An Assessment of the Deep Underground Science and Engineering Laboratory (DUSEL)

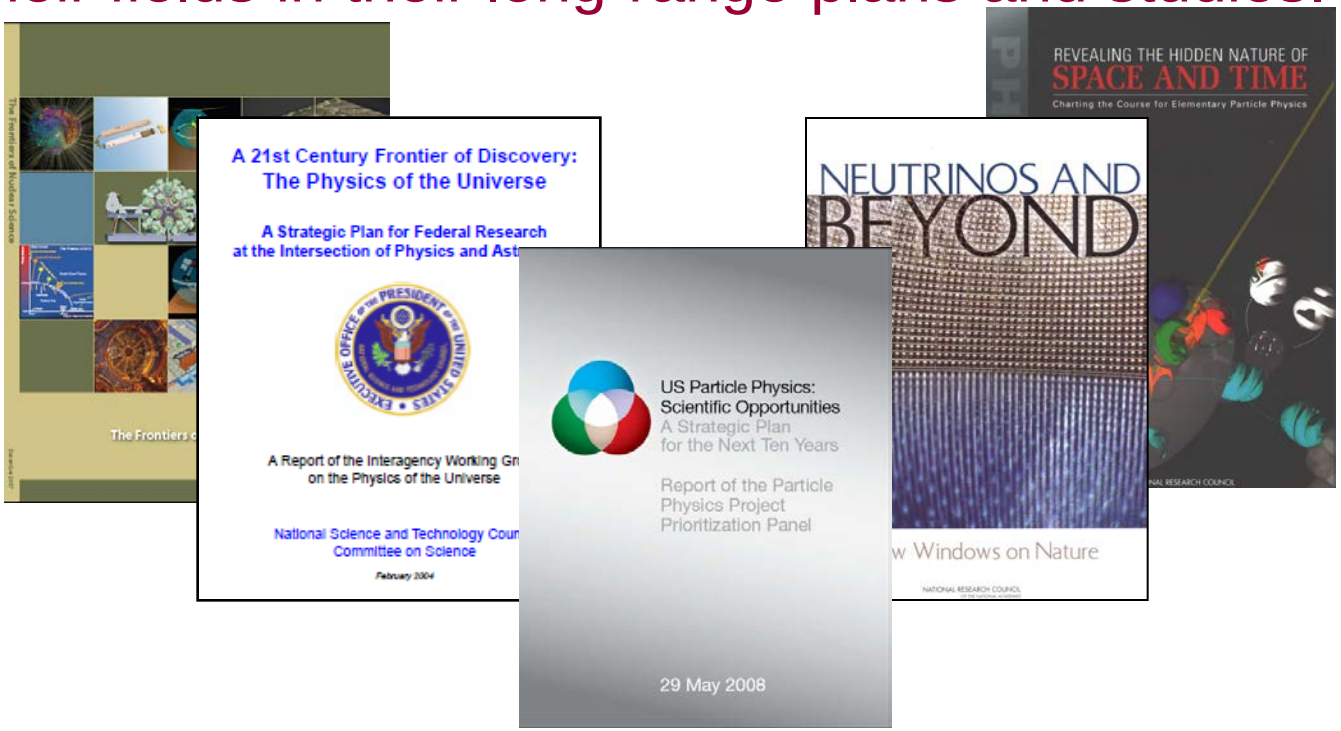
Board on Physics and Astronomy
National Research Council

