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DUSEL
S1 study

DUSEL more than Physics
DUSEL Physics Justifications
Findings and recommendations
Comparison with other strategies

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Site Independent Study (S1)

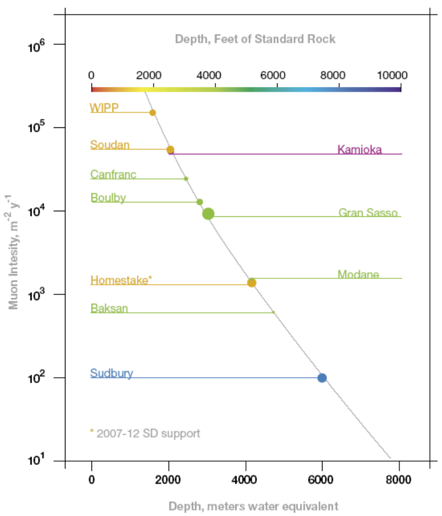
Mission from the NSF

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.

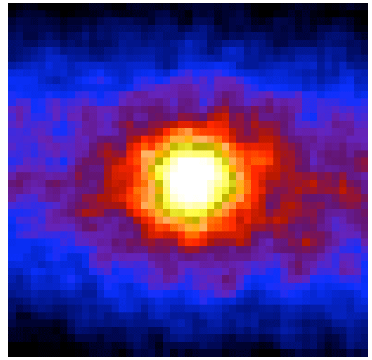
Deliverables

- 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

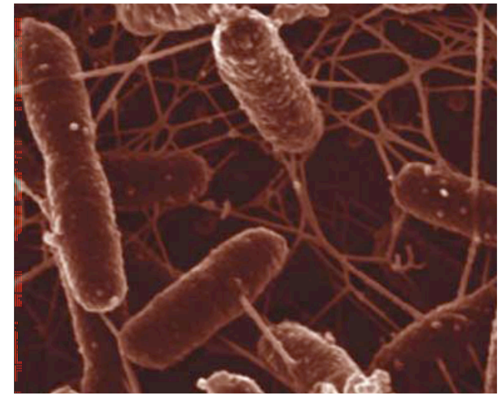
Physics: protection from μ's



Neutrino picture of the Sun

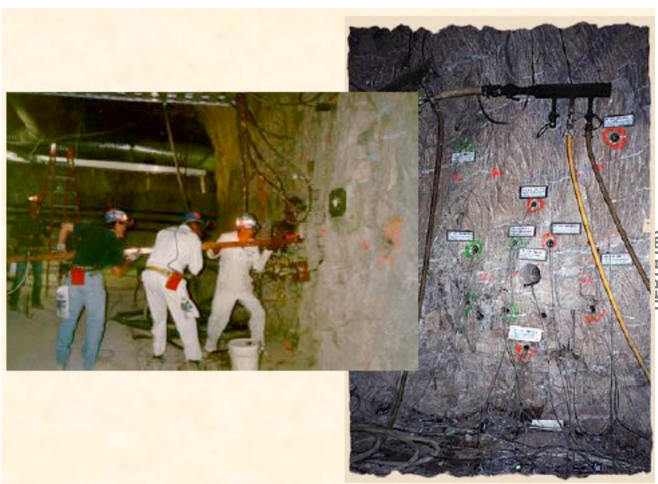


Geo-microbes

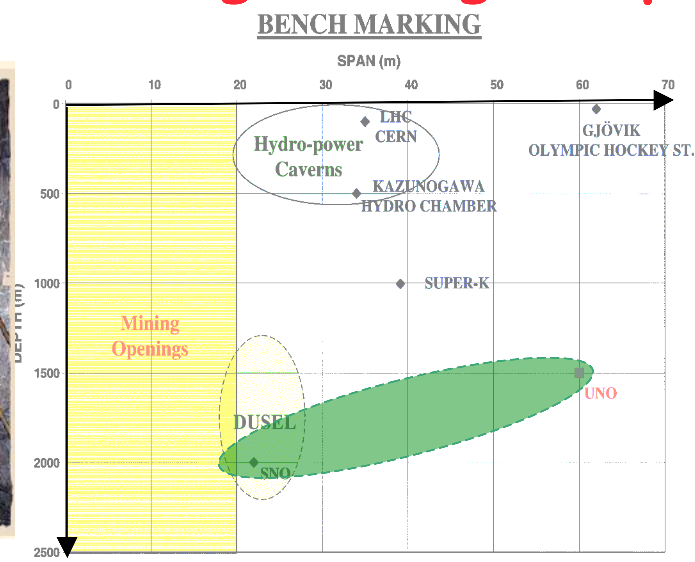


Deep Science

Frontier Science and Engineering Deep Underground



Large Block Geo Experiment Coupled Processes



Size of cavity vs depth

Undergraduates in South Africa mine

Scientific Motivation

Extraordinary increase of interest in 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 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 how life evolved on earth and about life on other planets?
  - Unprecedented opportunity for long term *in situ* observations
- 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

The Frontier is at Large Depth!

