Kimballton: An ideal site for DUSEL

A national resource for research in physics, life sciences, chemistry, geosciences and engineering.

Robert J. Bodnar
R. Bruce Vogelaar
for the 150+ members of the Kimballton Team

http://www.kimballton.org
DUSEL Candidate Sites

- Icicle Creek
- Soudan
- Homestake
- Sudbury
- Henderson
- San Jacinto
- Kimballton
- WIPP
The Kimballton site is located less than 30 minutes from Virginia Tech

- largest research university in Virginia
- 28,000 students
- technical infrastructure and academic environment in the immediate vicinity of laboratory is unique
- Blacksburg named one of “Ten Dream Towns-The Perfect Places to Live Big, Play Hard and Work (if you Must)”
Butt Mountain

Massive Middle Ordovician Limestone (host rock for DUSEL) at Pembroke on the New River (a few miles from portal)
Butt Mountain Synclinorium
NSF Vision: “Before you tell me what you want to build, tell me the questions you want to answer” (Mike Turner)

- What is ‘Dark Matter’?
- Why Does the Universe Have More ‘Matter’ than ‘Anti-Matter’?
- Are Neutrinos Their Own Anti-Particles?
- Is the Sun Getting Hotter? is There a Nuclear Reactor Within the Earth?
- What is the Survivability of Life in Extreme Environments
- Can We Realize a ‘Transparent’ Earth?
- How do Mineral and Hydrocarbon Deposits Form?
- What are the Scaling Laws for Rock Masses?
- Can We Accurately Predict Rock Failure?
- How Can We Better Manage Our Water Resources?
- What is the Role of Mineral-Microbe Interactions in Geochemistry?
- Can We Enhance the Sustainability of Earth’s Resources for Future Generations?
- etc…

… the science defines DUSEL!
S1 Physics Goals ..... 

- fundamental nature of neutrinos
- neutrino luminosity of the sun
- dark matter
- neutrino mass/mixing matrix
- CP violation in the neutrino sector
- proton decay
- stellar explosions
- relic supernova neutrinos
- interior structure of the Earth using geoneutrinos
- nucleosynthesis
- low-background counting
Require the Following …

• Low Background Counting
  – using HPGe, scintillation, proportional counter detectors
  – relatively small
  – requires depths of 1000 or more mwe

• Solar neutrino detectors
  – using a variety of conventional and cryogenic technologies
  – are of medium size (100-1000 tons)
  – require depths of 2000-4500 mwe

• Double beta decay and dark matter detectors
  – use a variety of detection technologies (particularly those based on cryogenics)
  – relatively small (<1 ton)
  – needs a deep site (>6000 mwe)

• Other topics above
  – based on water Cerenkov, liquid scintillation or liquid argon technologies
  – very large (100 kilotons -1 megaton)
  – can operate at moderate depths (~4000 mwe)
  – high cost → designs that permit multi-science functions: detection of high energy neutrinos from terrestrial accelerators, proton decay searches, geophysics, supernova astrophysics and cosmology, etc.

Requires shallow, intermediate and deep halls;
Kimballton (and others) can provide these…
... and a *large* multi-purpose detector?

Currently being considered:

- UNO – Water Cerenkov Detector (MT)
  (Competition from Hyper-K in Japan)
- LANND – Liquid Argon Detector (100 kT)
- Hyper Scintillation Detector (HSD)
  - Liquid Scintillation Detector (100 kT)
The science portfolio of HSD includes:

• Geophysical structure and evolution of the Earth studied via global observation of anti-neutrinos from the earth’s interior
• Supernova astrophysics and cosmology (observation of live supernovae; detection of the supernova relic background)
• Elementary particles: (search for the decay of the proton; long baseline experiments using high energy neutrinos from BNL or Fermilab)

The basic advantages are:

• sensitivity to events of both low and high energy, ranging 4 orders of magnitude from ~100 keV to ~1 GeV;
• sensitivity to heavy particles that are invisible in Cerenkov detectors (giving 10x the sensitivity to Cerenkov detectors for certain proton decay modes)
• sensitivity to antineutrinos that can be specifically tagged by capture on protons (of importance to all the above topics, i.e. by reducing background).

