IceCube Maintenance & Operations
Fiscal Year 2008 Final Report

October 1, 2007—September 30, 2008

Submittal Date: September 12, 2008

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-0639286.

Foreword

This FY08 Annual Report is submitted under Cooperative Agreement Number ANT-0639286. This report covers the 12-month period beginning October 1, 2007 and concluding September 30, 2008. The cost data contained in this report has not been audited. Cost information is based on actual data through July 31, 2008 with projected performance through the end of the federal fiscal year (September 30, 2008). Actual Performance data through September 30, 2008 will be provided as a supplement to this report no later than November 15, 2008.

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Section I – FY08 Summary of Accomplishments and Issues

Detector Operations

Data - Quality

Production of analysis quality data ranks top among the deliverables of the detector operations group. The IceCube online monitoring system continues to operate as a web-based tool whereby collaboration member institutions staff rotating shifts to examine the monitoring output of each run and report inconsistent behavior to the run coordinator and instrumentation maintenance personnel who track detector problems including malfunctioning channels. In addition to the online monitoring system which examines low-level quantities from the data stream, the verification group has established a web-based monitoring system which examines higher-level production of the data such as track reconstructions.

Data - Throughput

The transition from IC-22 to IC-40 detector configurations saw a jump in the event rate from 680 events per second (2.7 MB / sec data rate) to 1150 events per second (5.5 MB / sec data rate). The 18 new strings from the 2007-2008 deployment season were commissioned and accepted into the IceCube DAQ on April 4, 2008 and the online filter began real-time filtering on April 20, 2008. The IceCube DAQ continues to accept trigger information from AMANDA and the data streams from the two detectors are joined in a Joint Event Builder together producing 6.5 MB per second which is written to tape and also passed to the online filter which selects interesting physics events for satellite transmission.

Data - Archive

The satellite data is transferred daily via TDRSS to the UW Data Warehouse where it is archived permanently.

System Sustainability - Technical Documentation

A complete system-level document detailing the technical aspects of IceCube is still forthcoming. An assortment of operation manuals from the various subsystems are available on the IceCube Wiki and in the DocuShare documentation archive located at the following links:

Wiki: http://wiki.icecube.wisc.edu
DocuShare: https://docushare.icecube.wisc.edu/dsweb/HomePage

System Sustainability - Software Library/Revision History

The IceCube application-level DAQ and online software sources are kept under version control in the Subversion archive at http://code.icecube.wisc.edu. The migration of the DOM low-level source code (C, assembly and VHDL sources) from LBNL to UW has taken place and the LBNL repository is now being phased out.

System Sustainability - Maintenance and Upgrade Procedures

Only tagged, released software is run for production data. Test runs which are marked as such are allowed by request to the run coordinator with sufficient justification and for a limited time. Released DAQ software must pass a standard battery of tests on the Northern Hemisphere test system prior to deployment at Pole. A special 24-hour period is set aside for such new

deployments of code which are only tagged as *release candidates*. After the 24-hour final acceptance test run is complete, the previous stable revision of the code is redeployed until review of the monitoring and verification outputs is finished. The release candidate must pass this review before it is designated a final release and deployed permanently at SPS.

