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DUSEL S1 study

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

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.

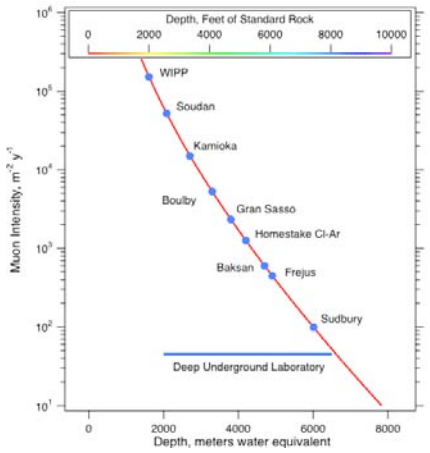
Deliverables (in coming weeks)

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

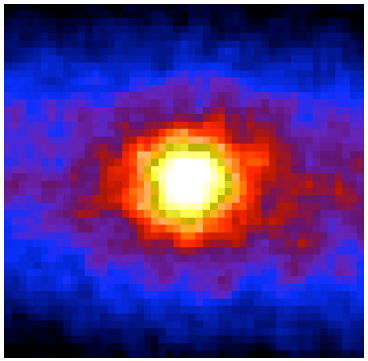
Web-based technical synthesis directed at scientific community Justifications and support the main report.

External review

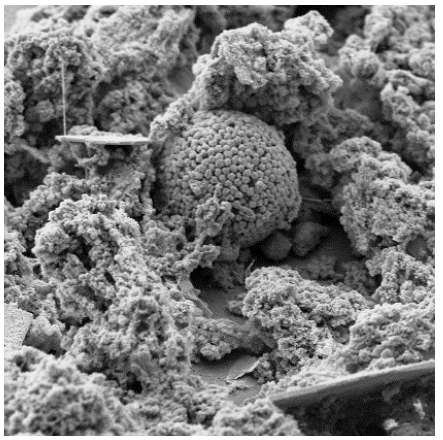
Why deep?



Neutrino picture of the Sun

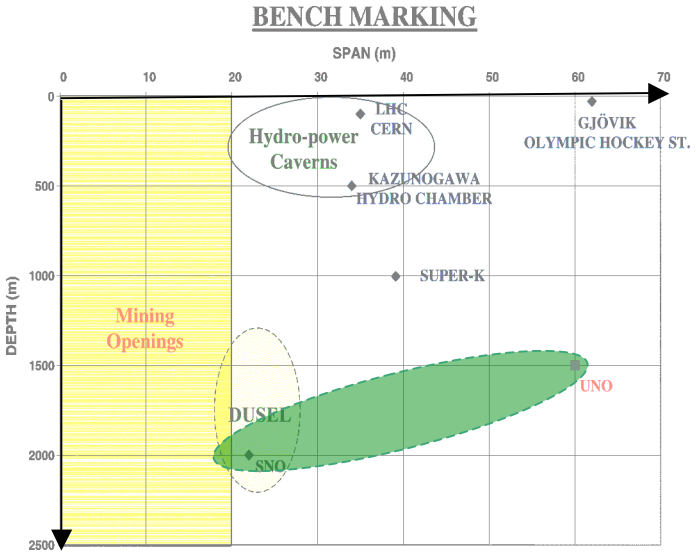


Geo-microbes



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 of 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

Other Motivations

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 technologies

Neutrino tomography of the earth?

In situ observation, 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

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

Neutron active shielding (300MeV) is difficult and risky
Rejection of cosmogenic activity is challenging

