

A POLICY-CENTERED
ANALYSIS OF THE
PROPOSAL TO CREATE A
UNITED STATES NATIONAL
UNDERGROUND SCIENCE
LABORATORY

Prepared by

Daniel Stanton

**Department of Civil and Environmental Engineering
South Dakota School of Mines and Technology**



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FOREWARD

Founded in 1980 through the collaborative efforts of several professional engineering societies, the Washington Internships for Students of Engineering (WISE) has become one of the premier Washington internship programs. Its goal is to groom future leaders of the engineering profession who are aware of and can contribute to the important intersections of technology and public policy.

During their ten weeks in Washington, D.C. the WISE interns interact with leaders in the Congress and the Administration, industry, and prominent non-governmental organizations. Meetings with congressional Committees, executive office departments, and corporate government affairs offices are daily activities. In addition, each of the 15 students researches and presents a paper on an engineering-related public policy issue.

The topic for this paper was selected based on the following criteria:

1. Opportunity to research the interface between engineering and public policy;
2. Availability of current information;
3. Opportunity to actively engage leaders in the engineering, science and policy fields;
4. Opportunity to make a significant contribution to a current issue.

The proposal to transform the Homestake Gold Mine into a U.S. National Underground Science Laboratory fit all of the above criteria. In particular, because it is an important issue to the state of South Dakota, it leveraged the WISE experience by providing a venue for frequent and meaningful contact with the offices of the Governor and the congressional delegation.

This paper is not intended to influence or challenge the peer-review process; rather, it provides a framework for discussing the larger arena, including politics and economics, within which the scientific community must function when working on large projects that have the potential for significant impact.

EXECUTIVE SUMMARY

The strongest arguments prove nothing so long as the conclusions are not verified by experience. Experimental science is the queen of sciences and the goal of all speculation. (Roger Bacon)

Within the scientific community, many researchers agree that the case for establishing a U.S. National Underground Science Laboratory (USNUSL) is both compelling and urgent. Their planned experiments require a world-class facility of greater depths than are currently available, and a USNUSL could stimulate as yet unimagined research.

The politics, logistics and economics of constructing a large underground research facility would be complex. As a result, the opportunity created by the closure of the Homestake Mine is remarkable not only for the scientific research it could enable, but also for the convergence of support it offers from traditionally competitive political factions.

The greatest challenge to the current proposal is that posed by the time constraints of the Mine closure, which will necessitate the rapid mobilization of all of the stakeholders in the science, economic and political arenas so that a solid consensus can be reached before the opportunity slips away.

Given this information, it may be possible to realize Princeton physicist John Bahcall's prediction that "Homestake will become a gold mine for science discoveries about physics, astronomy, biology and geology."ⁱ

INTRODUCTION

What I am going to tell you about is what we teach our physics students in the third or fourth year of graduate school... It is my task to convince you not to turn away because you don't understand it. You see my physics students don't understand it... That is because I don't understand it. Nobody does. (Richard P. Feynman)

“What is a neutrino, and why should I care?” The questions sound simple, but the answers are not.

Perhaps the biggest problem is that no one knows enough about neutrinos to even describe them very well. They are particles, but they are also waves. They are smaller than electrons - small enough to pass right through the entire Earth as easily as water passes through a screen. But even though they are small, they are still very important; billions of neutrinos are produced in the sun every second, and the universe is littered with neutrinos that have been floating around since the Big Bang. Current physics textbooks claim that neutrinos have no mass, and that assumption has been a cornerstone of the Standard Model that physicists use to describe everything from atoms to galaxies. But in July of 2001 the Brookhaven National Laboratory announced that neutrinos do, in fact, have mass. That means that the Standard Model, as we know it today, is wrong! What seems most clear is that the things we don't know about neutrinos vastly outweigh the things that we do.

Using neutrinos as an example, it is no wonder that the High Energy Physics Advisory Panel's Subpanel on Vision for the Future of High Energy Physics offered the following advice to the Department of Energy in its 1994 report:

“We must ensure that the U.S. (research) program is responsive, flexible, dynamic, and progressive. By its very nature, basic research in science explores unknown realms. General principles and patterns of understanding guide the search, but history provides much evidence – in fact history almost guarantees –

that we will encounter surprises. These will lead to new insights and motivate new directions of research out of which new paradigms will emerge.”

This spring, a committee of leading physicists developed a plan to convert the 125-year-old Homestake Gold Mine in the Black Hills of South Dakota, which has housed a neutrino experiment for thirty years, into a world-class underground science laboratory. But their proposal to expand the nation’s research infrastructure, now under peer-review by the National Science Foundation, also involves a fascinating web of issues ranging from science to politics (both locally and nationally), to labor and economics, to education and even the environment. As a result, this relatively obscure proposal, built around a complicated branch of physics, has become the focus of surprisingly broad attention.

