IceCube Maintenance & Operations
Fiscal Year 2011 Mid-Year Report

October 1, 2010 - March 31, 2011

Submittal Date: March 31, 2011

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 FY2011 Mid-Year Report is submitted as required by the NSF Cooperative Agreement ANT-0937462. This report covers the six month period beginning October 1, 2010 and concluding March 31, 2011. The status information provided in the report covers actual common fund contributions received through February 28, 2011 and the full 79-string IceCube detector (IC79) uptime through 28 February 2011.

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Section I – Maintenance and Operations Status and Performance

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.

- Operations Management and Science Support: The FY2011 Maintenance and Operations Plan (M&OP) was submitted and reviewed by NSF. The personnel supporting IceCube M&O during FY2011 were identified by name as part of the IceCube M&O five-year proposal. Updates and changes to the personnel plan are made in consultation with the Operations Director, Collaboration Spokesperson, and the Leads at the Collaborating Institutions to ensure coverage on all critical M&O tasks.
- Computing Infrastructure Management: We continue to manage computing resources to maximize uptime of all computing services and ensure the availability of required distributed services, including storage, processing, database, grid, networking, interactive user access, user support, and quota management.
- Financial Management: The IceCube Research Center (IRC) at the University of Wisconsin-Madison created three separate accounts for collecting IceCube M&O funding and collecting and reporting related costs: 1) NSF M&O Core Account; 2) U.S. Common Fund Account; 3) Non U.S. Common Fund Account. A total of $6,900,000 was released to UW-Madison to cover the M&O costs during FY2011, including a total contribution of $928,200 to the IceCube M&O U.S. Common Fund. A total amount of $877,560 was committed during the first half of the fiscal year to the six U.S. sub-awardee institutions. Sub-awards were issued through the established University of Wisconsin-Madison requisition process (details in Section III).

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 South Pole.

Software Coordination **–** A review panel for permanent code was assembled for the IceTray-based software projects and to address the long term operational implications of recommendations from the Internal Detector Subsystem Reviews of the on-line software systems. The permanent code reviewers are working to unify the coding standards and apply these standards in a thorough and timely manner. The internal reviews of the on-line systems mark an important transition from a development mode into steady-sate maintenance and operations. The reviews highlight the many areas of success as well as identify areas in need of additional coordination and improvement.

Work continues on the core analysis and simulation software to rewrite certain legacy projects and improve documentation and unit test coverage. The event handling in IceTray is being modified to solve two related problems: 1) the increasing complexity of the triggered events due to the size of the detector and the sophistication of the on-line triggers and 2) the increasing event size due to different optimizations of the hit selections used in different analyses.

Education & Outreach – The anticipation and completion of construction of the IceCube array gave rise to a growing number of outreach opportunities during this period.

1. For the second year, a high school science teacher and Knowles Science Teaching Fellow, traveled to the South Pole to help with IceTop. Katherine Shirey, a high school physics teacher from Arlington, VA, was selected from candidates who applied through the NSF's PolarTrec program. Ms. Shirey will be communicating via a live broadcast and through blogs with her students and other classrooms around the country. Her adventures were featured in the Washington Post and other media outlets.

2. The UW Space Place hosted a series of four talks by IceCube scientists and researchers about the nature of cosmic rays, working in Antarctica to construct IceCube, collecting the data, and new discoveries. Speakers included Professors Halzen and Westerhoff, researcher Krasberg, and driller Benson.

3. IceCube staff and grad students participated in a number of science fairs on and off campus, including the inaugural celebration of the Wisconsin Institutes for Discovery, the annual Physics Fair, Science Expeditions and the second year of Explorando las Ciencias at the UW Space Place. Several Spanish speaking graduate students described IceCube to an enthusiastic crowd from Madison’s Spanish speaking community. Lawrence Berkeley National Lab hosted a lab-wide open house on October 2nd for about 3000 visitors. Seven IceCube scientists spoke with many of the visitors and provided interactive displays for them.

4. Albrecht Karle gave the Plenary Address at the Wisconsin Association of Physics Teachers annual meeting. This meeting was held in conjunction with the Minnesota Association of Physics Teachers and the Wisconsin Society of Physics Students. Prof. Karle brought the audience up-to-date on the IceCube construction project and recent analysis results.