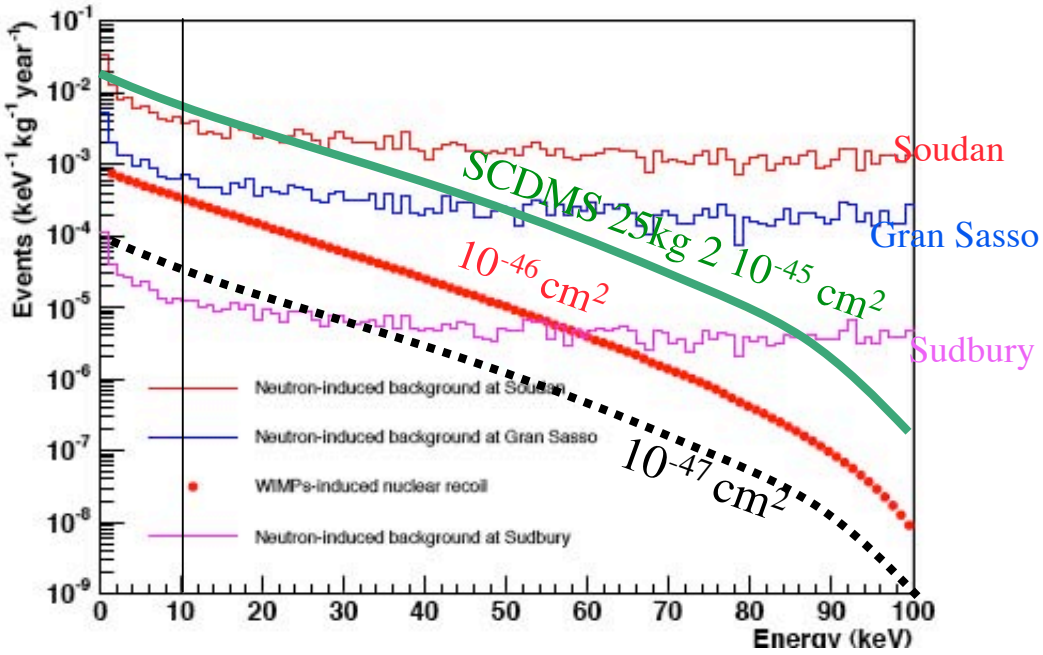
Biology

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

Earth science/ Engineering

Get closer to conditions of earthquakes
Scale/stress
Complementary to other facilities

Frontier WIMP searches need depth



Mei, Hime astro-ph0512125
$M_{WIMP}=100GeV/c^2$

Raw neutron rates

With passive shield/μ veto
Rejection of multiples

Shallow+ active neutron veto?

e.g. 90% efficiency at Soudan would be OK for SCDMS 25kg

But:

Risky : shielding notoriously difficult

No safety margin: rates known within factor 2?

Have to fight 2 backgrounds instead of 1

No path to future

Loss of sensitivity hurts

Discovery potential

Complementarity to LHC

Eventually γ background from n and μ activation

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).

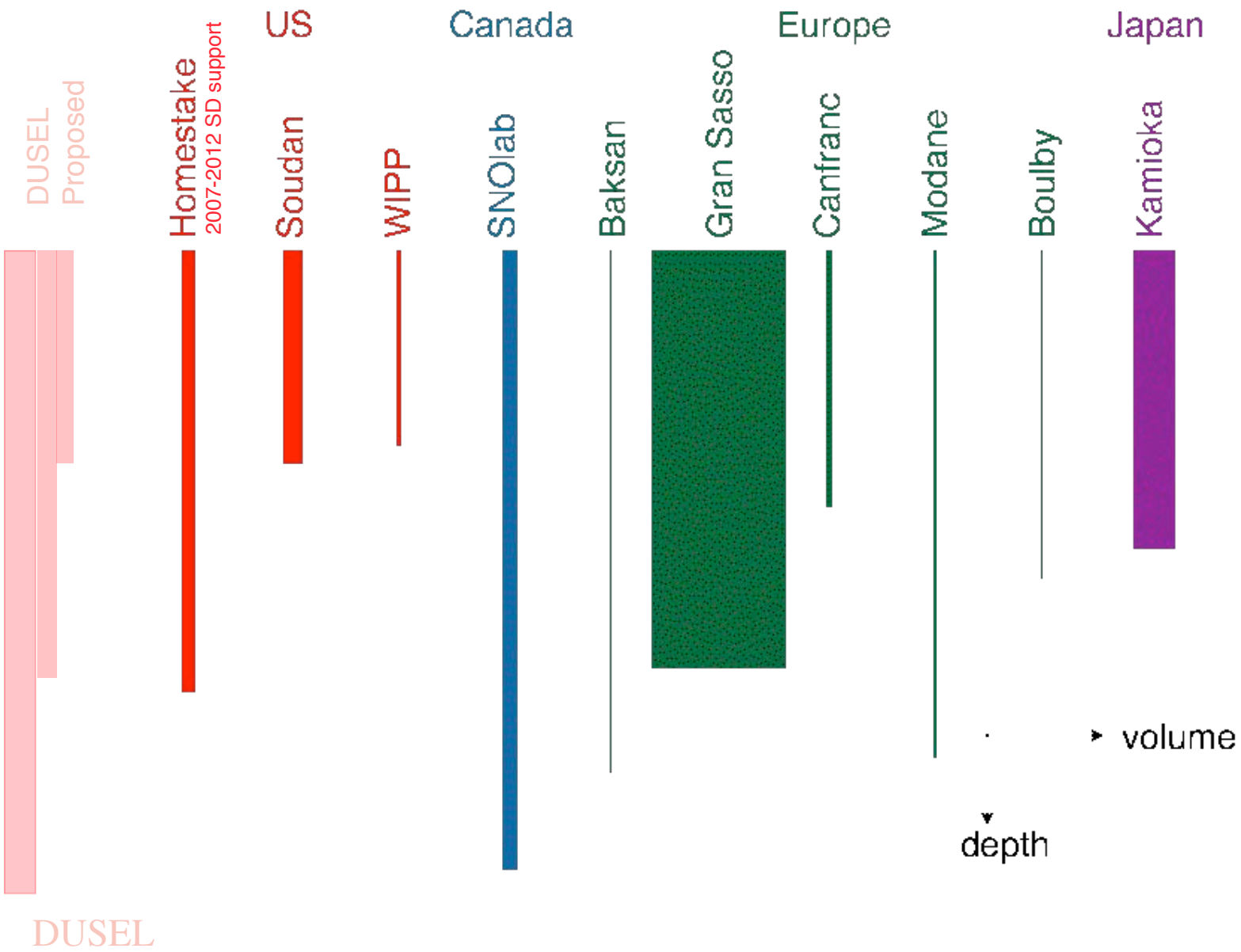
There is a significant opportunity for the U.S.

