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The Deep Underground Science and Engineering Laboratory

Site Independent Study

- The process
- The science
- Infrastructure requirements
- S2 decisions
- What remains to be done

6 Principal Investigators
B.Sadoulet, UC Berkeley
(Astrophysics and Cosmology)
Eugene Beier, U. of Pennsylvania
(Particle Physics)
Hamish Robertson, U. of Washington
(Nuclear Physics)
Charles Fairhurst, U. of Minnesota
(Geology and Engineering)
Tullis C. Onstott, Princeton
(Geomicrobiology)
James Tiedje, Michigan State
(Microbiology)

DUSEL Process

Solicitation 1: Community wide study of

- Scientific roadmap: from Nuclear/Particle/Astro Physics to Geo Physics/Chemistry/Microbiology/Engineering
- Generic infrastructure requirements
- Proposal supported by all 8 sites
  Approved by NSF (January 05)
- Interim report April 24

Kimballton
SNOlab
WIPP
Henderson Mine
Homestake
Soudan
San Jacinto
Cascades

Solicitation 2 : Preselection of ≈3-5 sites

- 8 proposals submitted February 28.
- Panel late April. Decisions public by July 19: 2 sites

⇒Solicitation 3

⇒Selection of initial site

⇒MRE and Presidential Budget (09) -> 2011-2015

See www.dusel.org

Solicitation 1 Organization

6 PI's responsible for the study

in particular scientific quality/ objectivity

14 working groups

Infrastructure requirements/management

Education and outreach

2 consultation groups

- The site consultation group (Solicitation 2 sites)
- The initiative coordination group: major stakeholders (e.g. National Labs)

4 workshops building on NUSL/NESS

Berkeley Aug 4-7

Blacksburg Nov 12-13

Boulder Jan 5-7

Minneapolis July 21-23

External review à la NRC

Rolling out workshop in Washington Late Jan 06

Printed report directed at generalists

Agencies

OMB/OSTP/Congress cf. Quantum Universe

+Web based reports with technical facts

for scientists and programs monitors

Originality of the approach

Science driven!

Study of several solutions and sites

Multidisciplinary from the start

Not only physics. astrophysics but Earth sciences, biology, engineering
Internal strategy inside NSF : interest many directorates ->MRE line
NSF=lead agency but involvement of other agencies:DOE (HEP/Nuclear, Basic Sciences) , NASA (Astrobiology), NIH, USGS + industry

Adaptive Strategy

This is an experimental science facility, not an observatory

Specifically adaptive strategy to take into account

- The evolution of science
- International environment (available facilities -e.g. SNOLAB, MegaScience coord.)
- Budgetary realities

