THE NATIONAL UNDERGROUND SCIENCE AND ENGINEERING LABORATORY AT HOMESTAKE: PROJECT BOOK, REFERENCE DESIGN STAGE

A Facility for Physics, Astrophysics, EarthLab,
Applied Science and Engineering, and Outreach/Education

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submitted by

The Homestake Collaboration

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The Ross headframe, Homestake Mine. Scientific access to the three levels of the proposed National Underground Science and Engineering Laboratory, on the 4850, 7400, and 8000 ft levels, will be via the Ross hoist and No. 6 Winze.

A. PROJECT SUMMARY

This submission is the **Project Book for the National Underground Science Laboratory, Homestake, at the Reference Design stage**. This submission represents a major step beyond the conceptual proposal our group submitted in June 2001. Much of the past two years was invested in strengthening and broadening the science case – an effort that involved not only our collaboration, but many of our colleagues in the broader science community who are interested in underground science. The science case itself has changed, with major new discoveries in neutrino physics occurring since June 2001, and with the development of a compelling program of NUSEL earth science. The community's arguments for NUSEL are summarized in the **Science Book**. In parallel with the science effort, our group has learned a great deal about the Homestake site and how it can be best adapted to meet the science requirements. This has led to the **Science Timeline and Reference Design**, and a facilities development plan much improved over that of the conceptual proposal. We describe this design – the access to underground, the underground and surface campuses, and the options remaining to be explored – and the engineering studies that allow us to assign costs and contingencies. We also describe the work remaining to be done and the program plan for producing a **Baseline Definition** of the Homestake project.

This project began in September 2000, when the INT hosted a group of 200 neutrino physicists in Seattle to discuss, in connection with the NSAC Long-Range Plan (LRP) for nuclear physics, possible priorities for this subfield. The deliberations of one of the meeting's working groups, on Underground Science Laboratories, was dramatically influenced by a proposal Lande made at this meeting, conversion of the Homestake Gold Mine into a National Underground Science and Engineering Laboratory (NUSEL). The availability of this very deep site, with massive shafts and lifts, sophisticated utilities, ventilation, and communications systems, and established operations costs, prompted the NSAC Town Meeting group to make the creation of NUSEL its highest priority. The National Science Foundation and Department of Energy responded by supporting an *ad hoc* study group, the Bahcall Committee, to consider the scientific case for NUSEL and the suitability of possible sites. The Committee's membership included leading underground scientists from particle, nuclear, and astrophysics. Its consultants included experts in earth science and large project management. The Bahcall Report, submitted to NSAC as a LRP White Paper, made a compelling scientific case for NUSEL and identified Homestake as the recommended site. In its final deliberations the NSAC LRP group made creation of a deep underground science laboratory its highest midscale construction priority for the next decade. Because Homestake closure plans limited the window in time when this site would be available, NSAC also wrote the NSF, urging the agency to proceed immediately with NUSEL-Homestake.

Following this decision a national group of underground scientists, several of whom had taken part in the Bahcall Committee and the Seattle, Oakland, and Santa Fe NSAC LRP meetings, collaborated on a NUSEL-Homestake proposal. This MRE proposal was submitted to the NSF in early June 2001, and was reviewed by the Physics Division later that summer. The results of the reviews – the Physics Division conducted two panel reviews in addition to soliciting written reviews – were shared with the proposers in October 2001.

Since submission of the original proposal, the creation of NUSEL and the associated science have generated extensive discussions in the scientific community. In HEPAP's long-range plan, which was debated over the last six months of 2001, neutrino physics, dark matter searches, and other underground science received strong support. Two high-level NRC committees reviewed the science arguments for NUSEL, both concluding that a deep US laboratory is needed. Major changes in the science have resulted from discoveries subsequent to June, 2001, including the

