Deep Underground Science and Engineering Laboratory (DUSEL) Project Overview

Kevin T. Lesko
Principal Investigator

National Academies Keck Center
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Presentation Outline

• DUSEL’s Science Goals and Partnerships to Achieve these Goals
• DUSEL Project
  – Facility
  – Experiments
• Facility Design, Project Timelines, Estimates, and Partnerships
• Summary
Developing DUSEL Catalyzes Transformational Science

DUSEL will promote critical science, exploit synergisms, maximize the benefits of a dedicated facility with its best-in-class EH&S program, and integrate Education and Outreach functions within a world-class facility

- Neutrinos - discover new physics, known-unknown physics
- Dark Matter - identify ~25% of the known-unknown universe
- Dark Life - limits of life, life in extremes, life in isolation, new life
- Origin of the Elements - how, where did the elements originate
- Symmetries and High Energy Scale Physics - matter/antimatter asymmetry, the universe at extreme energies and physics of the early universe -- the Intensity Frontier
- Natural Resources - understanding, probing & predicting
- Engineering - safer, deeper, larger & faster
- Energy and Carbon Research - imperative societal questions
- Education and Outreach - welcome, attract, excite & engage
DUSEL’s Scientific Goals have been Extensively Reviewed and Documented

- Bahcall Committee Report 2001
- Nuclear Physics Long Range Plan 2002
- Connecting Quarks to the Cosmos
- HEPAP Long Range Plan 2003
- Neutrinos and Beyond
- EarthLab
- Physics of the Universe
- The Neutrino Matrix
- Discovering the Quantum Universe
- Deep Science
- Nuclear Physics Long Range Plan 2007
- 2008 P5 Report (also 2010 update of P5)
- 2009 PASAG
- 2010 NRC Study now underway
DUSEL Founded on a Suite of Critical, Multidisciplinary Experiments

Founded on Four Experimental Physics Pillars and

Three Research Tenets:

1. Dark Matter Searches
2. Long Baseline Neutrinos from FNAL
3. Proton Decay
4. Neutrinoless Double Beta Decay

- Diverse multidisciplinary research efforts in Biology, Geology, and Engineering
- Additional well-motivated experiments
- Integral Education and Outreach
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- Additional well-motivated experiments
- Integral Education and Outreach

DUSEL’s Suite of Experiments is congruent with all scientific and agency guidance
DUSEL Facility Designed to Host this Suite of Critical Experiments

- Physics
  - Long Baseline Neutrino and Proton Decay
    - Water Cherenkov and/or Liquid Argon Detectors totaling 200kT WCE
  - Dark Matter
    - at least one Generation-3 experiment
    - R&D, Generation-1 and -2 as consistent with Sanford Lab scope
  - Neutrinoless Double Beta Decay
    - a ~ tonne-class experiment
    - Generation 2 (~100-kg) effort as consistent with Sanford Lab scope
- Nuclear Astrophysics Facility
- Advanced Low Background Counting & Assay

- Biology - Geology - Engineering
  - Fixed Ecohydrology sites and distributed efforts
  - Fixed Coupled Processes site
  - Fixed CO$_2$ Sequestration (vertical) site
  - Fixed Geophysics and Geology sites and distributed efforts
  - Initial efforts as consistent with Sanford Lab scope (~16 efforts)

- Education and Outreach Facility
  - Initial efforts as consistent with Sanford Lab scope
### DUSEL’s Experiments is Well-aligned with Critical Science Questions

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<td>Proton Decay</td>
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<td>Engineering &amp; Energy</td>
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NRC DUSEL Study
Development of the Critical Suite of Experiments is Progressing Well

- Experiment Collaborations are conducting substantive R&D and design tasks: funded by NSF and DOE
- Sanford Lab and South Dakota investment plays a critical role in hosting pre-DUSEL experiments and continuing into DUSEL construction period
- The DUSEL facility is designed to house world-leading experimental programs
- Choices between competing technologies, selection of final collaborations and definitions of the participation levels to be established in the future as the collaborations advance their designs
- The support for DUSEL’s experiments is shared between the DOE and NSF
Kirk Canyon Adit