Physics

- Neutron and activation of materials
  - Neutrinoless double beta decay
  - Dark Matter
  - Neutral current/ elastic scattering solar neutrino
  - New ideas (e.g. related to dark energy)
- Neutron active shielding (300MeV) is difficult and risky
- Rejection of cosmogenic activity is challenging

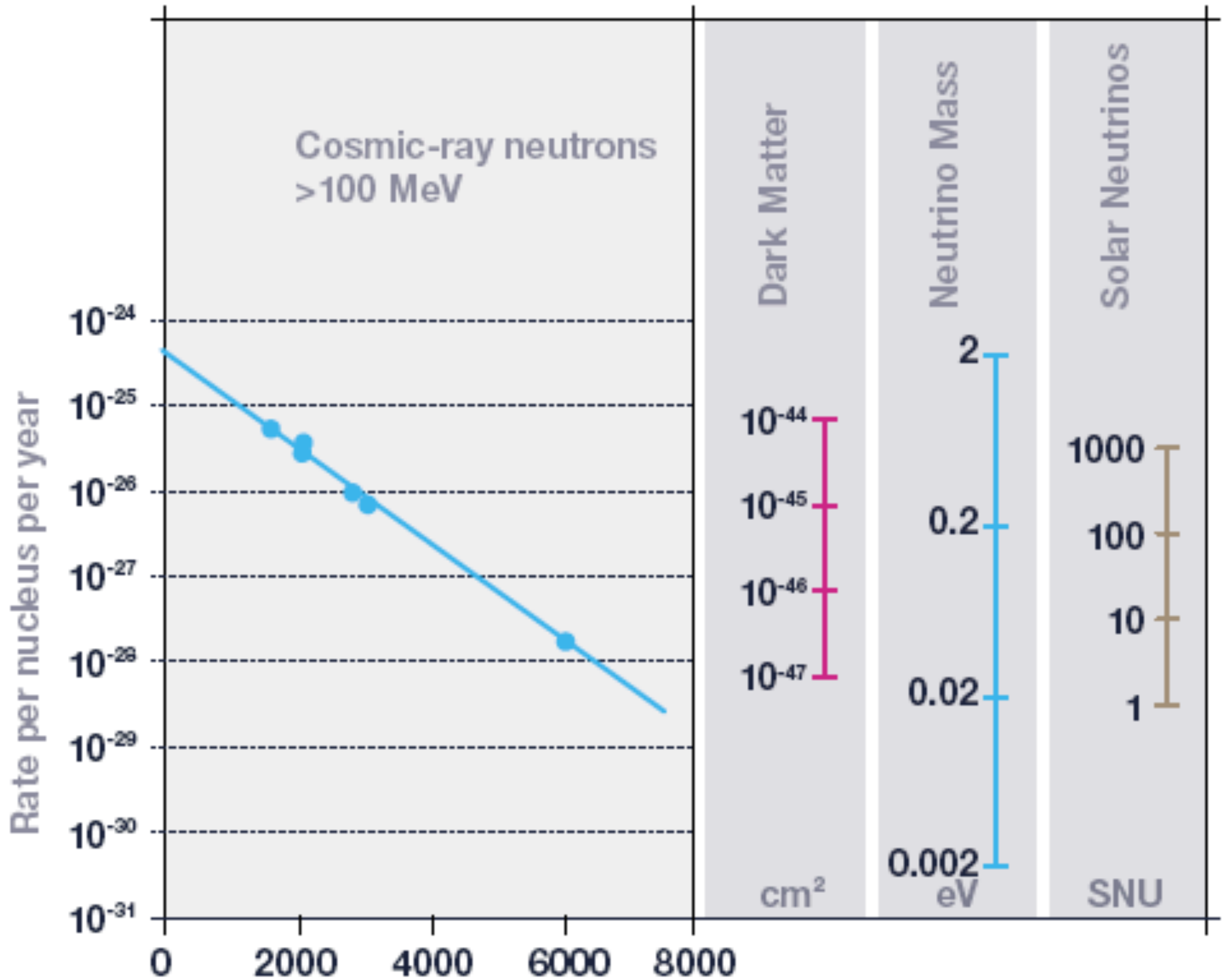
Biology

- DUSEL = aseptic environment at depth
- Study microbes in situ (at constant pressure, microbial activity at low respiration rate)
- Deep campus: Platform to drill deeper -> 12000ft (120°C)

Earth science/ Engineering

- Scale/stress dependence of rock properties
- Get closer to conditions of earthquakes
- Complementary to other (mostly nuclear waste study) shallower facilities

