The International Workshop on Neutrinos and Subterranean Science (NeSS 2002) was held September 19-21 in Washington, DC, pursuant to a request from the executive branch of the U.S. government for a workshop to develop a roadmap that will guide neutrino and subterranean science investigations worldwide over the next few years. The interdisciplinary meeting was structured around scientific working groups that covered six sub-disciplines of physical science – double beta- decay, proton decay, neutrino oscillations, dark matter, solar neutrinos, astrophysical and cosmological neutrinos; three sub-disciplines of geoscience – geology, geengineering and geobiology; as well as the topics of national security, and education and outreach. Despite the short lead-time, some 320 participants from all over the world attended the workshop.

**Consensus Of Working Groups**

- The great potential and intense activity in this field demand the creation of a program for science done underground, including geobiology, geophysics, physics and astronomy.
- IceCube will probe the sources of the highest energy particles by observing high-energy neutrinos from distant regions of the Universe. It is different in design and goals from experiments to detect low energy neutrinos or search for dark matter and rare processes in the low-background environment of an underground laboratory.
- Concerning the two major elements of the charge to the workshop there was also unanimous agreement of the working group leaders that both of these efforts should be supported.
- The workshop brought into focus the enthusiasm for the physics and geosciences goals that could benefit from the existence of a national underground laboratory as well as the national security benefits.
- A new program in the areas of underground science, with an under ice detector in Antarctica and a national underground laboratory in the Continental United States, could have a coordinated and important education and outreach benefit built into all aspects of the program from its inception.

The original request from the executive branch requested information on the IceCube neutrino telescope and "research on neutrino collectors, including applications for underground research". In parallel, a committee of the National Research Council, the Neutrino Facilities Assessment Committee (NFAC), was established with a similar charge. The two activities have been coordinated and members of the NFAC participated in the NeSS workshop.

**A principal conclusion of the Workshop is that the goals of IceCube and a national underground laboratory are, in fact, two separate research endeavours.** IceCube will be a high-energy neutrino observatory that instruments a large volume of ice at the South Pole to detect high-energy neutrinos from distant regions of the Universe. In contrast, there is a group of detectors designed to measure rare low-energy processes of a fundamental nature that require the low-background environment of a deep underground location.
The presentations highlighted the proposed experiments’ ability to complement both accelerator based physics programs and each other. While the depth requirements varied among experiments, with some experiments requiring great depths and some requiring only modest depth, many specific examples were presented in which the various experiments could benefit from being in a common facility or facilities with the infrastructure to support these different types of experiments. There was also considerable excitement expressed by the physicists about the science proposed by the geosciences working groups, and it was clear that these groups could do more than just co-exist in a common facility. These conclusions are supported by the record of the meeting in the working group executive summaries and in the presentations themselves. The following brief summary includes some observations on the relation among the different sub fields.

Specifically, the working groups reported on the compelling scientific need for an underground facility that would enable:

- Experiments to search for and measure rare, **neutrino-less double beta decay** that will address the nature of the neutrino and its absolute mass. They seek to answer the fundamental question whether the neutrino is its own antiparticle.

- **Dark matter experiments** whose goal is to detect the approximately 30 per cent of the Universe that is neither visible nor likely made up of ordinary (baryonic) matter. These experiments have the potential to discover the supersymmetric particles predicted by many particle physics theories.

- The next generation of **solar neutrino experiments** that are needed to measure in detail the process and parameters of neutrino transformation that has been observed in recent measurements. In combination with the information that can be provided by a low-energy, high-intensity underground accelerator, we could also significantly improve our understanding of the nuclear reactions that power the Sun and supernovae.

- Experiments that, using beams of neutrinos from accelerators at large distances, measure with precision **neutrino oscillations and CP violation**. The goals of these experiments are to measure the parameters of the standard model and to gain an understanding of the origin of the matter – anti-matter asymmetry in the universe.

- The next generation of **proton decay** detector. Most current models of particle physics based on ideas of higher unification have proton decay as a compelling prediction. Previous generations of detectors have yet to discover it. The next generation detectors need to be a factor of nearly 20 times bigger to reach the predicted lifetime range.

- A **geosciences laboratory** that gives scientists the opportunities for studying coupled processes in the Earth at depth. These include growth and survival of novel microscopic life forms, fluid flow, rock deformation and geochemical processes.

- A laboratory for low background counting and seismic detection of explosions that could provide new capabilities for addressing needs in **national security**.
In addition to experiments that could be housed in an underground facility, there was a convincing case made for:

- A detector for **high-energy astrophysical neutrinos**. This detector would open a new window on the universe and on the most energetic phenomena known. This type of observatory requires a detector with a volume of the order of a cubic kilometer, made by placing detectors in a large, natural volume of clear water or ice. This will allow for detecting neutrinos in the energy range above the background of atmospheric neutrinos, while also using the atmospheric neutrinos as a calibration beam in the TeV energy region. There was consensus that the science sufficiently warranted the effort for both approaches to be pursued – water, in the northern hemisphere and ice, at the South Pole. These two efforts are complementary, both technically and in sky coverage.

The first two days of the workshop were divided between parallel sessions of working groups and plenary talks from leaders of the field. In order to reach a consensus overview of status and prospects for its sub-field, each working group heard presentations from a broad spectrum of scientists and considered conclusions of previous relevant reviews and workshops. These conclusions were presented to the entire workshop in plenary talks on the last day. They were also collected in a set of working group executive summaries that were made available to NFAC before its final meeting.

The summaries are on the web at [http://umdgrb.umd.edu/goodman/ness02/summaries/](http://umdgrb.umd.edu/goodman/ness02/summaries/)

All talks presented during the workshop, parallel as well as plenary, are posted at: [http://umdgrb.umd.edu/goodman/ness02/talks/](http://umdgrb.umd.edu/goodman/ness02/talks/)

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