Excavate as we go ≠LN Gran Sasso

Potentially multi-sites

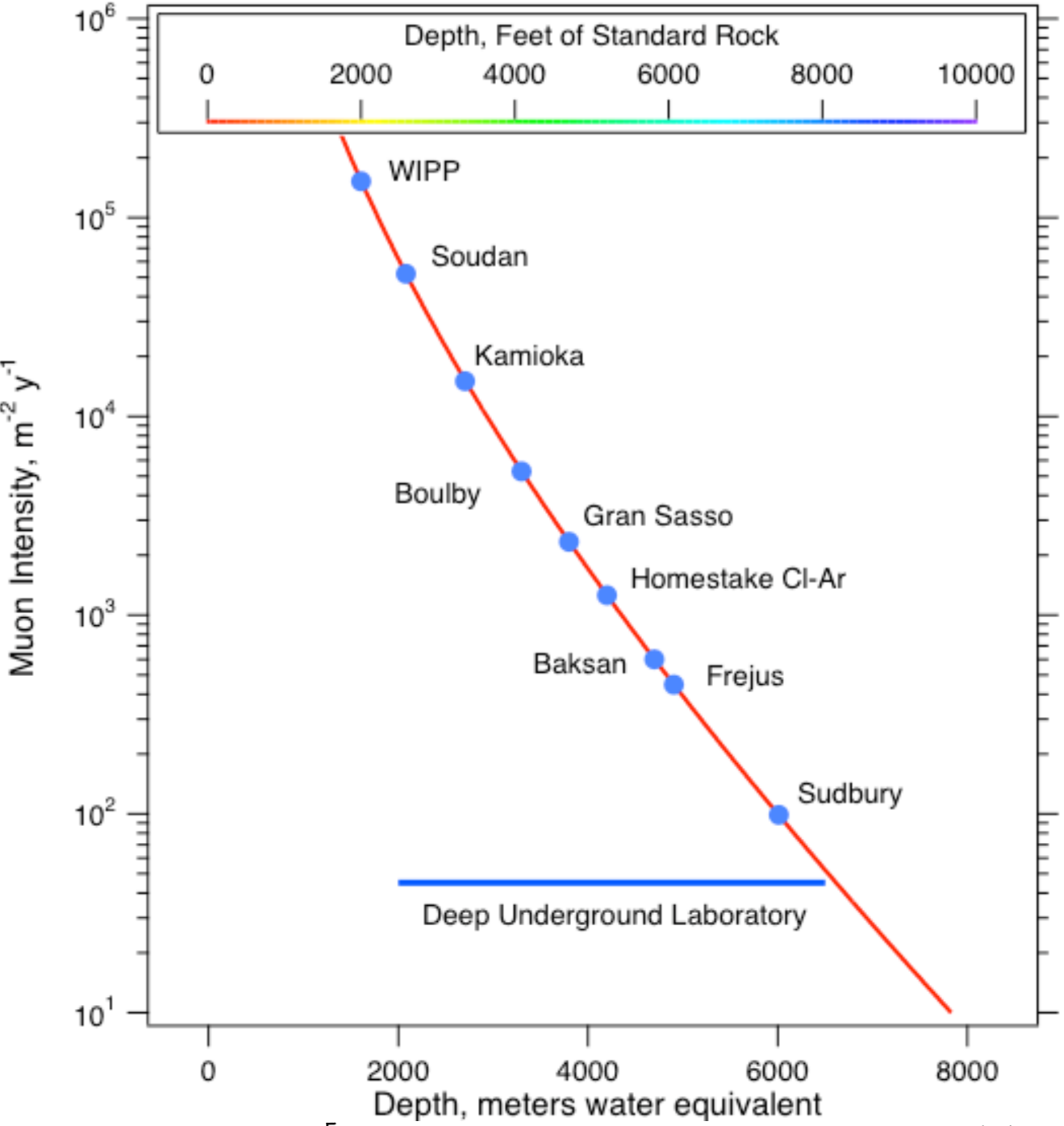
Although some advantages of a single site in terms of technical infrastructure and visibility
not necessary provided we have a common management (multi-campus concept)
variety of rock type and geological history
closer to various universities (important for student involvement)

Modules that can be deployed independently (in time or space)

Decoupling of large detector from deep science

Education and outreach included from beginning

Rare Process Physics needs low cosmic-ray rates



Major Questions in Physics

What are the properties of the neutrinos?

Are neutrinos their own antiparticle?

3rd generation of neutrinoless double beta decay. (250kg ->1 ton)

What is the remaining, and presently unknown, parameters of the neutrino mass matrix? θ_{13} ? hierarchy of masses? CP symmetry?

Do protons decay?

Current theories ≈ within factor 100 of current limits

>factor 10 possible=> may allow a spectacular discovery!

Immediately related to

- the completion of our understanding of particle and nuclear physics
- the mystery of matter-antimatter asymmetry

Surprises very likely!

Major Questions in Astrophysics

What is the nature of the dark matter in the universe?

e.g. weakly interacting massive particles (WIMPs) ?
Supersymmetry? Complementary to LHC/ ILC

.

What is the low-energy spectrum of neutrinos from the sun?

sun but also fundamental properties of neutrinos.

Neutrinos from Supernovae:

Long term enterprise for galactic SN!
Relic SN neutrinos
Local galaxies <-> Gravitational detectors + optical ≈ 1 day later

Underground accelerator (cf. Luna)

-> Nuclear cross sections important for astrophysics and cosmology

Follow on surprises and new ideas

Geoscience: The Ever Changing Earth

Processes taking place in fractured rock masses

Cracks =>Dependence on the physical dimensions and time scale involved.

- *in situ* investigation of the Hydro-Thermal-Mechanical-Chemical-Biological (HTBCB) interactions at work
- This understanding is critical for a number of problems of great scientific and societal importance
  - ground water flow
  - transport of foreign substances
  - energetic slip on faults and fractures.

Approach the conditions prevalent in the regions where earthquakes naturally occur

help us answer questions such as

- Earth crust and tectonic plates motions?
- Onset and propagation of seismic slip on a fault?
- Prediction of earthquakes?

Requires A deep laboratory, with long term access (>20yr)

Which rock? Initially any kind would be interesting

Eventually all types should be available internationally

igneous, metamorphic and sedimentary (+salt)

Subsurface Engineering

Mastery of the rock

What are the limits to large excavations at depth?

- petroleum boreholes: 10km Ø 10cm
- deepest mine shafts: 4km Ø 5m
- DUSEL experimental areas: 10-60m at a depth between 1 and 3km

Much experience will be gained through the instrumentation and long term monitoring of such cavities at DUSEL

Technologies to modify rock characteristics e.g. in order to improve recovery: go beyond hydrofracture, role of biotechnologies

Transparent Earth

Can progress in geophysical sensing and computing methods be applied to make the earth "transparent", i.e. to "see" real time processes ?

