The Deep Underground Science and Engineering Laboratory

Cross-disciplinary, community-wide, site-independent study

Washington, DC.
April 3-4, 2006

Goals

At the time we are finalizing a "high level document" similar to "The Quantum Universe"

- Presentation of our draft findings and recommendations
- Feedback from our "final customers"
  - Emphasis and missing arguments
  - Specific recommendations
  - Presentation: title, level, formulation, graphic design

Bernard Sadoulet, UC Berkeley, Astrophysics/Cosmology
Eugene Beier, U. of Pennsylvania, Particle Physics
Charles Fairhurst, U. of Minnesota, geology/engineering
Tullis Onstott, Princeton, geomicrobiology
Hamish Robertson, U. Washington, Nuclear Physics
James Tiedje, Michigan State, microbiology

Judy Jackson, Fermilab, Director, Office of Public Affairs
Elizabeth Arscott, UC Berkeley, Editor

Site Independent Study (S1)

Mission from the NSF

1) to organize a dialog inside the community
about a multidisciplinary, Deep Underground Science and Engineering Laboratory in the U.S..

2) to discover whether there is a compelling scientific justification for such a laboratory, cutting across our many disciplines

3) If there is, to specify the infrastructure requirements
for such a laboratory that will address the needs of a broad cross section of science over the next 20-30 years and complement other facilities worldwide.

Deliverables (in coming weeks)

High Level Report directed at generalists (government+funding agencies) in the style of "Quantum Universe."

Web-based technical synthesis directed at scientific community Justifications and support the main report.

External review

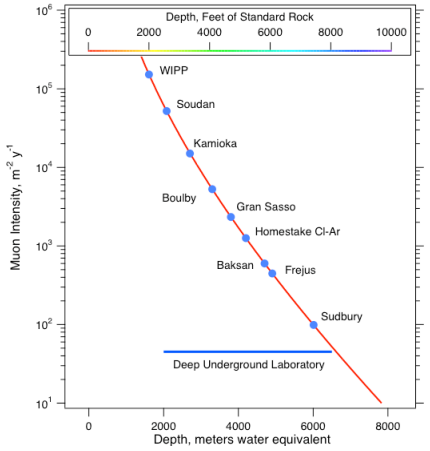
Since our last visit March 05

2 sites preselected by NSF (Homestake, Henderson)

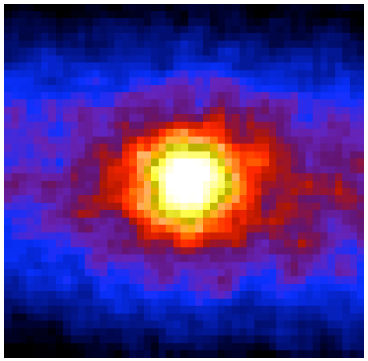
Neutrino Science Assessment group reiterated importance of science

"The Gathering Storm" report and American Competitiveness Initiative

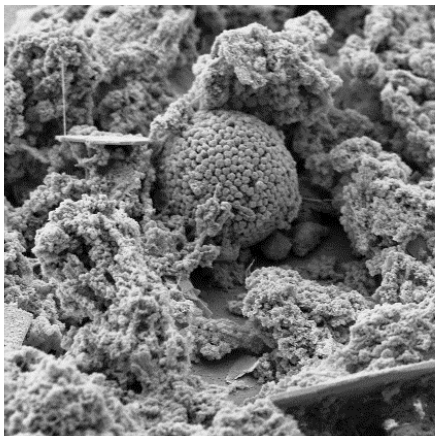
Why deep?



