The 1999 NSERC and SNO-ARC Science Review of SNO

Version 0.9

December 16, 1999

Executive Summary - PKS/MV

1 Introduction PKS/MV

The NSERC Subatomic Physics Grant Selection Committee (GSC 19) and SNO Agency Review Committee (SNO-ARC) commissioned independent reviews of the Sudbury Neutrino Observatory (SNO) in fall 1999. The NSERC review follows on similar annual reviews that have been arranged by GSC 19 in the context of the project grant renewals for the Canadian SNO collaborators. The recently reactivated SNO-ARC also established a Science Subcommittee that was mandated to give advice to both SNO-ARC and SNO on the science and management of the project. The memberships of the two committees are listed in Appendices B and C.

These two committees coordinated their reviews so that a common set of presentations by SNO collaborators were made to both committees on 8 December 1999. The committees then split up on December 9 for presentations on funding (GSC committee) and more detailed discussions on specific issues such as calibration and the long range plan (SNO-ARC subcommittee). The agenda for the two-day review is provided in Appendix D. A common set of recommendations on scientific and technical matters was arrived at by the two committees, and so this report documents the findings of the review. In the case of the NSERC review, Appendix A of this report details the committee's funding recommendations to GSC 19.

The committees wish to thank the SNO collaborators and NSERC staff for arranging a productive two-day review. In the opinion of the two committees, the needs of an NSERC GSC review and the SNO-ARC Science Subcommittee review have such a large overlap that a more efficient process could be established. Since the SNO-ARC Science Subcommittee is an ongoing one, it is suggested that this committee be augmented by two GSC members to perform the funding review in the future.

2 The Science - FH/EK/EB

A series of experiments, covering almost three decades of neutrino observations of the sun, have established an electron neutrino (ν_e) flux of about half the value calculated. The set of available data cannot easily be reconciled with standard solar model (SSM) calculations because they are incompatible with the existence of the so-called ^{7}Be neutrinos. Moreover, the SSM appears robust from the theoretical point of view and have been confirmed by helioseismology studies. Therefore, the assumption has been that the solution to the "solar neutrino problem" resides with the particle physics of the neutrino, and not with the astrophysics of the sun. SNO has the potential to reveal the properties of neutrinos responsible for the deficit in flux, with oscillations providing the best motivated explanation. The prospect that SNO provides the first conclusive evidence for ν_e oscillations has been reinforced by the recent indirect observations of ν_μ oscillations in the atmospheric neutrino flux.

In the last year, the results from the competing SuperKamiokande experiment show that that it will be more difficult than expected for this experiment to provide an unambiguous solution to the solar neutrino problem. Their much larger detector has made impressive observations of the solar neutrino flux confirming, once more, the ν_e deficit. It does not have the capabilities, however, to establish the origin of the deficit with good statistical significance. Hints provided by measurements of the time- and energy-dependence of the solar neutrino flux have not converged on a particular solution to the problem. SNO has the tools to step in and resolve the solar neutrino problem over the three year timeframe discribed in its current scientific plan. While new detectors such as Borexino will be commissioned during this time, they are unlikely to be ready to compete. In any case, data from all the presently running experiments (SNO, SuperKamiokande, GNO and SAGE), which detect neutrinos with different energy thresholds and are therefore sensitive to different nuclear reactions in the solar model, will be of high scientific value as they will both increase our knowledge of the sun and the nature of neutrinos.

Using D_2O as a target, SNO has the unique capability to measure both the flux of electron neutrinos via the charged current (CC) interaction as well as the flux of other neutrino flavours via the neutral current (NC) interaction. One can therefore observe the reappearance of the oscillating ν_e as a neutrino with a a different flavour. This is done with a modest detection efficiency in SNO until, after one year of running with pure D_2O, magnesium salt ($MgCl_2$) is added to the D_2O in order to raise the NC detection efficiency to 83%. In the third year of the scientific plan, neutron detectors will be inserted in the SNO detector to replace the magnesium salt, resulting in a lower NC detection efficiency, but a potentially better separation of the NC events from events resulting from ν_e interactions.