Prior to World War II there was essentially no relationship between scientific research and politics.ⁱⁱ For better or worse, that is no longer the case. Today, the 711 government-funded research laboratoriesⁱⁱⁱ in this country are heavily dependent upon the federal appropriations process and, as a result, upon the political machine. This paper discusses the scientific relevance of the United States National Underground Science Laboratory (USNUSL) proposal, identifies the unique opportunities offered by the Homestake site, and analyzes the political process that the proposed lab has, and will continue to, face.

THE BUILDING BLOCKS: GETTING A PROJECT GOING

"New ideas pass through three periods:

- 1. It can't be done.*
- 2. It probably can be done, but it's not worth doing.*
- 3. I knew it was a good idea all along!"*

(Arthur C. Clarke)

To initiate any major government program in the United States, there must typically be a crisis that results in a consensus. The crisis provides momentum, while the consensus simplifies the otherwise protracted process of political approval. Additionally, in order for a large-scale scientific initiative to be successful in the long-term, it must make a compelling case in at least three general areas: science, politics and economics. These building blocks – the crisis and consensus, combined with a case that appeals to science, politics and economics – should be defined and developed early in the proposal process. In the following sections, each will be evaluated with respect to the USNUSL proposal.

CRISIS AND CONSENSUS

The whole problem with the world is that fools and fanatics are always so certain of themselves, but wiser people so full of doubts. (Bertrand Russell)

There are two critical issues that add urgency to the USNUSL proposal: the first is the imminent closure of the Homestake Mine, generally accepted to be the best site for locating the USNUSL,^{iv} and the second is the momentum that has been created by recent discoveries about neutrino properties.

If the proposal is not considered before the Homestake closes on December 31, 2001 then the Mine will begin to fill with water, and that will result in high reclamation costs and the outward migration of a highly skilled workforce. Likewise, the current excitement surrounding neutrino research provides valuable visibility at a time when research budgets are spread over a wide range of scientific disciplines; if too much time elapses, neutrino research could be eclipsed in the public eye by another field of study. These two issues provide a compelling motive for quick action on the USNUSL proposal and, as a result, offer a golden opportunity for creating the necessary consensus.

THE SCIENCE CASE

"... When people thought the Earth was flat, they were wrong. When people thought the Earth was spherical they were wrong. But if you think that thinking the Earth is spherical is just as wrong as thinking the Earth is flat, then your view is wronger than both of them put together." (Isaac Asimov)

Scientific discoveries fuel our modern technological society, so most people agree in principle that it makes sense for the government to support scientific research. Yet one of the most remarkable ironies of our technological age is that it empowers the general public to remain ignorant about current research, while leading them to expect (and sometimes demand) that science provide solutions to all of their problems. Put another way, we live in an era of costs and benefits, but we have not yet reconciled the profound differences between running a business and expanding our knowledge of the universe – the difference between commerce and science.

Unlike businesses and government organizations that have clearly defined and measurable outcomes, the practical possibilities that scientific research creates are seldom within the scope of human imagination at the outset. Who could have imagined that scientists researching electrons – and the subsequent emergence of electricity – would eventually allow us to travel through space, send messages almost instantaneously around the world, and provide heat and light to the nation? How

many Americans honestly expected that research into the structure of the atom would allow us to defeat Japan during World War II? Experience teaches us that while individual experiments may seem esoteric and are often difficult to appreciate, scientific inquiry as a whole is an investment that returns enormous dividends.

The scientific community generally strives to maintain independence from public, political and economic pressures. Yet there are a number of very legitimate reasons for public and political interest in scientific research. Advances in science and technology have been a determining factor in the outcome of every military engagement that the United States has encountered in at least the last 100 years. It is reasonable to assume that the outcomes of those engagements, particularly World War II and the Gulf War, would have been significantly different if that research had been first completed elsewhere. It is also important to recognize that scientific discoveries represent a sort of Pandora's box; while those who develop the technology first have a strategic advantage, all useful technologies will eventually be propagated to other nations as well, resulting in an "even playing field." Therefore, if technology is viewed from the standpoint of national security then in order to maintain strategic advantage it is critical that a nation support continual research on the boundaries of existing knowledge. Finally, those who develop a technology first are in the strongest position to set standards for its safe and ethical use.

Assuming then, without regard to motives, that there is general support for the practice of government funding for research, there are two primary strategies that could be employed for building a scientific case to justify creation of the USNUSL. The first is to focus on the need within the physics community for a deep lab simply for neutrino research, and the second is to broaden the case (and potentially support) by emphasizing the opportunity for a variety of other scientific disciplines to use the facility. Given the recent level of media attention that has been devoted to neutrino research, including prominent placement in the Washington Post, the New York Times and an entire episode of Nightline, it may well be that the neutrino case is strong enough to stand on its

own. Therefore, the neutrino case will be presented first, and it will then be followed by a series of arguments intended to appeal to a broader, multidisciplinary scientific audience.