Neutrino picture of the Sun

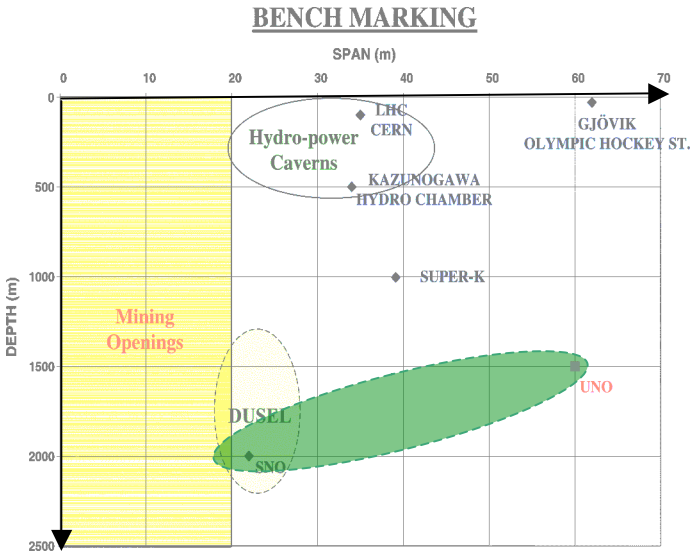


Geo-microbes

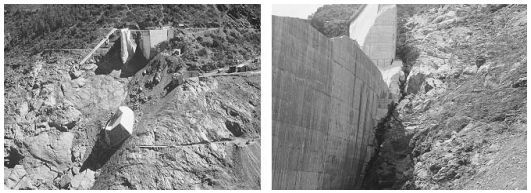


Ground Truth

Frontier Science and Engineering Deep Underground



Size of cavity vs depth



Malpasset dam failure 1958

Undergraduates in South Africa mine

Scientific Motivation

Extraordinary increase in interest into underground science and engineering

3 Fundamental Questions that uniquely require a deep laboratory

- What is the universe made of? What is the nature of dark matter? What is dark energy? What happened to the antimatter? What are neutrinos telling us?
  - Particle/Nuclear Physics: Neutrinos, Proton decay
  - Astrophysics: Dark Matter, Solar/Supernovae neutrinos

- How deeply in the earth does life extend? What makes life successful at extreme depth and temperature? What can life underground teach us about life on other planets and about how life evolved on earth?
  - Unprecedented opportunity for biology to have access to organisms out of contact with rest of the evolution for 500 million yrs

- How rock mass strength depends on length and time scales? Can we understand slippage mechanisms in high stress environment, in conditions as close as possible to tectonic faults/earthquakes?
  - Earth Sciences: Mechanisms behind the constant earth evolution
  - Engineering: rock mechanics at large scales, interplay with hydrology/chemistry/biology

Exciting potential for cross disciplinary synergies

Pushing the rock mechanics envelope <-> physicists needs for large span cavities at great depth

"Transparent earth" Not only improvement of standard methods but new tehnologies

In situ observation, low radioactivity, geoneutrinos, education etc…

Relevance for Society

The fundamental understanding generated by underground science and engineering and the development and testing of new methods and equipments directly benefit the nation's well-being.

- **Underground construction:** the new frontier (urban, mining,fuel storage)
  - Urgent to understand at the fundamental level rock mass behavior
  - Increased predictability and efficiency => lower costs
  - Lower risks to human safety
- **Resource extraction:** Critical need for recovery efficiency improvement
  - Fundamental understanding + Imaging-> New methods
  - Use of subsurface micro-organisms
  - Comprehensive evaluations of equipment at *in situ* pressures and temperatures.
- **Environmental stewardship**

  Understanding the complex interactions between rocks, fluids and micro-organisms has critical importance for managing
  - Water reserves
  - Remediation (e.g. with micro-organisms)
  - Waste isolation and carbon dioxide sequestration.
- **Health and safety**
  - Making progress in understanding rock failure in structures and earthquakes
  - Novel microorganisms from deep underground may lead to new processes for biochemical synthesis (already temperature ersistance enzymes),
- **National security**
  - Ultra sensitive detection methods based on radioactivity

+ Training next generation of scientists and engineers

Motivations for a National Facility

Although

Science is international in nature

U.S. scientists and engineers managed to play a pioneering role without a dedicated U.S. deep underground laboratory

There is no substitute for a premier national facility with unique characteristics

Strategic advantage for U.S. scientists and engineers in the :

- Rapid exploration of new ideas, new technologies and unexpected phenomena as they emerge in the next decades.
- Full exploitation of existing national assets, such as accelerators.
- Maximization of the program's impact on our society, with benefits for our economy, environment, health, national security, and the education of the next generation of U.S. scientists and engineers.