Even before a precise measurement of the neutral current flux, the oscillation models compatible with previous observations of the solar flux can be distinguished after accumulating several thousand charged current events. How conclusive this observation will be will depend on the result; and the statistical significance is unlikely to be compelling. It is therefore an important issue to determine how one decides the duration of the pure D_2O data taking with a stable and well-understood detector before moving on to the definitive neutral current measurements. During this period, SNO will also provide information on the possible "high-energy anomaly" observed by the SuperKamiokande collaboration in the form of an excess of events near the endpoint of boron spectrum.

Other science missions of SNO include measuring the properties of atmospheric muons and the detection of galactic supernovae. The scientific importance of observing a supernova with a detector like SNO far outweigh the low probability that such an event will occur during its lifetime. The participation in the SNEWS early warning network enhances the science reach of this effort. It will allow astronomers to make the important early observations that were not possible with SN1987A.

Finally, we note that of the currently operating detectors, SNO has the lowest energy threshold and is sensitive to all species of both neutrinos and antineutrinos. This is a direct result of the very deep underground location of SNO, which reduces backgrounds arising from cosmic ray muons, and the very low radioactivity levels achieved by the collaboration in the instrumentation and water.

In summary, with its potential for measuring the neutral as well as the charged current interactions of neutrinos, SNO holds the key to solving the solar neutrino problem. It will possibly provide the first direct observations of solar neutrino oscillations. The detector has started data taking with an adequate time window to deliver results before competing detectors will be commissioned.

3 Detector Commissioning Status

3.1 Operations - PKS/JW

The SNO collaboration has made very good progress in commissioning the detector over the last seven months since the water fill was complete. This was evidenced in all aspects of the experiment. The team now is focussed on understanding the detector and optimizing its performance. Since the water fill was completed at the end of April 1999, all systems of the detector have been commissioned and brought into routine operation. Significantly, the last major changes to detector configuration were made in the middle of October (the photomultiplier tube (PMT) high voltage was increased by 100 V), and since then the collaboration has been focussed on operating the detector with increasing efficiency, while at the same time calibrating the detector and measuring background rates.

The electronics and data acquisition (DAQ) systems are operating smoothly, with typical trigger rates in the neighbourhood of 15-20 Hz. The detector is operating with a typical trigger threshold of order 17 hit tubes, corresponding to an energy threshold near 2.0 MeV. The "livetime" of the detector – in this case the fraction of time that the detector was ready to detect supernovae events – was reported to have reached 94% in the month of November, an impressive figure given the complexity of the detector. Livetime for solar neutrino collection was significantly lower due to conflict between certain operations during calibration and normal data taking.

The operations team appears to be well-managed and highly competent. The committee is confident that the necessary structure is in place to operate the detector, although overall personnel resources are stretched when one accounts for the large number of parallel tasks that must be underway to support the calibration, operation and analysis activities.

3.2 Calibration - PKS/JW

The SNO detector has an arsenal of calibration sources designed to measure the optical response of the detector, its energy resolution and background rates. The optical calibration, performed using a laser source and a diffuser ball suspended in the D_2O, appears to be well understood, although this work is not yet complete. An understanding of the optical transmission and detection of photons is a fundamental issue, and must be established before a detailed energy calibration can be completed. The committee was shown preliminary results of the optical calibration, demonstrating that the agreement between observed performance of the detector and the Monte Carlo (MC) predictions was at the few percent level. The non-uniformities of the illumination of the source remain to be completely resolved, though a reasonable plan exists to address this issue.