THE SCIENCE CASE, BASED ON NEUTRINOS

...if he had looked down he might have seen the stars in the water, but looking aloft he could not see the water in the stars. So it cometh often to pass, that mean and small things discover great, better than great can discover the small. (Francis Bacon)

A pamphlet recently published with support from the NSF provides a simple introduction to the neutrino:

“You can’t see them, hear them, or touch them, but neutrinos are everywhere. Whistling right by you – and through you! – even as you read these words. There are a million of them in every gallon measure of space, having an enormous impact on our everyday world. Without them, continents wouldn’t drift, volcanoes wouldn’t erupt, the sun wouldn’t shine.

They probably shaped the evolution of galaxies, and may be the stuff that holds our universe together even as other forces send it flying apart. Oddly, then, while neutrinos play so lively a part in the world around us, we know very little about them.”

The search for neutrinos, numerous as they are, is still in its infancy. Neutrinos are at the cutting edge of physics research. Physicists Frederick Reines and Clyde Cowan were awarded the Nobel Prize for the first experiment that confirmed the existence of neutrinos, and their colleague, Brookhaven National Laboratory researcher Raymond Davis, is credited with originating a whole new field of physics known as “underground astronomy” by setting up a neutrino detector nearly a mile below the surface of the Earth. That detector, in the Homestake gold mine, operates to this day.

This solar telescope resembles a huge, gray oil tank with rounded ends. Forty-eight feet long and 32 feet in diameter, it is filled with 100,000 gallons of dry-cleaning fluid. This chemical reservoir traps neutrinos as they shoot through Earth and provides data about the furnace powering the sun. The principle behind the detector is that when a neutrino bumps into a nucleus of chlorine, the chlorine turns into traceable radioactive argon. By counting argon atoms, it is possible to count the number of neutrinos that have been caught in the detector.

The Homestake results have rattled solar physics for three decades, spawned even bigger subterranean neutrino observatories around the world, and forced particle physicists to rethink their notions about neutrinos. Deep in the core of the sun, where temperatures reach up to 15,000,000° K, hydrogen nuclei – protons – collide and merge. During one second, half a billion tons of hydrogen are converted into helium, releasing a flood of neutrinos in the process. Each second, 66 billion of them rain down on every square inch of Earth's surface and pass right through.

By 1971 the Homestake "telescope" reported that it was capturing about one neutrino every other day, between a third and a half of what solar physicists were expecting. Holding fast to their models of nuclear burning, theorists blamed either Davis's equipment or his chemistry. But after running numerous checks, Davis was sure his results were right. Solar physicists couldn't completely explain how the sun shined. Over the next three decades, the Homestake result stood firm. Later, bigger and more sophisticated neutrino observatories were built in Japan, Russia, Italy, and Canada that confirmed Davis's initial findings.

As a result of this intensive international research, a new theory was developed that neutrinos come in three "flavors": the electron neutrino, the muon neutrino, and the tau neutrino. As the sun releases its storm of electron neutrinos, some change their identity or oscillate before they get to Earth, into the other flavors that the Homestake tank can't detect. To do that, however, neutrinos would have to have a tiny bit of mass. Because the cosmos released hordes of neutrinos at its birth, the mass of this cosmic ocean of shadowy particles could be affecting the universe's

evolution and destiny. It is hard to believe that this astounding revelation first appeared in a bit of cleaning fluid buried in a historic gold mine.

More recent analysis of the Homestake neutrino data also suggests that the neutrino signal varies with the eleven-year solar cycle. When the sun is most active, meaning that the number of sunspots is at its highest, fewer neutrinos are detected. This effect reverses when solar activity is on the wane. But it also registers higher neutrino counts when solar flares pop off; the highest count occurred during a run in the 1970s when the sun emitted a particularly powerful solar flare. At the time, the detector registered double its normal count of neutrinos. But no other neutrino observatory is seeing either of these effects, although they should be capable of doing so. ^{vi}

Recent results from the Super-Kamiokande detector in Japan provided evidence that neutrinos could have mass.^{vii} Then, on June 18th, 2001 the Associated Press announced that physicists had truly solved the neutrino mystery encountered during research in the Homestake Mine.

“Representatives of the Sudbury Neutrino Observatory in Canada announced that neutrinos made by nuclear reactions in the sun’s core change from one type to another during the 93-million-mile journey to Earth. And only particles with mass can change form. The neutrino’s mass cannot be much, around a billionth of a proton’s. But its mere existence has profound implications: the standard model, the reigning theory in particle physics, does not allow particles that change their form to have mass. So that theory will have to be patched up – though not discarded – to accommodate the new observations. Because they originate deep inside the sun, neutrinos may provide an unprecedented view of what goes on there.” ^{viii}

Clearly, underground research is providing us with knowledge at the frontiers of particle physics, nuclear physics and astronomy. The past decade in particular has yielded fundamental progress in underground experiments in such diverse and exciting fields as nucleon decay, atmospheric neutrino oscillations, the solar neutrino measurements, searches for dark matter, and the

measurement of nuclear fusion cross sections at stellar temperatures. But in order to participate in these recent discoveries, U.S. scientists have had to either take their equipment to other countries or, in a few cases, to make use of non-optimal facilities in the U.S.