5. During the period of this report IceCube researchers gave over 50 talks and interviews for groups ranging from pre-school to retired folks. Interviews were for radio, webcasts, and television. IceCube winterovers conducted a number of teleconferences with schools and media around the world.

6. After the completion of construction IceCube was the subject of over 90 press and web media stories around the world including the Washington Post, NPR, Wired, Scientific American and IEEE Spectrum. The YouTube video of the deployment of the final string was viewed over 19,000 times. The National Science Foundation issued a press release (10-238) for IceCube’s completion and featured IceCube on its website with photos and video. UW—Madison, Lawrence Berkeley National Lab, and Penn State also press releases as did some of the European collaborating institutions.

Detector Operations and Maintenance

Detector Performance **–** The full 79-string IceCube detector (IC79) operated 93.0% of the time during the period from 1 October 2010 through 28 February 2011. Figure 1 shows the cumulative detector time usage. Good performance, i.e., better than previous years, was achieved during the austral summer construction and maintenance season. Seven new strings and eight IceTop stations were commissioned. The initial in-ice verification, calibration, and geometry of the full detector were completed in 66.2 hours of detector time. Data from various verification tools (e.g., dust loggers, in-ice cameras, etc.) studied details of the ice properties for 31.6 hours of detector time. All 52 detector control and processing compute nodes were replaced on the South Pole System (SPS) resulting in a loss of merely 1.5 hours of detector uptime. Unexpected downtime due to routine hardware failures was 0.5%.

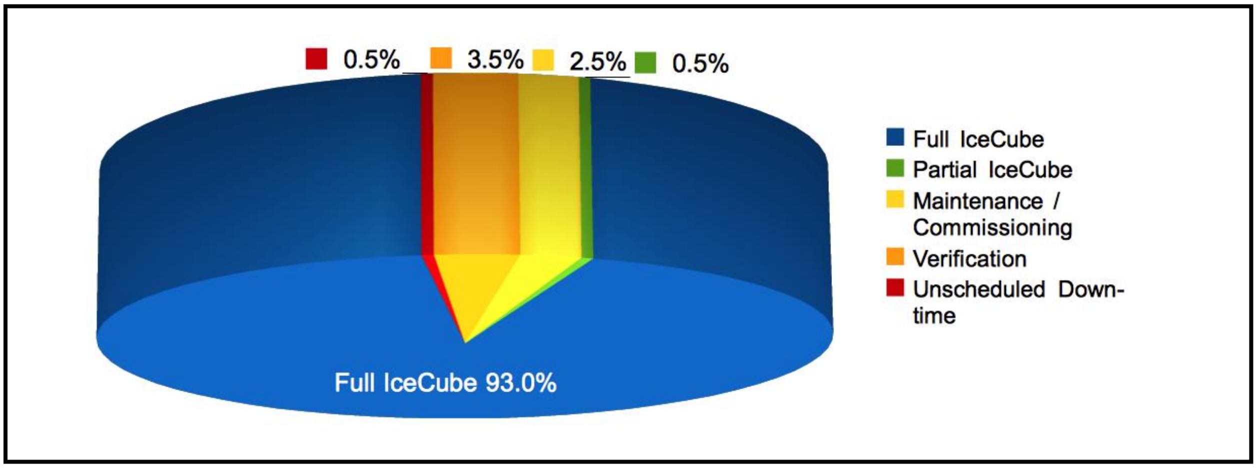


Figure 1: Cumulative IceCube Detector time usage, 1 October 2010 – 28 February 2011

The average detector uptime was 97.2%. Of this, 89.4% of the data was standard analysis, clean uptime. Figure 2 shows improved stability in the average monthly uptime over the past three years.