Detector Performance - DAQ Uptime

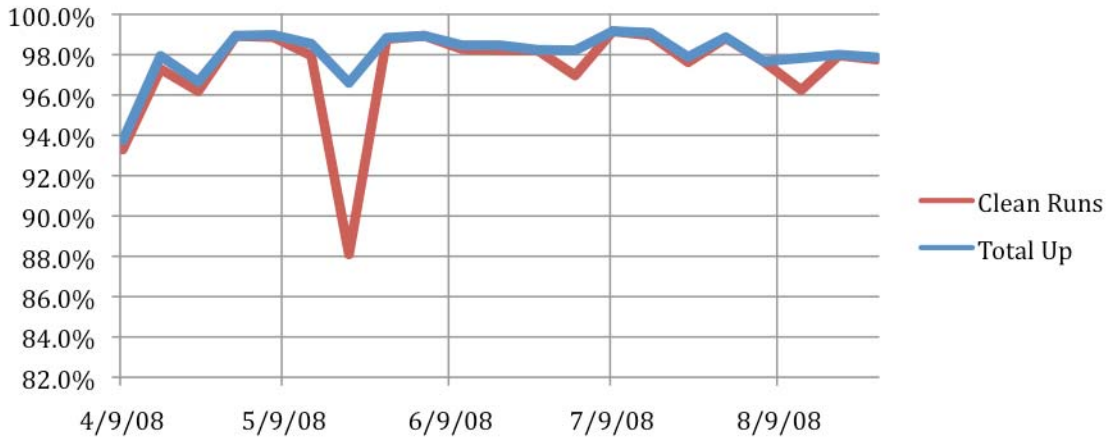

Figure 1. Graph of pDAQ Uptime from beginning of IC-40 run.

The IceCube DAQ uptime (weekly average) since April 4, 2008, is shown in Figure 1. The uptime is expressed as a fraction and plotted as two quantities. Total uptime shows the availability of at least some portion of the detector to transient astrophysical events (galactic supernovae, GRBs, etc.) Clean run uptime establishes some quality cuts and represents an estimate of the detector availability for a general science analysis. In both cases the availability of the detector for the IC-40 run has been well in excess of the 95% goal.

The noticeable dip in detector availability during mid-March occurred due to a confluence of unrelated occurrences: in addition to scheduled maintenance, the detector lost time due to DAQ hardware failures and computing cluster file system problems. We are working on improvements on the cluster monitoring in order to detect and react quickly to the latter two classes of problems.

Detector Performance - Satellite Bandwidth Utilization

Approximately 35 GB per day of data are sent north to the Data Warehouse. The bulk of this data is filtered data, while the remainder is from the supernova system, the monitoring system, and the data verification system. Figure 3 shown on page 9 shows the data transfer over the TDRS system from October 1, 2007 to September 9, 2008. During this period, about 11 TB of data was transferred at about 32 GB per day.

Detector Performance - DOM Mortality

Failures in the IceCube digital optical module hardware can be broadly classed into two categories: (1) failures during or immediately following deployment – so-called “infant mortality”, and (2) spontaneous failures thereafter. A further sub-classification groups the failures into those, which render the sensor completely or nearly useless, and those, which are with reasonable effort, mitigable. As of September 1, 2008, 2560 DOMs have been deployed,

2484 of which operate at full functionality. The remaining 74 DOMs' problems are classified into various categories:

- 26 have broken LC hardware
- 34 are unplugged, most because they did not refreeze in time for the IC-40 run
- 14 are dead (uncommunicative) or otherwise useless

Two new DOMs failed during the past 12 months in ice.

Detector Performance - Science Data Volume Growth

The combined IceCube and AMANDA detectors produce over 500 GB per day raw data which must be taped at the South Pole. This data remains an insurance policy in the event that the collaboration decides that it is necessary to refilter the raw data. Currently it appears that no substantial refiltering activity will take place for the IC-40 run.

The move from IC-22 to IC-40 saw a large jump in raw data output. During this time the physical extent of the array almost doubled — something that will not take place in future years. Nevertheless, the filtered data stream grew only modestly, from 25 GB per day to 35 GB per day. In the future years the collaboration expects to see improvements in the online filter both from improvements in the algorithms and growth in computing power available at South Pole. Simultaneously, the collaboration seeks to maximize the science potential and push the sensitivity of the array down to detect the weak cosmic neutrino fluxes. Moreover new science goals are being developed. The satellite bandwidth requests will continue to increase in coming years in an attempt to meet these goals.

Detector Performance - Problem Reports

Detector hardware problem reports are handled via the Non-Conforming Materials (NCM) process developed for the IceCube MRE production phase of the project. Software problem reporting is sub-system dependent: the IceCube DAQ group uses the Mantis bug reporting software while the online and monitoring system uses the RT issue tracking software package.