Three calibration runs using a ^{16}N source that provides a 6.1 MeV γ have been performed, and this calibration already provides an energy calibration at this energy that has an uncertainty better than 6%. The ultimate goal is to have an understanding of the energy calibration to an uncertainty of 1%, which requires periodic ^{16}N runs and the deployment of additional sources. These calibration sources are:

- U and Th sources to measure the characteristics of the principle background sources in the D_2O,
- a $(p, t\gamma)$ source that provides a 20 MeV γ calibration point,
- a ^{8}Li source to provide a β source with a continuous energy to measure the efficiency of the "data cleaning" operations and test the understanding of the detector's energy response, and
- a number of lower-energy sources for background studies and low-energy calibration points.

The collaboration has as its highest priority the analysis of the existing calibration data and the deployment of the U, Th, $(p, t\gamma)$, and ^{8}Li sources in order to meet its initial physics milestones. The reviewers agree with this strategy.

The collaboration noted that personnel resources may limit its ability to implement these additional calibration sources on a schedule consistent with the first physics milestone of May 2000. The committee is not convinced that the schedule is credible either, given the limited personnel involved in the calibration effort. The reviewers recommend that the collaboration make every effort to identify additional scientific personnel in order to ensure that these additional calibration sources are deployed and the calibration data analyzed early enough to allow SNO to meet its May 2000 physics milestone.

3.3 D_2O, H_2O and Radioactive Backgrounds

The key to the SNO detector is the 1000 tonnes of D_2O suspended in a spherical acrylic vessel at the centre of 7000 tonnes of light water (H_2O) shielding. The light and heavy water both must be maintained ultrapure for optical clarity and low background radiation. The radioactivity in the water is required to be less than one uranium disintegration per day per tonne of water. The heavy water is valued at 300M$ and therefore has to be accounted for very carefully. Although the heavy water is insured against a catastrophic loss or dilution with light water, the cost of restoring heavy water that has been diluted (downgraded) or lost through normal operation is considered part of the operating and decommissionining costs.

The structural integrity of the acrylic vessel is essential to the safe operation of the experiment. Analysis of the stresses on the acrylic require the level of the heavy water be maintained within a 0.5 cm tolerance. The heavy water itself is on loan from AECL to the end of 2000. Negotiations are underway to extend the loan, first to the end of 2001 and then to the end of 2003. The first date is well in hand and the collaboration is optimistic about achieving the second.

The SNO water handling team has done a highly professional job of designing, building, commissioning and operating the water systems. Moreover, they have met a number of significant challenges including some unsuspected experimental conditions that became apparent once the water was in place. Some important milestones over the last year are noted here:

- February, 1999 – Light water regassed.
- May 1, 1999 – Detector full.
- June, 1999 – Radioactive assays start.
- July, 1999 – Atmospheric pressure of the deck changed to exclude radon. The cover gas was removed from the light water.
- August, 1999 – A flow of nitrogen gas is introduced to the neck of the acrylic vessel. In November the gas is humidified to stop static electric discharges.
- September, 1999 – The recirculation of the D_2O reaches the design flow rate of 150 lpm. Radon gas levels decline.
- November, 1999 – The radon levels are close to the design criteria. The first full ^{16}N calibration is made.

The water operations require a specially trained team of six operators, four assistants and three others in charge of maintenance, cleaning and other functions. The team works six twelve-hour day shifts and three twelve-hour night shifts per week. The water system may only be run when there are at least two operators underground at the experiment. The ongoing operations include running the circulation systems for the heavy and light water and making radioactive assays. Recently the water team has moved one technician to the surface to help with the assay chemistry and funding for a replacement for the underground position has been requested. The committee supports this improvement to the water operation team.

The radiation levels in the water have improved and are approaching design. Radon levels are an important indicator of the uranium content of the water, and weekly assays are scheduled. Radon levels in the $\mathrm{D_2O}$ have dropped to approximately the design criteria following the stable application of a flowing nitrogen cover gas for the $\mathrm{D_2O}$. The price that has to be paid is a loss of 200 ml of $\mathrm{D_2O}$ per day. The radon in the light water is nearing design specification, with the largest source of radon appearing to be from air entering from the mine. The water team is working on sealing leaks into the light water cover-gas volume.