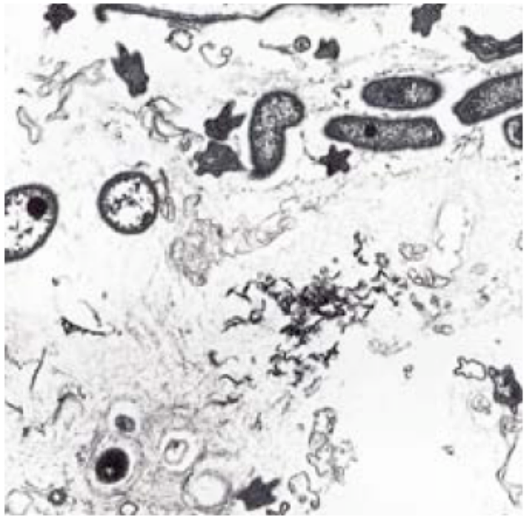
Physics/Astrophysics Justification



Biology at depth

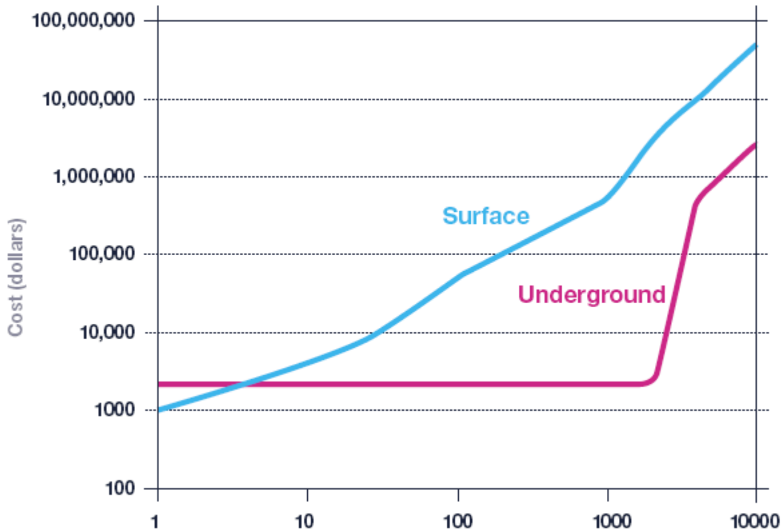
New type of organisms

e.g. star shaped cells collected at 2000m
Never seen before!
Genome?



Deep drilling => 80->120°C

Reduction of cost
Higher spatial control
Improved control of contaminati



Other Motivations

Exciting potential for cross disciplinary synergies

Pushing the rock mechanics envelope <-> physicists needs for large span cavities at great depth
"Transparent earth" Improvement of standard methods + new technologies
Neutrino tomography of the earth (need 1%accuracy)? U/Th mapping (Core)?
Sensors, low radioactivity, education etc...

Relevance to Society

- **Underground construction:** the new frontier (urban, mining,fuel storage)
- **Resource extraction:** Critical need for recovery efficiency improvement
- Water resources
- **Environmental stewardship**
  - Remediation (e.g. with micro-organisms)
  - Waste isolation and carbon dioxide sequestration.
- **Risk prevention and safety**
  - Making progress in understanding rock failure in structures and earthquakes
- **National security**
  - Ultra sensitive detection methods based on radioactivity

Training next generation of scientists and engineers

+ public outreach: better understanding of science

Need for New Underground Facilities

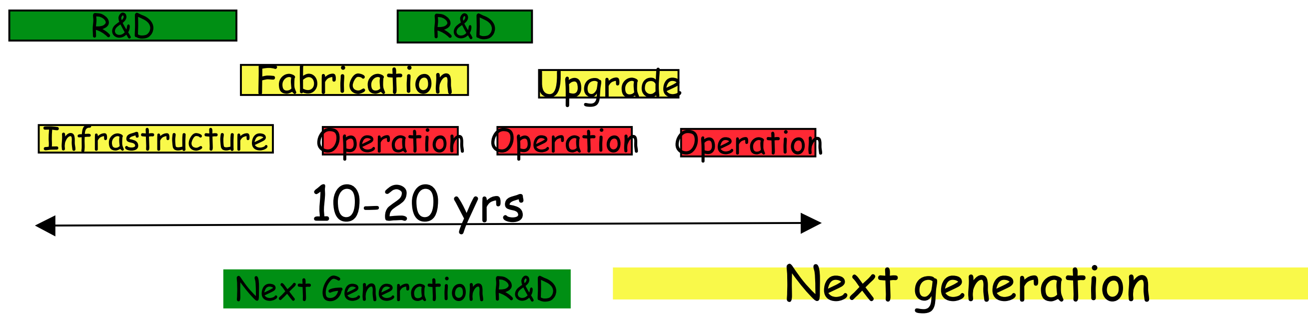
Chronic Oversubscription of underground facilities