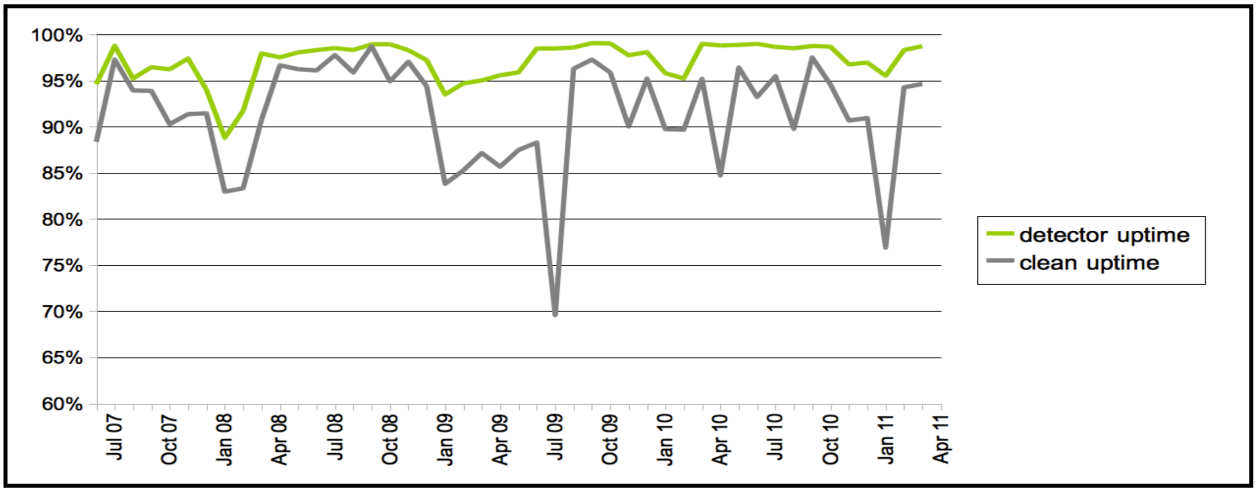


Figure 2: Total IceCube detector uptime and clean uptime since June 2007

The preliminary good run list for IC79, including May to November 2010, found 97% of the data suitable for physics analysis. The remaining 3% primarily consisted of calibration runs using non-standard triggers and in-situ light sources such as the LED flashers. These data are not suitable for normal analysis. However, a partition of the detector is operated with full physics triggers during calibration runs and these data would be analyzed in the event of an extraordinary astrophysical transient event.

IceCube Live Experiment Control is running V1.5.0. The *Recent* run monitoring page was upgraded to include the annotation of individual runs, sets of runs, periods of downtime, and a comment search feature. A real time view of the Processing and Filtering system was added to the *Status* page. Initial steps were taken toward merging run verification and run monitoring into IceCube Live aided by in-kind contributions. Scripted deployments of IceCube Live were implemented on the test and production servers on the South Pole System (SPS) and on the northern hemisphere servers at UW-Madison in advance of the SPS hardware upgrade.

The Data Acquisition (DAQ) released a new software version, *Hobees2*, in December. The run deployment process was streamlined and the server installation was tested and scripted for an efficient installation on the new SPS hardware to minimize detector down time.

Supernova DAQ (SNdaq) found 97.4% of the available run data met the minimum analysis criteria for run duration and data quality. Runs shorter than 10 minutes are now excluded because they contain insufficient data to identify an actual supernova candidate. The remaining down time was caused by operational issues that were subsequently mitigated.

The online filtering software is running release V10-11-00. Minor corrections and adjustments for the new SPS hardware and operating system were included in this release. Scripted software deployments were implemented and tested in advance of the SPS hardware upgrade.

The appropriate frequency of updating DOM calibration for in-ice and IceTop data taking was studied and widely discussed. In-ice calibration is very stable and the decision was made to calibrate in-ice DOMs once per year, at the start of the physics run. IceTop DOMs are affected by weather and seasonal muon rates and will continue to be calibrated monthly.

Two remote-controlled camera systems were connected to the bottom of string 80 for deployment on December 18. The cameras were operating during the entire descent down the hole while LED lamps and lasers lit up the ice wall structure. The overall structure of the dust layers in the deep ice was clearly seen and a volcanic ash layer was observed at 306 meters, exactly as predicted. The cameras now reside a few meters below the deepest optical module, at 2,453 and 2,458 meters. Short daily observations were taken during the freezing of the hole and continued once per week through March 2011 after which time monthly observations will be taken. The observations showed that the frozen hole consists of very transparent ice with some fissures and a central column of ice containing bubbles. The ice bubbles correspond to about 15% of the refrozen ice. The freeze-in period lasted two and a half weeks during which time the pressure in the hole reached 530 bar.