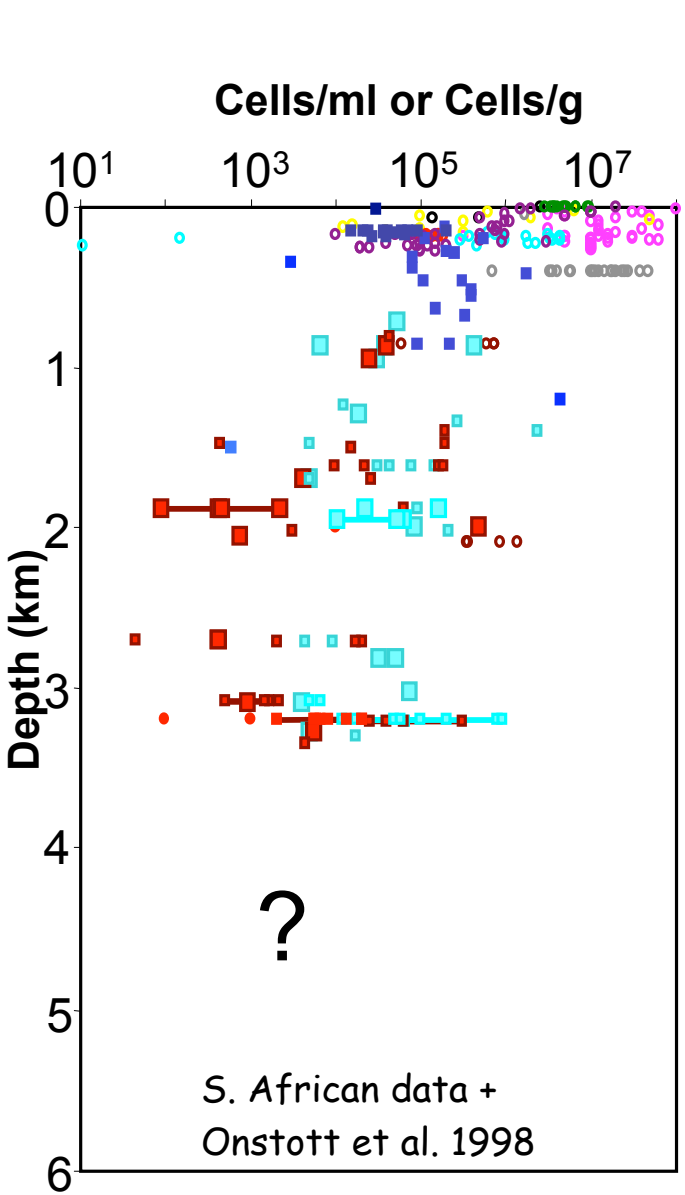
Remote sensing methods tested/validated by mining back

In particular, relationship between surface measurements and subsurface deformations and stresses: important for study of the solid Earth

Great societal impact

- Large underground constructions
- Groundwater flow,
- Ore /oil recovery methods and mining/boring technology
- Contaminant transport
- Long-term isolation of hazardous and toxic wastes
- Carbon sequestration and hydrocarbon storage underground (sedimentary rock)