THE SCIENCE CASE, BASED ON MULTIDISCIPLINARY SCIENCE

"If we knew what it was we were doing, it would not be called research, would it?" (Albert Einstein)

The questions addressed by underground experiments are among the most fundamental and exciting problems in modern science, and it appears that underground experiments will continue to be at the forefront of fundamental science in the coming decade. The next generation of underground experiments, however, is more challenging technically than previous studies and will therefore require significant resources in addition to good planning and management. Creating a USNUSL will help to establish the conditions that will enable the science, which must be done with large, sophisticated equipment, to succeed in a cost effective way. One of the many advantages that a USNUSL could provide would be a coherent research program whose priorities are constantly reviewed in order to produce the best science results.

The following general suggestions for underground research, collected from research scientists at various universities and at the Pacific Northwest National Laboratory, provide a glimpse into the depth and breadth of research opportunities that a USNUSL could create:

BIOLOGY

- Dosimetry
- New organisms
- Bioremediation

- Subsurface microbial ecology: relationship of microbial communities to subsurface chemical and hydrogeologic properties.
- Deep waste disposal: role of microorganisms in governing the integrity of deep (e.g., nuclear) waste containers and the chemical form and mobility of chemicals released from containers.
- Biological diversity: discovery of new microorganisms and microbial products with potential applications in industrial processing and pharmaceutical development

GEOLOGY

- Ground water studies
- Chemical transport
- Thermal-mechanical behavior
- Nuclear waste management

SEISMOLOGY

- Vibration free requirements
- Seismic testing
- Detection of explosives testing
- Detection of weapons testing
- Tunnel depth could get away from surface “noise” sources and complex structure
- Horizontal shafts/drifts could allow placement of array sensors at depth

SOCIOLOGY

- Physical stability
- Behavioral sciences
- Biorhythms
- Human Factors Experiments

- Human biorhythm studies
- Group behavior
- Small group isolation studies

MEDICINE

- Low dosage/high accuracy positron emission tomography
- Low dosage medical diagnostics
- Dosimetry measurements
- Phantom studies

ACOUSTICS

- Acoustically quiet studies
- Communications
- Optics
- Total darkness
- Laser testing
- Vibration free requirements

PHYSICS

- Gravitational studies, including reduced-gravity environment and gravity wave detection
- Infrared detector and shield developments
- Shock dynamics, vibration free environments
- Low-level radiation measurements
- Cosmic ray elimination/studies
- Cosmology
- Astrophysics

- Fundamental particle physics
- Experiments designed to measure double-beta decay, detection of dark matter particles, cosmions, axions, weakly interacting massive particles, and other exotic particles, electron decay, and neutrino mass measurements using internal source beta endpoint measurements.
- Experiments in cosmic-ray physics, measurement of solar and cosmic neutrinos, and measurement of magnetic monopoles.
- Low Level Radiological Measurements
- Environmental low-level waste analysis, ground water monitoring, materials analysis from low yield weapons tests, high sensitivity neutron activation trace element analysis, forensic studies. (Classified national security tests)
- Radiation Detector Technology Development
- Low-level gamma-ray spectrometry, neutron detectors, superconducting detectors, storage and fabrication of detectors and components.

MATERIALS SCIENCE

- Low cosmic ray background environment for semiconductor packaging. Cosmic rays are of concern to those in the computer industry in general due to so-called soft errors associated with the formation of alpha particles from isotopes of U and Th which result when cosmic particles hit these isotopes. The generated alpha particles degrade computing significantly.^{ix}

THE POLITICAL CASE

Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world. Science is the highest personification of the nation because that nation will remain the first which carries the furthest the works of thought and intelligence. (Louis Pasteur)

In a recent editorial, former Republican Speaker of the House Newt Gingrich stated that:

“We need a science budget for the next generation based on opportunities in science rather than on bureaucratic and political infighting in Washington. Five major increases in federal funding for scientific research need to be considered:

1. There should be an increase in peer-reviewed money allocations to allow more high-quality proposals to get full funding.
2. We must begin to fund a new generation of large projects that could create great breakthroughs.
3. Money needs to be available for highly innovative, ‘out of the box’ science.
4. We need a new commitment to integrate the hobbies and funnel the interests of amateur scientists into real discovery.
5. We must have new approaches to learning that combine the discovery process, virtual reality, and a 24-hour/7-day-a-week Internet-based opportunity for the committed learner.”^x

