature eliminates the small gap in data-taking during the periodic 8-hour run transitions, and we expect to roll it out during 2014.

- Development toward the "Great_Dane" release of the DAQ. This release will include delivery of I3Moni2.0 monitoring quantities to IceCube Live; enable DOM message packing to improve the efficiency of communication on the in-ice cables; and will support supernova DAQ muon subtraction (see SNDAQ section for more details).

The single-board computer (SBC) in the IceCube DOMHubs was also previously identified as a bottleneck in DAQ processing. After the successful upgrade of 10 hubs in the 2012–2013 polar season, the remaining 87 DOMHubs were upgraded in December and January of the 2013–2014 season. The hardware upgrade was achieved ahead of our aggressive schedule (see Figure 7). Because most of the detector remained running while sets of 2 to 4 hubs were upgraded, total detector uptime remained high (97% in January).

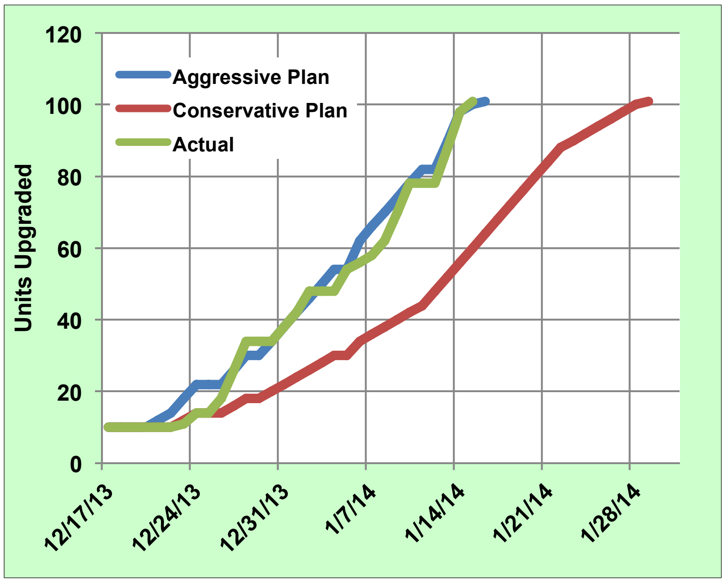

Figure 7: DOMHub SBC upgrade plan and realized timeline during the 2013–14 pole season.

In addition to the SBC hardware upgrades, most of the South Pole System servers (see the computing section for more details) were upgraded this season, and the operating system on all DAQ, DOMHub, and processing / filtering machines was also upgraded. Critical data-taking servers were upgraded and swapped into the detector with only 3 to 5 minutes of downtime. The significant software upgrades did result in some instability during January 2014, with some DAQ crashes at run transitions and random DOMHub machine lockups (approximately every 3000 hub-hours). These issues impacted the clean uptime for January, but both were resolved in February 2014.

The supernova data acquisition system (SNDAQ) found that 97.2% of the available data from November 12, 2013 through February 21, 2014, met the minimum analysis criteria for run duration and data quality for sending triggers. The trigger downtime was 0.6 days (0.4% of the time interval) from physics runs under 10 minutes in duration. This arose mainly during the pole season, when most of the DOMHub single board computers were replaced. Supernova candidates in these short runs can be recovered offline should the need arise; in addition, buffered hitspool data are available for an even larger fraction of the time.

New SNDAQ releases "Kabuto 1" (Nov. 11, 2013) and "Kabuto 2" (Dec. 13, 2013) were installed, featuring fabric installation support, improved hitspooling communication and monitoring, NIST-based leap second handling as part of a re-designed time class, as well as many small improvements and bug fixes. They include full I3Moni 2.0 support, including end-of-run summaries, Iridium transmission of supernova alarms and short datagrams, as well as the possibility to page the winterovers. Some problems with an increased latency in the alarm transition, a better handling of rare payload gaps and problems due to a high I/O load are currently under investigation.