Assays for radium contamination in the $\mathrm{D_2O}$ are made to estimate the amount of uranium (^{226}Ra) and thorium (^{224}Ra) using MnO_x and seeded ultrafiltration techniques. The uranium assays are at 10^{-15} gram U per gram water, well below the required levels. The thorium assays have only yielded upper limits so far that are near the required levels. A direct observation confirming the thorium concentration is required, and the collaboration is working on a high flow system with eight parallel columns of MnO_x to solve this problem. A system to detect lead is also being developed (this is a .

The water team is also developing the plant that will produce the $\mathrm{MgCl_2}$ brine and remove it from the $\mathrm{D_2O}$. This operation is critical for the neutral current measurement of phase 2 of the SNO experiment. The system will be reviewed in the next couple of weeks. The schedule calls for the brine to be produced and underground by September 2000.

The total inventory of heavy water received by SNO from Ontario Hydro is 1,106,484 kg. The isotopic purity of the bulk water is checked regularly and has not changed. Approximately 170 kg of heavy water has been lost, mostly by absorption in the acrylic vessel. Further losses from evaporation are expected to be 73 kg per year. The cost of replacement is approximately $300 per kg. Another 2025 kg have been isotopically downgraded as part of the initial setup and due to ongoing assays. There is a further 30 kg that is isotopically pure but contaminated. This water can be cleaned on site.

The downgraded water can be returned to Ontario Hydro for upgrading at a cost of $8 per kg, so that the cost of upgrading the present inventory will be about $20 000. The SNO collaboration would like to start returning degraded water to reduce their stored inventory. Ontario Hydro has requested a delay while it develops an appropriate facility. Over the longer term upgrading costs are expected to be roughly $10 000 per year.

4 Physics Analysis - PS/RK

The SNO collaboration has over the last year put together a comprehensive analysis plan, consisting of a series of "supporting analyses" and a set of "physics analyses." Working groups have been established for each of the supporting analyses, although the personnel effort in many of these groups is limited to only one individual (who in many cases has multiple responsibilities). Convenors have been identified for organizing each working group, and a gant chart detailing the analysis effort over the next three years has been developed. Each group has clear goals and is working toward a common schedule and set of milestones.

The organization of this analysis effort is an impressive first step toward getting science out of SNO, and the reviewers applaud the collaboration for the commitment to this structured process. The reviewers endorse the collaborations commitment to use the SNOMAN framework as the basis for all "final, publishable analyses." The collaboration was able to report significant progress on all major analysis fronts: software and databases, detector support, calibrations, data flow, data cleaning and event characterization. They have set as important milestones the completion of the optical calibration by April 2000, the energy calibrations by July 2000 and a preliminary measurement of the charged-current and elastic scattering (CC/ES) flux by February 2001.

However, much remains to be done, and personnel resources appear to be a limiting factor in analysis progress. There are approximately 10 full-time personnel working on solar neutrino analyses, an additional 6 physicists working partime on solar neutrinos, 4 physicists involved in analysis of through-going muons, and 2 physicists working full-time on the supernova watch. Of these analysis efforts, the reviewers were satisfied that sufficient resources were allocated to the latter two topics. However, the reviewers were very concerned that the analysis effort on solar ν's was too dispersed and not sufficiently focussed. The collaboration reported that four independent groups were involved in solar neutrino analyses. Although it is important to have several independent analyses on this topic, given it is where SNO is expected to have the greatest scientific impact, the reviewers believe that four such analyses are simply too many given the limited physicist resources. The reviewers recommend that the solar neutrino physics analysis efforts be more focussed with a smaller number of independent efforts.