Mr. Gingrich’s statement is particularly relevant because selecting a site for the USNUSL is clearly, in part, a political process. Awareness and support by citizens, governments and institutions are important. Local governments and institutions can provide valuable support, especially in the early stages of the laboratory development. In addition, the USNUSL will need to meet local regulations and codes with respect to construction, transportation of materials and other operational aspects. Finally, support from State Congressional delegations will likely have a real effect on the progress of USNUSL.^{xi}

The National Science Foundation is highly regarded among government-funded entities because of its commitment to the peer-review process instead of accepting guidance from Congress or the Executive branch. Nonetheless, the Department of Energy’s recent experience with the

super-conducting super collider makes it all too clear that large scientific projects must have political support if they are to receive and retain their funding. It is therefore both useful and necessary to discuss the political backing that the USNUSL proposal has currently established.

In evaluating the political climate in the United States, it is essential to consider party issues. On the Democratic side, probably the most significant political figures are South Dakota's senators, Tom Daschle and Tim Johnson. Because Tom Daschle is the Senate Majority Leader, he is in a position to encourage committee chairman to look favorably on the project and to get USNUSL legislation onto their agendas. Tim Johnson sits on the Budget Subcommittee for VA, HUD and Special Programs, which authorizes all funds for the National Science Foundation. His presence on that subcommittee should tend to make it easier for NSF to justify the cost of the project during budgetary reviews. Both senators have stated that this project is a high priority for them, and have assigned assistants to coordinate their efforts.

On the Republican side, it is equally important to consider the support offered by South Dakota Governor Bill Janklow, and by Congressman John Thune. They have both offered backing for the proposal because the USNUSL promises economic and educational opportunities for the state. Their involvement is critical since both men have strong ties to the Bush Administration. Governor Janklow, now approaching his term limit and hoping to designate a Republican successor, was a friend of President Bush when they served together in the Republican Governors' Caucus. Congressman Thune has indicated that he does not plan to run for another term in the House, and is considered a likely opponent during Senator Johnson's next election. Given the delicate balance currently gripping the Senate, and uncertainty about the upcoming House election cycle, it seems that it would behoove the national Republican Party to support a project that is so popular in the state. Ironically, Senator Daschle's support for the project may well be the strongest political motivator for broad Republican support; if the Republicans are seen as opposing the project, then it will be more difficult for them to gain another Senate seat and they could jeopardize one more in the House.

Moreover, the primary thrust of the USNUSL proposal is clearly for basic research, so supporting the proposal fits naturally with the Republican platform's position on scientific funding.

This situation, in which strong political support is available locally and nationally from both parties, both houses of Congress, and apparently the White House, is virtually unheard of in government programs. In fact, it creates the ironic potential for the USNUSL to be discredited within the scientific community as a "pork barrel" project. This puts an even greater burden on NSF to ensure that the proposal is evaluated fairly, through the established peer-review process. Nonetheless, if the project is ultimately approved then this political support could pave the way to obtaining funding at a level that might not be otherwise possible.

POTENTIAL SUPPORTERS

In addition to their primary government funding agency, which in the case of the USNUSL would appear to be NSF, large scientific projects typically draw from a variety of other funding sources. This cost-sharing approach enables many organizations with similar needs to maximize the return from their limited budgets. A USNUSL on the scale that is currently being discussed would offer significant advances in both size and capability over all existing facilities, and would therefore be in a strong position to obtain support from research organizations throughout the world. Given the research opportunities currently envisioned, a short list of potential supporters could include:

- Brookhaven National Laboratory
- Domestic and foreign universities
- Japan Power Reactor and Nuclear Fuel Development Organization
- Lawrence Berkeley Laboratory
- National Aeronautics and Space Administration
- National Institute of Health
- Semiconductor manufacturing companies
- U.S. Bureau of Mines

- U.S. Department of Defense
- U.S. Department of Energy (Basic Energy Sciences, Office of Civilian Radioactive Waste Management)
- U.S. Department of State

OUTREACH

In its Strategic Plan, NSF states the following:

“Enhancing the scientific and technological literacy of the American people is seen as one of the keys to global competitiveness and to personal enrichment and quality of life, as well. Citizens who are scientifically and technically literate will be better able to participate in the democratic society by making informed decisions on matters involving science and technology. They will understand the need for a strong and robust science and technology enterprise, support its inclusion as a Federal funding priority, and encourage and motivate young people to study science and mathematics. Stronger efforts to disseminate the results of research are necessary to gain the understanding and support of citizens and legislators. Creative uses of museums, zoos, radio and television, libraries, and other non-academic organizations will be increasingly important in meeting this responsibility.”