IC86 Physics Run Preparation – The IC86 physics run will begin on 28 April 2011. Seven new in-ice strings and 8 IceTop stations were commissioned. The TFT board is finalizing the physics filter content. The DAQ *Jupiter* release will improve reliability of the central server, resolve a long-standing bug affecting extremely long trigger requests, and deliver the Slow Monopole trigger. On-line filtering improvements will include better system stability when many very short runs are taken consecutively.

The spacing of the DOMs within the detector array has been verified to within 1 meter using LED flashers combined with deployment data from pressure sensors and the drill. Ninety-eight percent of all IC86 in-ice DOMs are functioning normally. Significant DOM anomalies were noted on Strings 1, 7 and 14 as follows.

- All String 1 DOMs have unusually high data rates, Figure 3. No contributing factors were identified during string deployment or commissioning activities. The rates are asymptotically decreasing with time. This unusual situation is being studied. Special string configurations are being considered as part of including String 1 with the IC86 physics run.
- 11 DOMs on String 7, between positions 34 and 46, have operational issues. Seven DOMs do not power up, two do not trigger, and two have low rates. All are being studied and may not be included at the start of the IC86 physics run.
- Surface cable damage on String 14 disabled sixteen DOMs. It was quickly repaired by engineering personnel and the string operates normally.

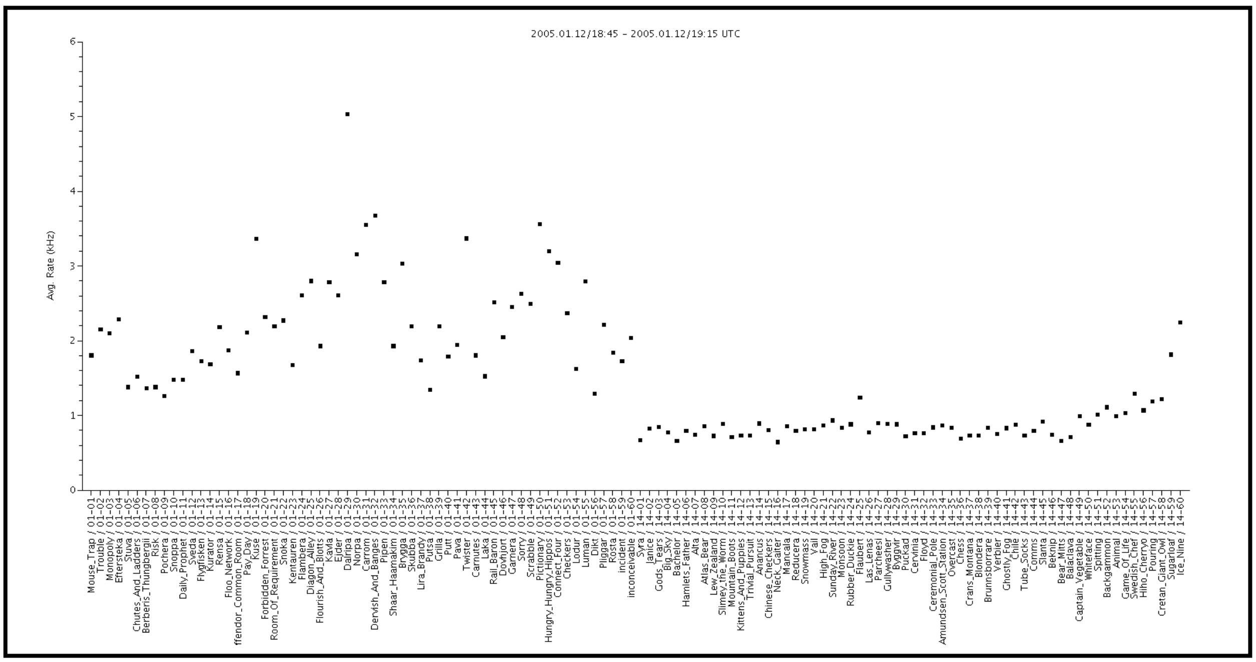


Figure 3: String 1 DOM rates (left half) and a *normal* String (right half)

TFT Board – The Triggering, Filtering and Transmission (TFT) board is in charge of adjudicating SPS resources according to scientific need. Working groups within IceCube submitted approximately 20 proposals requesting data processing, satellite bandwidth, and the use of various IceCube triggers. More sophisticated online filtering data selection techniques are used on the SPS to preserve bandwidth for other science objectives.

