Report of the IceCube Science Advisory Committee's May 5-6, 2008 Meeting

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(Not attending: K. Wyatt Brown, John Carlstrom, Rocky Kolb, Paul Manstch, Jay Marx)

Introduction and Summary:

A meeting of the IceCube Science Advisory Committee (SAC) was held at Madison, Wisconsin on May 5-6, 2007. The Committee heard a number of presentations (see attached agenda) related to the status of the construction project, the operations and data collection for the experiment and plans for data analysis and physics measurements with the IceCube detector.

The committee was very impressed with the IceCube progress over the past year. A new record 18 strings were deployed with few problems. The goal is to deploy 20 strings per year over the next two years and then finish up with 6 strings in the third year. The project is on track to reach a completed IceCube detector with 80 standard strings and 6 "Deep Core" strings in 2011. During this year, data from 22 strings were collected over a running period of 318 days with 96% livetime. The IceCube data set is now equivalent to Amanda but with much better capabilities; physics results from the 22 strings are expected over the summer. (Over the next several years, Amanda will be phased out since it is expensive to operate and maintain. The plan is to replace and improve on the Amanada capability with a 6 string inner core.) Data collection from 40 strings has begun and should continue with little deadtime over the 2008/2009 time period. By many measures, the IceCube progress this year has been outstanding. The Committee applauds collaboration for this success along with the continuing emphasis on safety.

The data and physics analysis has also been progressing well. The analysis is organized around three detection channel working groups and eight physics topic working groups. The physics topics include: point sources, diffuse sources, gamma-ray bursts, cascades, cosmic ray physics, and solar WIMP searches. A mock data challenge associated with point sources has been accomplished over this year and has shown that the analysis chain is working well but that care needs to be taken for discovery claims. The Committee was glad to see that real physics analysis is now starting using the IceCube data but would like to understand in the future how the analysis will be organized and how sufficient manpower will be gathered to cover all of the physics opportunities.

The IceCube collaboration is now faced with several decisions on the deployment of the final 40+6 strings. Funding and contingency looks good for reaching the goal of 80+6 strings and the deployment plan looks reasonable. Two endgame options were presented to the SAC for comment: 1) a low energy enhancement option with a 6 string inner "Deep Core" using optimized DOM spacing and new high QE PMTs and 2) an option to spread out the 9 outer strings for better coverage of high energy events. The Committee feels that these are very interesting possibilities but is worried that the optimization of the total system has not been adequately considered. Decisions on the outer string option needs to be made by January, 2009 and should be made using physics simulations of the capabilities of the total IceCube system.

Several R&D projects are also being pursued in the area of radio and acoustic detectors for ultra-high energy events. The Committee supports the concept of this type of R&D since it takes advantage of the special opportunity for a test bed of new techniques that IceCube provides. These efforts may lead to a major new detector in the future with much improved discovery potential. On the other hand, these efforts need to be much more focused and motivated with respect to the physics, and the program needs to be much more formally structured with specific goals and milestones. Tests of new detectors should go hand-in-hand with simulation studies that both give a context for the R&D results and also indicate the eventual physics capabilities of such systems.

As presented, the next several years will be a difficult time for the collaboration since the construction funding will be winding down and funding for scientists and students for physics analysis will be switching to university base grants. We were told that the funds for about 20 out of the 27 scientists who have been supported on the MREFC and M&O grants will be eliminated. A large fraction of these young scientists are crucial for maintaining the US strength for physics analysis and therefore it is imperative that funding be secured for the next several years to allow this group to participate in the physics program of IceCube. If funding for 15 of these individuals can be obtained, the US effort can be brought to a healthy number, 28 scientists and 27 students plus faculty. We recommend that the IceCube collaboration consider submitting a new coordinated supplemental grant proposal to empower the universities to play a leading role in the IceCube physics program by providing additional funding for young university scientists who have spent their previous years building and commissioning IceCube.