Chronic oversubscription of facilities worldwide

Fast rising demand and interest (e.g. 85 letters of intent for Homestake 2007-2012)

Space crunch will not be significantly alleviated by opening of SNOLab in 2007 : saturated by 2012? (moreover almost totally physics).

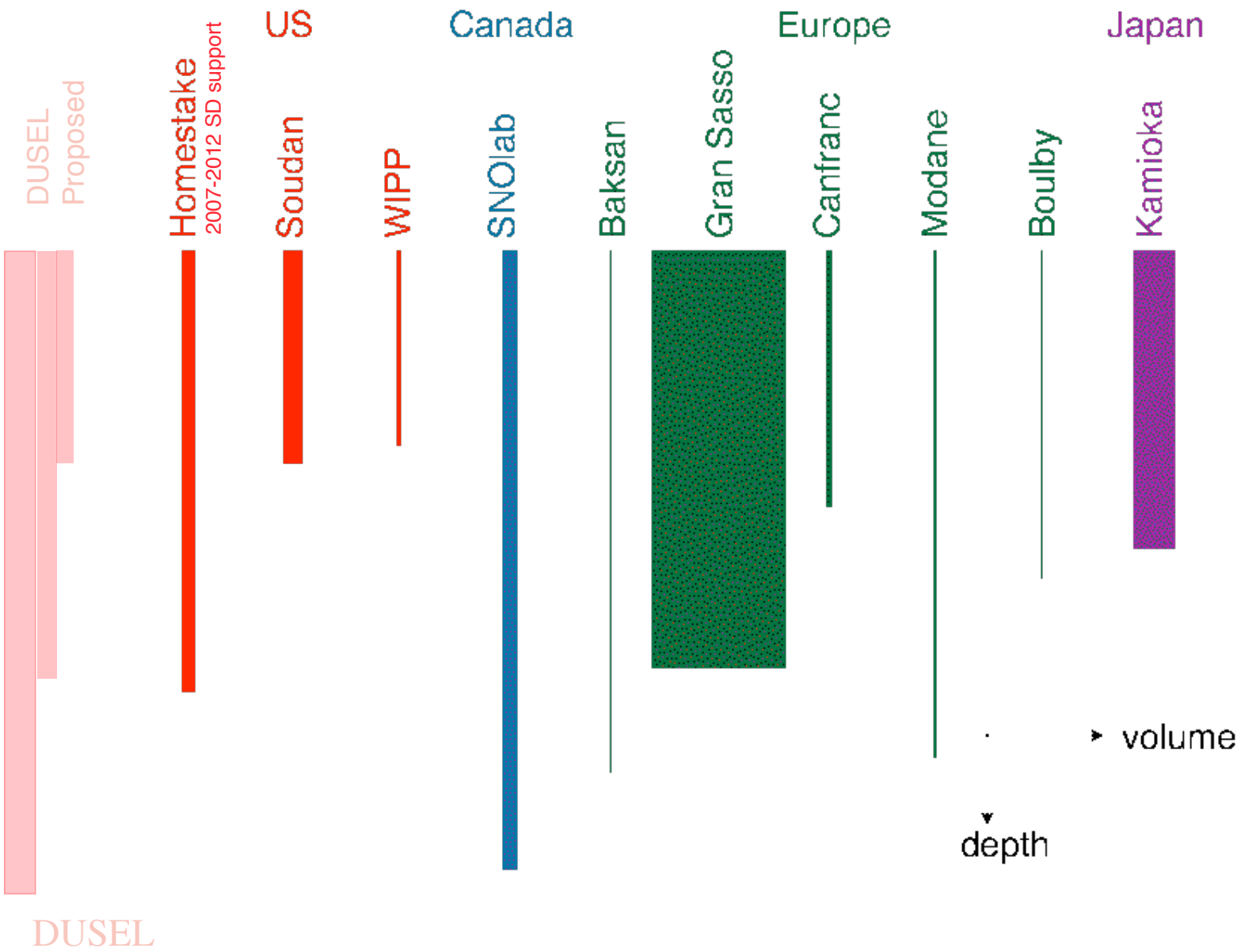
There is a significant opportunity for the U.S.