186 surface acres
7700 subsurface acres

Open Cut

Waste Water Treatment Facility

Yates Complex

Ross Complex

Town of Lead

Kirk Canyon Adit

1 km
Cross Section of the Homestake Site
Cross Section of the Homestake Site

Yates

Ross

Oro

Hondo

4850L

7400L

800L

#6 Winze
South Dakota and Sanford Lab Participation Critical in Preparing for DUSEL

• Major Financial Support from the State of South Dakota
  – $50M from State (HUD grant and General Fund)
  – $70M from Philanthropic Donation (T. Denny Sanford)
  – Owns the Property

• Partnership to “achieve DUSEL”

• DUSEL assimilates Sanford Lab at MREFC Construction

• Facility work well-advanced (site preparation & risk reduction)
  – Rehabilitation of Surface and Underground Infrastructure
    • Lifts & Shafts
    • Pumps & Water Treatment
    • Facility Stabilization and Rehabilitation
    • Initial Operations, Environment, and Safety Program
  – Options to acquire additional property to expand access to the site
    (including Rock Disposal sites)
South Dakota’s Investments are Critical for DUSEL

• Trained and talented workforce
• Key infrastructure
  – shafts - deferred maintenance
  – safety improvements
  – water pumping and treatment
• Surface and Underground Space & Science during DUSEL construction
  – Surface Assembly Lab
  – Majorana Temporary Space
  – Davis Campus
  – Transition Space
• Education and Outreach
  – Davis Bahcall Scholarships
  – Neutrino Day
  – Significant Cultural Outreach (GEAR UP)
  – Workshops and Field trips
  – Public Lectures
### Initial Science: BGE and Characterization

#### Research Groups and Locations

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<thead>
<tr>
<th>Location</th>
<th>Groups</th>
<th>Instruments/Equipment</th>
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<tbody>
<tr>
<td><strong>Surface</strong></td>
<td>USD/BHSU</td>
<td>Gamma, Rn, Muon</td>
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<td>Regis</td>
<td>Climate station</td>
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<td>SDSMT</td>
<td>Signal propagation, Mag field, Ross/Yates</td>
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<td>USGS</td>
<td>Microgravity</td>
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<td><strong>300L</strong></td>
<td>DUGL</td>
<td>Low-frequency seismometer</td>
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<td>USD/BHSU</td>
<td>Rn</td>
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<td></td>
<td>SDSMT</td>
<td>Signal propagation</td>
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<td></td>
<td>BHSU</td>
<td>Biology baseline samples</td>
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<td><strong>800L</strong></td>
<td>DUGL</td>
<td>Low-frequency seismometer</td>
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<td>USD/BHSU</td>
<td>Gamma, Rn, Muon/neutron</td>
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<td></td>
<td>Regis</td>
<td>CO₂ sequestration</td>
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<td></td>
<td>LBNL</td>
<td>MAJORANA – Pb, Cu storage</td>
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<tr>
<td></td>
<td>PODS</td>
<td>Geology (pet, ore dep, struct)</td>
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<td><strong>1250L</strong></td>
<td>SDSMT</td>
<td>Climate station</td>
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<tr>
<td></td>
<td>USD/BHSU</td>
<td>Rn</td>
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<tr>
<td><strong>1700L</strong></td>
<td>SDSU</td>
<td>Bio samples</td>
</tr>
<tr>
<td><strong>2000L</strong></td>
<td>SDSMT/FNAL/UW</td>
<td>Water-level tiltmeters (x3), climate</td>
</tr>
<tr>
<td><strong>2000L</strong> (cont)</td>
<td>DUGL</td>
<td>Low-freq seismometer (x3)</td>
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<tr>
<td></td>
<td>USD/Regis</td>
<td>Gamma, Rn and muon/neutron</td>
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<tr>
<td></td>
<td>BHSU</td>
<td>Seeps, fungus samples (x2)</td>
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<tr>
<td></td>
<td>LBNL</td>
<td>CO₂ sequestration</td>
</tr>
<tr>
<td><strong>2600L</strong></td>
<td>SDSMT</td>
<td>Climate station (x2)</td>
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<tr>
<td><strong>3350L</strong></td>
<td>Utah</td>
<td>Extensometers</td>
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<tr>
<td><strong>4100L</strong></td>
<td>DUGL</td>
<td>Low-freq seismometer (x3)</td>
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<tr>
<td></td>
<td>UW/MT</td>
<td>Optical extensometers</td>
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<td></td>
<td>SDSMT/UCB</td>
<td>Seismometers/tilt</td>
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<td>BHSU, Many</td>
<td>Biology sampling</td>
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<td><strong>4550L</strong></td>
<td>USD</td>
<td>Gamma, Rn</td>
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<td></td>
<td>Many</td>
<td>Bio samples pump water</td>
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<td><strong>4850L</strong></td>
<td>SDSMT</td>
<td>Hydrometry probes</td>
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<td></td>
<td>LBNL</td>
<td>CO₂ sequestration (removed)</td>
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<td></td>
<td>BHSU, Many</td>
<td>Biology samples</td>
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<td></td>
<td>USD/BHSU</td>
<td>Rn</td>
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<td>Many</td>
<td>Core holes (hydrology, bio)</td>
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</table>
**MAJORANA DEMONSTRATOR**