Increase in the community

- Importance/interest of the science: neutrinos, cosmology
- Shift from accelerator based experiments
- Fast progress at boundaries between fields

Life cycle of experiments

- Getting longer



- Overlap between running of previous generation and construction of next

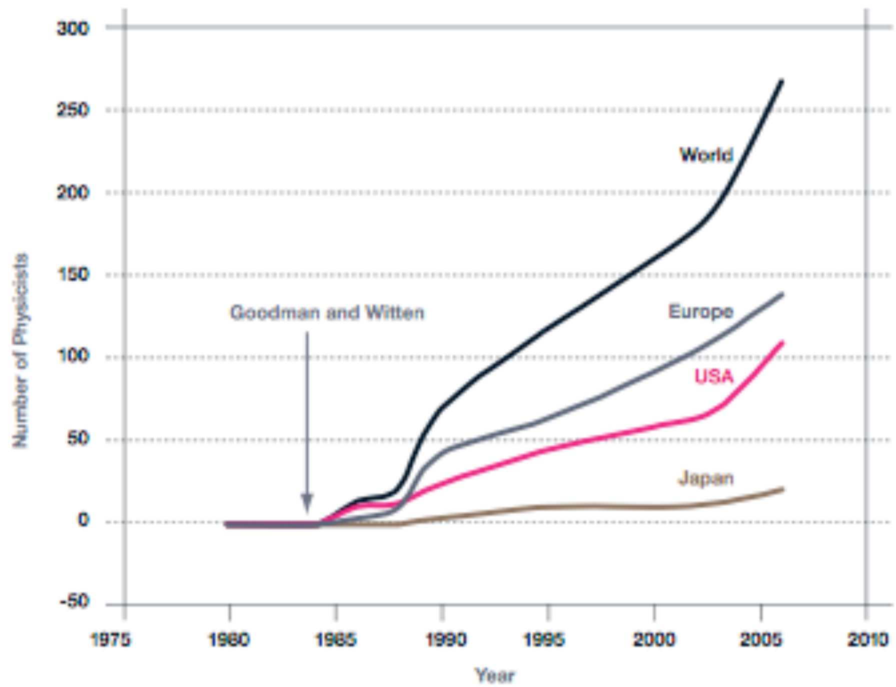
For important questions, need for several experiments

- Decrease risk: several technologies => R&D at nearly full scale
- Dependence on target: e.g matrix element for 2ß , A^2 for WIMPs

