Report

of the

NSF Annual Review Panel

for

IceCube

Performed for the
National Science Foundation

Conducted at University of Wisconsin in Madison, WI
June 11-12, 2008

July 21, 2008

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Executive Summary

A site visit to carry out the fourth annual review of the IceCube project was conducted by a Panel of experts on behalf of the National Science Foundation on June 11 – 12, 2008 at the University of Wisconsin in Madison, Wisconsin. This fourth annual review covered all aspects of the project. It follows a very successful drilling season at the South Pole that saw the installation of eighteen strings of detectors in the ice, four more than the goal of fourteen for the season. The combination of AMANDA and the forty strings of IceCube is now the largest neutrino detector in operation in the world.

Written material provided in electronic form by the IceCube collaboration to the Panel in advance of the meeting was examined, oral presentations were heard and subgroups of the Panel met with appropriate members of the IceCube collaboration to assess progress on the project. The format of the review followed the pattern of reviews of other large projects with roughly equal times devoted to plenary presentations followed by expanded breakout sessions with individual groups for in-depth discussions. In these sessions, the details of progress along with costs experienced on each of the WBS elements were examined. This arrangement provides a very effective format for the annual review of a project of this scale. Based on these evaluations, the Panel discussed its findings in executive session and generated the written summary conclusions and observations given below. Details of the assessment of the progress on the IceCube project are given in the full text of this report.

The IceCube Annual Review Panel formulated the following summary observations:

1. The IceCube Collaboration is to be congratulated on the very successful past drilling season. Placing 18 strings in the ice along with the associated IceTop modules safely in spite of communication failures with the drill is an outstanding accomplishment.

2. IceCube is now ½ km^3 of instrumented ice making it by far the world's largest neutrino detector and the Panel is eagerly awaiting the results from the IC40 run now underway.

3. The independent firn drill has added significant efficiency and safety improvements to the drilling process. The Panel encourages IceCube to continue to automate the operation of the firn drill to further increase personnel efficiency.

4. Fuel usage for the remaining installation of IceCube in the current economic environment is the largest uncertainty for the timely completion of the detector. The Panel concurs with the contingency analysis leading to assigning 500K$ for this component and urges IceCube to continue to protect at least this amount in the contingency account. This can be reassessed at next years' annual review and adjusted accordingly at that time.

5. The contingency for IceCube continues at the rate of 24% of the cost to complete. The Panel appreciates the careful management of the project that has made this possible

while working to restore the original 80 string scope of the project. However, multiple calls on contingency are under consideration including scope beyond the base line, increased preops, and polar support in general. The Panel recommends careful consideration of contingency utilization plans to insure that the remaining 10M$ in contingency is sufficient to complete the project.

6. The Panel finds the physics argument for the relocation of six strings to form a deep inner core detector for IceCube compelling. Installation of one string of this reconfiguration this coming season will provide an opportunity to fully assess both the high quantum efficiency DOMs and the effectiveness of the redistribution of DOMs on the string.

7. The Panel is very pleased with the generous contribution from the Wallenberg Foundation in Sweden along with additional funding from Germany and Belgium for the needed hardware for the six strings that will form the deep inner core detector.

8. The Panel is concerned about the risk in shipping the special cable and the high quantum efficiency DOMs to the South Pole in time for testing and preparation for installation of this first string for the deep core in the third hole of the season. We recommend that the drilling team be prepared to adjust the drilling sequence to accommodate this potential risk.

9. The possible delay of the start of LC-130 flights to the South Pole by one week puts at risk achieving the goal of installing 16 to 20 strings during the coming season. The Panel urges the NSF/OPP to carefully review this and hopefully restore the start date to the original plan.

10. The remaining holes to be drilled for IceCube represent a valuable resource with respect to R&D opportunities for installing prototype detectors that have the potential of providing a much larger neutrino detector with its much higher neutrino energy reach. The Panel urges the NSF and IceCube to develop a timely and detailed plan (before the next annual review) including definition of impacts so that this opportunity is not lost.

11. There is good progress on understanding the level of support needed to effectively operate and maintain IceCube. It is clear that the current level of support is insufficient to make the most effective use of the very large capital investment of the IceCube MRE. FY09 planning indicates a significant shortfall in funding for the base grants in support of M&O. The Panel recommends resolution of this problem as soon as possible.

12. The needed tasks in taking the raw DOM data to a refereed publication were presented by the collaboration. A first pass mapping of these tasks onto the M&O projected needs results in a US staff of 28 to 31 fte's. This is 40% more than that supported by the current awards.

13. The model that moves some of the M&O tasks to the individual PI's in the IceCube Collaboration will only be successful if the PI's individual proposals have a high success

rate in the review process and are funded at a level that supports the needed effort. The Collaboration should work with the NSF to agree as quickly as possible (before the next annual review) on a list of tasks that should properly be covered by the central M&O funding and those that should be in collaborators operations grants. The Panel urges IceCube and NSF to make every effort to avoid shortfalls in the needed M&O effort.

14. One component of maintaining and operating an instrument like IceCube that is often a problem is securing support for R&D to take full advantage of the instrument's capabilities and expand those capabilities in a cost effective manner. IceCube and NSF should explore ways to insure that this important component is not ignored.

15. The increase in the data rate from IceCube by an order of magnitude from that originally planned is both a surprise and an opportunity. The ability to run with a significantly lower energy threshold opens new physics opportunities that should not be lost. The Panel urges IceCube to take full advantage of this change while respecting the bandwidth constraints from the South Pole.

16. The IceCube data handling system is nearly complete with little effort remaining to complete the MRE project. The Panel is pleased with the execution of this task that meets all the specifications and it appears to provide a very effective data acquisition system.

17. IceCube, NSF/OPP, and RPSC continue to work together to plan the deployment of the IceCube strings in an efficient and cost effective manner. The Panel urges IceCube and RPSC to work together in creative ways to limit the impact of the likely shortfall in flights and needed resources at Pole due to the current Polar programs budget situation.

18. IceCube is working towards a sensible policy to provide public access to IceCube data. The Panel urges IceCube to continue to develop a policy before the next annual review that is both affordable and adequate to satisfy the commitment to provide public access to the data.

