

The Deep Underground Science and Engineering Laboratory at Homestake

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Abstract. The National Science Foundation and the international underground science community are well into establishing a world-class, multidisciplinary Deep Underground Science and Engineering Laboratory (DUSEL) at the former Homestake mine in Lead South Dakota. The NSF's review committee, following the first two NSF solicitations, selected the Homestake Proposal and site as the prime location to be developed into an international research facility. Homestake DUSEL will provide much needed underground research space to help relieve the worldwide shortage, particularly at great depth, and will develop research campuses at several different depths to satisfy the research requirements for the coming decades. The State of South Dakota has demonstrated remarkable support for the project and has secured the site with the transfer from the Homestake Mining Corp. The State, through its Science and Technology Authority with state funds and those of a philanthropic donor has initiated rehabilitation of the surface and underground infrastructure including the Ross and Yates hoists accessing the 4850 Level (feet below ground, 4100 to 4200 mwe). The scientific case for DUSEL and the progress in establishing the preliminary design of the facility and the associated suite of experiments to be funded along with the facility by the NSF are presented.

1. Introduction

In March 2004 the US National Science Foundation (NSF) announced a three-solicitation process to revitalize its efforts to create a dedicated deep underground research laboratory. The first solicitation focused on defining the science goals for a deep laboratory and defining many of the laboratory's critical parameters and characteristics. The principal investigators for this effort, led by Professor Bernard Sadoulet, produced Deep Science [1] summarizing their findings including the key scientific questions to be addressed with a deep laboratory. Grouping the fundamental questions by disciplines Deep Science presents the DUSEL science program as:

Physics

- What is the universe made of?
- What is the dark matter?
- What are neutrinos telling us?
- What happened to the antimatter?
- Are protons unstable?
- How did the universe evolve?

- How do biology and geology interact to shape the world underground?

- How does subsurface microbial life evolve in isolation?

- Did life on earth originate beneath the surface?
- Is there life underground as we don't know it?

Geology

Biology and Geology

- What are the interactions among subsurface processes?
 - Are underground resources of drinking water safe and secure?
 - Can we reliably predict and control earthquakes?
 - Can we make the earth “transparent” and observe underground processes in action?

Geology and Engineering

- What are the mechanical properties of rock?
- What lies between the boreholes?
- How does rock respond to human activity?
- How does water flow deep underground?
- How can technology lead to a safer underground?

The Report goes on to assess physical characteristics and key parameters for DUSEL including:

- Depth – the facility should access depths in excess of 7000 mwe and support a variety of different depths for different research requirements.
- Rock Type – the rock type should be geologically interesting and able to support large excavations.
- Pristine Regions – the rock mass should possess pristine and undisturbed regions for research.
- Distance from Accelerators – the facility should be sited at an appropriate distance from accelerators capable of producing neutrino beams (> 1000 km).
- General Accessibility – the facility should be a dedicated facility supporting continuous access. The facility should support access by all research disciplines and be truly international.
- Management – the facility should be managed in a style to facilitate DUSEL’s research and education goals.
- Adaptability and Expandability – the facility should be able to expand and adapt to support decades of research.

2. Current status of DUSEL Planning – Facility Preliminary Design

With the selection of Homestake as the site to be developed for DUSEL, a cooperative agreement between the University of California Berkeley and the NSF was established. The focus of the agreement is the development of a preliminary design for the facility and the integration of the plans for an initial suite of experiments into the facility plan. This preliminary design including both the facility and the suite of experiments would become the basis of application to the Major Research Equipment and Facility Construction account for the construction of DUSEL and its experiments. The requirements for the preparation of the application are defined in NSF’s Large Facilities Manual [2].

The table presented below, outlines major milestones in the creation of the DUSEL Proposal including the NSF’s S-4 and S-5 solicitations. The S-4 solicitation, anticipated to be \$15M distributed over three years, would fund experimental collaborations to prepare conceptual and preliminary designs of candidate Initial Suite of Experiments for consideration for inclusion in the DUSEL Proposal. S-5 would select the experiments to be integrated into the proposal. S-4 funding is neither a sufficient nor a necessary condition to be considered by S-5 for inclusion in the ISE. Following this schedule, the earliest construction of DUSEL could begin would be Fiscal Year 2012 at the earliest.

3. Initial Suite of Experiments for DUSEL

The envisioned DUSEL proposal and presentation to the National Science Board would include a suite of experiments to be funded concurrently with the facility construction. The MREFC funding would cover normal construction costs. Current preliminary estimates and general discussions with the agencies indicate the MREFC proposal would be in the range of \$500 to 600M with approximately an equal split between experiments and facility costs.

The suite of experiments would be fully multidisciplinary, with candidates anticipated from physics, geology, biology, engineering and education and public outreach. To help facilitate and coordinate the experimental collaborations the NSF working with the DUSEL project have established a coordination committee, the DUSEL Experiment Development Committee (DED), to serve as a point of contact, to provide coordination, and in general to assist the experimental collaborations with

their interactions with DUSEL. The DEDC consists of Dr. Steve Elliott, Los Alamos National Laboratory; Professor Derek Elsworth, Penn State (Chair); Dr. Daniela Leitner, Lawrence Berkeley National Laboratory; Professor Larry Murdoch, Clemson University; Professor T.C. Onstott, Princeton University; and Professor Hank Sobel, UC Irvine.