5 Management Issues - MV

The SNO collaboration has taken significant steps over the last year to improve its management structure. The Scientific Management Committee and the Senior Executive Committee were replaced by a Scientific Board (SB) that meets at least monthly. The SB includes one representative from each SNO institute, the national spokepersons, the scientific officers (director, two associate directors, analysis coordinator), and key group leaders. Two members are elected at large by the collaboration, with the intent that they represent the junior members of the collaboration. The scientific board is responsible for setting policy on topics such as the length of data runs in each configuration of SNO, run plans within each configuration, and publication and conference talks. The board's decision must be ratified by the collaboration. This management scheme seems to be working well.

The collaboration has also reorganized the supervision of the operation of the water systems and the detector. David Sinclair was appointed as Associate Director - Science with overall responsibility for running the experiment. Tony Noble replaced Sinclair as Associate Director of underground operations with main responsibility for the water systems. Richard Van de Water is the head of the detector working group and is responsible for the day-to-day operation of the detector systems. Finally, Josh Klein is continuing as analysis coordinator. This team is effective and the committee feels that SNO operations run smoothly.

Last year's GSC site review committee expressed concern over the long term staffing of key management positions related to the fact that several individuals would have to return to teaching duties, or to retirements. The SNO collaboration has responded to this issue by designating replacements and/or deputies for these key individuals, and the situation seems to be in hand.

6 Schedule and Longer Range Science Plan - KP/EB

A.B. McDonald presented the SNO Long Range Plan (as of December 1999) to the combined SNO-ARC Science Committee and the NSERC Review Committee on the 8th December. In essence, the plan proposes taking data over the next three to four years to attack the solar neutrino problem in four stages:

1. running in pure D_2O,
2. adding $MgCl_2$ to the D_2O,
3. using the ^3He Neutral Current Detectors (NCD's), and
4. running in pure H_2O.

This is consistent with the main goal of SNO, which is to determine independently the total flux of "active" neutrinos from the neutral current (NC) interactions in heavy water and to compare this with the flux determined only from the charged current (CC) interactions. The charged and neutral current measurements are unique to SNO. When complete, this should allow the different possible solutions to the "solar neutrino problem" (large and small angle MSW effect, "just-so" vacuum oscillations, sterile neutrinos) to be resolved.

The scientific goals for the four stages outlined above are clear, and are detailed below.

6.1 Running in Pure D_2O

The scientific objectives for running with pure heavy water are:

- to measure the integral ne flux with the CC interaction with $E_n > 7.5$ MeV,
- to measure the energy spectrum with CC interaction with $E_n > 7.5$ MeV,
- to measure the integral ν_e flux with the Elastic Scattering (ES) interaction with $E_n >$ 7.5 MeV,
- to make an initial measurement of the ES/CC ratio, and
- to make an initial measurement of the NC/CC ratio.

This last measurement will require a proper understanding of the radioactive backgrounds.

This is a sensible initial programme, which will allow experience to be gained with running the detector over an extended period in stable conditions, and will also test the calibration, data reduction and data analysis techniques. The results from the ES interactions could be compared to the SuperKamiokande data.

A sufficiently precise measurement of the spectral shape could, in principle, yield valuable information on the origins of the neutrino oscillations, but this probably requires a longer run for this to be statistically significant than is justified, given the importance of the NC measurements. There is a risk that a measurement of the ES or NC rate, combined with the CC rate and the SuperKamiokande data, will allow almost anyone to do 'quick and dirty' analysis to 'resolve' the solar neutrino problem. The collaboration needs to have a clear strategy for deciding what data can be shown publicly.

6.2 Adding $MgCl_2$

By adding salt ($MgCl_2$) to the D_2O, the sensitivity to neutral current events is significantly enhanced. Techniques have now been developed which allows the NC/CC ratio to be deduced statistically from the data, making this a robust technique. The operation is relatively quick - it should take about a week to introduce the salt though a brine solution - and reversible - removing the salt by reverse osmosis will take about one month. This should yield the first statistically significant measurement of the NC/CC ratio.

Given that this procedure is relatively quick, and could be repeated should problems or inconsistencies arise, it makes sense to perform this test early.

Would we like to see a technical evaluation of the impact of MgCl2 on the integrity of the acrylic vessel?