Science Operations

The category of science operations covers the following broad areas for IceCube operations:

- Online Filtering at the South Pole for data transmission over satellite
- Northern Hemisphere Data warehouse system
- Simulation production and coordination
- Northern Hemisphere production processing and reconstruction of data
- Core online & offline development framework, code repository and build system
- Calibration and high-level detector verification

Online Filtering at the South Pole for data transmission over satellite

The online filtering system at the South Pole is responsible for taking all data readout by the DAQ system in response to basic trigger algorithms, and selecting neutrino candidate events or other physics selected events for transmission over the satellite to the Northern Hemisphere where further processing and analysis is performed. In addition to filtering the data, the online system merges the separate events from the IceCube and TWR DAQ systems into a single frame

and performs calibrations on the data. The merged events are moved out to an online reconstruction farm, which then applies fast reconstruction algorithms that are used for event selection. Currently, there are three data streams from the online system: (1) all data is passed to a tape archiving system at the South Pole for archival storage, (2) the filtered data is compressed and queued for transmission over the satellite, and (3) an event summary DST is written with reconstruction information for all events which is also sent to the Northern Hemisphere over the satellite. The DST stream applies more sophisticated track fitting algorithms for events with larger number of hits so we have a "sky map" with reasonable angular resolution for all moderately sized events.

The increase in detector size from 22 to 40 strings increased the trigger rate by approximately 50% to 1200 HZ. This higher data rate required more selective filters to be developed during this year to allow for the limited satellite bandwidth allocated for IceCube. More demanding likelihood based reconstructions are applied to the events at the online filtering farm to allow more restrictive event selection at pole without impacting the final physics selection. The higher cpu usage needed for these more advanced algorithms was only partly provided by additional hardware and extensive software optimization was used to achieve this goal.

Details and documentation are maintained on a wiki webpage located at: http://wiki.icecube.wisc.edu/index.php/TFT_2007_Season_Planning. Figure 2 shows a recent snapshot of the status page, and details the various filters with their individual passing rates.

IceCube Detector Summary

Status as of : 2008-09-09T21:27:04Z

Date	DAQ	TWR	SN	PNF	SPADE	Run	Events
2008-09-09T21:27:04Z	Started	Started		Started		111617	1602148

Current DAQ Run	
Number	111617
Start Time	2008-09-09 21:06:26.619128
physics	1602148 events
monitor	5084564 events
sn	3047900 events
tcal	2929342 events

Previous DAQ Run	
Number	111616
Start Time	2008-09-09 13:02:37.983031
Stop Time	2008-09-09 21:04:18.177532
physics	36956420 events
monitor	110301397 events
sn	70708524 events
tcal	70678466 events

Previous TWR Run	
Number	111615
physics	6577792 events

PnF Summary for Run	
Number	111617
Event	1590000
Clients	0
Trigger Rate	1275.04
Processing Rate	1329.43
Summary Age	PT4S

PnF Physics Filter Rates

Filter	Hz	Filter	Hz
AtmMuonFilter_08	0.367521	CascadeFilter_08	15.9145
DownGoingContained_08	12.265	EHEFilter_08	1.07692
FilterMinBias_08	0.470085	I3DAQDecodeException	0
ICDownStarting_08	1.74359	ICLowEnergyContainedFilter_08	4.76068
ICMuonFilter_08	19.8291	IceTopSTA3_08	2.13675
IceTopSTA3_InIceSMT_08	1.99145	IceTopSTA8_08	0.487179
InIceSMT_IceTopCoincidence_08	1.51282	JAMSFilter_08	3.51282
LECascadeFilter_08	7.03419	LowUpFilter_08	11.3333
MoonFilter_08	12.8547	PhysicsMinBiasTrigger_08	0.384615
TWRDAQDecodeException	0	Total	84.9829
ULEEFilter_08	1.54701		

Figure 2. A snapshot of the IceCube status page showing the trigger and filter rates.