A.J. Lankford, UC Irvine
NRC Committee Chair

HEPAP
October 27, 2011

Context for Study

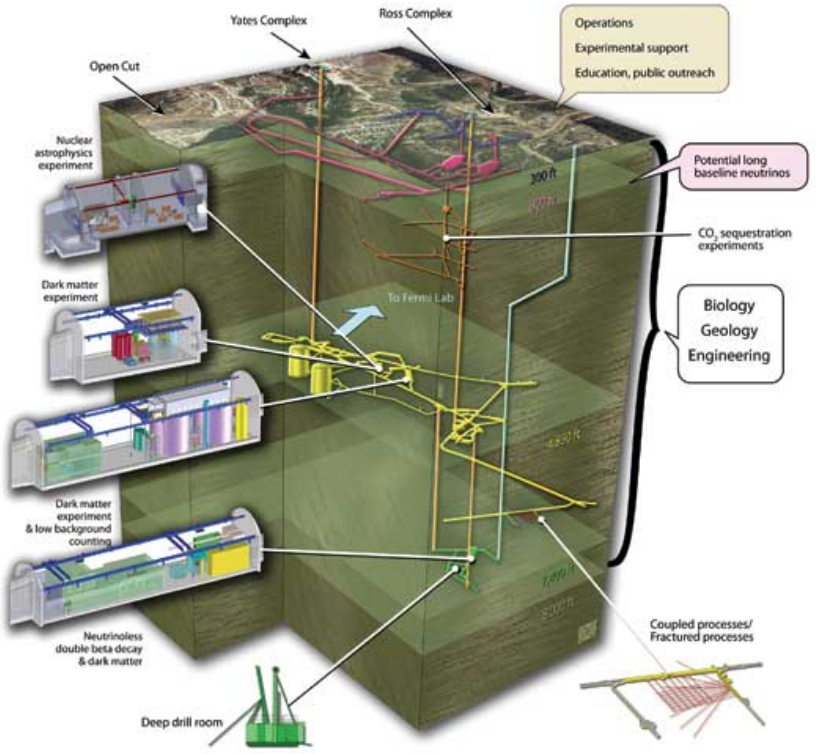
- U.S. research community has historically played a leading role in underground science
- Both the U.S. particle and nuclear physics communities have recognized certain underground experiments as a top priority for their fields in their long-range plans and studies.



Context for Study

- Underground research facilities:
  - Required to address several critical physics questions
  - Offer opportunities to address other important science questions

- Efforts to develop a major U.S. facility resulted in a proposal for the Deep Underground Science and Engineering Laboratory (DUSEL), to be located in an abandoned gold mine in Lead, South Dakota.



Context for Study

- Consistent w/ 2004 National Science & Technology Council report:

  A 21st Century Frontier of Discovery:
  A Strategic Plan for Federal Research
  at the Intersection of Physics and Astronomy;
  A Report of the Interagency Working Group on the Physics of the Universe

  - NSF stewarded development of concept for a national facility.
  - DOE collaborated on conceptual development of physics expts.

- In preparation for final deliberations, NSF and DOE commissioned this independent NRC study.

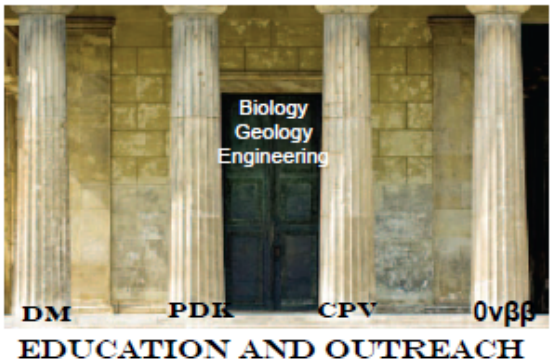
Overview of DUSEL as Proposed

DUSEL Founded on a Suite of Critical, Multidisciplinary Experiments

Founded on Four Experimental Physics Pillars

and

Three Research Tenets:



1. Dark Matter Searches
2. Long Baseline Neutrinos from FNAL
3. Proton Decay
4. Neutrinoless Double Beta Decay

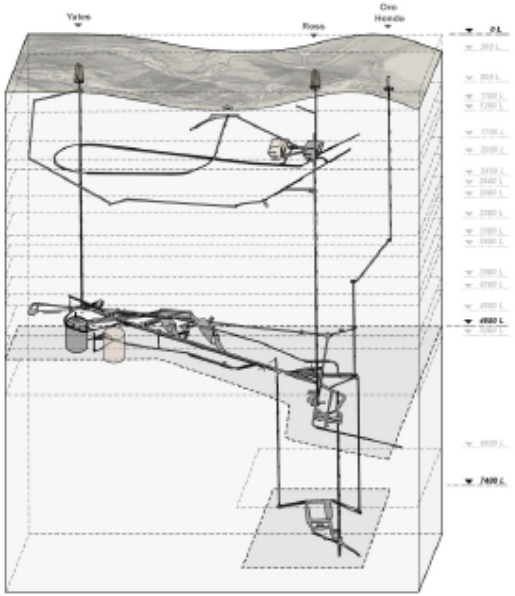
- Diverse multidisciplinary research efforts in Biology, Geology, and Engineering
- Additional well-motivated experiments
- Integral Education and Outreach