The Committee heard that IceCube has negotiated a three year M&O funding plan with NSF that will provide funding for accomplishing much of the data acquisition, monitoring, and data storage over this time period. This is inline with the previous SAC recommendation to seek funding for M&O costs through a single proposal from UW. The Committee is encouraged that such a proposal has been submitted and approved in principle but is worried that the allocated funds are insufficient to accomplish the M&O tasks necessary for the experiment. It is clear that IceCube has an outstanding record of accomplishing the construction project close to schedule and within budget. It is now imperative to provide the M&O funding so that the physics potential of the experiment can be exploited. Since this is an international experiment, other countries should also be providing their fair share of M&O support. The Committee requests that the M&O funding plan be fully described at the next meeting and that the IceCube collaboration work with the NSF and other country agencies to assure that the M&O tasks are fully covered in a fair and adequate division.

The Committee was charged by IceCube management by being given a list of questions to be addressed in our deliberations and in our report. Additional questions and interpretations were made by the Committee and the report is organized according to these questions with finding, comments, and recommendations.

Question 1.

a) Are the progress and plans for science analysis satisfactory given that half of IceCube is in the ice and operating? In particular, do we have the right balance among the different science topics?

b) Comment on the collaboration's plans for coming out with physics results on the various topics. How does the schedule of milestones for the analysis/calibration development, assessments of systematic uncertainties, and expected data samples fit with this plan.

Findings and Comments: The balance among the science topics seems reasonable. The analysis efforts are pursuing topics in many directions, all of which have important discovery potential. With this broad program, there is, however, a possible drawback that this may be stretching the manpower too thinly thus not fully exploiting the data. We were informed that some groups are manpower limited with just a handful or so of junior researchers. This clearly is not sufficient and may require better consolidation of the analysis effort. The plan for basic analysis results and plan for publications provided to the Committee is an excellent start. It sets many ambitious goals execution of which will be challenging in view of limiting manpower. We recommend that this plan be widely circulated and discussed within the collaboration, if that has not already happened, and then developed further.

We recommend that each analysis topic establishes its own set of necessary tasks to be completed and clear milestone dates for their execution. We would further suggest that by the time of our next meeting the Committee is presented with much more information on the plans for assessing systematic uncertainties for each of the main upcoming topics for the next 1- 2 years. A list of basic questions includes: What are the dominant sources of systematic uncertainties?, How are they assessed and cross-checked?, and What are the prospects for improvement over time? This will necessarily be iterative, as the detector and analysis issues are better understood, but now is the time to start. We emphasize that for many topics the result (measurement or non-detection) is the easy part: experimental cross checks, validation, and error assessment often require most of the effort.

We commend the Collaboration for developing the mock data challenge technique and emphasize that it should become a standard intrinsic procedure of every analysis topic. This is an excellent tool for exploring a wide parameter space of factors affecting the results and for evaluating systematic uncertainties.

The Committee would also recommend to the Collaboration to aggressively disseminate IceCube results in topical conferences. Many experiments, for example, allow only one preliminary result that is reported at conferences unmodified until the final result (defined by refereed publication) is ready. This often energized the collaboration, provides an incentive to write papers and allows results to emerge in a timely way. It is also often used and an effective PR tool and provides exposure for younger members of the Collaboration. The analysis coordinator and collaboration management should provide a standard checklist and nominal path that conference talks and papers must follow.

Question 2. Is our plan for optimizing the detector in the final three deployment seasons appropriate?

The SAC was presented with two proposals to change the baseline layout of IceCube: a) insertion of a dense inner detector mostly in the deep, clear ice section below the so-called dust layer, and b) a relocation of 9 outer strings at somewhat more distant positions as compared to the original plan.