The supernova data acquisition state has reached a stable state, and consequently the frequency of software releases will slow to the rate of 1–2 per year. Future efforts will include the incorporation of external SNEWS alarms, updates for new compilers (clang) and new versions of external software, and the online subtraction of atmospheric-muon-induced hits based on DAQ trigger information, which will be provided in a forthcoming DAQ release.

The online filtering system performs real-time reconstruction and selection of events collected by the data acquisition system and sends them for transmission north via the data movement system. Version V13-05-00 is currently deployed in support of the IC86-2013 physics run. Efforts for the past 6 months have included system testing and support work for the SPS computing system and operating system upgrade performed during the 2013-2014 pole season and preparing for the IC86-2014 physics run. The hardware and operating system upgrade have resulted in a ~50% increase in the online filtering system capacity. Software system work continues to prepare software release for the IC86-2014 physics runs which will see an updated filter selection set from the IceCube physics working groups and a new output file format containing the SuperDST records for all events, intended to be an additional long term data archive of IceCube data with a smaller storage requirement than the raw waveforms. Additionally, work is underway to finalize the I3Moni 2.0 effort, where data-quality monitoring values are now available for direct reporting to the IceCube Live system.

A weekly calibration call keeps collaborators abreast of issues in both in-ice and offline DOM calibration. It has been demonstrated that the single photoelectron (SPE) peak of each DOM can be corrected using data from background events. Efforts continue to improve our knowledge of the absolute sensitivity of the DOMs in the ice, using muon data, laboratory measurements, neutrino events from physics analyses and noise hits in the DOMs. Online verification software is being merged into the upcoming I3Moni 2.0 framework. Software modules have been written that output the SPE distributions and baselines in the I3Moni2.0-compliant format. Flasher data continues to be analyzed to reduce ice model systematics, with a major focus on the hole ice, low-brightness flasher data, and multi-wavelength flashers. The current version of the ice model, based on multi-string flasher data collected in 2012, agrees with the flasher data to within 15%, compared to 20-30% in previous published versions of the ice model. A stress test of the DAQ was conducted with flashers in January 2014, demonstrating that the latest version of the DAQ can handle 3 times the normal trigger rate, due to the recent upgrade in the trigger system.

A procedure for tracking IceTop snow depths is in place and continues to work well. However, despite ongoing snow management during the austral summer season, the increasing snow depth on the IceTop tanks continues to increase the energy threshold for cosmic ray air shower detection each year, and complicates analyses due to uncertainties in the snow density. We are revisiting the snow management plan with the station contractor for the upcoming season. Additionally, we continue to work to integrate IceTop and related environmental monitoring functions into IceCube Live, including stratospheric temperature data used for muon rate corrections.

***IC86 Physics Runs* –** The third season of the 86-string physics run, IC86-2013, began on May 2, 2013. Preparations for the IC86-2014 physics run are nearly complete, with updated DOM calibrations from March 2014, but minimal changes to filter settings. DAQ trigger settings are not changing from IC86-2013, and the run start is expected in late April 2014.

The last DOM failures (2 DOMs) occurred during a power outage on May 22, 2013. No DOMs have failed during this reporting period, even with the short string power outages required for the DOMHub upgrades. The total number of active DOMs remains 5404 (98.5% of deployed DOMs).

***TFT Board* –** The TFT board is in charge of adjudicating SPS resources according to scientific need, as well as assigning CPU and storage resources at UW for mass offline data processing (a.k.a. Level 2). The IC86-2013 season was the first instance in which L2 processing was handled by the TFT from beginning to end. The result is a dramatic reduction in the latency for processing of L2. For the IC86-2011 season, L2 latency was several months after the end of the data season. For IC86-2013, the latency is 2–4 weeks after data-taking.

Working groups within IceCube will submit approximately 20 proposals requesting data processing, satellite bandwidth and data storage, and the use of various IceCube triggers for IC86-2014. Sophisticated online filtering data selection techniques are used on SPS to preserve bandwidth for other science objectives. Over the past three years, new data compression algorithms (SuperDST) have allowed IceCube to send a larger fraction of the triggered events over TDRSS than in previous seasons. The additional data enhances the science of IceCube in the search for neutrino sources toward the Galactic Center. During the 2014-2015 season, we expect to implement changes to the methodology for producing online quasi-real-time alerts. Neutrino candidate events at a rate of 3 mHz will be sent via a combination of Iridium satellite and e-mail, so that neutrino coincident multiplets (and thus candidates for astrophysical transient sources) can be rapidly calculated and distributed in the northern hemisphere. This change will enable significant flexibility in the type of fast alerts produced by IceCube.