**Project:**

→ Investigate neutrinoless double beta decay using 40 kg Ge (some natural, some enriched $^{76}$Ge)
→ Demonstrating technology for 1-tonne detector (requires < 1 bkgd count per year near signal region!)
→ Electroform copper for shielding and detector components
→ ~ $20M DOE Effort

**Collaboration:**

→ ~93 researchers (including students)
→ 18 institutions + Sanford Lab

**Milestones:**

→ Jun/Aug 09: Pb, Cu onsite
→ Dec 09: Temp lab work begins
→ Winter 10: Occupy TCR, e-form
→ Fall/Winter 11: Davis Campus
Large Underground Xenon (LUX-350)

- **Project:**
  - Direct search for dark matter using 350 kg of xenon
  - Occupy Surface Laboratory to exercise procedures, test installation and detector operation
  - Small water tank to allow operation (larger one underground)
  - NSF and DOE support

- **Collaboration:**
  - ~52 researchers (including students)
  - 14 institutions + Sanford Lab

- **Milestones:**
  - Sep 09: Grad students onsite
  - Dec 09: Surface Lab activity starts
  - Winter 10 ->: Surface detector ops
  - Fall/Winter 11: Davis Campus
Initial Science: Physics

Center for Ultra-low Background Expts at DUSEL

- **Project:**
  - South Dakota Governor’s Research Center ($3M funded 2009-2014)
  - Manufacture high-purity crystals (Ge; possibly NaI, CdWO₄)
  - Activities include crystal growth, zone refining and detector development
  - $3M from DOE EPSCoR (3 yrs)

- **Collaboration:**
  - ~54 researchers (incl students)
  - 7 institutions + advisors

- **Milestones:**
  - May 09, 10: Collab meeting at Lab
  - Jun 10: Xstal pullers, Ge at USD
  - Next 2 yrs: Surface labs
  - Summer 12: Underground lab
Stewardship Model: Sharing Responsibilities Between the Agencies

- **steward** verb: supervise arrangements, keep order, manage or look after (another person’s) property

- NSF & DOE are working closely together to steward DUSEL’s science

- Physics Efforts Coordinated through the Joint Oversight Group (JOG), Working Groups Established for:
  - Long Baseline Neutrinos and Proton Decay
  - Neutrinoless Double Beta Decay
  - Nuclear Astrophysics
  - Dark Matter Searches

- JOG will negotiate and mediate major decisions parsing scope, funding, timing between the agencies and projects

- Integration of LBNE with DUSEL efforts serves as an effective model for other major experiments
## Agencies’ Stewardship Model for DUSEL