From : *DUSEL Project Overview*
Kevin Lesko
at NRC DUSEL Study
Dec. 14, 2010

Proposed Initial DUSEL Program

DUSEL Facility Designed to Host this Suite of Critical Experiments

- Physics
  - Long Baseline Neutrino and Proton Decay
    - Water Cherenkov and/or Liquid Argon Detectors totaling 200kT WCE
  - Dark Matter
    - at least one Generation-3 experiment
    - R&D, Generation-1 and -2 as consistent with Sanford Lab scope
  - Neutrinoless Double Beta Decay
    - a ~ tonne-class experiment
    - Generation 2 (~100-kg) effort as consistent with Sanford Lab scope
  - Nuclear Astrophysics Facility
  - Advanced Low Background Counting & Assay
- Biology - Geology - Engineering
  - Fixed Ecohydrology sites and distributed efforts
  - Fixed Coupled Processes site
  - Fixed CO_2 Sequestration (vertical) site
  - Fixed Geophysics and Geology sites and distributed efforts
  - Initial efforts as consistent with Sanford Lab scope (~16 efforts)
- Education and Outreach Facility
  - Initial efforts as consistent with Sanford Lab scope



Statement of Task

The committee will undertake an assessment of the proposed DUSEL program, including:

- An assessment of the **major physics questions** that could be addressed with the proposed DUSEL and associated physics experiments,
- An assessment of the impact of the DUSEL infrastructure on research in **fields other than physics**,
- An assessment of the impact of the proposed program on the **stewardship** of the research communities involved,
- An assessment of the **need to develop** such a program in the U.S., in the context of similar science programs in other regions of the world,
- An assessment of **broader impacts** of such an activity, including but not limited to education and outreach to the public.

Sponsored by National Science Foundation, U.S. Department of Energy

DUSEL Committee Membership

Committee composition

1. Multi-disciplinary – Experts in particle physics, nuclear physics, particle astrophysics, biosciences, geosciences, subsurface engineering.
2. International – Experts from nations in Europe, Asia
3. Independent – No participants in - DUSEL project, proposals for DUSEL science, current Sanford Lab research, DUSEL advisory committees.
4. Leaders of large experiments, underground facilities

ANDREW J. LANKFORD, Chair, Univ. of California, Irvine
YORAM ALHASSID, Yale University
EUGENIO COCCIA (Italy), Univ. of Rome "Tor Vergata"
CHARLES FAIRHURST (NAE), Itasca Consulting Group
BRADLEY FILIPPONE, California Institute of Technology
PETER FISHER, Massachusetts Institute of Technology
TAKAAKI KAJITA (Japan), University of Tokyo
STEPHEN E. LAUBACH, The University of Texas, Austin
ANN NELSON, University of Washington
RENE ONG, University of California, Los Angeles
FRANK J. SCIULLI (NAS), Columbia University
MARJORIE SHAPIRO, University of California, Berkeley and E. O. Lawrence Berkeley National Laboratory
JAMES M. TIEDJE (NAS), Michigan State University
DAVID WARK (UK, Royal Society), Imperial College London

Peer Review Panel Membership

Lisa Alvarez-Cohen (NAE), University of California, Berkeley	Joseph Hezir, EOP Group, Inc.
Frank Calaprice, Princeton University	Mark Peters, Argonne National Laboratory
Francis Halzen, University of Wisconsin-Madison	John Schiffer (NAS), Argonne National Laboratory
Wick Haxton (NAS), University of California, Berkeley	Yannis Yortsos (NAE), University of Southern California
Ernest Henley (NAS), University of Washington	

The review panel was chosen to have a similarly broad set of expertise and perspectives.

Review oversight provided by:

Julia Phillips (NAE), Sandia National Laboratories, Review Monitor, and James Brau, University of Oregon, Review Coordinator.