19. IceCube has drilled ~50% of the planned holes but some of the components essential to production are showing signs of wear and unreliability including the generators and hot water heaters. The Panel recommends giving restoration of these components high priority.

20. The IceCube safety record was examined and found to be excellent compared with industry standards. IceCube continues to employ training and accident investigation as a high priority. The Panel commends IceCube on this excellent achievement.

21. The Panel recommends a significant effort should be made in the upcoming year to develop a realistic strategy to match the outstanding E&O opportunities presented by IceCube with broader national goals in this area and to seek additional funding to grow the program to achieve this mission. The plan should be ready for presentation at the next annual review.

The IceCube project is now in its seventh year (PY07) after successfully installing eighteen additional detector strings at the South Pole during this past austral season. They are preparing the materials needed and transporting them to the South Pole for the installation of sixteen to twenty more detector strings during the coming austral season. If they are successful in installing at least sixteen additional strings this coming season, the IceCube collaboration will be well on their way to complete this ambitious project on schedule and within the total allocated budget.

Introduction

This review is the fourth annual review of the IceCube project. The project has had a very successful past season with the installation and initial commissioning of eighteen additional strings along with fourteen IceTop detector modules. The focus of this review was on lessons learned during this past season and their plans to install at least sixteen additional strings along with sixteen additional IceTop modules during the coming season. Project costs were also reviewed to make sure that there were no large deviations from the baseline cost estimate. The project continues to be on schedule and within the baseline cost with an excellent chance of installing more than the baseline 70 strings with the total baseline budget.

Implementation (Drilling, Installation, Logistics, Management, and the Endgame)

Drill Performance:

Finding:

The performance of the drill for the FY07-08 season was excellent and the successful drilling of 18 holes exceeded the planned goal of 14.

Comments:

The project performed exceptionally well last year. The goal for FY07-08 is to drill 20 holes while the plan calls for drilling 16 holes.

Recommendation:

The IceCube team and the RPSC support people are to be congratulated on their fine performance. In order to meet the ambitious goal of 20 holes, the planned drilling start date must not slip. Budgetary cuts that have resulted in later and reduced C-130 flights can easily impact the 20 hole goal unless people and freight are delivered timely. The timing of flights and freight must be closely watched to assure a successful season.

Generators

Finding:

The IceCube generators have not been reliable, and are a concern for IceCube.

Comments:

There are three packaged 225 kW (site derated to 165 kw) generator sets that are used for the main drill, and one separate CRREL 225 kW (site derated to 165 kw) generator set that is used for the independent firn drill (IFD). These generators all have problems that could put the program goals in jeopardy. Some issues are:

1. None of the three main drill generators can be operated independently without the control module, so loss of the module could mean loss of all generation control without significant rework.

2. The generator heat exchangers (HX) are not presently protected with pressure relief valves, that could allow a high pressure event to destroy the waste heat HX units.

3. There is no dry silencer, so all generator exhaust must be routed through the waste heat HX exhaust silencer. Under certain wind and load conditions, the generator engines over heat if the generator is loaded over 80 kW, and if there is no thermal load on the drill. This results in the need to operate a second generator to avoid overheating.

4. There were wear metals found in the engine oil sample in generator #2.

5. There are indications that the rear seals on generator G-1 and G-2 are worn and leaking.

6. The turbochargers for generators G-1, G-2, and G-3 are all worn and need to be replaced.

7. It takes two of the three generators to produce sufficient power to operate the drill.

8. Fuel starvation has been a problem on generator G-3.

9. New voltage regulators need to be installed on all of the generators.

10. The intake fan motor that cools the generator room has not been working properly.

11. The communication cables from generator G-1 to the PDM have exhibited problems.

12. Access needs to be installed to the front guard of the engine.

13. The engine oil dipstick is not calibrated to measure the level of engine oil while it is operating at rated speed.

14. The CRREL genset that powers the independent firn drill went through a minor overhaul, but it needs a major overhaul on the engine.

Recommendations:

All of the 14 issues noted above must be addressed. The present plan is to have on-site people start some of the generator repairs in late October or November. Specific plans and recommendations are as listed:

1. Due to the critical nature of the generators for the project, the generator repair status in the bi-weekly telecom on IceCube should be included.

2. Develop plans to rework the generator controls to allow independent operation so a major failure or destruction of the control module will not cripple the balance of the generator operation.

3. The plan to add pressure relief valves (PRVs) and pressure-temperature relief valves (PTRV) was reviewed and streamlined from the initial plan. Several hand operated valves will be removed that isolate the expansion tank, which will then permit the pressure relief radiator cap on the expansion tank to protect the exhaust gas HX unit without extensive rework. A PTRV will be added to protect the drill water HX unit. This work must be done before the start of the season.

4. A dry silencer and spring loaded diverter valve/actuator will be added as soon as possible during the upcoming season by an Australian Cat dealer who has experience and presence on the ice. In addition to enhancing safety, this fix will also allow the generators to operate under full load without overheating.

5. Wear metals will be monitored in oil samples in G-2, with an engine teardown and overhaul if needed.

6. Generators G-1 and G-2 will be cleaned so the presence or extent of rear seal leaks can be observed. If the seals are in fact failing, plans need to be made to replace them after this coming season.

7. The turbochargers for all three main drill gensets need to be replaced as soon as possible, hopefully before start-up this coming season.

8. The fuel starvation problem in G-3 has been tentatively traced to a bad fuel pump unit. The installation of the bottom feed day tank will also help to correct this issue, since air in the fuel may have been part of the cause of the failed fuel pump and fuel starvation issues.

9. New voltage regulators need to be installed on all three main drill units.

10. The module intake fan motors need to be corrected.

11. The communication cable from generator G-1 needs to be replaced.

12. An access to the front guard needs to be installed on each of the three main drill modules.

13. The motor oil dipsticks need to be marked to show proper motor oil levels when the engines are operting at 1800 RPM, so no shutdown will be needed for an oil check.