Baseline issues:

• at 770 km from Brookhaven or Fermilab, Kimballton subtends a larger solid-angle than other sites
• first appearance peak is at 1.9 GeV- good match with upgraded AGS accelerator at BNL
• reduced uncertainty due to matter effects if less then 1000 km, since beam stays in Earth’s crust.

Kimballton can accommodate a large detector
Geo-, Bio- and Engineering Connections

The EarthLab report summarized science that could benefit from an underground lab.

focused on crystalline rocks (Homestake)

identified important multi-disciplinary research

Kimballton can accommodate all science in EarthLab
S1 requirements...

- varied geology
- access at variable depths
- large, pristine blocks (proximal and distal)
- large, perturbed blocks (distal)
- remote very large block access
- run of mine access
- deep and ultradeep observatory

Kimballton (and others) can provide all of these...
But, being in sedimentary rock, Kimballton has a much broader reach. Here’s why …

- Sedimentary rocks, such as those at Kimballton, cover about 3/4 of the Earth's land surface.
- About 90% of the earth’s groundwater is currently being produced from sedimentary rocks.
- Nearly all (99+%) of the world’s hydrocarbon resources are hosted in sedimentary rocks (with about half in carbonate rocks similar to Kimballton).
- About 85% of underground mines are in sedimentary rocks (MSHA, 2002).
- Sedimentary rocks and deep aquifers in sedimentary basins constitute important reservoirs for carbon storage to address global warming issues.
Importance of research facilities in sedimentary rock was recognized by the National Research Council

“In situ facilities should be developed in a variety of rock types with different styles of fracturing. A number of excellent facilities already exist in crystalline rocks, but there is a dearth of in situ research facilities in bedded rocks, especially where more than one fluid phase is present. Consequently, less is known about how to effectively characterize flow and transport in bedded rocks. Research at facilities in bedded rocks would have a significant impact on understanding enhanced oil and gas recovery processes in fractured reservoirs.”

(NRC, 1996)
Example 1: Multidisciplinary Research Opportunities

Coupled Processes Related to Petroleum Reservoir Formation and Characterization

- Geology
- Geophysics
- Rock Mechanics
- Drilling Technology
- Geochemistry
- Hydrology
- Microbiology
- Etc.
Example 2: Carbon Management and Climate Change

The Kimballton plant fires 0.75MT of limestone, providing a major point source of CO$_2$ for carbon management research.

Sinks at Kimballton include: Deep aquifers, Deep gas deposits, Uneconomic coal beds, Deciduous forests.
Example 3: Water Resources

Kimballton provides access to varied lithologies at varying depths to study fluid flow at various spatial and temporal scales.
Example 4: microbial activity at depth

Kimballton provides access from the base of the rhizosphere to the hydrothermal zone to study the survivability and variability of life in extreme environments, and provides access to the same geologic units at several depths.
DUSEL at Kimballton provides opportunities to collaborate with the SECUREEarth initiative

- Drastic increase in oil and gas recovery
- Safe and economic CO$_2$ sequestration
- Safe and defensible disposal of nuclear waste disposal
- Sound basis for management and protection of water resources
- Efficient and reliable environmental cleanup
- Reliable and defensible predictions of Climate Change
- Drastically improved use of renewable energy
- Sound fundamental basis for transition to hydrogen economy

from: http://esd.lbl.gov/SECUREEarth/

Kimballton provides unparalleled synergy between many NSF divisions, DOE programs, and Industry
Constructability

Any DUSEL site is only viable if one has permission to build and use it, can build it for a reasonable cost, and in a timely fashion and with manageable risk, and also provide a safe work environment.
Local Geology

The folded nature of the geology provides surface outcrops of formations that occur at depth, providing confidence that we can predict which rocks units will be encountered at depth.
Large caverns already exist in limestone, and at the Kimballton site at 2300 ft.