Scientific/Engineering frontier

Societal return on investment

In line with recommendations of "the Gathering Storm" report and goals of the President's American Competitiveness Initiative

Science Underground



Summary of Findings (Draft)

Exciting scientific frontier: contribute unique aspects

- One of the three frontiers to unravel the mysteries of the Quantum Universe (+ accelerators and astrophysical observatories)
- Unique opportunity for Earth Sciences to get long term access to great depth and to large physical and time scales
- Unique chance for Geo-microbiology to observe *in situ* organisms at large depth for a long time
- Frontier engineering: fundamental knowledge about rock deformation/slippage, water flows, biological effects

Great synergy potential

Importance for society

- Fundamental knowledge
- Economic / environmental importance: underground construction, resource and water management, waste sequestration
- Education of next generation of scientists and engineers

An opportunity for the US to seize

- Strategic position at an important scientific frontier
- Potentially high return on investment in terms of societal benefits
- Needs for more facilities worldwide

Recommendations (Draft)

The U.S. should

1. **Seize the opportunity to strengthen its underground science and engineering program**

2. **Initiate the construction of DUSEL**

   A premier facility with unique characteristics able to attract the best projects worlwide

   Depth (>6000 m.w.e.≈ 6000ft -> 12000 ft biologists)

   Long term access (≥ 30 years)

   Premier infrastructure: easiness of access 24h/day 365 days/yr

   - Highly desirable: Small trailer or ISO 1/2 container (2.4 x 6.1 x2.6 m^3)
   - Dust, radon control, low vibration, electromagnetic noise
   - Local technical support, information infrastructure

   Evolutionary: Additional cavities (e.g. Proton Decay/ Neutrino long base line)

   Proactive Safety: not only existing regulations but also more effective approaches

   Capability to address unconventional requirements (with challenging safety issues: e.g., large cryogenic liquid experiment, fracture motion experiments)

   Unique combination with accelerators (L≥1000km)

   Multidisciplinary synergies, intellectual atmosphere.

Recommendations (Draft)

3. Concurrently establish a National Institute for Underground Science and Engineering (NIU)

Triple mission:

- Support technically and scientifically the U.S. research institutions engaged in underground science and engineering
  - Not only design and operate DUSEL but also:
  - Technical support
  - Long term R&D (instrumentation, low background, new approaches)
  - Theory, workshops -> vibrant interdisciplinary intellectual vitality
- Focus the national underground effort (critical mass, excellence)
  - + coordinate it with other national initiatives (accelerators, Earth Scope, SecureEarth)
  - and other underground labs nationally and internationally (in particular SNOLab)
- Maximize societal benefits
  - Interagency, multidisciplinary collaborations
  - Involvement of industry
  - Education of the next generation of scientists and engineers
  - A better general understanding of frontier science by the public

Initial Program (Draft)

4 phases

1) Before the excavation

Physics: R&D and low background counting facility.

Earth Sciences/Engineering: Full characterization of the site with a number of instrumented bore holes and imaging.

Biology: Use of bore holes for sampling

2) During excavation

Earth Sciences/Engineering: Monitoring of rock motion, modification of stress during construction

Tests of imaging methods

Biology: sampling ahead

3) First suite of experiments

See next two slides

4) Design potential extensions in the first ten years

Initial Suite of Experiments (Draft)