But budgetary constraints ≠ sum of all dreams

Expansion of the field

An example: Dark Matter



Similar plots for other subfields

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

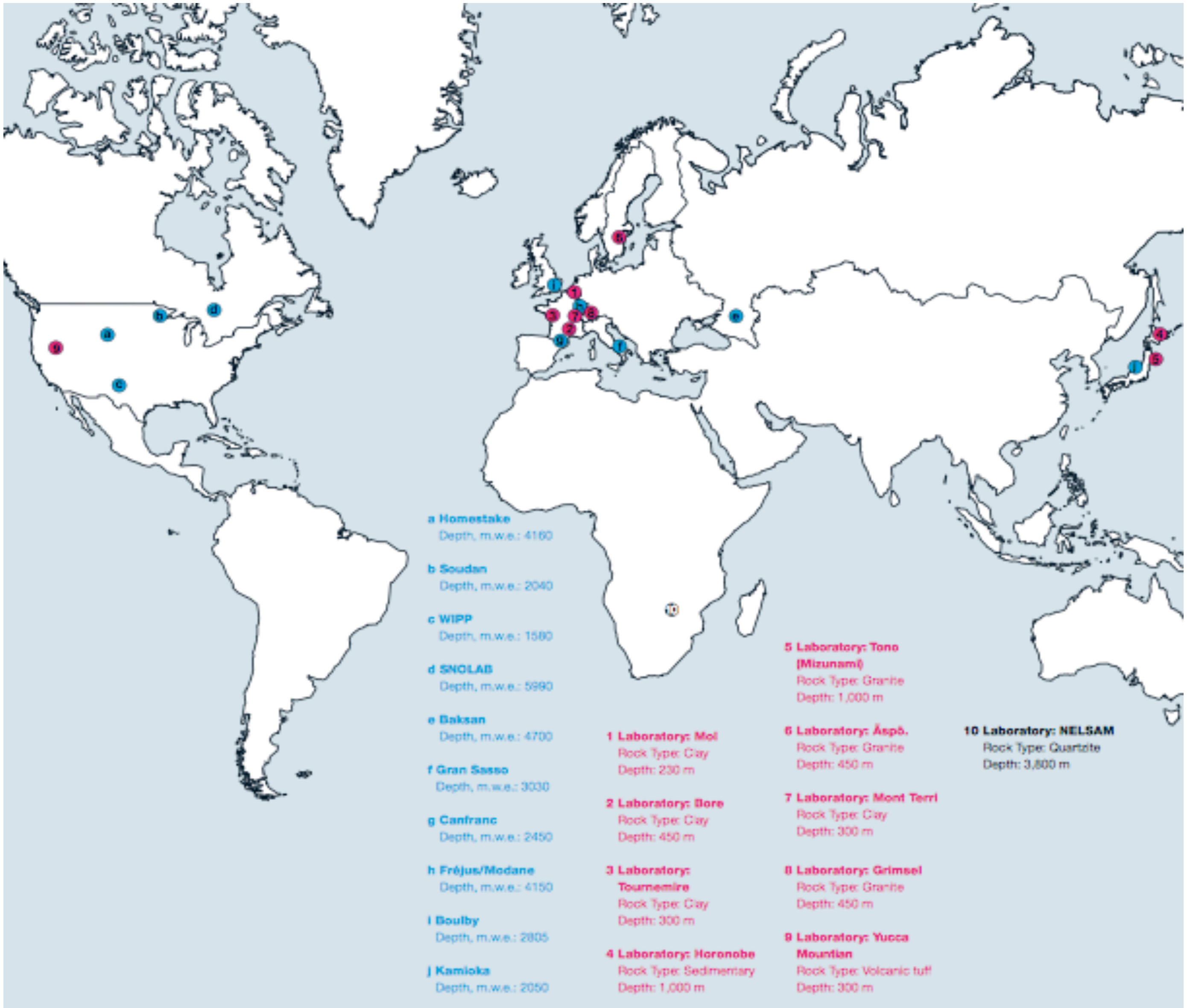
Push frontier science

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

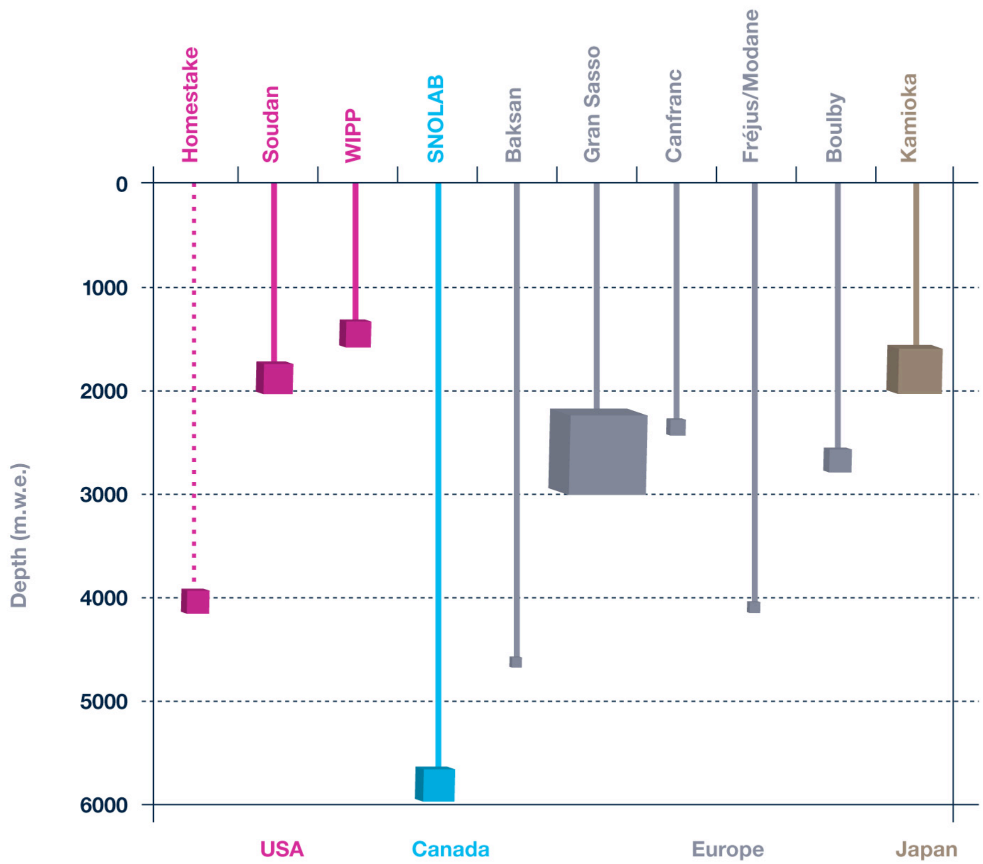
- Rapid exploration of new ideas, and unexpected phenomena
- Full exploitation of existing national assets, such as accelerators.
- Maximization of the program's impact on our society

U.S. one of the only G8 nations without national facility

Underground Facilities in the World



Facilities for Physics



*Interim facility at 4850ft supported by SD 2007-2012

Recommendations S1 report

Recommendation 1: Strong support for deep underground science

The past decade has witnessed dramatic scientific returns from investments in physics and microbiology at great depths. Underground research is emerging as a unique and irreplaceable component of science, not only in physics and astrophysics, but also in biology, earth sciences and many disciplines of engineering. We recommend that the U.S. strengthen its research programs in subsurface sciences to become a world leader in the multidisciplinary exploration of this important new frontier.