A recent breakthrough



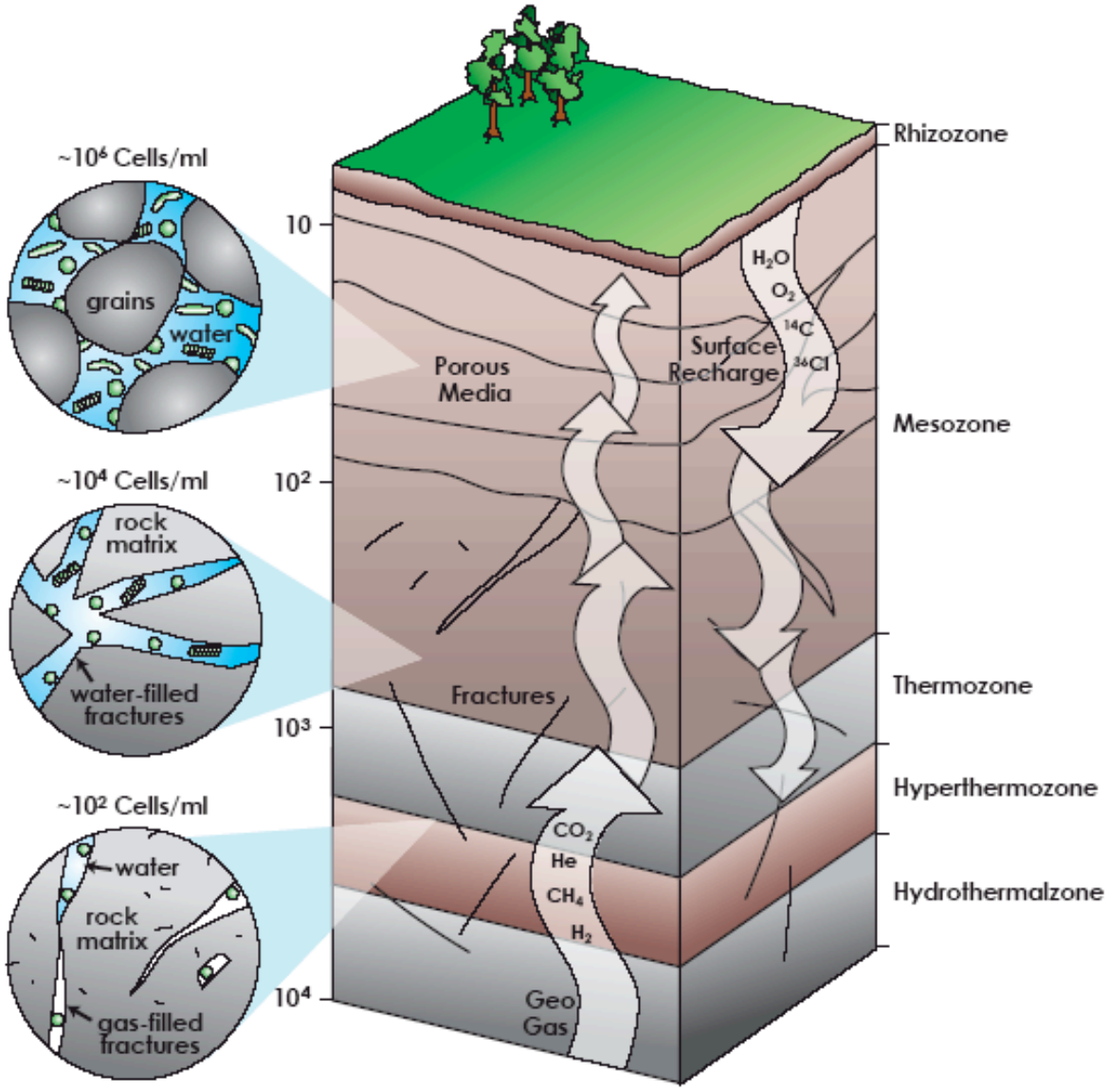


Fig. 2 of Earthlab report

Major Questions in Geomicrobiology

How does the interplay between biology and geology shape the subsurface?

Role of microbes in HTMCB

e.g. dissolution/secretions which may modify slipage or permeability

What fuels the deep biosphere?

Energy sources ("geogas": H2, CH4, etc.) ≠ photosynthesis?

How to sustain a livelihood in a hostile environment?

How deeply does life extend into the Earth?

What are the lower limit of the biosphere, imposed by temperature, pressure and energy restrictions?

=> What fraction does subsurface life represents in the biosphere?

Need for long term access as deep as possible

Current technology requires horizontal probes
(negative pressure to minimize contamination)

Long term *in situ* observation and access to the walls

Deeper bores with remote observation modules

Major Questions in Biology

What can we learn on evolution and genomics?

Isolated from the surface gene pool for very long periods of time.
Primitive life processes today?
How different?
How do they evolve? Phage?

The role of the underground in the life cycle

Did life on the earth's surface come from underground?
Has the subsurface acted as refuge?
What signs of subsurface life on Mars?

Is there dark life as we don't know it?

Unique biochemistry, e.g. non-nucleic acid based? Signatures?

Potential biotechnology and pharmaceutical applications!

A reservoir for unexpected and biotechnologically useful enzymes?

Same requirements as geomicrobiology
+ sequencing and DNA/protein synthetic facilities

Interim Report Infrastructure Requirements

Adaptive strategy: Not necessarily at the same site!