Date	Completed	Activity or Milestone
November 2007	x	Town Meeting In Washington DC
April 2008	x	DUSEL Workshops in Lead, South Dakota
Spring/Early Summer 08		NSF S-4 Solicitation to Fund Experimental Development
July 2008		Internal Review of DUSEL Project
Fall 2008		Funding of S-4 Proposals
December 2008		NSF Review of DUSEL Project
Summer 2009		Review and Selection of DUSEL's Initial Suite of Experiments (S-5 Solicitation)
Summer/Fall 2009		Integration of ISE into Facility and Preparation of Integrated Baseline Project and MREFC Proposal
Fall 2009		Completion of DUSEL Preliminary Design and Review by NSF
Winter 2010		Presentation of Proposal and Review by the NSF
March 2010 (earliest)		Presentation to the National Science Board
FY2012 (earliest)		MREFC (earliest possible date capital funding)

Table 1: Milestone Schedule for DUSEL Construction within the Major Research Equipment and Facility Construction (MREFC) Account.

The April workshop in Lead, South Dakota [3] was the initial meeting of the collaborations interested in creating proposals for the ISE. The working groups and disciplines presenting at this meeting are presented in the table below:

Working Group	Group Leader(s)
Physics	
Dark Matter	Dan Akerib, Case Western University & Rick Gaitskell, Brown University
Long Baseline Neutrinos & Nucleon Decay	Bob Svoboda, University of California at Davis
Neutrinoless Double Beta Decay	Giorgio Gratta, Stanford University
Nuclear Astrophysics	Michael Wiescher, University of Notre Dame
1-km Vertical Space	Yuri Kamshkov, University Of Tennessee,
Gravity Waves	Vuk Mandic, University of Minnesota
Low Background Counting and Assay	Prisca Cushman, University of Minnesota
Solar Neutrinos	Bruce Vogelaar, Virginia Tech
Studies of effects of energetic particles on electronic devices, biological systems, materials and structure imaging from CR.	Rob McTaggart, South Dakota State University
Geosciences, Geomicrobiology, and Engineering	
Baseline characterization and monitoring	Stephen Martel, University of Hawaii
Ambient rock deformation processes	Herb Wang, University of Wisconsin
Induced rock deformation processes	Leonid Germanovich, Georgia Tech
Ambient flow, transport, diversity and activity	David Boult, University of Massachusetts

Induced flow, transport and activity	Eric Sonnenthal, LBNL
Underground construction, mining and environment	Charles Fairhurst, University of Minnesota
CO ₂ Sequestration	Joe Wang, LBNL
Resource extraction	Jean-Claude Roegiers, University of Oklahoma
Subsurface imaging and sensing	Steven Glaser, UC Berkeley
Ultra-deep drilling and exploration	Tom Kieft, New Mexico Tech
Self-Initiated Working Groups	
Petrogenesis, Ore Deposits, & Structures	Derrick Iles, University of South Dakota
Geoneutrino Radiometric Analysis Group	P. Ila, MIT
Toxicology of Heavy Metals in Degenerative Diseases	Glenn I. Lykken, University of North Dakota

Table 2: April Workshop on DUSEL's Initial Suite of Experiments – Working Groups and Group Leaders.

The recent release of the Particle Physics Project Prioritization Panel (P5) report [4] of the High Energy Physics Advisory Panel highlights the significance of Homestake to the future of the domestic high energy physics programs, primarily establishing a world-leading long baseline neutrino program, simultaneously creating a major nucleon-decay program, as well as focusing the US Dark Matter and Neutrinoless Double Beta Decay efforts at Homestake DUSEL. The DUSEL Project team advocates a multi-chamber approach to creating the ~ megaton targets needed for the long baseline neutrino and nucleon decay programs. Beginning with a single 150kt capacity cavity has been demonstrated to create a scientifically well-motivated program with significant reach in determining θ_{13} , the neutrino mass hierarchy, and even in establishing the CP phase for sufficiently large values of θ_{13} .

4. Summary

The vision for DUSEL is presented in the Conceptual Design Report [5]. The near-surface campus at the 300 Level, major campus at 4850 Level, and deep campus at 7400 Level are presented in Ref [5]. In addition ~ a dozen of Homestake's 60 main levels would be used for biology, geology, and engineering activities. In particular the 8000 Level presents geomicrobiologists with attractive opportunities for searches for exotic life forms. The DUSEL Project Team is actively advancing the design of the facility and working to develop the Initial Suite of Experiments to be paired with the facility in the MREFC application. The Project Team is working closely with the experimental collaborations to understand the experimental requirements and to fold these requirements into the facility design and welcomes communication with interested experiments or potential experiments that would benefit from an underground facility. While the principal avenues for funding so far have been through the NSF's solicitations, the recent close coupling of the Department of Energy (HEP) efforts to DUSEL have opened additional mechanisms to fund research and development, experimental programs, and educational opportunities in and with DUSEL.

References

- [1] Deep Science, <http://www.deepscience.org/>
- [2] NSF Large Facilities Manual, NSF 07-38, <http://www.nsf.gov/pubs/2007/nsf0738/nsf0738.pdf>
- [3] Workshop presentations, whitepapers and summaries are available at: <http://www.lbl.gov/nsd/homestake/Workshops.html>
- [4] http://www.science.doe.gov/hep/hepap_reports.shtm.
- [5] <http://www.lbl.gov/nsd/homestake>.