Sudbury Neutrino Observatory demonstration that the solar neutrino flux is dominated by heavy-flavor neutrinos, the KamLAND verification of solar neutrino oscillations, the K2K results, and the identification of thermophilic methanogens at the 8000 ft level of Homestake. New communities, most notably those advocating NUSEL-Homestake as an "EarthLab" for earth science, geomicromiology, and rock mechanics/engineering and those concerned with applications of new detector technologies to a variety of post-9/11 issues, have joined the collaboration. A series of conferences and workshops – the Lead meetings on Underground Science and on Geomicrobiology, the Aspen Workshop on Underground Science, and the NSF-sponsored NESS02 conference – not only contributed to broadening the science, but also clarified the technical requirements (depth, space, utility needs) and readiness of proposed experiments. (These meetings were either organized by the NUSEL-Homestake Collaboration or strongly supported by our members. The materials from these meetings – talks presented, working group white papers – have been preserved on the NUSEL-Homestake web page, **http://int.phys.washington.edu/NUSEL/.**) Major improvements in the NUSEL design have occurred, allowing us to avoid the costly Yates shaft extension while providing a more versatile laboratory that meets the needs of our broader collaboration. Finally, we have continued to develop partnerships nationally and in the region with the goal of enhancing the public outreach potential of NUSEL-Homestake. This includes exploiting Homestake's unique location and history – the US mine most identified with the opening of the American west, located in a major tourist area – and developing links to K-12 and regional and national college and university students and educators. Of particular importance are the opportunities to work with NativeAmerican educators, through both established NSF programs at the tribal colleges and new ones, and to provide a major-science "anchor" for the EPSCoR states of the Northern Great Plains, which currently lack such a focus.

This "version #2" proposal summarizes the progress the Homestake Collaboration has made in developing and broadening the science case for NUSEL; in defining the technical requirements that NUSEL must meet; in integrating this project into national efforts in nuclear and particle physics, astrophysics, earth science and geomicrobiology, outreach and education, and applications to materials science and national security; in formulating a baseline design for NUSEL construction that takes maximal advantage of the extraordinary existing infrastructure of the Homestake Mine; in developing a project management plan; and in producing a Work Breakdown Structure sufficiently detailed to justify project funding in FY06. The version #2 proposal contains the following elements:

- An **Overview** of the project, with special emphasis on our work and that of the community since June 2001. The overview summarizes major changes in the science scope of NUSEL and how these changes impact the technical aspects of the proposal. The overview reviews the conclusions of the various review committees that have dealt with NUSEL, as well as community interactions with the DOE and other agencies relevant to NUSEL. The status of the Homestake site is also summarized.
- The **Science Book**, in which the science case for NUSEL is updated. Important contributions to the Science Book came from community meetings either organized by or strongly supported by our collaboration: the Lead physics, outreach, and geomicrobiology meetings; the Aspen underground science program; and NESS02. The Science Book contains an important chapter on NUSEL as EarthLab, as well as comprehensive discussions of applied science and outreach at Homestake.
- The **Science Timeline** section summarizes the technical needs and readiness of proposed experiments, and thus the schedule and parameters that NUSEL-Homestake should meet. We provide a strawman ``Timeline'' of such experiments, correlating this with our proposed NUSEL schedule.
- A **Program Plan and Reference Design** of the NUSEL-Homestake project, in which we describe the proposed conversion of the Homestake Mine into the world's deepest and most flexible underground science laboratory. We propose a specific plan for meeting the needs of

envisioned and far-future underground science, including optimizing prospects for a megadetector important to very-long-baseline neutrino oscillation experiments and next-generation proton decay searches. We describe the work remaining to be done to arrive at a **Baseline Definition** for the NUSEL-Homestake project, and some of our plans for reaching this milestone. This section concludes with a suggested **Management Plan**, pending future guidance from the NSF on this issue.

- A **Work Breakdown Structure**, including rather detailed description of the underground campus developments at the 8000, 7400, and 4850 ft levels and of the plans for optimizing access to the underground and the capacity for future hall expansions.
- A last short section, independent of the remainder of the proposal, in which we provide a qualitative assessment of the **current status of the mine** (including implications of the flooding that commenced June 2003).