Depth

Very Deep: ≥6000 mwe

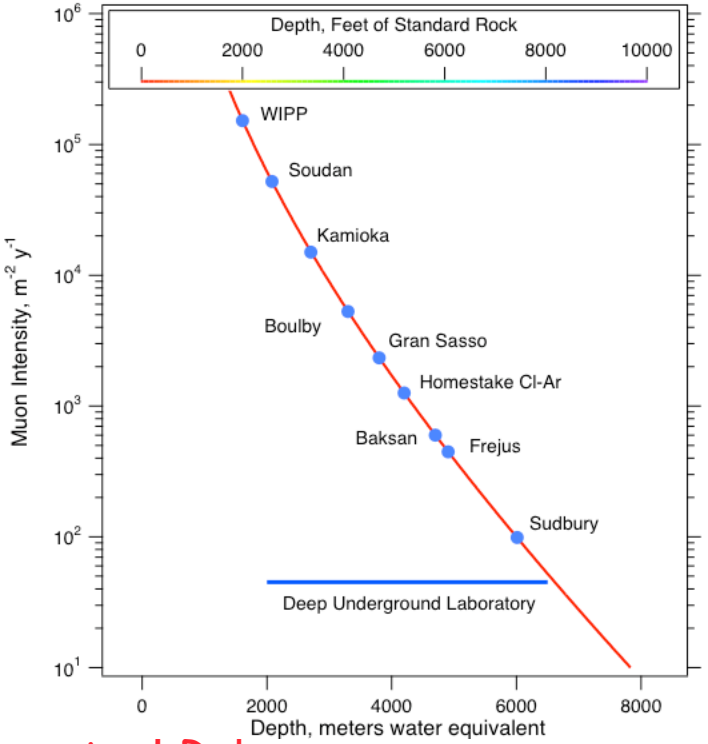
unique facility in the world for
- physics, astrophysics
- earth science
- biology

easy access, long-term

Very Large Caverns (1Mm^3)

Deeper is better
Limits by rock, economics
Hopefully >2700mwe (Kamiokande)

Intermediate depths automatic



Rock type

Physics: irrelevant if "competent rock", control Rn!
Earth Sciences: Any deep site will yield extremely important result
Eventually multiple rock types (at least internationally)

Pristine rock

Earth science/biology: not dewatered or destressed ≠ Physics
Absolutely pristine for ancient life/life not as we know it
No water contamination due to site exploration/construction or previous mining
Variety of physical scales, long time scales

Interim Report Infrastructure Requirements (2)

Distance from accelerators

Same Megaton detector for proton decay and neutrino long baseline
>1000km (1500-2500 km) for neutrinos super-beams @ 3 GeV
but new ideas in Europe (low energy beta beam @300MeV, 130km)

Access

Horizontal vs vertical: not a strong discriminator if large hoists
24/7/365 desirable but experiments can be automatized (but IMB experience)
Guaranteed long term access important: 20-30 years
Easy personnel access (including casual and E&O)
Proximity to universities and airport desirable