14. The CRREL genset had a minor overhaul this past winter, however, a replacement engine needs to be installed after the next season to assure reliable operation.

Water Heaters:

Finding:

The drill water heaters are showing signs of corrosion, so they may not last for the lifetime of the project. The original manufacturer is no longer in business and replacements are therefore not available.

Comments:

The project is only 50% complete in terms of the number of holes to be drilled, and it appears that the water heaters used presently may not last to the end of the job. External corrosion is obvious on the mild steel skin, but the internal heat exchanger condition is unknown. It would take some time to find replacement water heaters that are as efficient as those presently installed and that would fit into the existing space, which is very tight. UW has been working with the Sioux Corporation, a water heater manufacturer, to construct a replacement unit. A prototype unit has been made and initial testing is complete. The testing reflects an efficiency of 87-88%, whereas the original heaters tested at 92-95% efficient. The new heaters have a flue gas temperature of 276 deg F, which indicates that they are not operating in the condensing mode, which provides the additional efficiency. Also, having an elevated stack temperature over 212 degrees could cause deterioration of the ceiling assembly. Code clearances for the stack must be maintained.

Recommendation:

Testing and optimization of the new water heater should continue until the device is in the condensing range, with flue gas temperature below 212 degrees in order to provide the safest operating condition, as well as the most efficient one.

Deep Inner Core Detector

Finding:

The IceCube collaboration wishes to install a six string deep inner core detector ring in order to measure low energy neutrino events. This would be in addition to the existing updated goal of 80 strings, for a new total of 86 strings.

Comments:

It was reported that the hardware for these six deep inner core strings has been funded by the foreign IceCube Collaboration partners, although installation has not yet been funded.

The impact on the drilling program indicates that different cables are needed with revised breakout locations since the DOMS are spaced closer together, and the majority of them will be sited below the dust layer, using the dust layer as a veto.

The Panel's concern is the fact that the first deep inner core string was planned to be the third string installed during the coming season, yet the special cables are not on site at this point. The drilling people felt that it would not be any serious impact to change the drilling order to accommodate the possible late delivery of the cables and equipment for this string.

Recommendations:

1. The Panel recommends proceeding with deploying the first string of the deep inner core detector this year as a proof of concept.

2. The drilling team should be prepared to adjust the drilling sequence to accommodate any possible late delivery of cables and equipment for this string.

Safety Program

Finding:

There were two lost time injuries this last season, one due to an accident with a snow machine that resulted in a leg injury and the second a back strain from improper lifting. There were four other injuries that were not lost time but included two burns from hot water and steam. Steps are being taken to correct factors that contributed to the burns including improved drainage from the Y strainer and corrections to an overheated generator waste heat line.

Accident statistics for IceCube are very good in comparison to similar industrial situations. New training procedures are being implemented using NANA Corp Safe Start that incorporates pre-deployment training and monthly refresher training at the Pole that will further enhance safety for workers.

Comment:

The team recognizes the extreme importance of safety, and applauds IceCube efforts to keep workplace injuries to a minimum, with a goal of zero injuries.

Recommendation:

The panel encourages the continued investigation of incidents, as well as re-current safety training.

Logistics

Finding:

The movement of personnel, equipment and supplies to the Pole is closely coordinated between IceCube and RPSC. Current plan for initial flights calls for the first IceCube personnel (drillers) to arrive at Pole on the 5th and 6th of November. Baslers will be the initial aircraft. This will largely limit flights to personnel and baggage with minimal equipment deliveries. LC130 flights will not be available until after 3 November.

Comment:

The IceCube seasonal plan requires a drilling start date of December 1st. To meet this date, the following cadence of personnel and cargo are required at the South Ple Station:

- 9 IceCube Drillers on or before Nov 3rd
- 1 RPSC IceCube Project Coordinator on or before Nov 3rd
- 1300 lbs RPSC cargo on or before Nov 3rd (cargo required for generator repair and retrofit including exhaust bypass without silencer)
- 1300 lbs of IceCube EWHD cargo on or before Nov 3rd
- All other participants and cargo are delivered according to the established ROS dates, starting Nov 5th via LC130s.

Recommendation:

An additional Basler flight may be required beyond the 10 currently planned in order to meet the personnel, cargo, and RPSC support needed to ensure a timely start to the IceCube drilling season. The Panel urges that every effort be made to meet the support requirements in order to achieve timely completion of the project.

Winter Storage

Finding:

Drill camp winter storage that is positioned for the coming year has been a success and should be continued. A heated blanket is now installed over the hose reel to extend its life, and to store it within the manufacturer's temperature requirements. Heater operation monitoring indicates an intermittent signal suggesting risk of a future possible control failure. However, the heating elements can be switched to a manual control mode that will mitigate the issue.

Comment:

The Panel supports continued use of these winter storage strategies.

RPSC Equipment Availability

Finding:

Loader Felicia is needed for IceCube and arrangements for its availability have been coordinated with RPSC. Loader Felicia has been overhauled and will be available to support IceCube exclusively unless RPSC experiences other loader breakdowns requiring a shift of resources at the station.

Comment:

Loader availability is critical to IceCube operations, however overall station support is RPSC's first priority. There is a risk that pending overall South Pole program budget constraints may impact program O&M and equipment availability.

Recommendation:

RPSC should confirm availability of other loaders at the station and maintain close coordination on equipment status with IceCube to assure that necessary equipment resources are available.

Planning for the Retrograde of EHWD at the Conclusion of the Program

Finding:

There is no disposition plan for the drill at the end of the project.

Comment:

At the end of the drilling activity for the IceCube project, the entire Enhanced Hot Water Drill (EHWD) system will need to be returned to the States. It is unlikely that the drill would be useable without significant repair and modification for any future undefined project.

Recommendation:

The Panel recommends that NSF and UW/RPSC develop a clear understanding of what the disposition of the drill will be. Once that is known, an integrated resource loaded schedule is needed to develop the realistic cost for this effort.

Drill Electro-Mechanical Cable Failures

Finding:

Failure of communication cables prevented efficient drilling for the bulk of the season.