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



Oversubscription

Is this true?

Historically yes

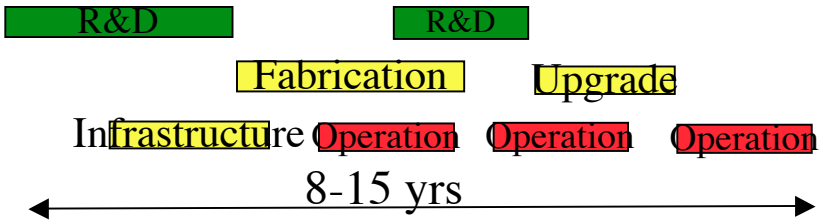
Only exception: currently Gran Sasso as ICARUS won't be expanded above 600 tons

Increase in the community

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

Life cycle of experiments

Getting longer



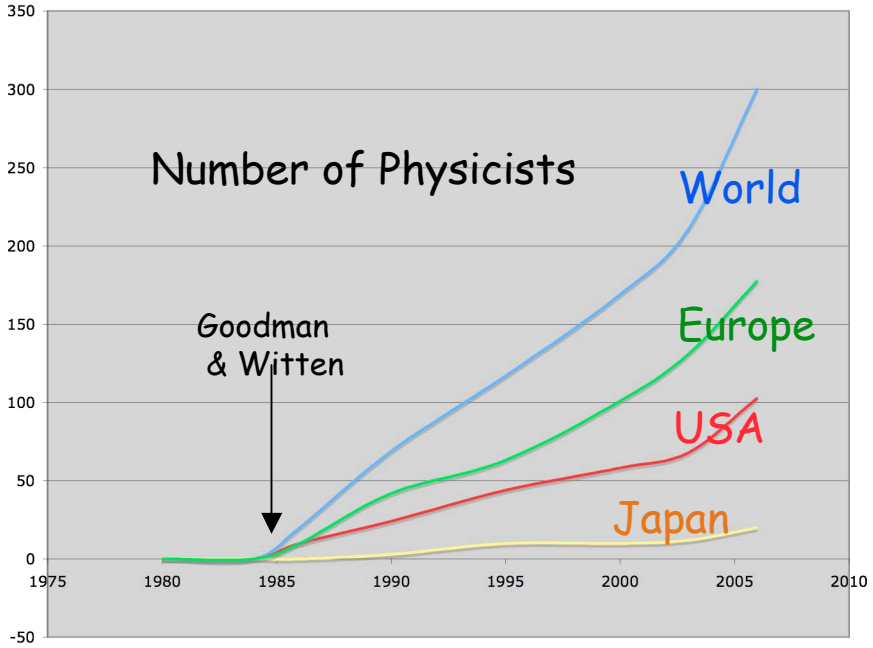
Overlap between running of previous generation and construction of next