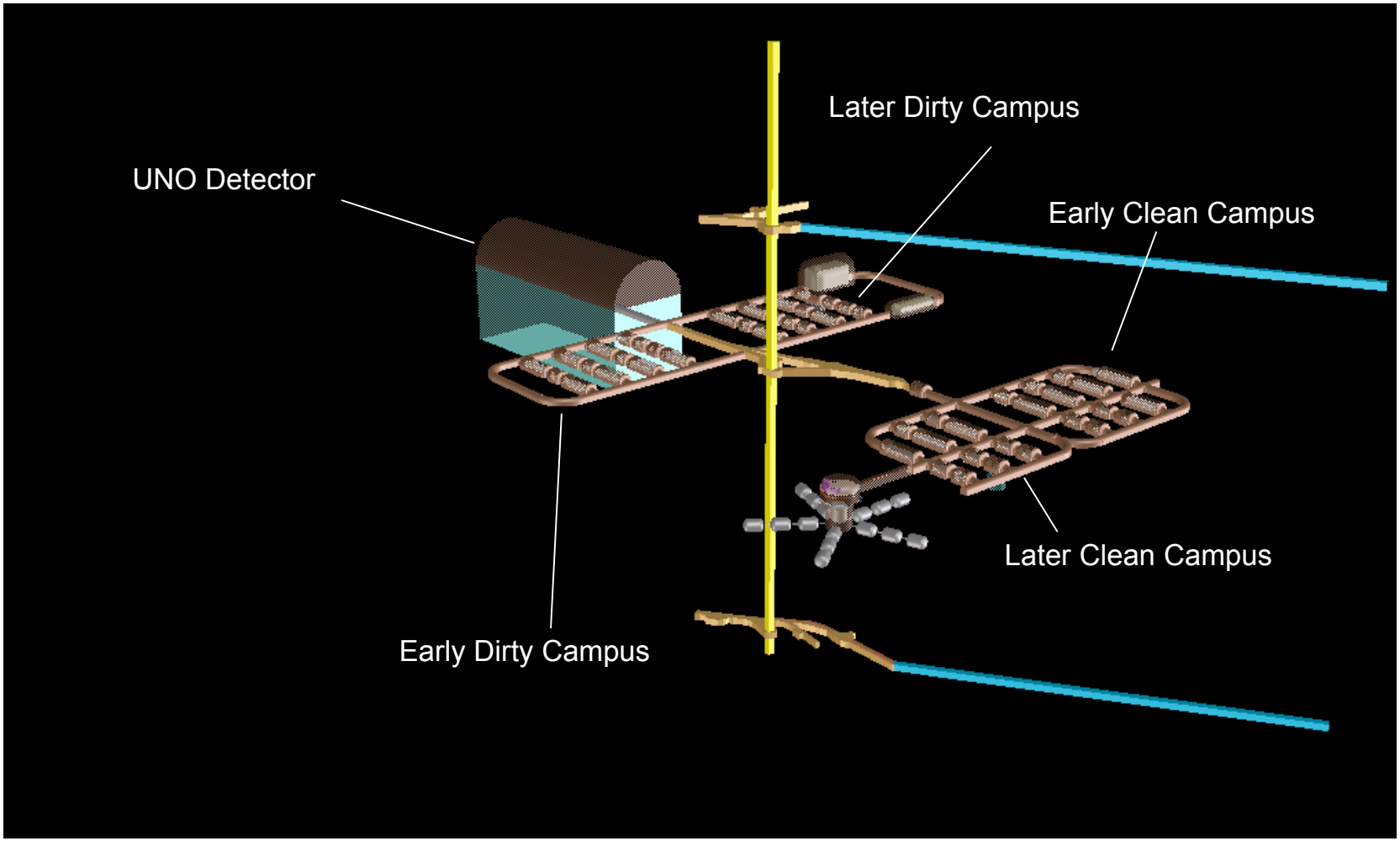
Safety and specific requirements

Proactive, meeting or exceed codes, MSHA,OSHA
But potentially dangerous experiments: large cryogenic (Ar,He,Ne), fault slippage
If strong scientific motivation, commitment from laboratory to work out adequate safety procedures