The average TDRSS data transfer rate during IC86-2013 was 95 GB/day plus an additional 5 GB/day for use by the detector operations group. IceCube is a heavy user of the available bandwidth, and we will continue to moderate our usage without compromising the physics data.

***Personnel* –** The primary contracted IceCube Live developer, John Jacobsen, left the project in January 2014. Matt Newcomb, a DAQ programmer, also left WIPAC in February 2014. Two software developer positions are open as of March 2014. A software developer position at WIPAC, shared between detector operations and analysis software support, was filled in December 2013 by physicist Jim Braun.

Computing and Data Management

Computing Infrastructure – IceCube computing and storage systems, both at the Pole and in the north, have performed well over the past year. The total disk storage capacity in the data warehouse is 2721 TB (terabytes): 1017 TB for experimental data, 1315 TB for simulation, 270 TB for analysis, and 119 TB for user data.

A disk expansion was procured during the 3rd quarter of 2013. The requirements for this new system were to provide highly reliable and performing storage to be integrated in the data warehouse Lustre file systems. The current data warehouse architecture relies on these file systems to host critical data that needs to be accessed by several users from large computing clusters, which can potentially place a high load on the system. Part of this disk expansion was targeting a net increase in storage space for hosting the new data generated by the experiment. Another part was targeting the upgrade of part of the disk servers that were reaching the end of their operative life. A major upgrade of the Lustre software version in the main file systems is also planned for this year (from v1.8 to v.2.4) so this disk expansion will provide the needed headroom for safely performing the upgrade and data migration as needed. Several storage solutions from different vendors were analyzed and finally a Dell Compellent system was selected. The main parameter driving the decision was the cost per unit space, but other aspects were also had into account such as the manageability, throughput, etc. The procured systems is composed by two SC8000 RAID Controllers and five SC280 dense enclosures, each of them hosting 85 hard drives. This new system will provide a total net capacity of 1152 TB.

In 2012, the IceCube Collaboration approved the use of direct photon propagation for the mass production of simulation data. This requires the use of GPU (graphical processing units) hardware to deliver adequate performance. A GPU-based cluster, named GZK-9000, was installed in early 2012, and it has been extensively used for simulation production since then. The GZK-9000 cluster contains 48 NVidia Tesla M2070 GPUs. An extension of the GPU cluster containing 32 NVidia GeForce GTX-690 and 32 AMD ATI Radeon 7970 GPUs was purchased during the second quarter of 2013. The new servers were deployed at UW–Madison during August/September 2013 as additional resources of the main IceCube CPU cluster, named NPX. This was done to facilitate the access to this collaboration resource to a larger number of users, by providing an interface as integrated as possible with the existing facilities already being used by most of the collaboration members. Figure 8 shows the GPU hours consumed by jobs running in this new GPU cluster. More than 320.000 GPU hours have been delivered by this new facility since it started running. The average occupancy of this new GPU cluster in the last three months has been over 85%, and users other than Simulation Production have carried more than half of the workload out. These metrics show both the high demand for GPU resources in the collaboration and the success of the simpler interface provided to users. A number of other sites in the collaboration are planning to deploy GPU clusters in the next months to reach the overall simulation production capacity goal.