Deep Inner Core Option:

Findings and comments**:** The scientific motivation for the adding of the dense core was very convincing. The arrangement increases, by up to a factor ~10, the detection volume for several important processes and searches. Examples include dark matter neutralino annihilation in the sun in the energy range of few GeV and TeV neutrinos where one has a very high chance to detect point sources. (The current observation of ground-based gamma astronomy indicate that many galactic and extragalactic sources cut off in energy in this energy domain, i.e., not due to absorption processes by the extragalactic background light, but by intrinsic cosmic accelerator limitations.) In view of the upcoming GLAST observations in the energy range up to 300 GeV the large increase in sensitivity of IceCube in the overlapping energy band is of great importance. The second benefit of the proposed arrangement is that it can profit from the veto shield capability of the upper part of the normal IceCube array to open up an entirely new range in observing modest energy neutrinos in the 'southern sky'. This has up to now been excluded by the presence of atmospheric background which needs to be suppressed in the order of 10^6. Due to the proposed arrangement of the new insert with respect to IceCube, most of the DOMs are above the new insert and will act as a multiple veto against downgoing atmospheric muons.

Recommendation: Since European collaborators already agree to finance the new strings and since the installation plan fits well within the current IceCube schedule and installation budget, the SAC fully endorses this project. The SAC sees a large increase in the scientific potential of IceCube due to this modification. The SAC would like to receive more detailed information on the angular resolution and background rejection, as well as the prospects to analyze cascade events. The SAC also recommends that it should be studied if the experiment could instrument the string in the center of the insert with the new higher quantum efficiency photomultiplier tubes; for this one would need to understand the possible complications in the normal analysis due to the higher noise and different photomultiplier parameters of the high QE tubes. With the installation of the new insert the Amanda detector will eventually be phased out. This should make data recording simpler and also free some resources for operating the new inner detector. The SAC supports this decision made by the Collaboration to eventually stop Amanda. The SAC recommends installing the first such deep core string with narrower spacing in the next drilling season to get an understanding of any potential problems as early as possible; the position of this first string should be chosen carefully with respect to the questions of optimization for the full IceCube detector.

Outer String Placement Option:

Findings and comments**:** For the other proposed change in layout, the IceCube collaboration proposes to shift the positions of the not as yet installed 9 strings of the baseline design to a somewhat larger spacing with respect to the original layout. The shift is motivated by trying to increase the IceCube sensitivity for events from neutrinos with energies above the PeV scale including the GZK neutrinos. According to the presented studies the gain in sensitivity for a configuration still complying with minimal extra costs and within the given schedule (still conserving some contingency) would be of the order of 1.15-1.4. While enhancing the high energy sensitivity, these changes would lose a bit in sensitivity around 10^{14} eV where according to the general understanding source signals are very unlikely to be present. Enhancing the sensitivity in the PeV domain is an important issue although the estimated gain is modest.

Recommendation: The justification for increasing the sensitivity in the PeV domain is convincing but not as strong as for the new inner detector because the gain is rather modest. As there is still some time left to make the final decision of selecting the exact locations, the Collaboration should try to further optimize the layout taking into account both the outer strings and inner core options. The collaboration must also be sure that the planned installation is fully in compliance with the given budget and installation plans to get IceCube fully operational in 2011. Also, any negative impact on the normal physics program should be carefully evaluated by full simulation and subsequent analysis.

The plan for the End Game of the Construction Project seems to be sound. The Committee was impressed with the detailed plan for contingency usage and was pleased to see there is still some funding available for unforeseen problems.

Question 3. How can we best support R&D for future possibilities that build on IceCube? Do we have the right balance between obtaining results from IceCube itself and exploring future possibilities?

Findings and Comments: R&D related to the IceCube experiment is a rather complex issue compared to many other experiments in particle astrophysics.

i) The installation at the South Pole requires a highly organized approach that is fairly costly and constrained by tight schedules.

ii) The main elements of the detector are frozen into the ice and are, thus, never accessible for maintenance or upgrades.

iii) IceCube is a unique installation with excellent discovery potential and will be one of the primary astroparticle detectors over the next decade.

iv) Any new detector idea requiring tagging of high energy cosmic neutrino events needs a large detector such as IceCube as a environment to verify its performance capabilities.