<table>
<thead>
<tr>
<th>Program</th>
<th>Steward Agency</th>
<th>Collaborating Agency</th>
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<tbody>
<tr>
<td>DUSEL Facility</td>
<td>NSF</td>
<td>DOE</td>
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<td>Dark Matter</td>
<td>NSF</td>
<td>DOE-OHEP</td>
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<td>DOE-ONP</td>
<td>NSF</td>
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<td>Long Baseline Neutrinos &amp; Proton Decay</td>
<td>DOE-OHEP</td>
<td>NSF</td>
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<td>Nuclear Astrophysics</td>
<td>NSF</td>
<td>DOE-ONP</td>
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<tr>
<td>Advanced low background &amp; assay</td>
<td>NSF</td>
<td>DOE</td>
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<tr>
<td>Bio/Geo/Eng</td>
<td>NSF</td>
<td>DOE (-BES/BER)</td>
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Stewarding Design Efforts Resulting in Melding the LBNE Organization with DUSEL

- Fully shared access to A/E, studies, estimates and reports
- Participation in reviews, cost scrubbing, workshops
- Shared engineering staff
- LBNE relying on DUSEL for LC design for CD1 review
Plans for Research Campuses Optimized for Science and Engineering Goals

Bio/Geo/Eng Experiments at 300, 800, 1700, 2000, 4100, 4850, 6800, 7400

4850L Campus
Physics and Bio/Geo/Eng

7400L Campus
Physics and Bio/Geo/Eng

NRC DUSEL Study
### High Level Milestone Schedule for DUSEL’s Suite of Experiments

<table>
<thead>
<tr>
<th>Science Goal</th>
<th>Known Technologies/ Collaborations</th>
<th>Generic Suite Deploy</th>
<th>Technology Choice/ Experiment Downselect</th>
<th>Ready to Install (begin detector installation)</th>
<th>Location</th>
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<td><strong>Physics</strong></td>
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<td>2</td>
<td>1 G3 DOE-Led</td>
<td>G2 2010-2017 Tech choice/PAC 2015</td>
<td>2018</td>
<td>7400</td>
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<td>Long Baseline Neutrinos &amp; Proton Decay</td>
<td>2 (WC/LAr)</td>
<td>1 WC DOE-Led</td>
<td>CD2 2013 CD3 2015</td>
<td>2018 (CD process informed)</td>
<td>800/4850</td>
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<td>PAC Review 2012-13</td>
<td>LE 2016 HE 2017</td>
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<tr>
<td>Advanced Low Background &amp; Assay</td>
<td>1</td>
<td>1</td>
<td>some need by expts before construction</td>
<td>Potential Sanford Lab options/ LM 2017</td>
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<tr>
<td><strong>Bio/Geo/Eng</strong></td>
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<tr>
<td>Construction and Engineering</td>
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<td>1</td>
<td>Community Review 2013 PAC Review 2015</td>
<td>2016 with LMs</td>
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<td>Dedicated Laboratories</td>
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<td>3</td>
<td>Community Review 2013 PAC Review 2015</td>
<td>2016, 2017 access driven</td>
<td>0-1700, 4850, 7400</td>
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## Approximate Experiment Durations and Future Upgrades or Choices

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<th>2024</th>
<th>2034</th>
<th>2044</th>
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<td><strong>DUSEL</strong></td>
<td>Construction</td>
<td>DUSEL Construction</td>
<td><strong>LBNE</strong> Enhanced SuperBeams?</td>
<td>Neutrino Factory?</td>
<td>Neutrino Factory?</td>
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<td><strong>Supernova and Other Neutrinos</strong></td>
<td>G1 @ Sanford &amp; WIPP</td>
<td>G2 ~ 1 tonne Detector Mass?</td>
<td>Additional Nuclei Detector Mass?</td>
<td>Additional Nuclei Detector Mass?</td>
<td>Additional Nuclei Detector Mass?</td>
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<td><strong>Neutrinoless Double Beta</strong></td>
<td><strong>LUX</strong></td>
<td>G2 G3 W-N</td>
<td>WIMP Mass</td>
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<td>G2 G3 W-N</td>
<td>WIMP Mass</td>
<td>WIMP Mass</td>
<td>WIMP Mass</td>
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<td>Cross section measurements of critical reactions in stellar Hydrogen and Helium burning</td>
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<td><strong>Seismic + Geophysics</strong></td>
<td>On-going Seismic Monitoring and Array Enhancements</td>
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<td><strong>CO2</strong></td>
<td>Initial Site Work</td>
<td>Distributed &quot;LUCI&quot; Laboratory</td>
<td>Distributed &quot;LUCI&quot; Laboratory</td>
<td>Distributed &quot;LUCI&quot; Laboratory</td>
<td>Distributed &quot;LUCI&quot; Laboratory</td>
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<td><strong>Fracture Processes</strong></td>
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<td><strong>Coupled Processes</strong></td>
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Large and Active DUSEL User Community