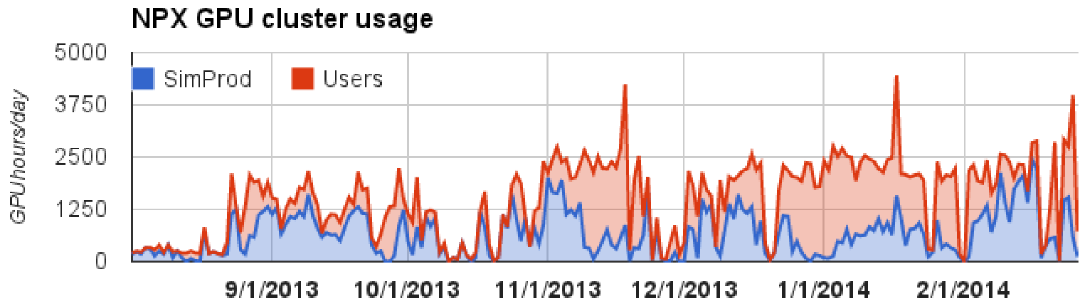

Figure 8: GPU hours consumed by the jobs completing daily in the new NPX GPU cluster. The contribution from Simulation Production jobs is shown in blue, and in red the contribution from other IceCube users.

A complete upgrade of the South Pole System (SPS) servers was carried out during the 2013-14 austral summer. This upgrade was mainly targeting to resolve performance issues that had been detected in parts of the system when operating under high trigger rate conditions. The previous set of servers was at the end of their three year planned lifetime, so a complete upgrade ensured that the homogeneity of the system was preserved. This is one of the main requirements for the SPS, given that it has to be operated for most of the year under complete isolation conditions. The server upgrade was extremely successful. All of the servers were replace during the month of December with almost no impact on data taking (DAQ uptime for that month was 98.08%). The server replacement also provides an important reduction of the energy needs, since the new servers consume 30-40% less power. Besides the server replacement, a prototype system that will archive data to disk instead of tape was deployed at SPS. This system will operate in parallel with the existing tape-based system during 2014 and will make use of the new JADE software, which notably improves the scalability and configurability of the current SPADE software. The data to be archived on disk will be the new SuperDST stream, which is currently planned to start being produced by the Processing and Filtering online farm from April 2014. This prototype will provide direct experience with the handling of disks and the procedures necessary to operate such a system. If it is successful, the tape-based system will be retired in the 2014-15 season. Finally, the remaining HP UPS systems were replaced during the 2013-14 season. The current system has 2 fully redundant UPSs per rack, including the DOMhub GPS receivers. This greatly reduces the detector downtime impact that short power outages might cause.

At the end of 2012, the IceCube Collaboration agreed to use the compressed SuperDST as the new long-term archival format for IceCube data. This significantly reduces the capacity requirements for the archive while keeping all the relevant physics information in the data at the same time. The decision taken was that this change will be implemented from the IC86-1 run onwards. A server, a small tape library for output, and a partition of the main tape library for input were dedicated to this task, which as of March 2014 had processed 54% of IC86-2 (all the tapes that had arrived from the Pole) and had begun IC86-1. Raw tapes are read to disk and the relevant files processed into SuperDST. A copy is saved in the data warehouse and another is written (using JADE) to LTO5 tapes. We started with IC86-2 tapes because the Supernova working group wanted some of the data.

A series of actions are planned with the goal of facilitating access and use of Grid resources to the collaboration members. With this objective, a CernVM-Filesystem (CVMFS) repository has been deployed at UW–Madison hosting the IceCube offline software stack and photonic tables needed for data reconstruction and analysis. CVMFS enables seamless access to the IceCube software from Grid nodes by means of HTTP. High scalability and performance can be accomplished by deploying a chain of standard web caches. The system was made available to all collaboration users in October 2013 and became the default software distribution mechanism at UW-Madison facilities in January 2014. In the last months, some IceCube sites in Europe have deployed and configured CVMFS in their computing clusters and several others are in the process of doing so. Also, a replica of the main repository (Stratum1) has been deployed at DESY Zeuthen. This provides load balancing and fault tolerance capabilities to this new software distribution infrastructure.

Data Movement **–** Data movement has performed nominally over the past six months. Figure 9 shows the daily satellite transfer rate and weekly average satellite transfer rate in GB/day through March 2014. The IC86 filtered physics data are responsible for 95% of the bandwidth usage.