Two distinctively different lines for R&D are currently being pursued:

a) Improving the detector performance using feedback from IceCube's own findings or from new results in high energy particle astrophysics from correlated fields such as very high energy gamma astronomy or from the current studies in ultrahigh physics such as AUGER. Findings over the next years might give new insight into estimated rates or new processes and it might be necessary to consider possible detector improvements within constraints given in i) and ii) above. The addition of the new dense array in the deep clear ice section is a good example. The full implications of the recently found deep clear ice sections are not yet completely evaluated and it is important not to preclude possible upgrades in the future.

b) Besides the direct improvement of the IceCube DOM concept other activities are concentrated on new detection techniques to find a much more cost-effective detection method that can increase the sensitive volume for extremely high energy events such as GZK neutrino events that are expected to be very rare. Such studies will likely require detector volumes exceeding IceCube by at least 2 orders of magnitude. Low-level R&D activities are concentrating both on the radio detection method and acoustic detection method. Both methods have been under consideration for many decades but no significant breakthrough has been achieved. Results from the current efforts and studies indicate that both methods are probably only be suitable for event energies above 10^{18}-10^{20} eV where the expected rates are extremely small. It is therefore absolutely necessary to link these R&D studies with a large existing detector such as IceCube to be able to tag and study such events.

Recommendations:

The SAC considers it essential that the IceCube collaboration keep an R&D activity ongoing to be able to respond (within the given special limitations of the experiment) to any new physics results linked to high energy astrophysical neutrinos, either from its own finding or from the results from related mutimessenger experiments such as dark matter experiments, gamma astronomy or the highest energy CR experiments. The SAC recommends that as the activities associated with the installation of the main IceCube detectors are winding down, the collaboration develops the program of studies and R&D to determine the possibilities for practical IceCube upgrades. IceCube offers a unique environment for doing these R&D studies and prototype installation in normal IceCube holes could be a cost effective way to do some initial R&D if it does not impact the regular IceCube installation schedule. These R&D efforts may require some modest additional funding which would need to be secured.

The SAC considers the current program of studies and R&D related to using radio or acoustical detection unsatisfactory. While the current activities in these areas are highly appreciated and considered very interesting, the SAC feels that a stronger engagement of the collaboration board in reviewing and coordinating these activities is necessary. Regular meetings defining milestones, providing critical review of progress and coordinating the activities towards the most promising approaches should be set up under the guidance of the collaboration board. The SAC feels that these R&D groups should not only concentrate their activities towards sensor development but also put an equal amount of resources into the understanding and simulation of the basic emission process and the transmission of the radio signal and, specifically, the acoustic signals in the rather complex ice medium. Eventually a complete (Monte Carlo) description from the signal generation, the signal transport and the detector response must be provided in a similar manner as has been done for the Cerenkov signal detection in IceCube or atmospheric Cherenkov signals in ground and fluorescence arrays.

With respect to possible future upgrades, the SAC recommends in about 2-3 years that an in-depth review be made concerning the decision to remove, scrap, mothball or keep operational the installation tools such as the drill and other equipment necessary to lower instruments deep into the ice in the far future.

Question 4. In view of the higher than planned raw data rate and limited satellite bandwidth, and given our available resources for operations, are we on the right track for optimizing data handling; including plans for triggering, filtering, data archiving, data processing and Monte Carlo production?

Data Rates

Findings: The IceCube data rate is significantly larger, by a factor of 2 to 3 with compression, than planned. The raw data rate into the online farm is 7.5 MB/sec for the current IC40 configuration, and expected to go to 15 MB/sec for IC86. This is the rate that is written onto tape, and filtered events are streamed out over the satellite link, which is now limited at about 40GB/day. The reasons for this high rate were given in terms of raw data size due to uncompressed waveform data and the event rate which is 2x higher than expected. We heard that adding the Deep Core option is expected to change data rates rather little, on the order of 1GB/day.