Gran Sasso (4700 ft depth)
Kimballton Limestone Mine

Over 50 miles of drive-in drifts down to 2300 ft and access to extensive coring provides in-situ information.
Seismic imaging and lineament studies support the geologic model.
Fracture data collection – Kimballton mine
Rock Strength
Kimballton rocks are as strong as those at other sites!
(Contrary to the assumption that all sedimentary rocks are weak)
Estimated Q-values and depth to squeezing for rock units at Kimballton

<table>
<thead>
<tr>
<th>Rock Unit</th>
<th>Most likely Q-value</th>
<th>SRF</th>
<th>Q</th>
<th>Critical depth for squeezing (km)</th>
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<tr>
<td>Middle Ordovician Limestone</td>
<td>32</td>
<td>0.5 to 1.0</td>
<td>32 to 64</td>
<td>3.7 to 7.5</td>
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<td>Copper Ridge Knox</td>
<td>21</td>
<td>0.6 to 0.8</td>
<td>21 to 26</td>
<td>2.4 to 3.0</td>
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<td>Martinsburg Formation</td>
<td>18</td>
<td>0.8 to 1.4</td>
<td>12 to 23</td>
<td>1.4 to 2.7</td>
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</table>

The rock falls into the ‘good’ range for tunneling.
Conceptual Design

• work in progress...

• goals:
  – shallow (early)
  – central (mid-term)
  – deep (completion)
  – manifestly expandable

two of several options being considered
Conceptual Design of DUSEL at Kimballton

Portal at Kimballton Mine

Mid-level Campus

Deep Campus

≈ 4 miles
Conceptual Design of DUSEL at Kimballton: Mid-level Campus
Conceptual Design of DUSEL at Kimballton: Deep Campus
Public Support/Opposition

An important consideration in determining the “constructability” of DUSEL is related to support or opposition by local governmental and community awareness groups. The Kimballton DUSEL initiative enjoys strong support from the local communities.

Something we don’t expect at Kimballton
Another important consideration is short and long-term environmental health effects. The Kimballton site involves mining environmentally benign limestone, and the rocks and water contain no known hazardous components.

DUSEL @ Kimballton will not have the problem seen here associated with a mine in Idaho.
Research Environment
visiting DUSEL should be a pleasant and rewarding experience

- Within 1 day’s drive of 50% of the U.S. population
- Less than 30 minute drive to top-50 research institution
- Within 45 minutes of airport serviced by four national carriers
- Moderate climate, without harsh winters or blistering summers
- Single-purpose DUSEL site
- Excellent E&O opportunities and existing programs

Virginia Tech Campus
(28,000 students)
Pleasant climate in winter AND summer

Average Monthly High/Low (30-80 degree in green)
Kimballton Science Team

over 150 researchers from 28 organizations, including
63 active senior researchers listed on the S2 proposal

CNA Consulting
Draper Aden & Associates
Duke University
Georgia Tech
Iowa State University
Michigan Technological University
Naval Research Laboratory
National Inst. Standards & Tech.
New Mexico Tech
MIT
North Carolina State University
Oak Ridge National Laboratory
Penn State University
Princeton University
Purdue University
Radford University
Schnabel Engineering
Technical Univ. Munich
University of Alaska
University of Alberta
University of Hawaii
University of Missouri-Rolla
University of North Carolina
University of Minnesota
University of Oklahoma
University of Tennessee
Virginia Commonwealth Univ.
Virginia Tech

new members are welcome
Support

VT administration (provided initial $1.6M)
Governor Mark Warner included a $150M bonding authority in his budget, contingent upon DUSEL being located at Kimballton
Virginia Senators Warner and Allen support DUSEL
Virginia Congressional Representatives support DUSEL
U.S. Forest Service supports DUSEL at Kimballton
Giles County Board of Supervisors supports DUSEL
New River Valley Planning District supports DUSEL
Blacksburg Partnership supports DUSEL
Giles County Rural Development Group supports DUSEL
<table>
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Kimbllton S2 Process Timeline