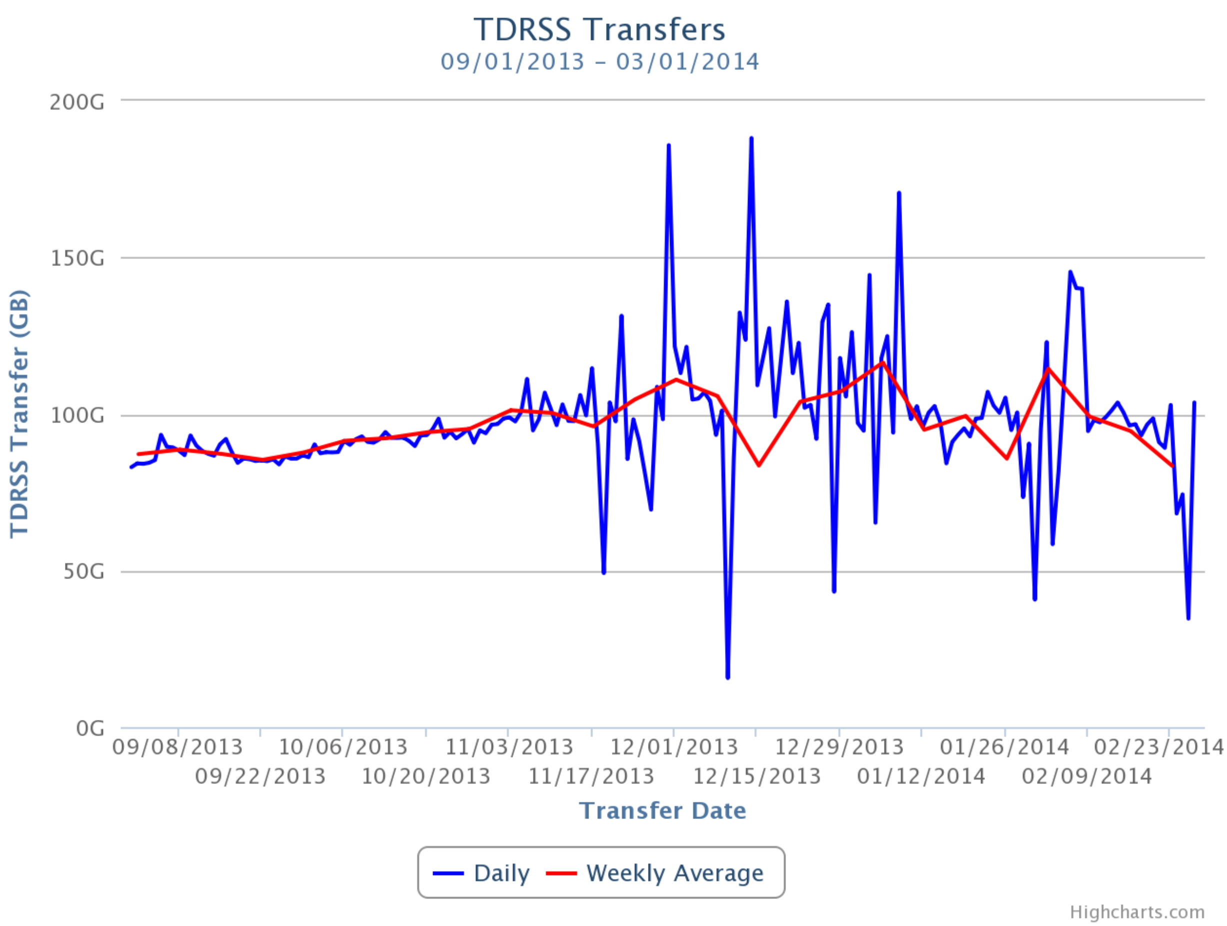

Figure 9: TDRSS Data Transfer Rates, September 1, 2013–March 1, 2014. The daily transferred volumes are shown in blue and, superimposed in red, the weekly average daily rates are also displayed.

Starting in November 2013, a series of unscheduled software and hardware outages caused unpredictable daily satellite transfer rates. Ongoing maintenance and additional transfer passes kept the average weekly satellite transfer rate close to our nominal rate. Science data transfer goals were met despite the unpredictable daily rates.