Comments: Currently the pulse shapes are compressed only through lossless compression of the data stream, as decided in 2005. The experiment has only started to look at waveform compression. There could be significant savings by storing just the information characterizing the pulse. This should be feasible at least for simple pulses that occur in the overwhelming cases (e.g. single downward-going muons). We were told that this is going to be looked at.

Recommendation: We recommend that the collaboration work out a compression system for, at least, the "simple" pulses, and plan to put this into operation. Smaller data rates will significantly increase the accessibility of data and will put less stress on the data storage systems and funding for upgrades.

Satellite:

Findings: Ice Cube is fully using the available bandwidth with the filter stream which is ~saturating the allocated bandwidth. Given the (large) event size, filtering is limited by the available satellite bandwidth. Currently the satellite supports a filter rate at the rate level of 80Hz. We heard there is 25% overlap between filters which is probably as low as it can be. At this point, the rates are such that satellite outages can still be recovered.

Comments: There is significant risk associated to the dependence on the satellite link. This is an old satellite with limited bandwidth. There is no TCP/IP support and, thus, no interactive operations of south pole systems from remote locations. There is no MoU defining the Satellite usage, just a Service Level Agreement.

Recommendation: An NSF roadmap for satellite bandwidth available to IceCube would be important to plan for the continued and extended needs for the satellite link. The need for 60GB sounds like reasonable requirement, and should become part of the NSF plan for the bandwidth provided from the pole.

Monte Carlo:

Findings and Comments: A well-functioning Monte Carlo (MC) production system is in place. Seven sites are contributing and requests from the physics groups get processed automatically. About 200M events are produced per month. It was stated that the MC efforts are still part of the "MREFC" for IceCube and the committee feels that this should become more connected to physics organization in the future. MC validation is not yet formalized and is being done as a "collaboration task" between the physics efforts and the software experts. Overall, the MC project looks like it is moving towards a good system.

Data Warehouse:

Findings: The Data Storage Systems have seen significant scalability and operational problems over the last year. The higher-than expected data rates have stressed the data warehouse systems, and have caused significant operational burdens due to insufficient storage space. There is a document describing the data storage requirements, and a plan to upgrade the Data Warehouse at a cost of about $1.4M. The addition of an Hierarchical Storage Management (HSM) system at the Data Warehouse, with a tape back-end for the disk storage systems, will significantly increase flexibility and scalability of the system.

Comments: The HSM in the data warehouse will enable IceCube to make full use of the full event streams once tapes are sent over from the pole. Currently this is limited due to the high effort required for making it useable for large-scale production. Making tapes and the full event stream (with the shipping delay) an integral part of the HSM will allow improved access to the full data samples and reduce the risks from compressing the filtered stream and increase the physics potential. With sample sizes of order 300TB/year, the current industrial technology developments will solve these issues over time and probably very soon. In conclusion, the plans for upgrading the data storage systems look sound and well thought through.

Recommendation: The experiment should plan for regular computing upgrades. This year's upgrade will come out of MREFC reserve but for the future a budget for these upgrades should be defined and the funding sought.

Data Challenges:

Recommendation: The SAC commends the experiment for taking up the data challenge efforts. The plan to include the low level insertions of signals that will test the end-to-end data handling chain should become part of the mainstream analysis plan.

Question 5. Comment on the possible requirement and issues related to IceCube providing public release of the data.

We were asked to comment this year again on the question of public data access. We reaffirm the findings in our 2006 report, reproduced below, and we do not see the value of public data access at this time. It would be much more productive and efficient to continue to grow the collaboration with new, strong groups that are well positioned to help with data analysis. The collaboration should look beyond existing members who start new groups at new institutions, and consider bringing in entirely new collaborators who could provide specific expertise where needed.