- Multidisciplinary Science and Engineering Users Community
  - Physics
  - Biology
  - Geology
  - Engineering
  - E&O
  - 700 to 1000 participants

- DUSEL Experiment Development Committee →
  DUSEL Users Research Association and Executive Committee
  - Charter
  - Workshops
  - Regular Interactions with DUSEL

- International Interest continues to grow
  - Some experiments have explicit international agreements and partnerships
  - Large scale experiments awaiting “selection” to begin more formal discussion
Experimental Requirements Drawn from S-4 and Other Collaborations

**Physics - S4**
- EXO (DBD) - Gratta (Stanford)
- GE1T (DBD) - Wilkerson (UNC)
- MAX (DM) - Galbiati (Princeton)
- LZ20 (DM) - Shutt (Case Western)
- GEODM (DM) - Golwala (Caltech)
- COUPP (DM) - Collar (Chicago)
- LBNE (Long Baseline Nus, PDK) - Svoboda (UCD) & LBNE Project (FNAL)
- DIANA (Nuclear Astro) - Wiescher (Notre Dame)
- (F)AARM (Low Background Assay) - Cushman (Minn.)

**Bio/Geo/Eng - S4**
- Transparent Earth - Glaser (UCB)
- Fiber Optic Array - Wang (Wisconsin)
- Fault Rupture - Germanovich (Georgia Tech)
- THMC (coupled processes) - Sonnenthal (UC/LBNL)
- CO₂ (Sequestration) - Peters (Princeton)
- EcoHydro - Boutt (U. Mass)
- Monitoring - Bobet (Purdue)

**Physics**
- Long Baseline Nus (LAr) - Fleming (Yale)
- N-Nbar (vertical shaft) - Kamyshkov (U. Tenn)
- Atomic Interferometry (vertical shaft) - Kasevitch (Stanford)
- Gaseous TPCs (DM and DBD)
  - Nygren (LBNL)
  - Sciolla (MIT)
  - Loomba (UNM)
- CLEAN (DM + Solar nu) - Hime (LANL)
- LENS (Solar nu) - Raghavan (VT)

**Bio/Geo/Eng**
- Seismic Arrays - Pavlis (U. Indiana)

**DUSEL/Sanford Initial Science**
- Majorana Demonstrator (DBD) - Wilkerson (UNC) Elliott (LANL)
- LUX (DM) - Gaitskell (Brown) Shutt (Case Western)
- LUX + Zeplin-3 (DM) - Gaitskell, Shutt, ...
- SD 2010 - Center (u/g xtal production) - Mei (USD)
- Seismic Arrays - Roggenthen (SDSM&T) Glaser (UCB)
- Bio sampling - Anderson (BHSU)
- Hydrochemistry - Stetler (SDSMT)
- Characterization Efforts - Mei (USD) Grey (Regis) Smith (LBL)
- DUGL (Gravity Wave) - Mandic (U. Minnesota)
Engaged DUSEL Program Advisory Committee

DUSEL Program Advisory Committee
- Michael Witherell
- Allen Caldwell
- Boris Kayser
- Hitoshi Murayama
- Peter Parker
- Michael Ramsey-Musolf
- Heidi Schellman
- Abe Seiden
- Yoichiro Suzuki

Mark Zoback
- Don DePaolo
- Steve Hickman
- Art McGarr
- Patricia Sobecky

DUSEL Preliminary Design Baseline and Approach to the MREFC Proposal – Is the Project on an appropriate path to complete a comprehensive Preliminary Design and one likely to obtain National Science Board approval?