Comments:

All three electro-mechanical cables were retrograded back to UW for failure analysis. Electrical and mechanical problems exist including outer jacket cuts and electrical shorts due to water leakage into the cable. UW is working with Cortland Cable to resolve the problems. One new cable is being procured and one of the three old cables is being repaired.

Recommendations:

1. The project should capture the knowledge gained on the mechanical cracking resolution by proper tensioning the cable while spooling the wire on spools and thermal management to reduce exposure to this failure mode.

2. The project also needs to work with the vendor to improve the down-hole electrical connector's reliability and develop on-site repair procedures.

Independent Firn Drill (IFD) Automation

Finding:

The IFD has been a success for the project enabling higher annual drill hole production by reducing drill time overall. The concept has proven to be operational, and it can now be automated.

Comment:

UW has designed a software program that can optimize and automate the IFD operation by measuring the weight on the drill stem in conjunction with the depth of the drill head. The IFD takes about 10-16 hours to drill to 40 meters.

Recommendation

The Panel recommends that the automation of the IFD continue, since it will save both fuel and personnel time on site.

New Drill Software

Finding:

The drill software has been re-written and tested during this past drilling season, and was found to be a vast improvement over prior versions.

Comment:

The software appears to be a success and the time needed to develop and implement it was well spent.

Recommendation:

The new software should continue to be optimized.

Drill Idle Changes

Finding:

When the drill is in idle, it uses 25 GPM of 50 degree C hot water, which is waste down the Rodwell. The hot water is circulated in order to minimize leaking at joints that are caused by worn or aged “O” rings.

Comment:

It is recognized that some hot water needs to be circulated in order to reduce leaking at the “O” rings, however, 25 GPM is excessive and wasteful. It takes 3 to 4 water heaters just to make up the hot water during the idle process. While some of the hot water can be used for further Rodwell development, it was found that the Rodwell was excessively developed, which indicates a waste of energy.

Recommendation:

The idle water consumption should be reduced to a minimum while still preventing leaking at fittings. It was suggested that a 50% or better reduction is possible, and this needs to be implemented.

Y-Strainer Fix

Finding:

Y-strainers are installed at hot water heaters in order to reduce clogging and rust in the units. During a flush down of one of the strainers, an employee was burned. The system is being re-designed to address the problem.

Comment:

The pressure on the system at the strainer is around 1,000 PSIG, and the water is hot. For this reason, a fixed valve and tubing system is going to be installed to a condensate tank so that operators do not need to handle a hose under high pressure.

Recommendation:

The Panel discussed the proposed fix, and endorses the concept. Minor revisions are appropriate as to where the blowdown valve is placed, and how the tubing is secured. If the blowdown valve can be located at the Y-strainer without interfering with access below the heaters, it would be preferred.

Fuel Accountability

Findings:

There was a discrepancy between the UW estimate of fuel consumption and RPSC estimate of 8.3%. Considering the escalating cost of fuel and the need for NSF to carefully monitor and tighten fuel purchases, more accurate fuel use estimation is required. Additionally, the fuel usage estimates by both UW and RPSC are not temperature compensated to API 60 Degrees.

Comments:

The difference in volume for temperature compensated or non-compensated fuel could be as much as 10%, with the project reporting a lower usage than actual if they are reporting cold fuel volumes. Also, the difference between RPSC and UW measurements needs to be resolved.

Recommendation:

Both RPSC and UW need to coordinate their fuel measurements to achieve more accurate data. Additionally, both should give both cold and temperature compensated fuel volumes.

Fuel Budgeting

Findings:

This year the project included a $500k contingency to cover the escalating cost of fuel. The actual increases in fuel costs could be 30% per year for the next few years.

Comment:

It is an excellent idea to protect the project cost for fuel using the proposed contingency.

Recommendation:

The fuel contingency should be closely monitored, and updated next season as well depending on the fuel cost changes. All possible fuel saving techniques need to be implemented to reduce the fuel consumption, although the panel recognizes UW's continued efforts in this area.

Fuel Oil Day Tank

Findings:

The fuel oil day tank in use for the project from inception to date is a top feed type tank. Air in the fuel has consistently been a problem, causing water heaters to flame out, leading to loss in production by the drill, excessive idle time, and lost driller labor while re-priming the water heaters.

Comments:

The use of a top feed day tank was believed to be a code or environmental issue. A waiver was prepared to see if NSF would accept a bottom feed tank, and on investigation it was found that there was no prohibition against using a bottom feed tank for a small (less than 660 gallons). The project therefore has acquired a 300 gallon stainless steel tank for early deployment to Pole for the IceCube project.

The new tank needs to be equipped with a spill prevention fill device and painted black to adsorb heat for better combustion efficency. A dike tank must be placed below the day tank to catch any spills, and an impact valve on the bottom needs to be installed to close in the event that the tank is upset.

Recommendation:

The Panel recommends proceeding with the tank retrofit provided that the safety features mentioned in the above comments are implemented.

Project Management and Deep Inner Core Array

Construction and Operations Management Organization

Comments:

The construction management organization is well matched to the project needs with experienced and effective managers in place. The level of communication between the groups seems high. They have established an excellent track record of success on all fronts - cost, schedule, and technical performance. Robust management tools are in place and actively used.

The operations management organization has been appropriate for the past years of operation. They have an excellent track record of success regarding technical performance (data acquisition, data filtering, calibrations, preliminary analysis etc.). The organizational structure should evolve as the end of the MREFC approaches, and the evolution plans should be developed now. A determination of the core functions required for strict operations (not analysis) should be made as the foundation for an M&O budget proposal.

Collaboration Management and MOU Based Service Work

Comments:

Similar to the Operations management organization, the collaboration management has been effective to date. Now is the time to make a paradigm shift from Construction to Operations & Analysis. The Panel suggests the collaboration better define how the University of Wisconsin will function as the central "lab" support organization during the Operations & Analysis phase in the context of a fully active collaboration.

Recommendation:

The Panel sees a need to get more university groups meaningfully involved in service work. MOUs should be developed soon which identify clear and critical roles for each participant.