Northern Hemisphere Data warehouse system

The Data Warehouse facility is comprised of online disk storage, tape library systems, archival backup storage systems and software systems to store data. This facility backs up and catalogs a number of data streams, which are then available to the entire IceCube collaboration. The primary data stored in online disk is the satellite data transmitted to the Data Warehouse after online filter selection, post satellite production processing data sets and Monte Carlo production data sets, as well as some lower level detector verification and calibration data.

Figure 3 below shows the satellite data transmission for the last 11+ months. This data is then processed with stages of higher level production processing algorithms (see section below) with various datasets stored in online disk and some earlier steps archived into the tape archiving system. The net effect is an overall increase in the size of the online data set.

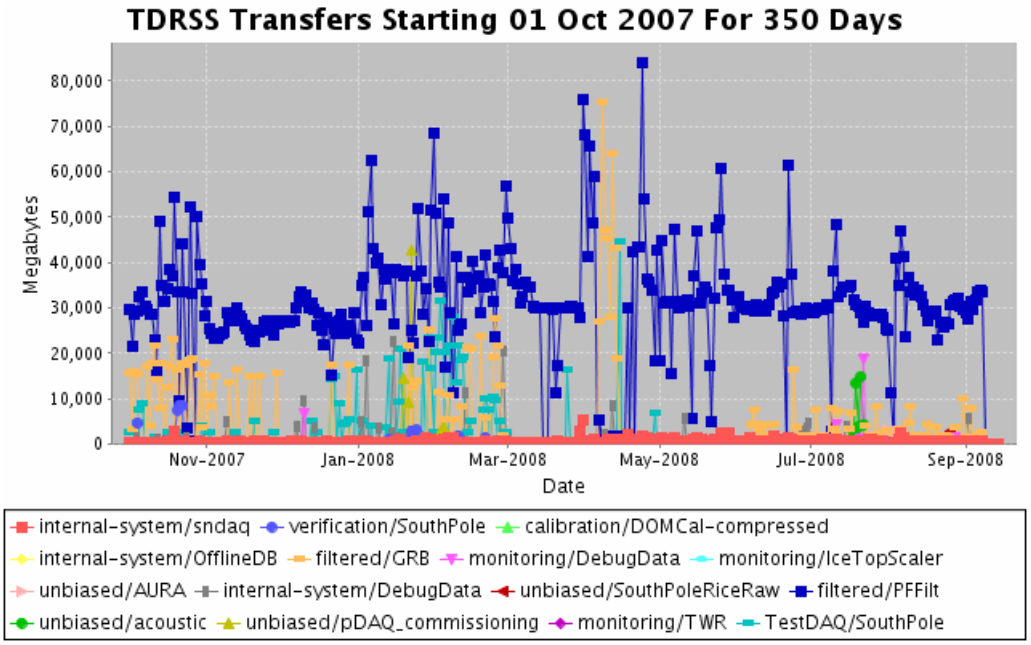

Figure 3. The daily rate of data transmitted over the satellite from IceCube. The typical rate since the beginning of IC 40 operations is slightly over 32 GB per day, with peaks due to backlog catch ups and calibration data.

Collaboration access to the Data Warehouse is provided in a number of ways, depending on the needs of the users. Details on how to access data can be found on the IceCube wiki and are located at http://wiki.icecube.wisc.edu/index.php/Data_Warehouse. Access methods include shell and scp copies, which allow for efficient transfer of large data sets as needed.

Issues experienced last year with the South Pole tape archiving system due to environmental conditions were fixed by moving the taping system to the B2 science area and providing localized humidification to the tape drives with a small ultrasonic humidifier. The new tape archiving system is functioning and will simplify data access for transient physics events.