Data Archive – The IceCube raw data are archived on LTO4 data tapes. Data archival goals were met despite some outages for maintenance. A total of 154 TB of data were written to LTO tapes, averaging 846.9 GB/day. A total of 17.5 TB of data were sent over TDRSS, averaging 96.3 GB/day. As mentioned previously, due to the limited lifespan of and difficulty of data migration from the raw data tapes, alternate strategies for long-term data archiving are being explored.

Offline Data Filtering – Following the final validation of the offline processing scripts for the IC86-2013 season data, processing commenced in June 2013. A newly established workflow facilitates rapid pre-processing checks and post-processing validation. We are now consistently maintaining a reduced latency of 2 weeks or less between data collection and processing. We also have fewer needs for reprocessing due to configuration or processing errors.

Data collection for the IC86-2013 season is still ongoing, however, based on the resources already expended in the processing of 10 months of data, we estimate that we will need a total of 730,00 CPU hours on the NPX4 computing cluster in UW-Madison for processing data for the whole season. We also estimate the use of 120TB of storage space at the UW-Madison storage center. This estimate includes allocation for both the input data transferred from the South Pole to the storage center, and the output data resulting from offline processing.

Replication of both the Pole-filtered and offline Level 2 data at Deutsches Elektronen-Synchrotron (DESY) is proceeding as planned. We have added more monitoring and reporting tools to aid the smooth operation of the backup process.

In preparation for the new season scheduled to start in May 2014, we have started compiling the scripts for the offline processing of the IC86-2014 data. These will be validated using test data from the new season configuration planned to be collected in April 2014.

Simulation – The current production of IC86-2011 Monte Monte Carlo Carlo began in mid-2012. A transition to a combined production of IC86-2011, IC86-2012, and IC86-2013 simulation started at the beginning of 2014, and direct generation of Level 2 simulation data is now used to reduce storage space requirements. A new release of the IceCube simulation metaproject, IceSim 4, is in the final testing phase, and comparison datasets with IceSim 3.3.2 are available for verification. IceSim 4 contains improvements to low-level DOM simulation, correlated noise generation, Earth modeling, and lepton propagation.

We have progressed toward having 100% of all simulations based on direct photon propagation using GPUs or a hybrid of GPU and spline-photonics for high-energy events. Producing simulations of direct photon propagation using GPUs began with a dedicated pool of computers built for this purpose in addition to the standard CPU-based production. Benchmark performance studies of consumer-class GPU cards have been completed and provided to the collaboration as we scale up the available GPUs for simulation.

The simulation production sites are: CHTC – UW campus (including GZK9000 GPU cluster); Dortmund; DESY-Zeuthen; University of Mainz; EGI – German grid; WestGrid – U. Alberta; SWEGRID – Swedish grid; PSU – Pennsylvania State University; LONI – Louisiana Optical Network Infrastructure; GLOW – Grid Laboratory of Wisconsin; UMD – University of Maryland; IIHE – Brussels; UGent – Ghent; Ruhr-Uni – Bochum; UC Irvine; PDSF/Carver/Dirac – LBNL; and NPX3 – UW IceCube. There are plans to incorporate additional computing resources in Canada and Denmark, and to expand the pool of GPU resources at several computing centers.

Data Release

Data Use Policy – IceCube is committed to the goal of releasing data to the scientific community. The following links contain data sets produced by AMANDA/IceCube researchers along with a basic description. Due to challenging demands on event reconstruction, background rejection and systematic effects, data will be released after the main analyses are completed and results are published by the international IceCube Collaboration. The following two links give more information about IceCube data formats and policies.

IceCube Open Data: http://icecube.umd.edu/PublicData/I3OpenDataFormat.html

IceCube Policy on Data Sharing:
http://icecube.umd.edu/PublicData/policy/IceCubeDataPolicy.pdf

Datasets (last release on 5 Sep 2011): http://icecube.wisc.edu/science/data
The pages below contain information about the data that were collected and links to the data files.