Study Timeline/Changing Landscape

Nov. 2010 – Committee fully constituted

Dec. 2, 2010 – NSB decision not to recommend a bridging award

Dec. 14-15, 2010 – First Meeting – Washington

- DUSEL's future uncertain.
- Barish: "NSF / NSB key decision will be after PDR, whether to proceed to FDR?"

Dec. – Feb. - Committee discussions regarding course

Feb. 3-4, 2011 – Second Meeting – Irvine

- More detailed input, where needed
- Committee decides to complete study as soon as possible.

Feb. 14, 2011 – President's FY2012 budget request

- "NSF eliminates funding for DUSEL."

Feb. 28, 2011 – DOE commissions cost & schedule review of options for major physics expts (Jay Marx, Mark Reichanadter)

Throughout the above process, the Committee received assurances from the agencies that its report is important to proper consideration of the proposed science.

Mar. 25-27, 2011 – Third Meeting – Irvine

- First draft of report completed shortly thereafter.

April 20,2011 – Report to Review

July 12, 2011 – Public Release of Report

Focus of Committee's Task,
particularly in light of evolving circumstances – p. 1

- **Intellectual merit of proposed underground science**
  - Assessment of the major physics questions
    - Take the presented initial suite of experiments as the list of physics questions to assess. **(No assessment of specific future opportunities enabled by an underground research facility (URF).)**
  - Assessment of impact of infrastructure on fields other than physics
    - How will infrastructure of a URF constructed for physics experiments enable important research in other fields?
    - Consider the presented suite of BGE experiments as indicative of the type of non-physics science/engineering questions that could be addressed.
  - Intellectual merit is assessed:
    - In general context of frontier research worldwide,
    - Not in comparison with any particular project or investment.

      (Committee was not constituted for this purpose, or to set priorities either within or across scientific disciplines.)
  - Project costs and implementation plans were not reviewed.
    - Such review naturally occurs during the CDR/PDR/FDR and CDx processes.
    - Nor was agency stewardship model or management reviewed.

Focus of Committee's Task,
particularly in light of evolving circumstances – p. 2

- **Intellectual merit in national, international & disciplinary contexts**
  - Assessment of impact on stewardship of research communities
  - Assessment of need for U.S. program in international context
- **Assessment of broader impacts**
- Committee also considered:
  - To what extent can each of these issues be addressed in the absence of a DUSEL-like national laboratory?
    - Without a national facility
    - With a more limited national facility

Science Assessment – Physics (1)

Three underground experiments to address fundamental questions regarding the nature of dark matter and neutrinos would be of paramount and comparable scientific importance:

- **The direct detection dark matter experiment,**
- **The long-baseline neutrino oscillation experiment, and**
- **The neutrinoless double-beta decay experiment**

Each of these three experiments addresses at least one crucial question upon whose answer the tenets of our understanding of the universe depend.

Science Assessment – Physics (2)

The three major physics experiments provide an exceptional opportunity to address scientific questions of paramount importance, to have a significant positive impact upon the stewardship of the particle physics and nuclear physics research communities, and to have the United States assume a visible role in the expanding field of underground science.

The U.S. particle physics program is especially well positioned to build a world-leading long-baseline neutrino experiment due to the availability of the combination of an intense neutrino beam from Fermilab and a suitably long baseline from the neutrino source to an appropriate underground site such as the proposed DUSEL.

(continued on next page)

Science Assessment – Physics (2, cont'd.)

In light of the leading roles played by U.S. scientists in the study of dark matter and double-beta decay, together with the need to build two or more large experiments of each of these two types, U.S. particle and nuclear physicists are also well positioned to assume leadership roles in the development of one direct detection dark matter experiment of ton- to multi-ton scale and one neutrinoless double-beta decay experiment on the scale of a ton.

While installation of U.S.-developed experiments in an appropriate foreign facility or facilities would significantly benefit scientific progress and the research communities, there would be substantial advantages to the communities if these two experiments could be installed within the United States at the same site as the long-baseline neutrino experiment.