Project Controls, Variance Analysis, and Change Control Logs

Comments:

The IceCube team has mature management tools in place that are actively used. The Project Monthly Reports include management sections with highlights, cost/schedule performance and status including updated estimates to complete, change control logs, and risk assessments tied to potential contingency draws. The reports also include updates on drilling, detector commissioning, and data acquisition.

The Project was able to provide detailed labor profiles, procurement profiles, and contingency analyses that appear to be routinely used when making management decisions. The project completes a "rebaseline" once per year that defines the path forward and results in an updated contingency usage plan. Overall, the management team is making very effective use of project controls and tracking tools.

Deep Inner Core Plans

Comments:

IceCube proposes to rearrange the Digital Optical Module (DOM) geometry on 6 strings in order to provide a small subvolume of the detector that is sensitive to low-energy (few TeV to PeV) neutrino-induced showers. The 60 DOMs on the string will be distributed with 7.5 m spacing on the bottom half of the string, with a few DOMs spaced 10m above the dust layer. These "deep core" strings will be deployed with 72m horizontal spacing, half the normal separation in the center of the IceCube array. Events within this fine-grained detector volume will be selected using the upper parts of the conventional strings as a veto, to eliminate downward-going muons. In this way, the deep inner core can be used to view downward-going neutrino events, allowing IceCube for the first time to explore the southern celestial hemisphere. Furthermore, recent results have shown that specific source candidates in the galactic disk have gamma ray spectra suggesting that this lower energy range might be optimal for neutrino detection. With improved sensitivity to low energy neutrinos in the deep inner core, the detection of the possible annihilation of WIMPs in the sun will be extended to lower energies. Finally, the deep inner core would allow good-statistics studies of the high energy end of the atmospheric neutrino spectrum, which existing detectors such as Super-Kamiokande can only explore through the limited information provided by upward going muons. At these energies, the production mechanism for atmospheric neutrinos begins to be dominated by kaon rather than pion decay, and direct measurements will be of value in calibrating existing models used for simulations; furthermore, extension of neutrino oscillation measurements into the TeV to PeV range is of significant value. The Panel strongly supports the scientific goals addressed by the deep inner core plan.

The creation of a deep inner core detector represents a unique opportunity to expand the overall scientific capability, and the IceCube team is to be commended for establishing a successful collaboration with key foreign institutions resulting in important in-kind contributions.

The Panel agrees with the need to get a deep inner core installed early (i.e. within next 2 drilling seasons and suggests that IceCube consider adjusting the stated goal of "80 strings plus 6 deep inner core strings" to something like "achieve as close to 80 strings as possible over the next two seasons which must include 6 special strings for the deep inner core". The Panel agrees that third season must be part of the plan, and should be used to achieve as many additional "regular" string deployments as funds permit.

Recommendations:

1. The Panel strongly supports the scientific goals addressed by the deep inner core plan and urges the IceCube Collaboration to implement it expeditiously.

2. The IceCube Collaboration should complete an analysis of the scientific impact of:
a) if less than 80 "regular" holes are instrumented with 6 for deep inner core,
b) if less than 70 "regular" holes are instrumented with 6 for deep inner core, and
c) complete location optimization plan in case less than 80 "regular" strings are deployed in view of the need to function as a veto for deep inner core detector.

Endgame Budget Plans

Comments

Solid planning has been done including a risk and contingency analysis to achieve a stretch goal of 80 strings plus 6 specialized deep inner core strings. IceCube is to be commended for continuing its careful stewardship of project funding. Overall, contingency as a percentage of remaining baseline work is healthy, however multiple calls on contingency are now under consideration including scope beyond the baseline and increased M&O support. In light of the remaining level @ $10.5M, with only ~50% of the strings deployed, and the potential for reduced polar support, there is reason for concern.

Recommendations:

1. IceCube has an excellent track record for optimizing plans as the realities of each drilling season evolve. However, given the few seasons left and the concern about contingency, the Panel suggests the development of a strawman back-up scenario if the next two drilling seasons fall short. Such a back-up plan should include prioritization and timing of procurements, regular versus the deep inner core string deployment, and an analysis of how the contingency usage plan would be impacted.

2. The Panel suggests adding an analysis of the potential draw on contingency to maintain minimum operations and secure data collection if M&O funding support stays flat for several years.

Radio and Acoustic R&D

Comments:

The remaining drilling operations for IceCube provide a unique opportunity to support research into non-optical detector techniques, at negligible additional cost. Radio Cherenkov and acoustical detection of neutrino-induced cascades in the ice represent a practical way to implement effective detector volumes hundreds of times greater than IceCube, as will be needed for studies of GZK neutrinos and related topics of firmly-grounded scientific interest. The scientific motivation is compelling and the basic techniques are well developed already, but considerable study in situ is required to go from simulations and laboratory-scale tests to optimal detector designs. Issues such as acoustical and EMI backgrounds in the vicinity of the South Pole Station must be investigated in more detail than existing very preliminary studies have provided. The Panel strongly supports the scientific goals of the proposed research.

According to IceCube, installation of a suitable set of instrumentation can be done as a parasitic activity to planned IceCube string installation, simply by adding small transducers to the tops of strings during deployment. No additional on-site personnel are required, and the attachment operation requires only a few hours of extra effort per string. Members of the IceCube collaboration have the necessary expertise and the relatively inexpensive hardware (horn and batwing microwave antennae and receivers, acoustical transducers and readout electronics) is either on hand or may be procured at low cost. The main cost to NSF appears to be several thousand pounds of additional cargo to be delivered to the Pole.

The collaboration has not prepared a coherent plan for utilizing the opportunities presented by their existing drilling schedule. Instead they propose a hurry-up plan to add antennae and pingers to strings scheduled for deployment during the 08-09 season. This may have significant impact on carefully worked-out logistical plans developed for the overall South Pole Station program. It is true that postponing such deployments to the 09-10 season, when they could potentially be better fitted into the logistics plan in advance, would mean losing opportunities for iteration within the remaining IceCube string installation schedule. However, IceCube must work within the constraints of the South Pole Station program to the extent that they are not facing a true contingency situation affecting their core activities.

Investigators from outside the IceCube collaboration should also be given the chance to exploit the opportunity presented by IceCube drilling operations.