The large number of tourists who visit Mount Rushmore (nearly 3 million per year^{xiii}) and other Black Hills attractions provides a unique opportunity to educate and interest millions of Americans in fundamental science. In addition, the Black Hills has an existing focus on engaging people of all ages and cultures in science, as evidenced by the Journey Museum, Museum of Geology, Scientific Knowledge for Indian Learning and Leadership (SKILL) Program and the Children’s Science Center. Finally, the existing availability of broadband fiber-optic cabling to the Homestake Mine, and a video teleconferencing center in Lead, offer the capability of engaging people from around the world in a fascinating range of scientific experiments.

THE ECONOMIC CASE

Basic research, to which we owe everything, is relatively very cheap when compared with other outlays of modern society. The other day I made a rough calculation which led me to the conclusion that if one were to add up all the money ever spent by man on basic research, one would find it to be just about equal to the money spent by the Pentagon this past year. (Albert Szent-Györgyi)

Over the past decade the United States has allowed itself to slip behind the rest of the world in physics research, and this lag may have substantially increased overhead costs. A 1991 report published by the National Academies stated that it was “the largest and most efficient detectors (that) allow optimum use of the nation’s investment in telescopes.”

The same report, now a decade old, went on to state that:

“Promising new techniques are being developed to observe the solar neutrinos emitted during the key energy-producing reactions in the solar interior.... These techniques can reveal fundamental aspects of how the sun shines and, at the same time, provide important information about particle physics.”^{xiii}

Clearly, the call for solar neutrino research facilities is not new. The National Underground Science Laboratory Committee reported that the Homestake site has distinctive strengths, and preferred Homestake to the other sites it evaluated because of a lower initial cost to achieve breakthrough science, a shorter time until the first experiments could be performed, and fewer unknowns regarding laboratory development. But they also recognized that there is narrow window of opportunity because the Mine, which for decades was the largest gold mine in the Western Hemisphere, plans to close at the end of this year.

“The value of Homestake as a world-class laboratory site will diminish as the closing process proceeds. The Homestake proponents need to address transfer

of the site to the state of South Dakota and a few other issues rapidly, before the knowledgeable staff at Homestake leave the area."^{xiv}

Aside from the specifics of the Homestake proposal, the Committee also identified more general advantages to centralizing underground experiments in one underground laboratory, many of which could be classified as economies of scale:

- Sharing of common infrastructure including access, machine shops, administrative support, computing, and telecommunications;
- Provision for a common safety support that must oversee equipment and procedures for dangerous components such as flammable and cryogenic materials;
- Synergistic interactions among scientists doing different experiments in an environment where they can easily exchange ideas;
- Establishment of common facilities that can be used by different groups interested in, for example, low radioactivity materials or low level counting measurements;
- Creation of a support organization that can make possible the testing and implementation of new ideas within an established coherent scientific program;
- Providing a critical mass for outreach to the local population, especially K-14, and to the public at large;
- Provide a research center that would be a base for international collaborations to maintain scientific and technical staff for developing and carrying out large-scale projects;
- Provide a nurturing and exciting scientific environment in which students and young scientists would develop;
- Provide a center for international scientific meetings.

Other economic factors affecting the Homestake proposal include South Dakota's status as an EPSCOR state, which means that there is research money available throughout the government

that laboratories in more traditional sites such as California or New York would not be able to access, and the geographical location, right in the center of the nation, which could substantially reduce the amount of research money currently expended on travel costs by scientists forced to use Japanese, Italian and Canadian facilities.

Finally, there is a general consensus that much of the economic prosperity that the United States has enjoyed for the past decade is due to advances in the field of information technology. As circuits continue to shrink to microscopic levels, it may be of critical importance to our nation's semiconductor industry to have an ultra low -radiation facility such as the proposed USNUSL in which new materials can be tested and, perhaps, manufactured.

WHAT MAKES A SITE GREAT?

"Give me a firm place to stand and I will move the earth." (Archimedes)

The National Underground Science Laboratory Committee developed very detailed criteria for their vision of a world-class lab:

“In order to be world-class, the USNUSL must be deep. A depth of approximately 6000-7000 meters of water equivalent (mwe) is desirable for many classes of experiments and is required for certain experiments such as the next generation of solar neutrino and double beta-decay experiments. Above this level, interference from the cosmic ray related backgrounds constitute the limiting factor for high sensitivity experiments. The next generation solar neutrino detectors, dark matter searches, and double beta-decay studies require as low a cosmic ray produced muon flux as possible. The simplest and most reliable way to achieve lower cosmic-ray induced backgrounds is to do experiments at greater depths.”^{xv}

Once the Committee was formed, it received many Letters of Interest from scientists throughout the world who would like to perform pioneering experiments using such a deep underground laboratory. Currently, the deepest available general underground scientific laboratory is located at a depth of 3800 mwe in the Gran Sasso National Laboratory in Italy. Therefore, the United States would be in a position to lead the world in pioneering scientific investigations by establishing a USNUSL with a depth extending to 7000 mwe, nearly twice the depth of Gran Sasso.^{xvi}

The selection of an underground laboratory requires the evaluation of a broad range of technical criteria, with the recognition that no site is likely to be perfect for even a single underground physics experiment. Yet site selection for a multi-purpose laboratory is even more difficult because the best site for one detector may not be the optimal choice for another, very

different detector. Therefore, the Committee placed a high priority on sites that facilitate significant sensitivity improvements in a wide range of low background experiments. Such improvements could result from the following: (a) increase in sensitive mass, (b) decrease in impurities, (c) more sensitive instrumentation and/or electronics and (d) more difficult to handle or more costly materials.