Simulation production and coordination

Simulation production is responsible for providing large data sets of background and signal Monte Carlo for the collaboration working groups. All requests from the working groups go to the central coordinator at the University of Wisconsin-Madison, Paolo Desiati, who then maximizes the efficiency by producing common data sets wherever possible for all analysis. The Monte Carlo production is distributed among the collaboration in a coordinated way so as not to duplicate effort. The data sets are collected and cataloged at the UW Data Warehouse. Tools to distribute the production among the collaboration are provided by this category. The largest production site is at the UW Data Center with other major sites at DESY, Maryland, SUBR and the Swedish Grid.

Simulation for the 22 string detector configuration (IC-22) was complete and a improved version for production for the 40 string configuration (IC-40) was released. Shown in Figure 4 is the amount of background events produced for the IC-22 configuration at the different production sites for a cumulative total of 1 billion events. The figure shows a relative even share of the total production at the different production sites.

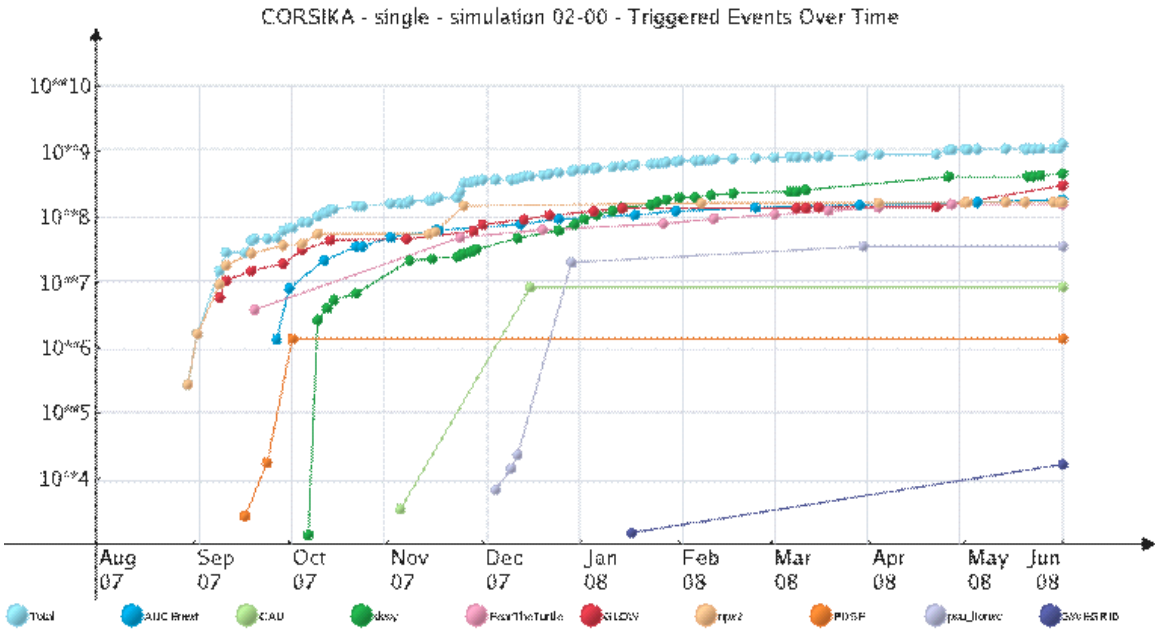

Figure 4. Time integrated distribution of produced background monte-carlo events showing the share of the individual compute clusters used.

Northern hemisphere production processing and reconstruction of data

This operations category represents the centralized production processing of the data for the collaboration. This is done in a centralized location coordinated with all physics working groups in order to avoid duplication of effort. The entire satellite data set is processed with successive levels of reconstruction and filtering, with the early stages of calibration and reconstruction common to all physics topics.

All data of the IC-22 configuration were processed at the Madison Data Center. Table 1 gives an overview of the used resources in this effort.

Number of jobs	> 115,000
Total CPU time	> 9,000 Days
Data produced	> 50 TByte (13 TByte online)

Table 1: Production processing statistics.