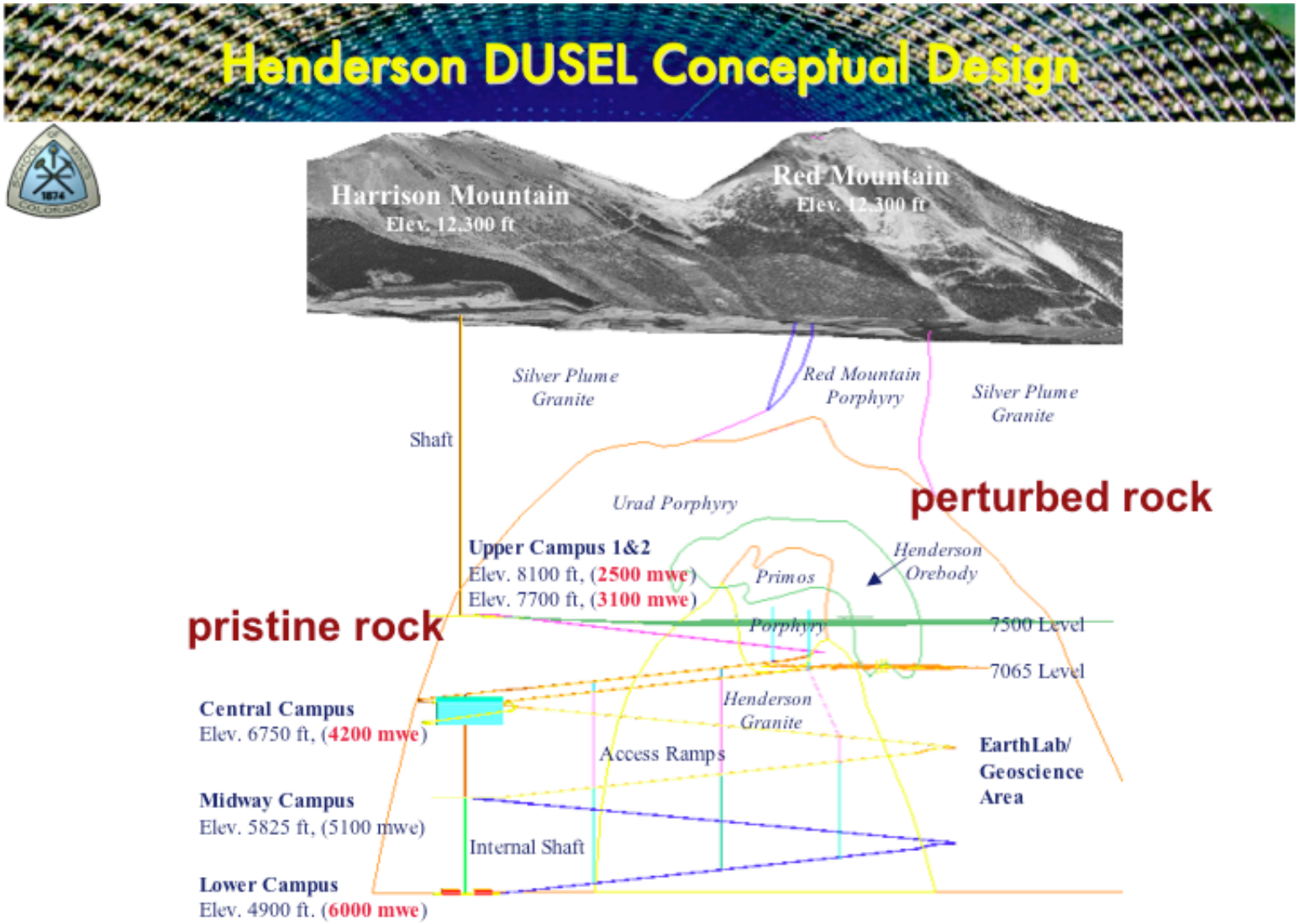
Management

Scientific direction
Common management if several sites: multiple campuses
Private ownership: can be financially beneficial, but also bring restrictions in particular long term guarantee, whole spectrum of science
Public ownership: restrictions from other activities

S2 decision:1) Homestake



S2 decision:2) Henderson



S2 Decision

Announced July 19- Study due in May 2006

Homestake

- Abandoned mine
  - Many drifts 8000ft
  - Some equipment useable, but somewhat old and flooded below 6000 feet
- State ownership (if Barik transfers title)
- Existing permits (e.g water) but may require new ones (NEPA)
- Diverse Geology, Biology will need to get out of flooded zone
- Possibility of science at 4850 feet as early as 2007 (no MRE investment yet)
- Somewhat remote, depressed economic area

Henderson

- Operating mine
- Requires significant excavation -> out of mining zone + 6000 m.w.e
- Vertical access+ramp,
  - Large modern hoist + large rock handling capability
- Private ownership: need to negotiate coexistence and eventual transfer
- Existing permits but may require new ones (NEPA)
- Possibility of geology and biology during construction
- 1h30 from Denver airport

Homestake :Early Implementation Plan

To preserve Homestake for DUSEL addresses water, title, access initially to 4850 and ultimately to 8000

Funded Initially by South Dakota

includes 4850 Lab access

5 years of **basic operations** of the site

Plans need to be tailored for the science programs

Plan was established and vetted last year to:

obtains title and access to the facility

deal with the water (upper water immediately ~ 2/3 of the 700 g/min), ensure lower water is stopped below 4850

refurbish lifts and shafts (Ross and Yates)

establish an interim facility at 4850 and above start science early!

establish a plan for growth into a national facility

Heated discussions in the community

Two important technical options not in S2 study

Horizontal access to study claimed advantages

- Efficiency of personal and material access,
- Flexibility
- Low operational costs

Green site, to study balance between initial investment cost and long term operational costs

=> Some serious considerations briefly untertained about a community based study without NSF support

Perceived flaws of the decision process

A closed process:

- Panel not officially known
- No face to face interactions to reassure proponents
- Superficial reports which do not allow to judge thoroughness

An uncorrected drift in the criteria of the committee

- Short term risks (permitting) and costs
- Prejudgment of the committee before study is made
- Perceived unwillingness from NSF to correct for this in its decision

Loss of an opportunity

To decisively move away from politics: unfortunately "conspiracy theories"

- Serious concern about "Pork Barrel" in House science committee

To increase confidence in NSF's capability to handle large projects

- A part of the community has walked away!

Saving the Dream

Science first: the Underground Frontier

- Excellent multidisciplinary scientific case! Unify behind the science
- Complementarity to other large projects (e.g. ILC) + unexpected discoveries
- Long term view: next 30 years -e.g. other sites in later phases e.g. sedimentary?

Minimize politics

- NSF: put in place an exemplary decision process for S3
  - Equal treatment of 2 sites to choose the best solution for the long term
  - Clear criteria, Serious technical analysis, Open discussions
  - Convincing for community and other stake-holding agencies
- Community: focus on future instead of past: make it work technically!
  - Not a single technical solution to a set of specifications
  - Stay united and positive

Define infrastructure requirements

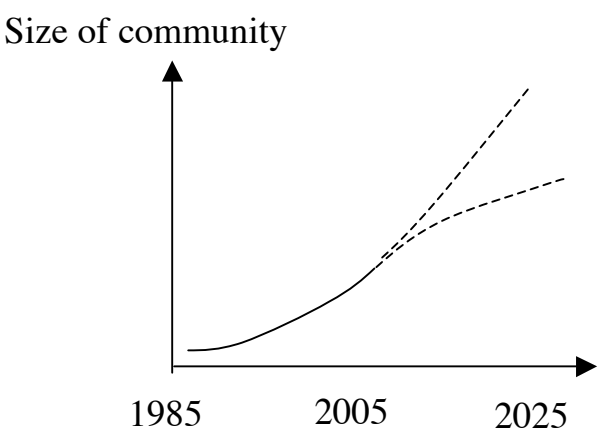
- What do we need for
  - A premier laboratory in the world
  - Ability to focus and support national underground science
  - Attractiveness for major international projects