Recommendation 2: A cross-agency Deep Science Initiative

In order to broaden underground research and maximize its scientific impact, we recommend that the U.S. science agencies collaborate to launch a multidisciplinary Deep Science Initiative. This initiative would allow the nation to focus the whole range of underground expertise on the most important scientific problems. It would aim at optimizing the use of existing or new underground facilities and at exploiting the complementary aspects of a variety of rock formations. The Deep Science Initiative should be coordinated with other national initiatives and take full advantage of international collaboration opportunities.

Recommendations S1 Report

3. Recommendation 3: A Deep Underground Science and Engineering Laboratory

The U.S. should complement the nation's existing assets with a flagship world-class underground laboratory providing access to very great depth (6000 mwe) and ample facilities at intermediate depths (3000 mwe) currently not available in the U.S.. Such a Deep Underground Science and Engineering Laboratory (DUSEL) should be designed to allow evolution and expansion over the next 30 to 50 years. Because of this long lifetime, the initial investment must be balanced with the operating costs. For maximum impact, the construction of DUSEL should begin as soon as possible.

- Easiness of access 24h/day 365 days/yr
  - Highly desirable: Small trailer or ISO 1/2 container (2.4 x 6.1 x2.6 m3)
  - Dust, radon control, low vibration, electromagnetic noise
  - Local technical support, information infrastructure
- Access to pristine rock
- Evolutionary: Additional cavities (e.g. Proton Decay/ Neutrino long base line)
- Proactive Safety
- Capability to address unconventional requirements (e.g. challenging safety issues: large cryogenic liquid experiment, fracture motion experiments)
- Unique combination with accelerators (L≥1000km)

- Multidisciplinary synergies, intellectual atmosphere.

Initial Program: 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 slide

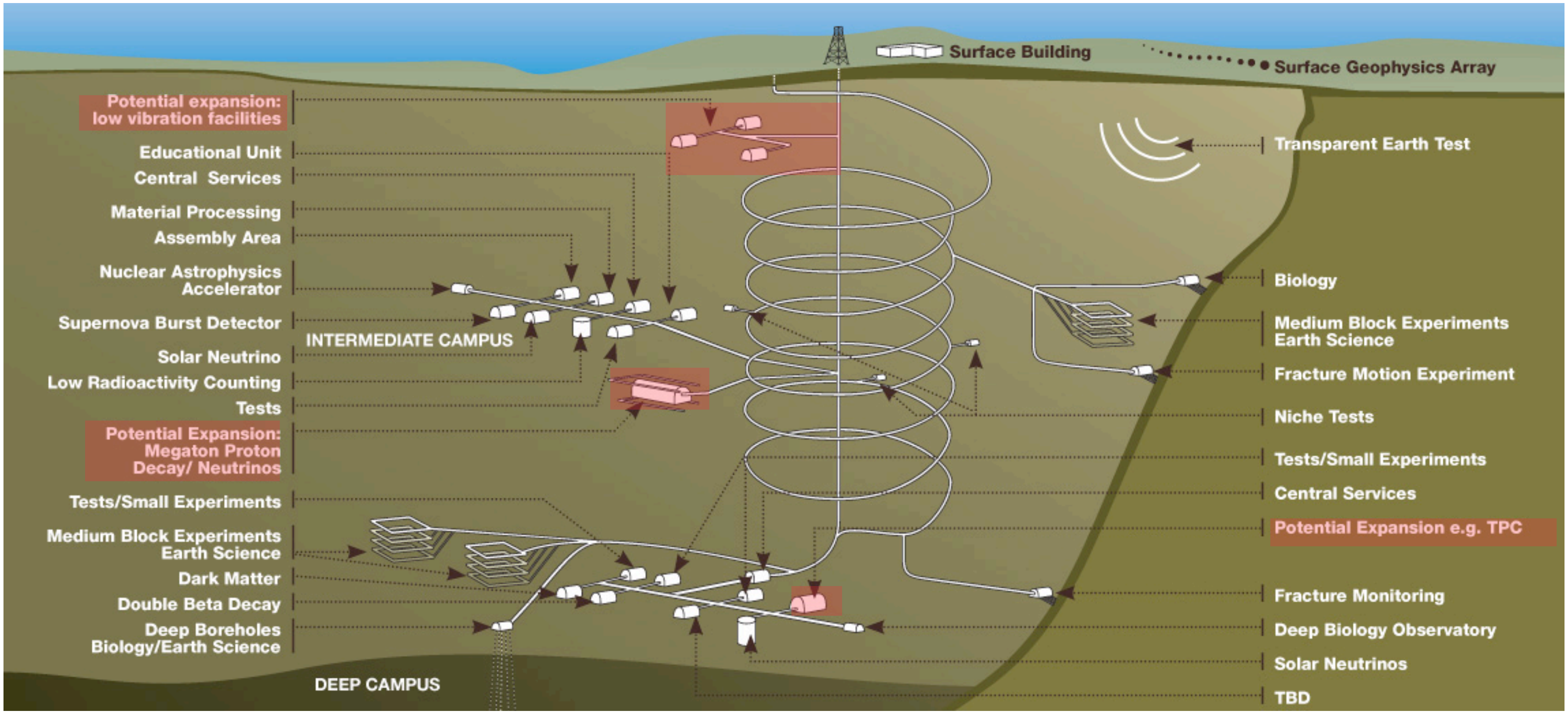
4) Design potential extensions in the first ten years