Computing and Data Management

Computing Infrastructure – Replacement of the SPS server hardware was completed during the 2010/11 austral summer. Detailed planning and close coordination with the detector subsystem experts enabled the transition to 52 new Dell servers without major incident. The South Pole Test System at UW–Madison was also upgraded with Dell servers to mirror SPS functionality. The DOM hubs and taping computers were not included in this replacement cycle.

DAQ, PnF and IceCube Live system experts deployed a set of scripts to ensure a seamless transition based on the Python-based 'Fabric' system (V0.9). Troubleshooting of these scripts was carried out in advance and the total detector downtime for the entire hardware upgrade was less than 1.5 hours. Advancements to the infrastructure include the following:

- Reduced and simplified to two server configurations to optimize sparing at Pole;
- Increased processing capability across all subsystems;
- Improved processing and filtering throughput by 25% and event reconstruction processing power by 100%;
- Doubled capacity of the taping system to accommodate the IC86 data rate;
- Installed two LTO-5 tape-changer units for evaluation;
- Prepared hot spares for critical systems to minimize detector downtime;
- Increased general spare inventory;
- Replaced Red Hat operating system with Scientific Linux (V5.5); and,
- Upgraded Nagios monitoring system with Dell plugins (V3.2.3).

Data Movement – Data movement goals were met despite some intermittent problems with the satellite link. A total of 115.6 TB of data were written to LTO tapes averaging 765.7 GB/day. A total of 13.7 TB of data were sent over TDRSS averaging 90.7 GB/day. Figure 4 shows the daily satellite transfer rates in MB/day through 28 February 2011. The steady IC79 filtered physics data, in yellow, dominates the total bandwidth. Figure 5 shows the data transfer backlog.