The properties of a laboratory that will facilitate significant progress, as outlined by the Committee, include:

- Fast, convenient access for personnel and instrumentation of varying size and weight;
- Large, clean, air-conditioned, well-illuminated experimental and support rooms with sufficient room for staging, assembly, monitoring and maintenance of large, complex detectors;
- A range of rock depths at one or more sites, some of which are equal to or greater than those available elsewhere in the world;
- A management plan and outreach strategy that will efficiently facilitate both the highest quality science and comprehensive public education and understanding.^{xvii}

WHY HOMESTAKE?

When we try to pick out anything by itself, we find it is tied to everything else in the universe. (John Muir)

The Homestake Mining Company announced in September that operations at its Homestake mine in Lead, S.D., would end in 2001. The mine has had negative cash flows since December 1999, and in the first six months of 2000 underground ore grades were lower and development costs higher than planned.

As a result, Homestake has adopted a mine-out plan to extract the remaining recoverable gold and help provide an orderly social transition for the local community. During this time, all developed ore will be mined out and processed. 362 Homestake employees in Lead will keep their jobs through 2001, but only 30 people will be employed over the next eight years to close down the site and make it environmentally safe.

The outcropping of ore that became the Homestake gold mine was first discovered in 1876 by Moses and Fred Manuel. (An outcropping of ore is called a lead, pronounced "leed," and that became the name of the mining town that sprouted over the site.) The Homestake Mining Company was incorporated in California in 1877 by a San Francisco syndicate headed by George Hearst, and today the company remains one of the oldest listed on the New York Stock Exchange which is still in its original business. The oldest continuously operated gold mine in the world, and once the largest gold mine in the Western Hemisphere, Homestake reaches to depths of more than 8,000 ft, making it one of the deepest mines in the world.

During an interview for Engineering and Mining Journal, a Homestake executive offered the following statement:

"This has been a very difficult decision for all of us," said Jack E. Thompson, Homestake chairman and CEO. "The Homestake mine has been an integral part of our company, as well as part of American mining history, for 124 years. It has survived two world wars, the Great Depression, and the ups and the downs of the stock market. In addition to producing approximately 40M-oz Au, it has developed several generations of highly skilled American operators, who have pioneered new methods of mining, mineral processing, and exploration. Throughout its rich history, the Homestake mine has been a pacesetter for high moral standards in relation to its people and the environment in which they live and work.^{xviii}

However, the National Underground Science Laboratory Committee has determined that Homestake provides an unparalleled opportunity for the United States to explore new frontiers in research that requires special environments.

"There is a very wide range of science that absolutely requires a deep underground location," said Kevin Lesko of the University of California's Lawrence Berkeley National Laboratory, the committee's co-chairman. Lesko said other topics for a national underground laboratory include the nature of the sun's interior, better understanding of supernovae, searches for dark matter, behavior and evolution of life in exotic environments, characteristics and stability of geologic structures, evaluation of groundwater resources, monitoring of nuclear weapons tests, and vulnerability of microelectronics and other materials to cosmic rays.

"The lack of interference from cosmic rays, radio waves and other disturbances that can be achieved at a Homestake laboratory represents a new frontier of science," Lesko said.

Recent advances in experimental techniques have enabled a new generation of more sensitive experiments aimed at a better understanding of the basic framework for particle physics,

called the Standard Model. New experiments in the very quiet environments available very deep underground could reveal new information that will help us understand how to make the Standard Model a better description of the universe in which we live. This U.S. laboratory would be unique, and scientists from all over the world could come to the laboratory to collaborate on major experiments.

The Committee also visited and studied other sites at places such as Carlsbad, NM and Soudan, MN. Existing laboratories at these sites are performing important underground science studies, but those sites are not as deep as Homestake. Carlsbad, in particular, could not make deep excavations at their laboratory without compromising the primary mission of the facility.