The production processing system was also used to process data at higher filter levels for physics analysis. Results from this higher level filtering were used in a data challenge to test the readiness of the point source analysis. This data challenge consisted of a scrambled subset of the reconstructed events, which was scaled up to represent the full expected background for the

analysis plus an artificially injected number of source events. Figure 5 shows the resulting skymap of the full sky neutrino map with an excess at the position of the injected signal. Table 2 compares the reconstructed position with the injected signal events position verifying the angular resolution of the IceCube detector.

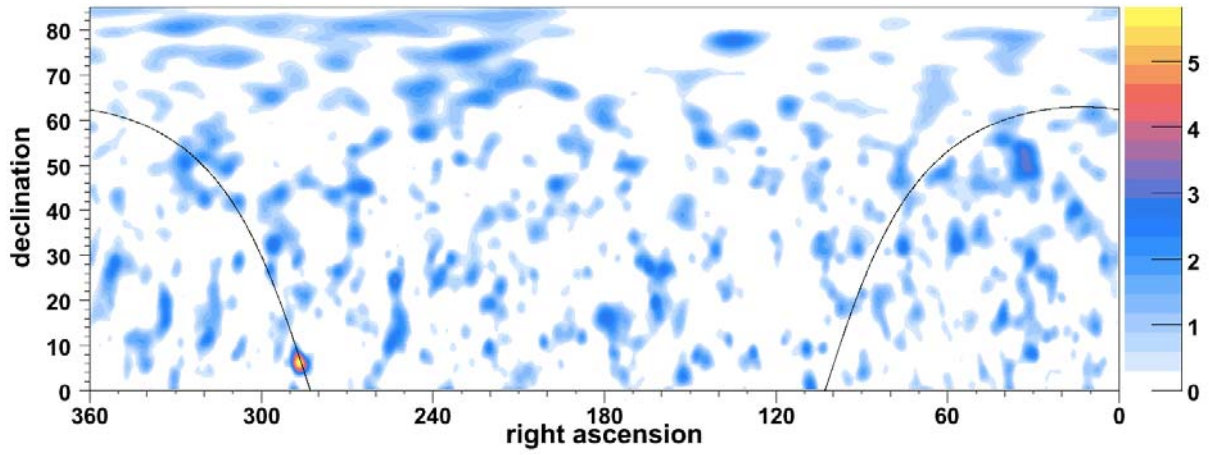

Figure 5. The reconstructed skymap of the data challenge showing the injected fake signal at the expected position.

	Right Ascension	Declination
Injected	287.0°	6.3°
Reconstructed	286.55°	6.05°

Table 2: Comparison of injected an reconstructed position during the data challenge.

Operations Support

Management & Administration

NSF funding totaling $3.0M was released to cover Maintenance and Operations cost and effort during FY 2008. All subawards for M&O support during FY08 were ready for signature when these funds were received, and shortly after M&O funds were received the subaward funding was fully committed. Deliverables tied to each contract are represented in its M&O Memorandum of Understanding (MOU) and the IceCube Operations/Analysis Plan. Additionally, this FY08 Annual Report is due September 30, 2008 covering the period October 1, 2007 through September 30, 2008.

Facilities and Real Property Management

UW real property inventories are tied to the funds used for their purchase. Since IceCube M&O funding is segregated within a unique account, all real property purchased with those funds is segregated as well.

Personnel Management

The personnel supporting IceCube M&O during the first 3 funding years have been identified by name as part of the submitted proposal from May 2007. The staffing plan was a joint effort of the University of Wisconsin-Madison and all subaward institutions.

Instrumentation R&D

Two complementary technologies for the IceCube Neutrino Observatory include the use of radio and acoustic sensors to extend the dynamic energy range within which neutrinos can be detected. The radio effort is largely a US effort led by the University of Hawaii at Manoa, Ohio State University, University of Wisconsin-Madison, University of Delaware-Bartol, Penn State University, and the University of Kansas. They are studying the feasibility of constructing a GZK radio detector to work in concert with the IceCube Neutrino Observatory and have submitted a separate proposal to the NSF related to this effort. The acoustic research is largely a non-US effort being led by DESY with the major US contribution coming from the University of California, Berkeley.