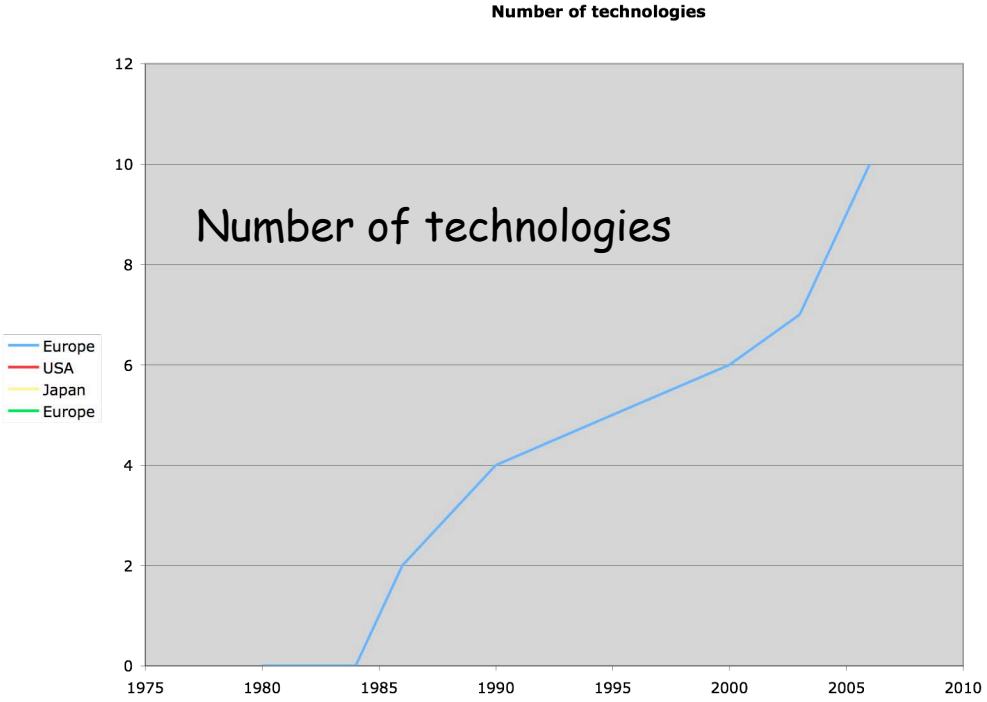
For important questions, need for several experiments

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

Growth Example of WIMP searches (preliminary)





SNOLab presumably SCDMS 25kg and Picasso -> > 2015
DUSEL next generation 150kg-1 ton (at least 1)
Need to start building infrastructure while SNOLab busy

Recommendations (Draft)

The U.S. should

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

2. **Initiate immediately the construction of DUSEL (≥2009)**
   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
   Access to pristine rock
   Evolutionary: Additional cavities (e.g. Proton Decay/ Neutrino long base line)
   Proactive SafetyCapability 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