Recommendations:

1. NSF should ensure ‘open access’ to the unique R&D opportunities provided by IceCube string deployment.

2. A coherent R&D plan including goals, budget, manpower, schedule, and a risk/benefit analysis tied to project completion should be developed and should form the basis for consideration of future R&D proposals.

Data Policy

Comments:

The IceCube collaboration provided a written summary of their data policy regarding public access. The policy is generally consistent with the intent of the NSF guidelines, however does not address issues of cost and responsibility for making the data available to the public.

Recommendations:

1. The Panel urges the IceCube collaboration to continue to develop a policy that is both affordable and adequate to satisfy the commitment to provide public access to the data.

2. The Panel suggests the policy should include a statement defining a usual embargo period, typically a few years, during which the collaboration has exclusive access to filtered data.

Data Systems, DAQ, Instrumentation, AMANDA, and Science

Instrumentation

Comments:

Currently a total of about 2500 DOMs have been deployed in IceCube. A handful failed spontaneously. The estimated 15 year survivability based on deployment so far is about 95%, which is within original estimates and should not degrade expected physics reach. About 3% of deployed DOMs have problems (of various kinds) requiring a non-standard configuration, but can nevertheless provide good information. This rate is acceptable. Overall noise rates and time resolution are also acceptable.

The DOM and cable designs are now fixed, and proven to work well in deployment. The only planned new element is the high quantum efficiency phototube proposed for the Deep Inner Core array, which presents minimal risk.

The Panel identified no particular areas of concern with the DOM instrumentation that are not already being addressed by the collaboration.

While the AMANDA component of the experiment is working and has been integrated into IceCube since the IC22 run, it consumes more resources-- power and attention for maintenance of a more complex system-- than the second-generation IceCube instrumentation.

Recommendation:

The Panel supports the collaboration's decision to replace AMANDA with the Deep Inner Core array.

Data Acquisition and Data Systems

The IceCube project successfully ran IC-22 during the last year. IC-22 is a complicated system of the detector strings, the SPS, SPST, the data warehouse, and associated compute cluster. That it was run as smoothly as it was is an impressive achievement. The Panel is suitably impressed and commends the collaboration.

Data Acquisition

Comments:

The IC-22 system achieved an uptime of 96% and a clean data uptime of 86%. The collaboration has a goal of 99% uptime for IC-40. These ambitious uptimes were called for in the last review in order to avoid missing rare astrophysical events. There is little sign that this pursuit is causing strain on the collaboration: the majority of the IC-22 downtime was planned. The project is to be commended.

This year saw the successful deployment of the pDAQ software, event builder hardware, and the integration of AMANDA into IceCube triggering while supporting the increase in data rates from the DOMs from 1 MB/s to 7 MB/s. The Panel is pleased that the critical technical expertise for this deployment was available despite its concerns in the last review. This past year was very successful for the DAQ system and the team is to be commended.

The manpower available for the DAQ effort is ramping down dramatically as the construction project winds down. The remaining upgrade seems to be for soft local coincidence, a physics enhancement.

The SPS compute cluster is working well and at 85% of capacity. The same can be said of the TDRSS data transmission channel. The TFT board plays an important role in constraining both the usage of the SPS by the filters of the science working groups and in the use of bandwidth by the resulting science outputs. The TFT board should be supported in any of its decisions that keep the collaboration living within its means. The increase in satellite data transfer rates shown to us are likely unsupportable. The NSF should provide guidance by means of a South Pole bandwidth roadmap.

Given the overall increase in data transmission rates and the associated burden in satellite bandwidth, the Panel recommends that lossy compression algorithms be explored and plans for implementation evaluated.

NSF should consider means to allow 24x7 low bandwidth TCP/IP access to the Pole.

The entire DA and Data Systems team reported that replacing AMANDA with a deep core detector would lessen the maintenance and analysis burden. As M&O is constrained, this is a compelling argument to proceed with AMANDA decommissioning. The Panel notes that the IceCube uptime including AMANDA was only 50%.

Lastly, the transition from IC-22 operations to IC-40 operations occurred from April 5, 2008 to April 17, 2008. The detector size nearly doubled and new filters were deployed to the online system. The transition period was impressively short and the Panel is suitably impressed, as it is by the project's goal of a one day transition out of IC-40 operations. The run coordinator, the TFT board, the data acquisition team and the SPS support team are to be commended.

Data Systems

Comments:

The data system has been largely completed under the construction project. An upgrade to the data system is planned using MREFC contingency funds. To a large extent this is due to the higher than expected data rates, in turn due to a better performing detector than expected. The Panel finds the upgrade plan reasonable.

The upgrade in part consists of a doubling of the spinning disk to 400 TB and an increase of secondary storage to 200 TB. The secondary storage is a HSM that provides a tape based file system. It is unusual to have more disk storage than a tape based file system storage. The Panel suggests reviewing the plan for use of the HSM system from a "slow disk" viewpoint rather than a "deep archive" viewpoint.

Once again the operation of a dual hemisphere compute environment is an impressive feat.

Simulations are a major task for this collaboration because of the decision to produce unfiltered events as a test of the online filters. The collaboration produced 25 days of unfiltered data using 9 different compute clusters, resulting in a 12 TB of simulations for IC-22. The production occurred outside of a grid environment (though the GLOW cluster is OSG compliant), itself an impressive achievement. The simulations are run through the on-line filtering algorithms and the off-line data processing steps on the central compute cluster. Simulations presently occupy ~25% of the data warehouse disk space. 25 days of simulated IC-22 data becoming available about the time of the switchover to IC-40 indicates that Monte Carlo production is lagging data production. The Panel evaluates the situation as one where the collaboration has learned how to produce large scale simulations and over the next year it should increase the rate of simulation production.

The 2007 NSF Review recommended that a single reconstruction package be used as a starting point for any analysis. The response of the collaboration was satisfactory, noting that the final version of this package was planned for spring 2008. In this review, there was little note of this reconstruction package. The Panel believes this package was used in the on-line systems, notably at the transition from IC-22 to IC-40, in the offline data processing system, and in the processing of the Monte Carlos; that is, that the collaboration performed as it said. Clarification on this point is requested.