Engineering Science & Technical Support

A low energy core (Deep Core), is being planned as part of the IceCube construction end-game strategy. The instrumentation for the 1st Deep Core string has been purchased and built, and is planned to be installed during the FY2008-2009 South Pole Season.

Education & Outreach Coordination

The International Polar Year website featured IceCube on its page *IPY Projects Related to Ice Sheets,* December 13, 2007, Ice Sheet Day. The page contained a brief description of IceCube, links to the IceCube web site, and a profile of an IceCube scientist. IceCube team members participated in two webcasts from the South Pole as part of the Exploratorium's "Dispatches from Polar Scientists" on December 28, 2007 and January 12, 2008.

The IceCube Project is featured in a video production of Wisconsin Public Television and the Research Channel. Several IceCube scientists and engineers participated through taped interviews. Other video from the South Pole and from previous IceCube productions was incorporated into the segment. Research Channel is now available to more than 30 million U.S. satellite and cable television subscribers and more than 1.6 million viewers visit its website each year.

IceCube scientists throughout the collaboration shared their South Pole experiences by maintaining websites and blogs, by communicating by telephone from the South Pole, by being interviewed by their hometown newspaper, by visiting schoolrooms and by participating in various local science fairs and exhibitions. The University of Wisconsin-Madison and the University of Maryland participate in QuarkNet. The University of Wisconsin-River Falls continues to work with the Upward Bound program.

Section II – Major Technical Accomplishments

Over the past year, Detector Operations has achieved several major technical accomplishments. In April 2008, the DAQ and the online filtering system were successfully upgraded to handle the 18 additional strings deployed during the 2007/2008 South Pole field season. This was a major detector enhancement as the size of the detector array doubled during this period.

Operating procedures have also been put into place to maximize detector availability. This includes procedural changes to the maintenance and calibration processes whereby at least half of the detector is kept in "live" mode during routine monthly calibrations. An automated paging system, used to alert the winterover operators and personnel in the northern hemisphere when a subsystem fails, was also implemented.

The experimental control framework is in the process of being enhanced by a new initiative called *IceCube Live!*, which will primarily serve as an alert system for Supernova detection. *IceCube Live!* will also allow for real-time control and monitoring of the operating detector, even over the low bandwidth Iridium link, and will comprehensively control all detector systems including DAQ, filtering, supernova triggers, GRB triggers, monitoring, verification, and SPADE. The system is not complete, however basic control and monitoring functions have already been demonstrated over the Iridium link.

Work is presently underway to implement a system level and environmental monitoring system which will supplement the detector control and monitoring system *IceCube Live!*. This enhanced monitoring will result in faster responses to system level problems and an even higher live time of the experiment.

Computing and Data Management functions have continued to provide support through the operation and maintenance of IceCube's core data systems facilities and services. There are about 450 user accounts at the IceCube Data Center, which includes technical, engineering, and administrative personnel in addition to the project's scientific members. Many services ranging from web and email to HPC computing are provided to this user community.

FY08 also saw several upgrades and additions to computing hardware and plans for expansion are well underway. At the South Pole the computing systems is now 90% complete, and is now in an annual upgrade and maintenance cycle. The South Pole computing system was upgraded to accommodate the additional strings which were deployed during the 2007/2008 austral summer. Over the past several months, personnel have been preparing, testing, and shipping computing equipment to Pole which will be used for annual maintenance and support new strings to be installed during the 2008/2009 field season.

The Data Warehouse currently holds 230TB of data and over the past year plans were made for an upgrade to support the project's data storage needs in the future. Upgrades to on-line storage, near-line tape based storage, backup systems, and storage infrastructure have been and are presently underway.

In Science Operations, the first 6 months of IC-22 data was re-filtered from tape in less than 3 month's time. As tapes arrived from the Pole, the latest version of the online filters were applied to this same set of data to obtain a consistent dataset.