- **DUSEL Generic Suite** – Is the proposed Generic Suite of Experiments appropriate to the vision of a world-class facility? Are there experimental elements missing from the suite? Should experiments be reconsidered for inclusion in the generic suite?

- **Planning for the Scientific Program** – Are the proposed preliminary plans and timescale for review and definition of the DUSEL scientific program, including the evolution of the experimental activities at the Sanford Laboratory, appropriate?

Planning Joint DUSEL-FNAL PAC Meeting this summer
Program Advisory Committee Actively Interacting with DUSEL

• The envisioned program in physics and astrophysics will address fundamental questions about the Universe and its fundamental laws, such as the question of why the universe contains matter but no antimatter, the nature of dark matter, the origin of neutrino mass, and the genesis of the chemical elements.

• The biology program will study life in extreme conditions underground to shed light on the origin and evolution of life.

• The geosciences program will have opportunities to study directly at depth variety of the thermal, hydrological, mechanical, chemical, biological-mass, and energy-transport phenomena on a scale not done before.

• The engineering program will study rock properties in situ to enable better design and use of underground space.
Facility Design Refined to Foster this Suite of Critical Experiments

- World-Class Facility
  - Research Campuses
    - Surface (~27,000 m²/ 1,100 m² total/assembly)
    - 4850L (~25,000 m² /6,200 m² total/science)
    - 7400L (~7000 m² /1,300 m² total/science)
    - Other Levels and Ramps (~30 km: ~50/50 ops/sci)
  - Dual Access to Research Campuses
  - Best-practices Life Safety Systems and Programs
  - Experimental Support
  - Design Enabling Future Expansion
  - Project Enabling Participation by Other Agencies
  - Integrated Education and Outreach Efforts
Surface Campus

- Yates - Science Campus
  - Administration
  - Science support
    - assembly
    - shops
    - offices
  - Science Underground Access
  - Education and Outreach
- Ross - Maintenance and Operations Campus
  - Support underground operations
  - M&O Underground Access
Completed Critical Geotechnical Investigations

- 300 & 4850 Level Mapping - Completed
- Geological Model - Developed
- Coring and Logging - Completed
  - holes 1, 2, 3: Sanford Lab
  - holes 3, M, N: LC 1
  - holes B, C: LC 2, LC3
  - holes D, J: 4850 Lab Modules
  - 5,399 feet of core: logged, teleview
  - “enough geotech for preliminary design” - Large Cavity Advisory Board
- **In situ** testing - Completed
- Laboratory testing - Completed

**Good news: Little Water, Good to Very Good Rock Quality**
Design of Underground Infrastructure Advanced to Support the Science Goals

- Maintenance shops, utility rooms, storage and containment areas
- Drifts and ramps required for access, egress, and ventilation
- Cyber-infrastructure controls and monitoring systems
- Material handling systems
- Air quality and ventilation systems
- Waste (rock) handling systems
- Electrical power distribution systems
- Dewatering systems
- Water inflow management systems
- Chilled water systems
- Life safety systems and areas of refuge
- Plumbing systems
- Compressed air systems
Midlevel Lab - 4850L

- Experimental Support
  - 2000kW (standby 100kW)
  - 1100kW (standby 160kW)
  - Chilled, industrial, potable water
  - 20T, 40T bridge and monorail cranes
  - 10Gbps
  - 15 - 30k cfm per LM ventilation
  - 100k cfm emergency ventilation
  - Fire-life-safety

<table>
<thead>
<tr>
<th>Experiment Space</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Height (m)</th>
<th>Floor Area (m²)</th>
<th>Finished Volume (m³)</th>
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<tbody>
<tr>
<td>LM-1</td>
<td>50</td>
<td>20</td>
<td>24</td>
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<td>DTA</td>
<td>43</td>
<td>16</td>
<td>5</td>
<td>688</td>
<td>3440</td>
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</tbody>
</table>
Large Cavity Design