AMANDA 7 Year Data: http://icecube.wisc.edu/science/data/amanda

IceCube String 22–Solar WIMP Data: http://icecube.wisc.edu/science/data/ic22-solar-wimp

IceCube String 40 Data: http://icecube.wisc.edu/science/data/ic40

Program Management

Management & Administration – The primary management and administration effort is to ensure that tasks are properly defined and assigned and that the resources needed to perform each task are available when needed. Efforts include monitoring that resources are used efficiently to accomplish the task requirements and achieve IceCube's scientific objectives.

- The FY2014 M&O Plan was submitted in December 2013.
- The detailed M&O Memorandum of Understanding (MoU) addressing responsibilities of each collaborating institution was revised for the collaboration meeting in Banff, Canada, March 2–8, 2014.

IceCube M&O - FY2014 Milestones Status:

Milestone	Month
Revise the Institutional Memorandum of Understanding (MOU v15.0) - Statement of Work and Ph.D. Authors head count for the fall collaboration meeting	**October 2013**
Report on Scientific Results at the Fall Collaboration Meeting	**October 7-12, 2013**
Post the revised institutional MoU's and Annual Common Fund Report and notify IOFG.	**December 2013**
Submit for NSF approval, a revised IceCube Maintenance and Operations Plan (M&OP) and send the approved plan to non-U.S. IOFG members.	**December 2013**
Annual South Pole System hardware and software upgrade is complete.	**January 2014**
Revise the Institutional Memorandum of Understanding (MOU v16.0) - Statement of Work and Ph.D. Authors head count for the spring collaboration Meeting	**February 2014**
Report on Scientific Results at the Spring Collaboration Meeting	March 3-8, 2014
Submit to NSF a mid-year interim report with a summary of the status and performance of overall M&O activities, including data handling and detector systems.	March 2014
Software & Computing Advisory Panel (SCAP) Review at UW-Madison	April 1-2, 2014
NSF IceCube M&O Performance Update	TBD
Submit for NSF approval an annual report which will describe progress made and work accomplished based on objectives and milestones in the approved annual M&O Plan.	September 2014

Engineering, Science & Technical Support – Ongoing support for the IceCube detector continues with the maintenance and operation of the South Pole Systems, the South Pole Test System, and the Cable Test System. The latter two systems are located at the University of Wisconsin–Madison and enable the development of new detector functionality as well as investigations into various operational issues, such as communication disruptions and electromagnetic interference. Technical support provides for coordination, communication, and assessment of impacts of activities carried out by external groups engaged in experiments or potential experiments at the South Pole. The IceCube detector performance continues to improve as we restore individual DOMs to the array at a faster rate than problem DOMs are removed during normal operations.

Education & Outreach (E&O) - The IceCube Collaboration has been successful in leveraging resources to engage broader audiences. The E&O team continues to interact with the E&O advisory panel and has a virtual meeting scheduled for May 2014 to review E&O plans for the next two years. Here we provide an update on the three activities highlighted in the FY13 M&O annual report along with a brief summary of a few other significant events during this period.

1) The IceCube Masterclass program is progressing well, and a beta version of the course material is on the web (https://icecube.wisc.edu/masterclass/). A test run with high school students and IceCube collaborators at UW-Madison, U-Delaware, U-Mainz (Germany), and Vrije Universiteit (Belgium) will be held on May 21, 2014. Approximately one hundred students will spend a day learning about particle astrophysics and working through a guided research activity analyzing IceCube data in search of astrophysical neutrinos.
2) The Interdisciplinary ArtScience panel discussion *Exploring New Worlds, Realizing the Imagined* took place at the Deutsches Museum in Munich, in conjunction with the fall IceCube Collaboration meeting, on October 9, 2013. The scheduled two-hour event ran long due to questions from a capacity crowd of approximately two hundred, roughly split equally between scientists and artists. Francis Halzen and Christian Spiering from IceCube, Mark-David Hosale from York University, Rachel Armstrong from the University of Greenwich in London, and Wolfgang Heckl, the general director of the Deutsches Museum, were panel members.
3) *Chasing the Ghost Particle, from the South Pole to the Edge of the Universe*, the fulldome IceCube video made in conjunction with the Milwaukee Public Museum, has been well received by both scientific and lay audiences. Premieres at the Milwaukee Public Museum, UW-Madison, and UW-River Falls drew capacity crowds of over 300 in Milwaukee and Madison and 80 in River Falls. Plans are underway to produce European versions, one narrated in German and one with Swedish subtitles. The show has also been purchased for showing at a Brussels planetarium, and numerous showings will take place in the US as well.