6.3 Using the ^3He Neutral Current Detectors

The NCDs enhance the sensitivity for NC detection by using 3He counters. This allows NC events to be recognised on an event by event basis, and may help reduce the systematic errors on the measurement of the energy spectrum.

The deployment of the NCDs is a major interruption to the schedule, and is estimated to take about 3 months, during which time the detector is open. [The SuperNova detection system will also be off during this time.] The deployment is not easily reversible, although it will be an advantage to identify NC events individually.

6.4 Running in pure H_2O

The main objectives are to confirm the radioactivity backgrounds and the ES measurements. It is clearly prudent to plan this at some stage, but for practical reasons this should be done last.

6.5 Discussion and Recommendations

The proposed long-range plan defines a coherent programme for achieving the scientific goals of the experiment. However, the Committee was not given sufficient detail to be able to judge whether this ambitious programme was realistic in the timeframe suggested. The committees make the following comments and recommendations:

1. The Committee endorses the general strategy for the NC measurements. In particular, the Committee believes that it is essential that the $MgCl_2$ run be completed before deployment of the NCD's.

2. The Committee is concerned that there is no set of criteria which determines the time at which the change over from pure D_2O to D_2O+$MgCl_2$ takes place.

3. The Committee would like to see a set of milestones against which progress for at least the first two stages of the long- term plan can be measured and monitored. The Committee recognises that this is an ambitious programme, and is concerned that without a clear schedule against which to operate, the scientific goals might be compromised.

4. The Committee believes that it will take at least until 2004 to complete this programme of work, and that it is therefore important to negotiate by June 2000 an extension for the use of the D_2O until at least 2004.

7 Photomultiplers, Bases and the HV Connectors

Last winter there were very serious problems with "wet-end breakdown" in the HV connectors leading into the photomultipler tube (PMT) bases. Since the regassing of the light water that surrounds the PMTs with nitrogen in March 1999, the breakdown problem in the connectors has been dramatically reduced. The detector has operated stably with minimal problems from high voltage breakdown or tube loss since that time. The PMT death rate, from all causes, based on about 6 months of operation, is presently 0.4% per year or about 1 per week, well in line with other large water detectors. Wet-end breakdowns still occur so there is no evidence that the HV problems are completely solved but there is no indication at this time that a connector replacement program will be needed.

The SNO collaboration has followed the recommendations of the External Advisory Committee on the High Voltage Connector, which reported to SNO-ARC in April, 1999. Several on-line and near-line monitoring tools have been implemented to track high voltage effects such as the presence of "sharkfin" pulses and blown terminator resistors in the PMT base to give an early warning of the onset of problems.

Sharkfins are large charge pulses with no light present, which are assumed to be due to micro-discharges in the connector. They appear as events in the ESUM trigger and can be monitored with the random PULSE_GT trigger. As they are characterized by a large (> 100 mV) pulse in one channel with pick-up in several nearby channels on the same HV distribution card, they can be easily identified for monitoring and for removal from the neutrino trigger data during the data cleaning process. The wet-end breakdowns are known to blow the terminating resistor in the PMT base after tens of discharges and this can be monitored by reflection tests or by checking for gain increases in a channel, since the loss of the 75 Ohm resistor causes the gain to double. If the sparking persists the series resistor can open, causing the tube to become inoperable. Another problem leading to tube loss is a water leak into the connector or PMT base which causes the high voltage to short out.

The most serious problem in terms of the neutrino background are "flashers," which are light emitting breakdowns inside the PMT. The light is picked up in several surrounding tubes and in tubes on the opposite side of the detector. These are not HV connector related and a significant fraction of the tubes exhibit flasher behaviour. Seismic activity increases the rate of flasher events. A sufficiently large number of tubes are involved to show up as a neutrino trigger, which currently has a threshold set to 18 hit tubes. The flasher signature has now been well defined so that these events can be removed during the data cleaning, although the efficiency of doing this has not been determined as yet.