The Committee's work is supported by grants from the National Science Foundation and the Office of Science of the U.S. Department of Energy. Other committee members include Barry Barish, California Institute of Technology; Frank Calaprice, Princeton University; Janet Conrad, Columbia University; Peter Doe, University of Washington; Thomas Gaisser, University of Delaware; Kem Robinson, Lawrence Berkeley National Laboratory; Bernard Sadoulet, University of California, Berkeley; Henry Sobel, University of California-Irvine; Michael Wiescher, Notre Dame University; and Stanley Wojcicki, Stanford University.^{xix}

APPENDIX A: CHARGE TO THE COMMITTEE

CHARGE TO THE COMMITTEE ON AN UNDERGROUND NATIONAL LABORATORY APPOINTED BY THE INSTITUTE FOR NUCLEAR THEORY AT THE UNIVERSITY OF WASHINGTON

The Committee on an Underground National Laboratory is asked to prepare a white paper that responds to the following issues:

The Scientific Justification for an Underground National Laboratory (50%)

To evaluate the scientific justification for a national facility for deep underground science.

The committee should consider the potential physics that will be produced by the next generation of solar neutrino, double beta decay, proton decay, dark matter, and related background-sensitive experiments. It should also consider the possible relevance of such a facility to other sciences and to industry.

Experiments (25%)

If the scientific justification for a national deep underground facility is judged to be sufficiently strong, the committee should consider the experiments such a facility might host and thus the attributes of the underground laboratory. Important issues include the depth; the number and dimensions of the experimental halls; access requirements (e.g., desirable lift dimensions in the case of vertical access); background radioactivity requirements that will influence ventilation, hall design, and other engineering aspects; and anticipated needs, such as cryogenic facilities, that could have major impacts on design. The committee's views on supporting facilities, both above and below ground, will also be very valuable. This includes power, data, and communications requirements; shops, computing facilities, and above-ground staging or laboratory space; and support facilities for visiting scientists (offices, library, living quarters, food services, administrative assistance). The committee should envision a facility-an above-ground campus, state-of-the-art deep laboratories, and

support facilities, services, and personnel-that would remove many of the existing obstacles to underground experiments. The goal is to move the US to the forefront of underground science.

Potential Sites (25%)

To evaluate the suitability of suggested sites (Homestake, San Jacinto, etc.). This should include the potential quality of the envisioned laboratory; estimated construction costs; the convenience of the site (road and air access, nearby towns); practical obstacles to developing the site; the certainty of the geology (rock quality, hydrology, seismology, etc.); the plan for operating, administering, and maintaining the facility; and issues of ownership, liability, and remediation (in case the site is eventually abandoned). It would be most appropriate to invite proponents of various sites to address these issues in presentations to the committee.

If an outstanding site (or sites) is identified, the committee should recommend procedures for formulating the strongest possible proposal. It would also be helpful if the committee could discuss possible administrative structures for the laboratory: how will the scientific community and host institution work together to guarantee that the best science is done? What structure-ownership, management, operations - will produce the strongest laboratory?^{xx}

GLOSSARY

- Detector:** A detector is any device that senses or captures matter or energy. Telescopes, for instance, are detectors that capture light. Scales are detectors that sense weight. Sensitive neutrino detectors must be placed deep in the Earth to shield them from “cosmic noise,” just as photographic film must be shielded from light.
- Mwe:** Meter Water Equivalent is the unit that is used to describe the effectiveness of a shielding material. Different materials block different amounts of radiation, so mwe is used to compare apples to apples in the realm of shielding.
- Neutrino:** A neutrino is almost nothing. Or, in the words of F. Reines, a neutrino is "... the most tiny quantity of reality ever imagined by a human being." Neutrinos are small, electrically neutral particles that are much smaller than atoms.
- NSF:** The National Science Foundation (NSF) is an independent U.S. government agency responsible for promoting science and engineering through programs that invest in research and education projects in science and engineering.
- USNUSL:** The United States National Underground Laboratory (USNUSL) is the name for the research facility that is currently being considered by NSF.

VITAE

Daniel Stanton is a senior in Civil and Environmental Engineering at the South Dakota School of Mines and Technology. He holds a Bachelor of Science degree in Workforce Education and Development from the Southern Illinois University at Carbondale, along with a number of information technology certifications including Microsoft Certified Trainer and Microsoft Certified Systems Engineer.

In 1999, Daniel was awarded the Dorothea Riter Award for Excellence in Technical Communications. The following year he became a South Dakota Regents' Technology Fellow, and was chosen to participate in the Leadership Rapid City program. In 2001, Daniel was selected as one of 15 students from around the country for the Washington Internships for Students of Engineering (WISE), rated among the top 100 internship programs in the country by the Princeton Review's Internship Bible. The WISE Program is run collectively by a consortium of engineering professional societies including IEEE, ASCE, ASME, ANS, AAES and NSPE with the mission of providing young engineers with a better understanding of science and technology policy.

Daniel served five years in the U.S. Navy, has worked on the staff of U.S. Senator Tim Johnson, writes a monthly technology column for the Rapid City Journal, and is the president of Stanton Associates.

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