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Data Policy (from SAC 2006 Report)

We were asked to comment on the data policy for IceCube, in particular the possibility of making the data public and how that might be done. Since IceCube is a facility-class experiment, this is not a surprising question. On the other hand, although IceCube is a breakthrough facility, no neutrino point sources have been detected yet. It therefore seems unwarranted to spend resources now on a realistic plan to release the data to the public. After sources have been discovered, and their number and characteristics are better understood, this could be reviewed. It might then make sense, for example, to develop an Associates program, driven by the science potential.

It should be noted that public release of data in a scientifically meaningful way is not a trivial undertaking. On general grounds, both of the following are necessary conditions for a successful data release plan:

1) The data are sufficiently rich that they can not be mined by the instrument team alone. In other words, there is real value added by guest investigators.
2) There are available the necessary incremental resources (which will not be insignificant) for making the data, all associated analysis software, and detailed information about the instrument, available to the community.

In principle, a data release plan should be known from the beginning of the project. For IceCube, this will be difficult because the construction project will extend over many years. Data formats, standards, and code architecture are all significantly affected by the sizable number of incremental requirements on the system inherent in public release of data. In addition, a user committee must be formed and actively engaged early to give feedback on the plans. Who would use the public data, in what ways, and how big a group is this likely to be?

It would be quite unusual and ill-advised to place the burden of data release and community support on the shoulders of the instrument team. The instrument team must focus all its efforts on producing a well-understood instrument that does great science. A separate science support center that interfaces with the instrument team is typically established -- and funded -- to provide these functions.
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Question 6. Comment on the organization of the SAC meeting and how best to use the SAC in the future?

The presentations at this meeting were very good in laying out the information and issues in a concise way.   The Committee through the presentations and charge was able to quickly assess the key points and work towards addressing them in the short time of the meeting. The charge to the Committee was presented as a list of questions to consider. This was a good method for structuring the meeting and deliberations but it is very important that these questions are carefully chosen to span all the important issues and topics. Also, having extra time for discussion and Committee executive sessions is very important to the goal of making independent assessments during the meeting. The Committee encourages IceCube to structure future SAC meetings with these guidelines.

The SAC has a broad spectrum of expertise and thus can give a global view of how the IceCube experiment fits into the more general framework of particle and astroparticle research. In addition, experts associated with large scientific experiments using large data samples, complex instruments, and large collaborations can bring insights into how scientific endeavors can excel in these environments. The Committee hopes that the comments of the SAC group are helpful for the IceCube program and encourages the collaboration to think about how the SAC can best be used in the future.

Agenda

Monday, May 5

Monday	Discussion Topic	Discussion Lead
08:30 – 09:00	SAC Closed Session	Mike Shaevitz
09:00 – 09:30	Overview & Response to SAC 2007 Report 2007 Plus comments on M&O and Base Grants	Tom Gaisser
	<u>Data and Operations</u>	
10:00 – 10:30	IC22 Data Analysis and Simulations	Gary Hill
10:30 – 10:50	Data Challenge Using IC22 Data	Chad Finley
	Break	
11:10 – 11:40	Filtering, Reconstruction, and Calibration Issues	Martin Merck
11:40 – 12:10	Data Management Status and Plans	Greg Sullivan
12:10 – 13:00	*Lunch*	
13:00 – 13:30	DAQ and Experiment Control "Live System"	Kael Hanson
13:30 – 14:00	IC40 Physics Run Preparations	Erik Blaufuss
14:00 – 14:30	Discussion	
14:30 – 16:00	<u>Construction Endgame and Future</u> Construction Project: Status and Endgame	Jim Yeck
	Inner Core Plans	Per Olof Hulth
	Outer Ring Plans	Albrecht Karle
	Break	
16:00 – 17:00	<u>R&D Activities</u> Radio Plans and Benchmarks	Hagar Landsman
	Acoustic Plans and Benchmarks	Justin Vandenbroucke
17:00 – 18:00	Open Discussion	

Tuesday, May 6

08:30 – 10:00	Open Discussion	
10:00 – 12:00	Report Writing	
	Lunch	
13:00	Closeout	Mike Shaevitz