Just one month after the switch to IC-40's configuration, full reconstruction and delivery of all IC-22 data for physics analysis was accomplished. Several physics analyses unblinding on this data have already been performed and publications are being prepared.

A successful analysis test using a data challenge was performed and this test verified the preparedness of the physics analysis for data unblinding. It also demonstrated the sensitivity of the point-source analysis.

During a week of workshop sessions, students were extensively trained in the analysis techniques used in IceCube.

Section III – Financial/Administrative Performance

The University of Wisconsin-Madison is using a separate account with supporting charge numbers to receive M&O funding and collect related costs. Separate accounts are also being used for each Subawardee. FY08 subaward funding has been committed through the established University of Wisconsin-Madison requisition process and Subawardees have submitted invoices to receive reimbursement for appropriate IceCube M&O costs.

The following table summarizes M&O responsibilities, budget, and costs for the primary awardee (University of Wisconsin-Madison) and its five subawardees. Listed responsibilities are applicable for FY08, and are expected to evolve with time.

Award Type	*Institution*	*Responsibilities*	*FY08 (Oct2007 – Sep2008)*			
			Budget (FTE)	*Budget (K$)*	*Funds (K$)*	*Cost (K$)*
Primary awardee	University of Wisconsin-Madison	Simulation production; analysis coordination; DAQ maintenance; Manage SPS, SPTS, winter-over personnel, data warehouse and UW Data Center; administer M&O grant; coordinate distributed CPU resources	15.47	2,865	2,281 (Note 4)	2,581 (Note 1)
Subawardee	Lawrence Berkeley National Laboratory	Run coordination; Detector Verification; Detector Calibration;	1.68	287	287	287 (Note 2)
Subawardee	Pennsylvania State University	Detector Verification, high level monitoring and calibration; TWR maintenance	1.87	166	166	166 (Note 2)
Subawardee	University of California-Berkeley	Calibration; Monitoring	1.15	133	133	133 (Note 2)
Subawardee	University of Delaware	Monitor IceTop data and detector performance and recalibrate; Operate test station; IceTop maintenance	1.92	204	204	204 (Note 2)
Subawardee	University of Maryland	Support IceTray software framework; on-line filter; simulation production; Tier 2 support; TFT board	2.00	311	311	311 (Note 2)
Total M&O Budget & Cost			24.08	3,966	3,382	3,682 (Note 5)
NSF Funds including US common funds (Note 3)					3,000	
Non-US Common Funds					382	
Total FY08 Funds					3,382	

Notes:
1). UW Cost reflects actual cost through July 31 2008 extrapolated to include the months of Aug. & Sep. 2008.
2). Subaward funding is considered expended when committed.
3). UW received $3.0M from the NSF in FY08. The funding includes the U.S. contribution to common fund projects that cover capital equipment and elements of data center operations.
4). UW Funds includes the Common Funds: NSF $642K and Non-NSF is $382K.
5). Estimated annual over-run at the end of FY08 is $300K (Available Funds 3,382 minus Actual Cost 3,682)

Section IV – Project Governance & Upcoming Events

The IceCube Maintenance and Operations MOU has been finalized and is in place. Institutional representatives from all IceCube collaborators have signed the final document. Common fund accounts are in place and contributions have been collected by the University of Wisconsin-Madison. Service work agreements are also in place and that work is being performed as planned. Preliminary discussion on the form of the next M&O proposal have begun. We anticipate submitting a proposal for steady state M&O in late spring 2009. Collaboration discussions regarding the steady state proposal and other M&O issues will take place during the fall collaboration meeting and the IceCube Collaboration Board meetings being held in Utrecht, Netherlands starting September 15, 2008.

Meetings and Events

Collaboration Meeting at Utrecht University	September 15 – 19, 2008
International Oversight and Finance Group at UW	(TBD, September 2008)
Spring Collaboration Meeting at UW	April 28 - May 2, 2009
International Oversight and Finance Group at UW (TBD, during Spring Collaboration Meeting)	