Deep Campus

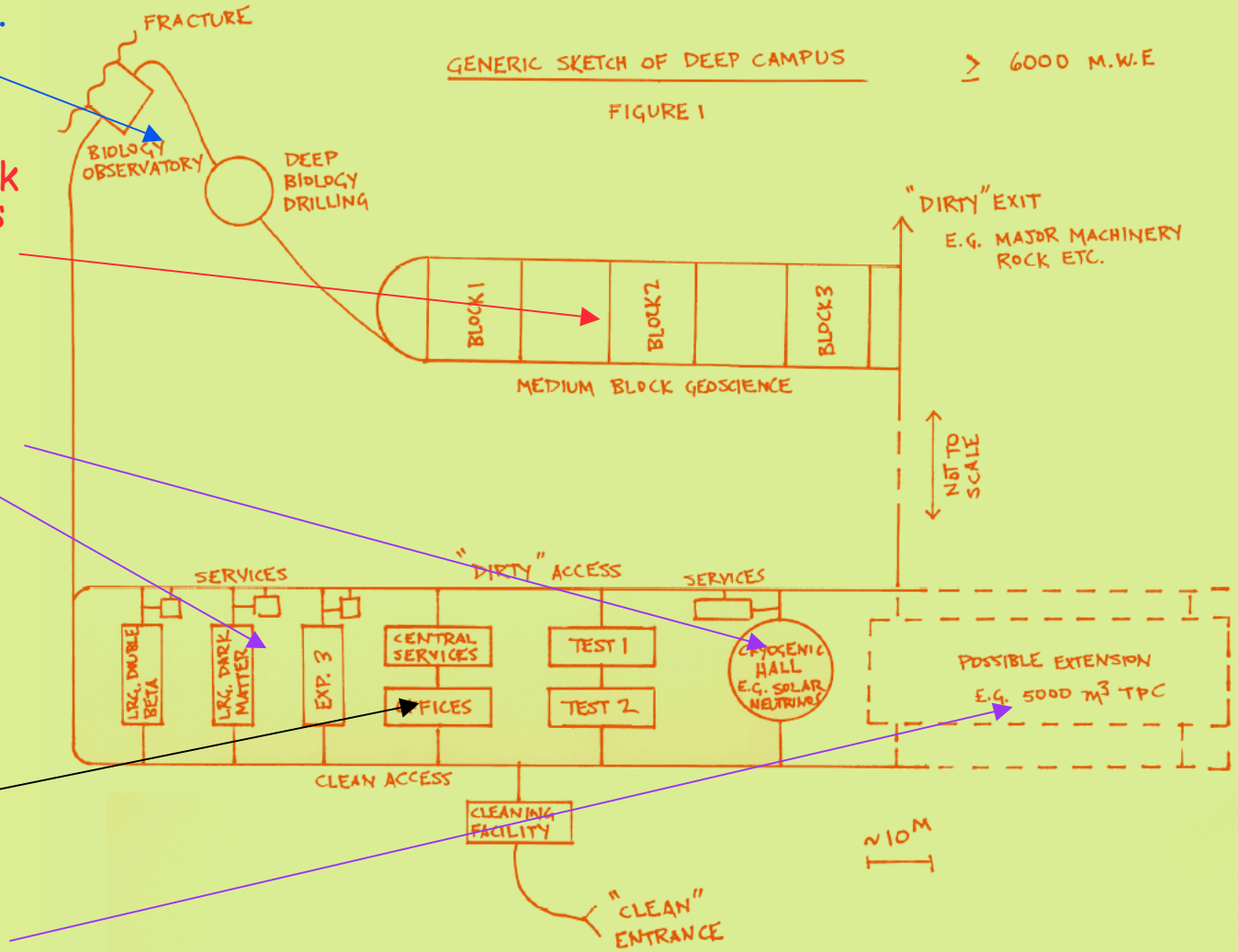
Biology observ.
Deep Biology Drilling

3 Medium block experiments

Dark Matter
Double beta
Exp. 3 TBD
Solar neutrino
2 test/small expt areas

Central services
Offices etc.

Possible extensions large hall e.g for TPC



Initial Suite of Experiments (Draft)

Intermediate levels

- Low background counting
- Underground fabrication facilities, Ge & Cu refining
- Potentially: Low vibration facilities for Atomic Molecular and Optical
- Outreach module

- Nuclear Astrophysics Accelerator
- SN burst detectors

- Intermediate level block experiments (coordinated to lower level)
- Fracture motion experiment: Far from rest of of laboratory!

- Intermediate biology observatories (coordinated to lower level)

- Potential expansions: Megaton neutrino/proton decay
  Laser gravitational wave interferometer

Conclusions

A real opportunity that the U.S. should not miss

- A important frontier of science and engineering
- Highly relevant for society: when coordinated with other efforts, unique
- Embodies the best principles and goals of the President's American Competitiveness Initiative

We need your feedback in the coming weeks

- What we presented today!
- Draft of the high level document