In October 1999, the voltages on all PMTs were increased by 100 V to improve the signal/noise and provide the design sensitivity threshold of 0.25 photoelectrons. During this increase the HV phenomena were closely monitored. Both the sharkfin and flasher rates increased and then settled to acceptable rates; sharkfins from 1.5 Hz to 2.5 Hz and flashers from 30 per hour to 50 per hour. The tube loss rate since that time has not noticeably increased. There are presently 160 PMTs not functioning in the detector, with most of these due to failures before the regassing was carried out in March.

Two other recommendations of the External Advisory Committee on the HV connectors were for the SNO collaboration to develop and test a replacement high voltage connector and to produce an implementation plan showing the cost and time impact if a repair were necessary. A new connector design has been produced but only variations of this connector have been tested to date. A draft report on the SNO Detector Connector Repair was submitted to the SNO collaboration and to the SNO-ARC Science committee at this meeting. The main conclusions/recommendations of the draft report, which still needs to be reviewed by the collaboration, are as follows:

- If a connector repair is required, a new wet-end male connector/full cable assembly replacement represents the best understood methodology at this time. (We note that this is solution 1. as recommended by the External Advisory Committee.)
- A dry repair with full cable assembly replacement will cost 5.18 million 1999 Canadian dollars, and will take 12.5 months of detector non-operation.

The committee has the following recommendations for the collaboration:

- Continue the close monitoring of the detector HV performance.
- Complete the development and fabrication of the production prototype of the replacement connector and test 10-20 of these, first in an initial long-term test at TRIUMF to be completed in 6 months and then in the SNO detector using the Berkeley underwater test sleds.
- The External Advisory Committee on the High Voltage Connector should continue to receive bi-monthly reports on the HV performance.

8 Future Science Opportunities - FH/KP/MV

9 Summary of Recommendations - PKS

The recommendations outlined in the report are summarized here:

1. The collaboration review the personnel requirements for the deployment of the highest priority calibration sources (U, Th, $(p, t\gamma)$, and ^{8}Li) and the associated analysis efforts.
2. The collaboration focus the solar nuetrino analysis efforts to make use of limited personnel resources in as effective a way as possible. The number of independent analyses should be reviewed and perhaps reduced.
3. The Committee endorses the general strategy for the NC measurements. In particular, the Committee believes that it is essential that the $MgCl_2$ run be completed before deployment of the NCD's.
4. The Committee is concerned that there is no set of criteria which determines the time at which the change over from pure D_2O to D_2O+$MgCl_2$ takes place.
5. The Committee would like to see a set of milestones against which progress for at least the first two stages of the long- term plan can be measured and monitored. The Committee recognises that this is an ambitious programme, and is concerned that without a clear schedule against which to operate, the scientific goals might be compromised.
6. The Committee believes that it will take at least until 2004 to complete this programme of work, and that it is therefore important to negotiate by June 2000 an extension for the use of the D_2O until at least 2004.
7. The collaboration should continue the close monitoring of the detector HV performance.
8. The collaboration complete the development and fabrication of the production prototype of the replacement connector and test 10-20 of these, first in an initial long-term test at TRIUMF to be completed in 6 months and then in the SNO detector using the Berkeley underwater test sleds.
9. The External Advisory Committee on the High Voltage Connector should continue to receive bi-monthly reports on the HV performance.