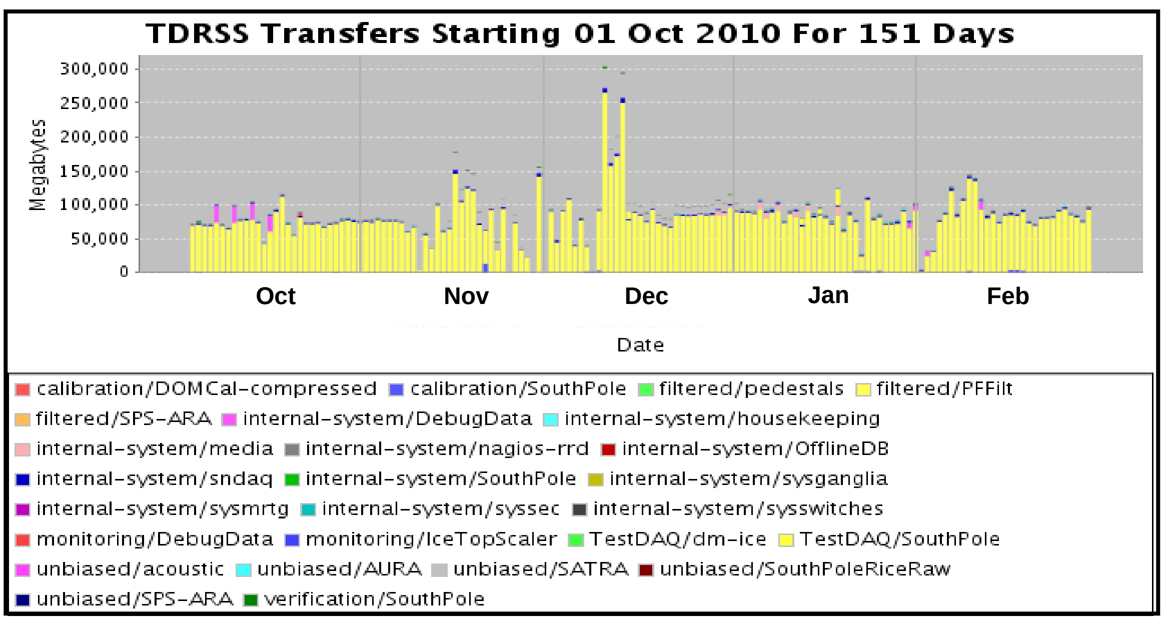


Figure 4: Daily data transfer rates across TDRSS

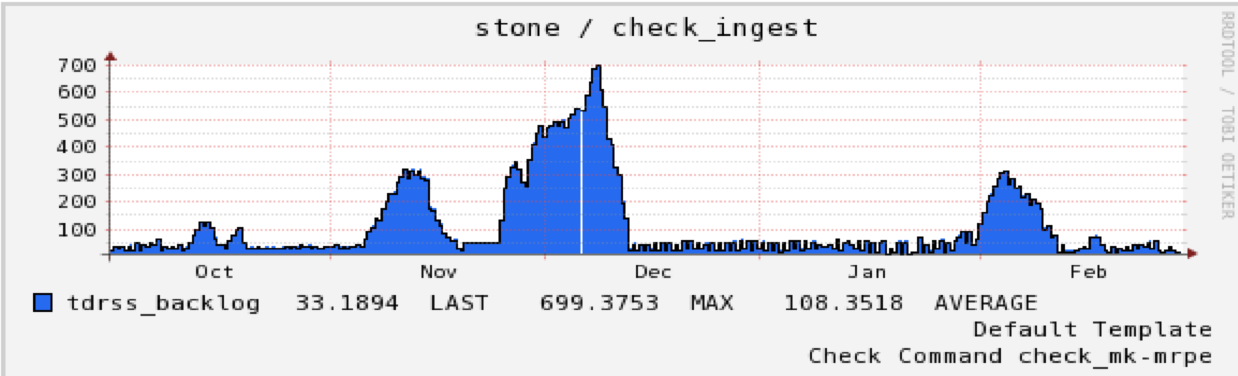


Figure 5: Daily data transfer backlog across TDRSS

Offline Data Filtering – The IC79 offline filtering script was finalized and processing commenced. The two-level processing in previous seasons was combined into one for IC79. For the first time, offline data filtering is done within the IceProd framework currently used for simulation production. In addition to fulfilling the objective of unifying the offline data and simulation filtering software, the various mass production features in IceProd are also harnessed for efficient data filtering. All processing is done on the npx3 computing cluster at UW–Madison. An average of 250 npx3 CPU cores are being used, resulting in 6000 CPU hrs per day. The storage requirement for the output level2 files is 200GB for 1 day of processed data or 6TB per month. Processing has reached an advanced stage. Offline data filtering is complete for 9 months of IC79 data taken from 31 May 2010 through 28 February 2011. It is expected that offline filtering will catch up with data taking by the end of March 2011.

Simulation – The IC59 production of simulation data has been completed with the exception of a few small datasets for special studies. Production of the background physics datasets using CORSIKA continued during the fall of 2010 and into the beginning of 2011 after an increase in available storage capacity for the data. A dramatic increase in the production of neutrino signal simulation data and special simulation data compensated for the reduced background data production. Production sites: Dortmund; EGEE - German Grid; SWEGRID – Swedish Grid; LONI – Louisiana Optical Network Infrastructure; GLOW – Grid Laboratory of Wisconsin; UMD – University of Maryland; NPX3 – UW IceCube; and, CHTC – UW Campus.