Science Assessment – Physics (3)

Two additional scientific capabilities of the long-baseline neutrino oscillation experiment would be of great scientific interest:

- **Its sensitivity to proton decay and**
- **Its sensitivity to neutrinos from supernovas.**

The stability of the proton is a crucial, fundamental scientific question. Moreover, the detection of neutrinos from supernovas would make a unique and valuable contribution to our understanding of one of the most important astrophysical phenomena. Both these capabilities add significant value to the neutrino oscillation experiment. However, these sensitivities are not so great as to be the primary considerations in choosing neutrino detector technology or a site for the experiment.

Science Assessment – Physics (4)

A small underground accelerator to enable measurements of low-energy nuclear cross-sections would be scientifically important. These measurements are needed to elucidate fundamental astrophysical processes such as thermo-nuclear reactions and the production of heavy elements in the sun and the stars.

Science Assessment – Other than Physics

The ability to perform long-term experiments in the regulated environment of an underground research facility could enable a paradigm shift in research in the subsurface engineering and would allow other valuable experiments in the geosciences and biosciences.

Programmatic Impact – Co-location (1)

The co-location of the three main underground physics experiments at a single site would be a means of efficiently sharing infrastructure and personnel and of fostering synergy among the scientific communities. The infrastructure at the site would also facilitate future underground research, either as extensions of the initial research program or as new research initiatives. These added benefits, along with the increase in visibility for U.S. leadership in the expanding field of underground science, would be important considerations when siting the three main physics experiments.

Programmatic Impact – Co-location (2,3)

A small underground accelerator facility to study the processes of nuclear astrophysics, if co-located with one or more of the main underground physics experiments in the United States, would benefit from shared infrastructure, personnel, and expertise.

In light of the potential for valuable experiments in subsurface engineering, geosciences, and biosciences that could be offered by an underground research facility, if such facility is constructed in the United States for physics experiments, scientists in other fields would greatly benefit from a mechanism that would allow them to perform research there.

Programmatic Impact – Stewardship

A facility for underground research would have a significant positive impact on the stewardship of the research communities involved. Such a facility would offer the particle and nuclear physics communities access to the underground research space they need to undertake a range of scientifically critical experiments, and it would allow the biosciences, geosciences and subsurface engineering communities to perform valuable long-term experiments in a regulated environment.

Programmatic Impact – National Facility

- **Development of an underground research facility in the United States would supplement and complement underground laboratories around the world.**
- **A U.S. facility could build upon the unique position of the United States that would allow it to develop a long-baseline neutrino experiment using intense beams from Fermilab.**
- **It could accommodate one of the large direct detection dark matter experiments and one of the large neutrinoless double-beta decay experiments that are needed by the international effort to resolve these critical scientific issues, while sharing infrastructure among these three experiments that are of comparable import.**
- **It could also host and share infrastructure with other underground physics experiments, such as an accelerator to study nuclear astrophysics, and with underground experiments in other fields.**
- **An underground research facility would benefit the U.S. research communities, and would guarantee the United States a leadership role in the expanding global field of underground science.**

Broader Impacts – Education & Outreach

- DUSEL would offer excellent opportunities for education and outreach.
- While,
  - Many of these opportunities for education & outreach of the proposed DUSEL are available to any major lab performing frontier research.
  - Most opportunities for education & outreach of the proposed DUSEL would be available at any URF.
    - e.g. attraction of underground “world”
- Some opportunities for education & outreach are special at the proposed DUSEL:
  - Educational programs for rural population of South Dakota
  - Education & outreach programs for underrepresented Native Americans
  - Outreach to tourists visiting sites of surrounding region

Summary of Science Assessment

Initial suite of DUSEL experiments = excellent science program

- **3 experiments of paramount & comparable scientific importance**
  - **Direct detection dark matter experiment**
  - **Long-baseline neutrino oscillation experiment (LBNE)**
  - **Neutrinoless double-beta decay experiment**

  potential breakthrough discoveries → paramount importance
- **2 additional LBNE capabilities of great scientific interest**
  - **Sensitivity to proton decay**
  - **Sensitivity to neutrinos from supernovas**
- **nuclear astrophysics experiment of scientific importance**
- **Capability to host a suite of valuable experiments in subsurface engineering, geosciences & biosciences**
  - **Could enable a paradigm shift in research in subsurface engineering**
  - **Multidisciplinary bio-geo research**