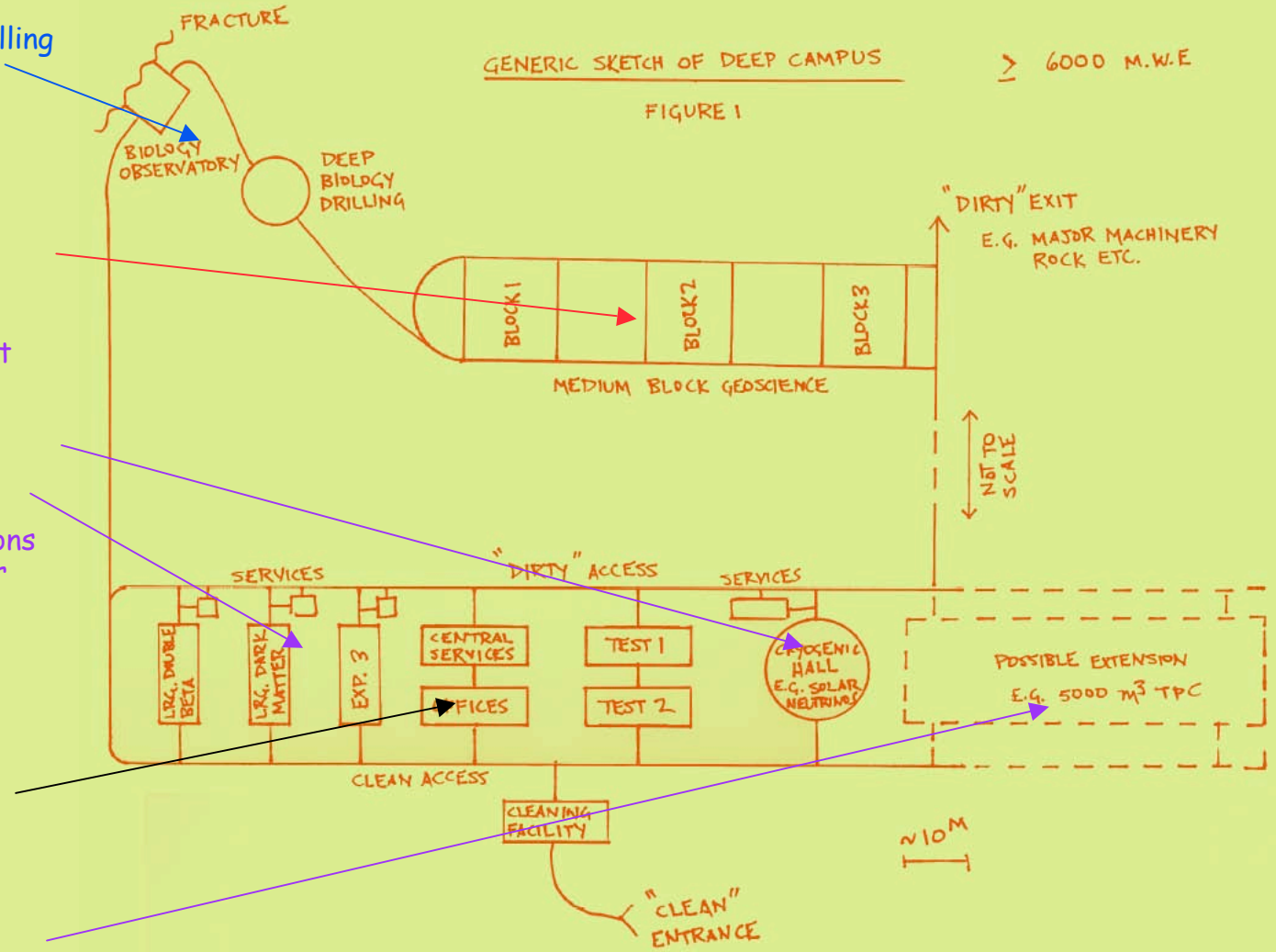
Biology observ.
Deep Biology Drilling

Geo/Eng
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

Geo/Eng
- 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

Cost issues

Can we afford DUSEL?

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

- National Institute: a question of priority to the field
- 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)
  Maintenance

was context of horizontal /vertical access debate

Impact on future projects:

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

But: different scale from ILC
enabling possible Proton Decay/Long Baseline neutrino detector

Comparison with Other Strategies

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

e.g. Soudan + SNOLab
Pioneer tunnel + SNOLab

2000 m.w.e. indeed suitable for a number of experiments
(automatic in any facility)

But attempting to perform frontier experiments with shielding
Risky (when given the choice teams choose depth)
Only temporary stop-gap
Potentially new ideas

A subsequent extension is not well adapted to MREFC structure
Another delay in implementing the dream of community

Conclusions

DUSEL well justified from a global multidisciplinary perspective

- Alignment with many of NSF interests

DUSEL will benefit the Physics Community

- Widens the underground frontier
  - Some of the most important experiments now
  - New unexpected ideas
- Multidisciplinary intellectual atmosphere, e.g. neutrino tomography?
- National Institute for Underground Science and Engineering:
  - Technical support
  - Long term R&D (instrumentation, low background)
  - Focus and coordination
  - E&O
- MREFC costs are initially not borne by community
  - But beware of large operating costs

Time scale is long: start now!