The data warehouse provides 33 TB of user space for the collaboration and a sandbox analysis cluster for collaboration members. This support of the science analysis by the collaboration is to be commended. Another point of clarification is whether the single reconstruction package/framework used by the collaboration for analysis as this partly motivates its support in M&O.

The Panel agrees with the SAC evaluation that data challenges are intrinsic part of the physics analysis procedure, as are the Monte Carlos. The line dividing data challenges and Monte Carlos as part of either M&O (funded through a central UW proposal) or analysis (funded through individual base grants) is fuzzy. Elucidating that line should be part of the program for the coming year. The SAC report suggested that moving 15 scientists from the MREFC grant to a supplemental analysis grant centered at the universities would both retain the critical experimental knowledge as well as providing a healthy distribution of faculty, scientists, and graduate students in the US IceCube collaboration. The preparation of such grant would focus attention on how analyses are to be organized and where sufficient manpower for the analyses is to be found.

Finally, the Panel notes that ~10 papers are listed as possible for 2008.

Commissioning, Data Verification, Monitoring, Calibration

Comments:

Commissioning of DOMs with flasher light sources and muon data has been successful. A number of problems have been identified and fixed, and data quality verification is keeping up with IC40 data. Verification is done via a web interface; an "alarm system" to warn of potential problems is being added.

Development of "IceCube Live" software, to provide better real time control and monitoring, has begun but has not been completed. This will be essential for running a detector of this complexity and the completion and implementation of this software should be pursued with high priority.

Good progress on calibration was also reported: timing and geometry calibration were completed ahead of schedule last season. Overall the calibration program seems on track.

M&O

The Panel was asked to judge experience in the new M&O phase and to comment on the need for any immediate corrections.

The Panel reviewed the profile of spending in the context of the May 2007 M&O request and the proposed funding of that request. For the first 18 months, the funding from all sources (including MREFC pre-ops) was anticipated to be $325K lower than the $5.9M. The best estimate of actual spending is $196-262K above the funded level. (Range is associated with a difference between proposed and actual pre-ops funds made available, presumably a project decision.) In the FY09 year, proposed funds from all sources would have shown a $325 excess over requested funds. The Panel did not find the 3% difference in the first 18 months as signifying the need for an immediate correction to planned work or funding.

However the Panel was concerned by a shortfall of more than $900K between the proposed FY09 funds available for M&O from all sources and the estimate for funds that actually would be available. This shortfall is mostly due to the difference between a $920 K proposed level of base grant supplements and an estimate that only $91K would be available for M&O from this source. The Panel was unable to further investigate this anticipated shortfall during this review, but this needs to receive more attention.

A problem observed by this Panel and previous Panels looking at M&O has been to get sufficient transparency to identify how needs and resources match up across the collaboration. One issue revolves around distinguishing between those activities that *must* occur to prevent deterioration of IceCube equipment or permanent loss of data and other activities that could be termed “level-of-effort”, that could be increased or decreased in response to realities at the funding agencies without permanent damage to investments made to date in IceCube. It is obvious how certain functions fit this scheme. For instance, a reduction of personnel over-wintering at the South Pole or a failure to update aging equipment risks deterioration of the physical plant and/or permanent loss of data. Funding levels for off-pole activities are somewhat less clear. Cuts in some areas might slow down the analysis and publication of results – an undesirable but survivable outcome – while cuts in other areas might create permanent bottlenecks, resulting in divergence between available and analyzed data. Another issue revolves around identifying what resources are available, compared to needs, for both M&O and analysis across the entire collaboration and which slices are under control of NSF. A good example of a task in this category, which the committee questioned, is the Monte-Carlo production. In a number of other collaborations, Monte-Carlo production would be considered a normal part of the analysis and would be done predominantly by graduate students as part of learning the craft of the field they are pursuing. The panel heard that IceCube considers this an essential M&O task to provide "physics-ready" data to the collaboration. We did not have sufficient time to delve further into this gray area, but it would have been useful to understand why this item should be handled differently for IceCube than for other cases.

A table for developing better clarity on these issues, at least with respect to labor, was initiated in the course of this review. Each row of the table was for a task, ordered to follow the data from the ice at pole to submitted journal articles. The columns denoted the task name, the FTE resources for completing the task from the central M&O grants, the in-kind M&O contributions from US base grants and non-US sources and the analysis contributions from the US base grants and non-US sources. A final column could have summed all resources across a task. One could imagine one such sheet for resources desired by the collaboration in a given year and another for available resources to support these activities. These sheets might give an annual snapshot of how reasonable is the matching of plans to resources and what the implications of mismatches might be. Further developing such an analysis for future reviews and proposals in addition to the more traditional analysis by WBS is encouraged.

A first pass mapping of these tasks onto the M&O projected needs suggests that a US staff of 28 to 31 fte's is necessary. This appears to be 40% more than that supported by the current awards.

The model that moves some of the M&O tasks to the individual PI's in the IceCube Collaboration will only be successful if the PI's individual proposals have a high success rate in the review process and are funded at a level that supports the needed effort. The Panel urges IceCube and NSF to make every effort to avoid shortfalls in the needed M&O effort.

Recommendation:

The difference between needs and anticipated available funding for M&O activities in FY09 needs to be understood and resolved as soon as possible.

Education and Outreach

IceCube has one FTE working on education and outreach, supported by UW, Madison. The E/O program has been doing some good things and making some connections with potential partners. This opportunistic style of E/O program is appropriate as a start-up phase, but for a project as large as IceCube, it is time to evolve further. Considering the hundreds of millions of dollars invested toward IceCube science and its inherent potential interest, it is reasonable to expect IceCube to have broader impacts that scale accordingly and further important NSF goals for education, manpower development and public science literacy. This will require a strategy to grow the program by matching IceCube opportunities to NSF needs.

Recommendation:

A significant effort should be made in the upcoming year to develop a realistic strategy for IceCube to match E/O opportunities with broader national goals in this area and to seek additional funding to grow the program toward this mission.