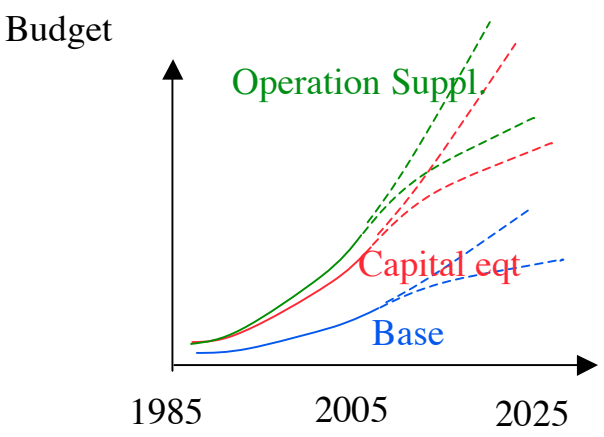
Show that a US DUSEL is not redundant (> SNOLAB)

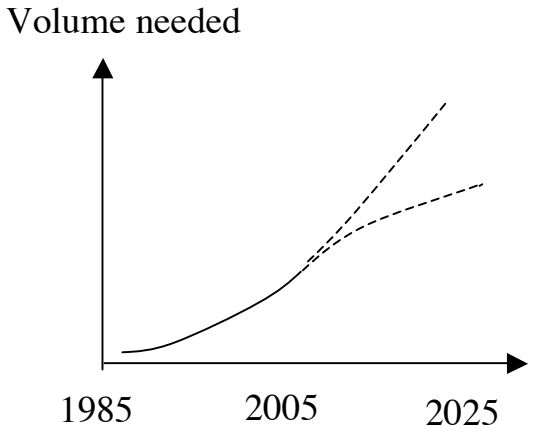
- Extrapolation of demand + duration of experiments => serious crunch ≈ 2012-2015
- Expansion capability, room for new ideas

Graphs we need! Qualitative Examples

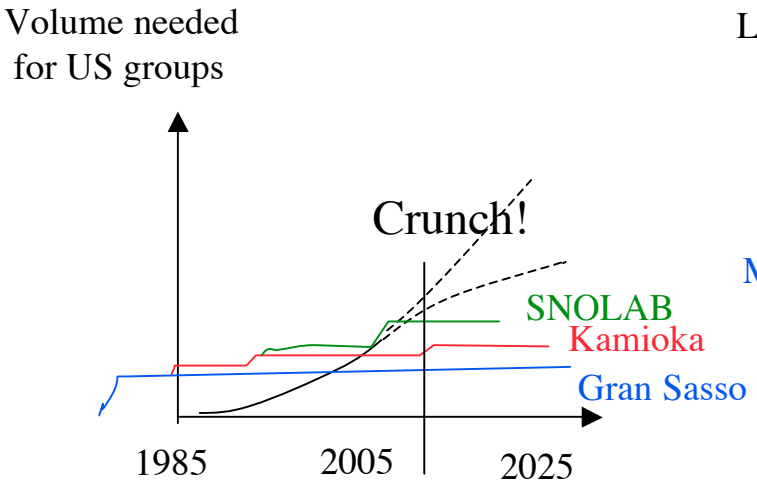
From each physics working group

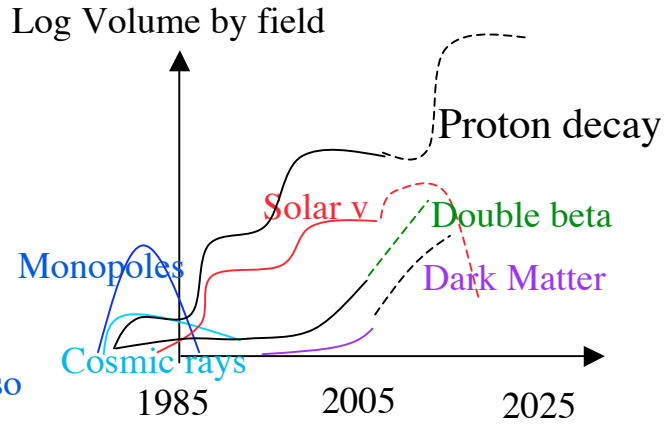






Physics overall





Conclusions

Compelling science

Even at time of budgetary problems, important to launch new and exciting projects: DUSEL is an excellent candidate!

Mobilize ourselves to make it a reality

Make it work pragmatically with a long term view

Help finish the reports of the working groups are you involved in

More precise definition of infrastructure requirements

Why we need DUSEL in addition to SNOLAB?