Summary of Programmatic Considerations - 1

The cost of the whole is less than the sum of the parts. *- ajl*

- **Co-location of underground experiments allows sharing infrastructure & personnel**

The value of the whole is greater than the sum of the parts. *- ajl*

- **A national underground research facility would foster stewardship of research communities in physics and in other fields.**
  - **Provide needed underground space for forefront research**
  - **Facilitate future underground research initiatives**
  - **Foster synergy among research communities**
  - **Provide focal point for training of scientific and technical workforce**
- **A laboratory performing frontier research is an excellent opportunity for education and outreach to the public.**
  - **An underground research facility would have special fascination with public.**
  - **The South Dakota site of DUSEL offers special opportunities with rural population and underrepresented Native Americans.**

Summary of Programmatic Considerations - 2

Is there a need to develop a URF in the U.S.?

- **A US URF would supplement & complement URF's around the world.**
  - **Supplement – additional, needed, quality and deep laboratory space**
  - **Complement – the challenging science demands multiple techniques to cross-check and combine**

  (I believe that it is fair to say that the international science community needs US participation in the likely transformative science program of underground research.)
- **U.S. is exceptionally positioned to build the long-baseline neutrino expt.**
  - **Intense neutrino beam from Fermilab**
  - **Suitably long-baseline between neutrino source and LBNE site**
- **U.S. is well positioned to continue to play a leadership role in the international, multi-experiment effort to address critical scientific issues of both dark matter & neutrinoless double-beta decay.**
- **General considerations**
  - **Stewardship of research communities**
  - ***Rising Above the Gathering Storm***

Final Remarks

- **Reiterating:**
  - **The proposed DUSEL offers:**
    - **Excellent science program**
    - **Strong programmatic impact**
  - ***The value of the whole is greater than the sum of the parts.***

    Merits of: stewardship, addressing need in the international context, education/outreach
  - ***The cost of the whole is less than the sum of the parts.***

    Merits of co-location.

- **If the proposed DUSEL cannot be achieved, strive to:**
  1. **Develop the 3 major physics experiments**
  2. **Benefit from co-location and stewardship**

These are not unique to DUSEL, but would be delivered by DUSEL.

Prepublication version of report: http://www.nap.edu/catalog.php?record_id=13204

Questions and Comments

Project staff:

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Back up slides

First Meeting – Dec. 14-15, 2010 - Washington

- **Perspectives from:**
  - NSF – Joe Dehmer, Ed Seidel
  - DOE/HEP – Dennis Kovar
  - NSB – Barry Barish (Caltech)
  - Program Advisory Committee
    - Physics - Mike Witherell (UCSB)
    - BGE - Mark Zoback (Stanford)
  - Fermilab – Pier Oddone
- **DUSEL Project Overview** - Kevin Lesko (LBNL)
- **Science Presentations:**
  - Long Baseline Neutrinos – Bill Marciano (BNL)
  - Proton Decay & Other Physics – Bob Svoboda (UC Davis)
  - Dark Matter – Bernard Sadoulet (Berkeley)
  - Biology – T.C. Onstott (Princeton)
  - Geoscience + Engineering – Derek Ellsworth (Penn State)
  - Nuclear Astrophysics – Michael Wiescher (Notre Dame)
  - Double Beta Decay – Steve Elliott (LANL)

Shortly after NSB decision not to provide bridge funding.

Second Meeting – Feb. 3-4, 2011 - Irvine

Shortly before release of President's FY2012 budget request.

- **International aspects – Eugenio Coccia (Rome)**
- **Additional information on selected topics:**
  - **Long baseline neutrinos**
    - **Neutrino target, beam line issues – Vaia Papadimitriou (FNAL)**
    - **LBNE technical challenges – Jim Strait (FNAL)**
  - **Geoscience/Geoengineering**
    - **Dewatering & DuRA – Larry Murdoch (Clemson)**
    - **Faulting studies – Leonid Germanovich (Georgia Tech)**

- **Jan. 27, 2011 teleconference to collect information:**
  - **DAEdELUS – Janet Conrad (MIT) & Michael Shaevitz (Columbia)**
  - **Gravitational wave experiments – Vuc Mandic (Minnesota)**
- **Other input via: references, input, direct investigation**