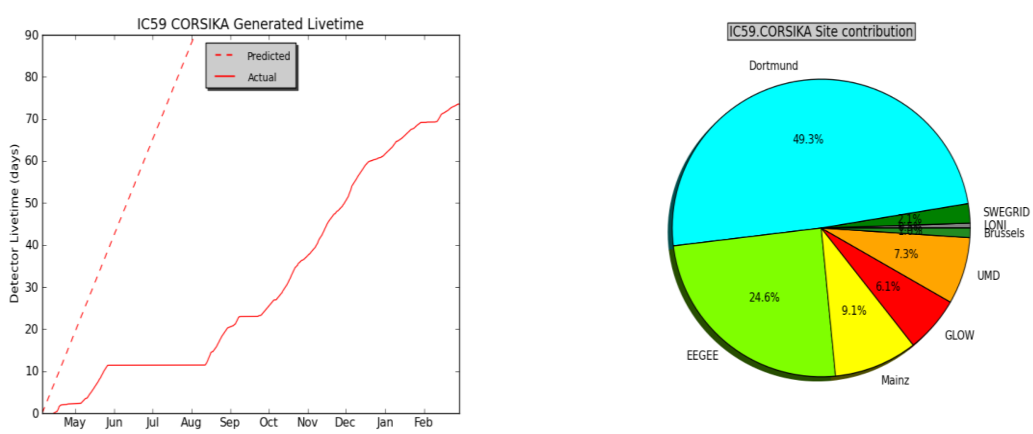
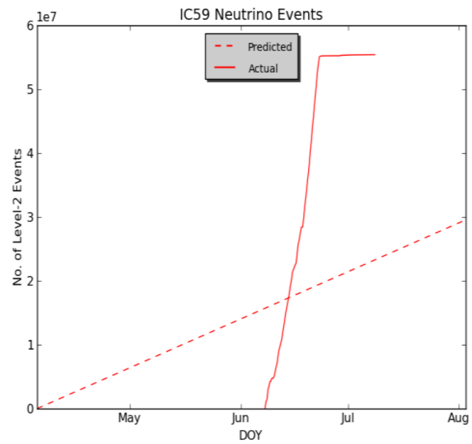


Figure 6: Left: Cumulative production of IC59 background events with CORSIKA generator (continuous line) compared with 2010 plan (dashed line). Right: Relative contribution of production sites to the background production.

Between June and August, the target of neutrino signal event generation, for all the types, exceeded the plan by more than a factor of two (Figure 7) with a total of 18 CPU-years used.



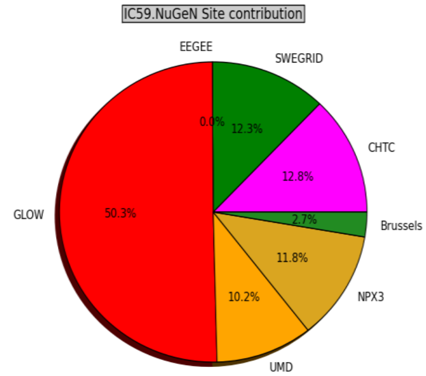


Figure 7: Left: Cumulative production of IceCube-59 neutrino events (continuous line) compared with 2010 plan (dashed line). The graph includes the generator of electron neutrinos, muon neutrinos and tau neutrinos. Right: Relative contribution of production sites to the neutrino signal production.

Production of IC86 benchmark datasets for background and neutrino signal (all types) exceeded the original plan. Benchmark datasets were produced with the newly developed direct photon propagation as an alternative to the current use of the bulky lookup photon tables. Dedicated physics datasets for IC40 were generated in DESY and in the Swedish Grid to address specific data analyses. Preparations are underway to begin production of the IC79 detector simulation which will start in the coming days.

The ICL fire suppression system installation was finalized by RPSC in November. A test plan was designed in conjunction with RPSC to simulate all possible ICL emergencies while minimizing the effects on the operating detector. The joint planning meshed well and the commissioning of the fire suppression system was a success. We thank RPSC for their professionalism and cooperative spirit in the planning and commissioning of the system.

A software professional was added at 0.5 FTE and a Programmer in Training at 0.5 FTE in shared support of DAQ and IceCube Live. A Data Migration Manager at 0.5 FTE was added in support of Data Management.

Section II – 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 Funds Account; and, 3) Non U.S. Common Funds Account.

A total of $6,900,000 was released to UW–Madison to cover the costs of Maintenance and Operations during FY2011. Of this amount, funds totaling $928,200 were directed to the IceCube M&O U.S. Common Fund Account and the remaining $5,971,800 were directed to the IceCube M&O Core Account (Figure 8).