On December 13, 2013, Francis Halzen participated in an international webcast hosted by *Physics World* to announce that IceCube had been selected as their 2013 Breakthrough of the Year. Supporting materials, including a multimedia gallery http://icecube.wisc.edu/gallery/press, were developed for the release. An NSF IRES proposal to send 18 US IceCube undergraduate students to European IceCube collaborating institutions for 10-week summer research experiences has been tentatively approved. The plan is to send three students in 2014, six in 2015, and nine in 2016.

Section III – Project Governance and Upcoming Events

The detailed M&O institutional responsibilities and Ph.D. author head count is revised twice a year at the time of the IceCube Collaboration meetings. This is formally approved as part of the institutional Memorandum of Understanding (MoU) documentation. The MoU was last revised in March 2014 for the Spring collaboration meeting in Banff, Canada (v16.0), and the next revision (v17.0) will be posted in September 2014 at the Fall collaboration meeting in Geneva, Switzerland.

Changes to the IceCube Governance Document reflecting the analysis procedure that have been in place since last summer were approved at the Spring collaboration meeting in Banff, Canada. The composition and term limits of the publication committee were also revised. A Memorandum of Understanding (MoU) is under preparation with LIGO, Borexino, LVD, VIRGO for multi-messenger astronomy with supernova neutrinos and gravity waves.

IceCube Collaborating Institutions

At the March 2014 Spring collaboration meeting, the South Dakota School of Mines and Technology with Dr. Xinhua Bai as the institutional lead, and Yale University with Dr. Reina Maruyama as the institutional lead, were approved as full members. The Moscow Engineering Physics Institute (Markus Ackerman for DESY/ Dortmund sponsor, A. Petrukhin, R. Kokoulin, A. Bogdanov, S. Khokhlov, E. Kovylyaeva) and Queen Mary University of London - (Ty DeYoung for PSU sponsor, Teppei Katori) were approved as associate members.

As of March 2014, the IceCube Collaboration consists of 43 institutions in 12 countries (18 U.S. and 25 Europe and Asia Pacific).

The list of current IceCube collaborating institutions can be found on:
http://icecube.wisc.edu/collaboration/collaborators

IceCube Major Meetings and Events

IceCube Spring Collaboration Meeting – Banff, Canada	March 3-8, 2014
IceCube Software & Computing Advisory Panel Meeting – Madison, WI	April 1-2, 2014
Neutrinos Beyond IceCube Workshop – Arlington, VA	April 24, 2014
IceCube Educations and Outreach Advisory Virtual Panel Meeting	May 14, 2014
IceCube Fall Collaboration Meeting – Geneva, Switzerland	September 15-19, 2014

Acronym List

CVMFS	CernVM-Filesystem
DAQ	Data Acquisition System
DOM	Digital Optical Module
IceCube Live	The system that integrates control of all of the detector’s critical subsystems; also “I3Live”
IceTray	IceCube core analysis software framework, part of the IceCube core software library
MoU	Memorandum of Understanding between UW–Madison and all collaborating institutions
SBC	Single-board computer
SNDAQ	Supernova Data Acquisition System
SPE	Single photoelectron
SPS	South Pole System
SuperDST	Super Data Storage and Transfer, a highly compressed IceCube data format
TDRSS	Tracking and Data Relay Satellite System, a network of communications satellites
TFT Board	Trigger Filter and Transmit Board
UPS	Uninterruptable Power Supply
WIPAC	Wisconsin IceCube Particle Astrophysics Center