Appendix A: Funding Recommendations

Appendix B: Membership of SNO-ARC Science Subcommittee

- Prof. Pekka Sinervo, Department of Physics, University of Toronto (chair)
- Dr. Ewart Blackmore, TRIUMF
- Prof. Francis Halzen, Department of Physics, University of Wisconsin
- Prof. Ed Kearns, Department of Physics, Boston University
- Prof. John Martin, Department of Physics, University of Toronto
- Prof. Ken Peach, Particle Physics Department, Rutherford Appleton Laboratory

Appendix C: Membership of the NSERC SNO Review Committee

- Dr. Michel Vetterli, TRIUMF (chair)
- Prof. Enrico Bellotti, Milano
- Prof. Patricia Kalyniak, Department of Physics, Carleton University
- Prof. Richard Keeler, Department of Physics and Astronomy, University of Victoria
- Prof. Jim Waddington, Department of Physics, McMaster University
- Ms. Kate Wilson, Team Leader for Subatomic Physics and Astronomy, NSERC (observor)

Appendix D: Agenda for Review

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Wednesday, Dec.8th: SNO Project Status
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 9:00 Committees in camera (15)
       - organisation of the two committees

 9:15 Introduction  A.B. McDonald (15)

 9:30 Status of Experiment (35) D. Sinclair
       - overview of commissioning
       - status of outstanding problems from last year
       - what new problems have arisen?
       - prospects for physics results

10:05 Water (35) T. Noble
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- rate of loss of D2O
- status of degradation
- assays: time & number
- contamination levels
- status of MnO2 fabrication
- status of MgCl2

10:40 COFFEE

10:55 Detector (30) R. Van de Water
- PMT's (status of HV breakdown)
- electronics & DAQ
- monitoring

11:25 DAQ (15) A. Hamian
- DAQ status
- Future development

11:40 Analysis (45) J. Klein

Organisation

Technical:
- status of software & databases
- status of data reduction
- online analysis

Physics:
- analysis chain & software
- Monte Carlo studies
- prospects for physics results

12:25 LUNCH

1:25 Calibration (30) A. Hallin
- what has been done?
- current development of new sources
- future sources

1:55 3He Detectors, U.S. Status H. Robertson (15)

2:10 Discussion of morning session (20)

2:30 Scientific Priorities & Strategy (45) A. McDonald

- Time required for CC measurement
- Competition
- Neutral Current Measurement

3:15 COFFEE

3:30 Special Topics
- Supernova Detection (15) C. Virtue
- Muons, Atmospheric Neutrinos (15) C. Waltham

4:00 Discussion of afternoon session (30)

4:30 Committees in camera (60)

5:30 Close-out meeting

5:45 Adjourn

7:00 Working Dinner

Thurday, Dec.9th

9:00 Committees in camera (60)

10:00 COFFEE

The two committees will split at this point.

Schedule for GSC Committee

Operations Grant:

10:15 Site Operations Grant (60) McDonald, Sinclair, Hepburn, Noble
- Services funded by this grant
- Staffing requirements
- Budget
- Organisation

Institutional Grants:

11:15 Overview (20) A. McDonald

- Group responsibilities
- # of people to satisfy these responsibilities
- Typical travel costs

This information should be given in tables we can refer to in later presentations. Questions to be reserved for individual groups.

11:35 Queen's (20) A. Hallin

11:55 Carleton (20) D. Sinclair

12:15 LUNCH

1:15 Guelph (20) J. Simpson

1:35 Laurentian (20) D. Hallman

1:55 UBC (20) C. Waltham

2:15 General Discussion

2:45 COFFEE

3:00 GSC Committee in camera (60)

4:00 Close-out meeting

4:15 GSC Committee in camera (60+)

Adjourn when required for travel

Thursday, Dec.9th

Schedule for SNO-ARC Sub-Committee

9:00 Committees in camera (60)

10:00 COFFEE

The two committees will split at this point.

SNO-ARC Science Sub-Committee

10:15 - 11:30 SNO-ARC Committee Meeting in camera

11:30 - 12:15 LUNCH

12:15 - 2:15

Calibration Details (A. Hallin) (20)

HV Connectors (R. Helmer) (20)

Run Plan (D. Sinclair) (30)

Review of Plan for Neutral Current Detection (A. McDonald)(30)

Discussion of Possible Future Projects (A. McDonald) (20)

2:15 General Discussion

2:45 COFFEE

3:00 SNO-ARC Committee Meeting in camera

4:00 Close-out