Deep Campus: large hall e.g for TPC

Intermediate depth: Megaton neutrino/proton decay

A Schematic View of DUSEL

A schematized view circa 2015 + possible expansions



Rough estimate (not vetted yet)

Deep level useable area/volume ≈ 3,500m^2 /25,000m^3 + 600m^2 /7000m^3

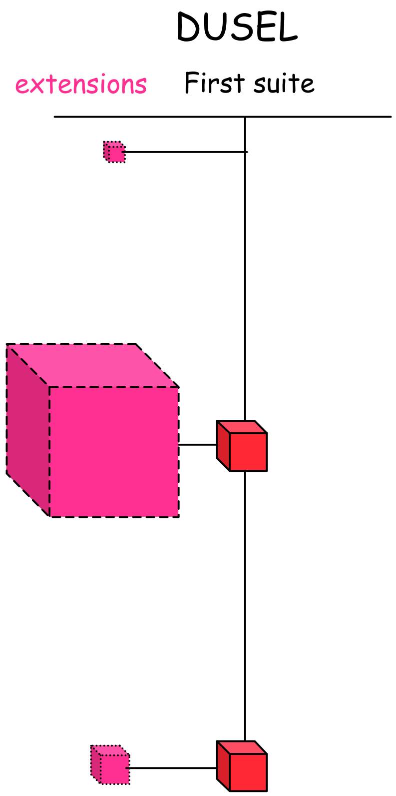
Intermediate campus area/volume ≈ 3,500m^2 /20,000m^3 + 20,000m^2/1.1x10^{6}m^3