Appendix A. Charge to the Review Panel

<u>DRAFT</u> Charge to the Review Panel for the June 11-12, 2008
Annual IceCube Construction Project Progress and Operations Review

The NSF requests that you review the annual progress for the IceCube Neutrino Observatory construction project, including updates to the IceCube cost and schedule baseline and adequacy of remaining contingency. In addition, we ask that you review progress in Operations and Maintenance (O&M), the award for which was put in place last year. The review will be held at the IceCube project offices of the University of Wisconsin in Madison, WI on June 11-12, 2008. We ask that you write a report describing your findings, assessment, and recommendations, and provide it to NSF by July 11, 2008.

The construction project includes the following subsystems: project support (management, integration), implementation (principally, drilling and deployment at the South Pole Station), instrumentation, data acquisition, data systems, detector commissioning and verification, pre-operations, and logistics support (provided by Raytheon Polar Services Company, the subcontractor to NSF that provides logistics support for NSF programs in Antarctica). We ask that you organize in a way such that each of these subsystems receives a detailed review of cost, schedule, and technical performance, of plans for the coming year, and of any longer term impact issues, with attention to appropriateness of any substantive changes to: (1) the baseline since the May 2007 Annual Progress Review, and (2) the contingency on the cost-to-complete in each key project area. In areas for which there is significant risk to cost, schedule, or meeting technical requirements (for example possible shortage of flights or fuel), we ask that the Panel assess project plans to mitigate and manage such risks through contingency and/or other means.

The construction project is now more than 80% complete in terms of earned value and 40 strings of Digital Optical Modules (DOMs) are deployed in the deep ice at the South Pole Station. The approved scope for IceCube is 70 strings, with the understanding that up to another 10 strings may be added making use of contingency funds if the overall project cost performance permits. The latter addition would restore the total size of IceCube to the 80-string configuration originally proposed to the NSF. Cost performance has indeed been good and the additional strings are now being planned. The IceCube completion schedule is anticipated to require three more deployment seasons at Pole: 2008/2009, 2009/2010, and 2010/2011. Based on what has been learned since the project began, the construction team has been evaluating options for the final string deployments to optimize the science output. As a result of the latter activity, the project team is now asking for authorization to deploy an additional 6 strings beyond the 80 planned originally, locating those strings at the center of the IceCube array and creating a compact array at the core of IceCube. The compact array would serve as an improved low-energy neutrino detector replacing AMANDA. We ask that you review 1) the rationale for this change to scope in terms of scientific return, 2) the funding plan for the added strings based on the use of available contingency plus additional funds from foreign partners, 3) the planned schedule for deployment of the 6-string compact array in the coming 2 austral summer seasons at Pole (2008/2009 and 2009/2010), and 4) the risks to achieving the overall science goals if they proceed with the 6 extra string plan and circumstances – either unexpected shortfall in contingency or lack of availability of flights or fuel – force stopping at 80 strings overall.

In addition to construction activities, IceCube project staff will present a progress report on Observatory operations, which began in May 2007. NSF support of operations support is now ramping up to the planned steady state level. We ask that you review progress in operations, any changes to planned staffing levels, how well-matched staffing levels are relative to needed level of effort, and make an assessment of risk associated with reaching the planned level of overall performance in exploiting IceCube for science and education.

The agenda has been constructed such that plenary presentations will be made on the morning and early afternoon of June 11th. The plenary talks and discussions will be followed by breakout sessions covering groupings of all key areas of the construction project (Level 2 elements of the Work Breakdown Structure [WBS]), operations, and 'end-game' plans for final string deployments, and these will take place for the bulk of the remaining time, interspersed with Executive Sessions for general discussion by the Panel. Breakout Sessions will include:

1. Drilling, Installation, Logistics, and Safety
2. Instrumentation and IT Systems Construction, M&O, R&D, and Analysis
3. Management, Construction Project Overall Performance, and Endgame

The Breakouts are shown in more detail following the agenda, including tentative panelist assignments to cover all the areas of construction and operations.

We thank you for taking on this task, as it is essential to provide in-depth accountability for all the large MREFC projects and related operations.

Appendix B. Members of the IceCube NSF Annual Review Panel

Review Panel

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Appendix C. Agenda for the Review

National Science Foundation Annual Review of the
IceCube Project
June 11-12, 2008
5th Floor, 222 W. Washington Ave., Madison, WI

AGENDA

Wednesday, June 11, 2008 – SuperNova Conference Room

8:00 am	NSF Executive Session	D. Hartill
8:30 am	Welcome & IceCube Science	F. Halzen
8:50 am	IceCube Collaboration Status and Overview	T. Gaisser
9:15 am	Construction Project and M&O Program Overview	J. Yeck
9:45 am	Detector Performance and Optimization Plans	A. Karle/P-O. Hulth
10:15 am	*Break*	
	Construction	
10:30 am	Drilling and Installation Results and Plans	T. Hutchings
11:00 am	RPSC Support	S. Clapp
11:20 pm	Data Infrastructure Construction	G. Sullivan
11:40 pm	South Pole Planning & Safety	J. Haugen
12:00 pm	*Lunch*	
	Maintenance & Operations	
1:00 pm	Detector Operations & Maintenance	K. Hanson
1:30 pm	Computing Technology & Support	J. Richards
1:50 pm	Software & Data Processing	M. Merck
2:15 pm	R&D Plans	A. Karle
2:50 pm	*Break*	
3:00 pm	Subcommittee Breakout Sessions[1]	
5:30 pm	NSF Full Committee Executive Session	D. Hartill
6:30 pm	Adjourn	

Thursday, June 12, 2008

8:00 am	Parallel Subcommittee Presentations/Discussions
10:00 am	Subcommittee Working Sessions
11:00 am	NSF Full Committee Executive Session
12:00 pm	*Working Lunch*
1:00 pm	Subcommittee Working Sessions

[1] Breakout sessions defined on the next page(s).

2:00 pm	Dry Run of Closeout Briefing
3:00 pm	Closeout Briefing with Collaboration and IceCube Management
4:00 pm	Adjourn