FY2011	Funds Awarded to UW
IceCube M&O Core Account	$5,971,800
U.S. Common Fund Account	$928,200
TOTAL NSF Funds	**$6,900,000**

Figure 8: NSF IceCube M&O Funds - Federal Fiscal Year 2011

A total amount of $877,560 of the IceCube M&O FY2011 Core Funds was committed to six U.S. subawardee institutions during the first half of FY2011. Subawardees are submitting invoices to receive reimbursement against their actual IceCube M&O costs. Deliverable commitments made by each subawardee institution are monitored throughout the year. Figure 9 summarizes M&O responsibilities and total FY2011 funds for the six subawardees.

Institution	Major Responsibilities	FY2011 M&O Funds
Lawrence Berkeley National Laboratory	Detector Verification; Detector Calibration.	$65k
Pennsylvania State University	Detector Verification, high level monitoring and calibration;	$34k
University of California at Berkeley	Calibration; Monitoring	$82k
University of Delaware, Bartol Institute	IceTop Surface Array Calibration, Monitoring and Simulation	$166k
University of Maryland at College Park	Support IceTray software framework; on-line filter; simulation production.	$499k
University of Wisconsin at River Falls	Education & Outreach	$31k
Total		**$878k**

Figure 9: IceCube M&O Subawardee Institutions - FY2011 Major Responsibilities and Funds

IceCube M&O Common Fund Contributions

The IceCube M&O Common Fund (CF) 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 updated the Ph.D. author count at the Spring Collaboration meetings in conjunction with the update to the IceCube Memorandum of Understanding for M&O.

Figure 10 summarizes the Common Fund contributions for Year 4 of IceCube Maintenance and Operations:

	PhD Authors *	Planned		Actual Received to date (02/28/11)
Total Common Funds	**127**	**$1,733,550**		**$1,712,704**
U.S. Contribution	68	$928,200		$928,200
Non-U.S. Contribution	59	$805,350	Cash Transfer	$729,904
			Approved In Kind	$ 54,600

Figure 10: Planned and Actual CF Contributions, for Year 4 of M&O, April 1st, 2010 – March 31st, 2011
** Based on IceCube Institutional Memorandum of Understanding v8.3*

CF contributions received to date are only $21k less than planned for fourth year of IceCube operations.

Common Fund Expenditures
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 were listed in the Maintenance & Operations Plan.

Section III – Project Governance & Upcoming Events

The detailed M&O institutional responsibilities and PhD authors head count are being revised twice a year for the IceCube collaboration meetings, as part of the institutional Memorandum of Understanding (MoU) documents. The MoU was last revised in September 2010 at the Fall collaboration meeting in Brussels and the next revision will be posted in April 2011 at the Spring collaboration meeting in Madison. Common fund accounts were created and contributions for year 4 of M&O have been collected by the University of Wisconsin–Madison. The revised IceCube Collaboration Governance Document (Rev 6.4) was submitted to NSF on February 23, 2011, as appendix to the FY2011 Maintenance and Operations Plan (M&OP).

IceCube Major Meetings and Events

IceCube Collaboration Meeting, Brussels	September 20-23, 2010
IceCube IOFG Meeting, Brussels	September 24, 2010
Special Devices Readiness Review	October 5, 2010
DAQ Subsystems and Test DAQ Review	November 17-18, 2010
Monitoring & Verification Review	November 30 – December 2, 2010
On-line Processing & Filtering Review	December 6-7, 2010
IceCube Collaboration Meeting, Madison	April 25 – May 2, 2011
IceCube Detector Completion Event	April 28, 2011
IceCube Invites Particle Astrophysics	April 29-30, 2011

Acronym List

CF	Common Funds
DAQ	Data Acquisition System
DOM	Digital Optical Module
IceCube Live	The system that integrates control of all of the detector's critical subsystems
IceProd	IceCube Simulation production custom-made software
IceTray	IceCube Core Analysis software framework is part of the IceCube core software library
ICL	IceCube Laboratory (South Pole)
IRC	IceCube Research Center
M&OP	Maintenance & Operations Plan
MoU	Memorandum of Understanding between UW-Madison and all collaborating institutions
PnF	Process and Filtering
SPS	South Pole System
TDRSS	The Tracking and Data Relay Satellite System is a network of communications satellites
TFT Board	Trigger Filter and Transmit Board