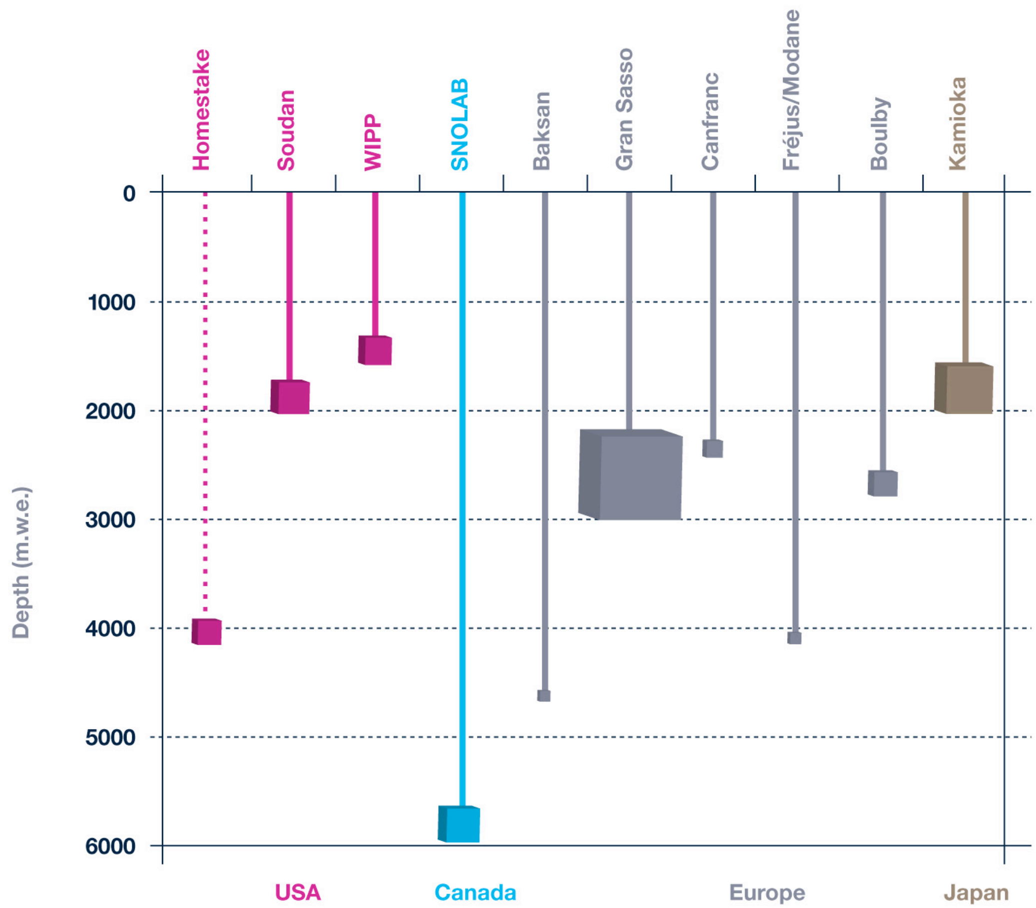
Low vibration facilities 300m^2/2000m^3

SNOLAB 400m^2/13,000m^3 (SNO) + 1,000m^2/7,000m^3

Gran Sasso 18,000m^2/ 180,000m^3

Complementarity of DUSEL





Can we afford DUSEL?

Interagency initiative is more than DUSEL

We cannot afford not to present at this frontier

MREFC line

Covers Facility + NSF contribution to first suite of experiments
(NSF-DOE working group)

=Line item

Strategy is to involve Geo/Bio/Eng to secure place in MRE queue

⇒Initially bring new resources to HEP/Nuclear community

Long term costs

Cost of operation will be eventually borne in part by Physics community

was context of horizontal /vertical access debate

- Facility operation and safety: potentially important discriminant
  - Water pumping, hoist operation, maintenance
- Easiness of access
  - Installation (e.g. 100-200 man-yrs of SNO, small experiments)
  - Emergency interventions, maintenance

Impact on future projects:

Although multidisciplinary, MRE would be seen as Physics possibly impacting other NSF initiatives in Physics

But: different scale from ILC

enabling possible extensions

e.g. Proton Decay/Long Baseline neutrino detector

Comparison with Other Strategies

Our recommendations explicitly include:

Full use of existing facilities (WIPP, Soudan)
Full use of international collaborations (SNOLab, Gran Sasso,Kamioka)
Science First!

Expansion of SNOLab

Limits of cooperation of INCO
Not everything needs to be deep
Not suitable for multidisciplinary enterprise
Strong reduction of benefits to U.S.

A shallow site + SNOLab + subsequent deepening

e.g. Soudan (existing ν beam) + SNOLab
Pioneer tunnel (already dug) + SNOLab
2000 m.w.e. indeed suitable for a number of experiments
(automatic in most facility. 3000 m.w.e better!)
But attempting to perform frontier experiments at lower depth with shielding because of lack of space is
risky (when given the choice, teams choose depth)
only a temporary stop-gap
Lack of space may inhibit rapid exploration of new ideas
A subsequent extension is not well adapted to MREFC structure
Sequential approach compromise initiative, delays a frontier facility

Time Scale

S1: site independent

- Draft of “Deep Science” posted on 9/25/06 after external reviews
- Report at HEPAP 10/12/06. Draft
- High Level Document printed early November
- Technical documents mostly finished, externally reviewed, all assembled in October
- Launch?

S2: site preselection

- Pre-selection of Henderson and Homestake 07/25/06
- Conceptual design submitted 06/24/06
- Reviewed by panel. Feedback given to sites

S3:site selection

- Announcement Sept 30,2006
- Proposals (including Conceptual Design) due Jan 9,2007. Open to any site.
- Selection of one site early 07
- Draft technical report Dec 07 feeding into MREFC process

MREFC process

- Started: contacts with other directorates within NSF
- Potential first decision in Dec 07 -> earliest start date FY2010

Involvement of other agencies

- Common working group with DOE . Common R&D initiative.
- Multidisciplinary discussions yet to be started outside NSF.

Conclusions

Deep Science: one of the frontiers in many fields! We need:

- Increase of funding to become worldwide leaders
- A cross agency initiative with appropriate coordination mechanisms
- New facilities at large depth (and ≥30 yrs access): DUSEL.

Deep Science Initiative >> DUSEL

- Optimal use of existing facilities + coordination with other national initiatives
- Full engagement in international collaboration
- DUSEL brings new resources by tapping MRFC

Significant chance to obtain necessary resources

- Powerful science
- Multidisciplinary perspective aligned with many of NSF interests

"Deep Science" will benefit the Physics Community

- Widens the underground frontier
  - Home for the most important experiments we foresee now
  - Flexible space for new unexpected ideas
- Multidisciplinary intellectual atmosphere, e.g. neutrinos=earth science tool !
- MREFC costs are initially not borne by community
  - But beware of large operating costs

Time scale is long: start now!