- Project stewarded by DOE
- Design initiated by DUSEL for LC1 including preliminary geotechnical site investigations
- Gained confidence in positioning, excavation design, excavation sequencing, ground support, and long-term stability
- Understand DUSEL and LBNE Scope
- Design and Engineering Teams well integrated
Deep Level Campus 7400L

- Deep Lab Module
- Deep Ecohydrology Lab
- Experimental support
  - 650kW + standby
  - Chilled, potable, industrial water
  - 20T, 40T bridge and monorail cranes
  - 10Gbps
  - 30k cfm ventilation
  - 100k cfm emergency ventilation
  - Fire-life-safety

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<th>Finished Volume (m³)</th>
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</thead>
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<td>LM-1 (DLL)</td>
<td>75</td>
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<td>15</td>
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<td>Drill Room</td>
<td>16</td>
<td>11</td>
<td>11</td>
<td>176</td>
<td>1,644</td>
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</tbody>
</table>

Experiment Space

- Length
- Width
- Height
- Floor Area
- Finished Volume
Other Levels and Ramps

- Refinement of the “levels of interest” defined in the CDR

- ~ 30 km of underground access available for science

- Levels chosen to maximize the access to the Homestake site areas of scientific interest

- Power, communications, ventilation, fire-life-safety
Facility Preliminary Design Developed to Host these Critical Experiments

- **Surface Campus**
- **0 to 1700L** (Vertical Experiments)
- **4850L**
  - 1 Large Cavity (+ Options totaling 200kT 4850L or 800L)
  - 2 Lab Modules + Davis hosting
  - ~4 - 5 Physics Experiments
  - Earth Science Experiments
- **7400L**
  - 1 Lab Module hosting
  - ~2 Physics Experiments
  - Earth Science Experiments
- **Other Levels & Ramps**
Facility Preliminary Design Developed to Host these Critical Experiments

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  - ~ 2 Physics Experiments
  - Earth Science Experiments
- **Other Levels & Ramps**
The DUSEL MREFC Project

• DUSEL will be a NSF Major Research Equipment and Facility Construction (MREFC) Project: including
  – Facility
  – Suite of Compelling Multidisciplinary Experiments

• UC Berkeley Providing Leadership for the Project
  – Reports to the Vice Chancellor for Research
  – Established the Berkeley Project Office
  – University Business Systems supporting Project
    • HR, Travel, Contracts, SPO, ...
  – UCB provides key leadership and managerial positions
The DUSEL MREFC Project

- South Dakota heavily invested in the DUSEL partnership
  - South Dakota Universities actively engaging in DUSEL’s science and E&O activities
  - South Dakota Universities have major roles in the DUSEL Construction Project
    - DUSEL’s South Dakota Project Office at SDSM&T
      - Established the Science and Technology Authority with significant state support and financing
      - Received title to the facility from Barrick and discussions with Barrick concerning other property and options for use
      - Investment in rehabilitating and stabilizing the site
      - Overseeing significant philanthropic donations
        - the Sanford Lab
- Championing Early Implementation Program (Early Science and E&O)
The DUSEL Design Organization Nearly Complete: ~55 Staff Members
Expert Advice Boards and Committees Actively Consulting with DUSEL Project

- Project benefits from extensive review and consultation

<table>
<thead>
<tr>
<th>Large Cavity Advisory Board</th>
<th>CyberInfrastructure Advisory Board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evert Hoek</td>
<td>Greg Bell</td>
</tr>
<tr>
<td>Ed Cording</td>
<td>Greg King</td>
</tr>
<tr>
<td>Derek Martin</td>
<td>Yuen-dat Chan</td>
</tr>
<tr>
<td></td>
<td>Jay Krous</td>
</tr>
<tr>
<td>Infrastructure Advisory Board</td>
<td>Eli Dart</td>
</tr>
<tr>
<td>John MacDonald*</td>
<td>Rohit Salve</td>
</tr>
<tr>
<td>Bob Dengler</td>
<td>Dale Finkelson</td>
</tr>
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<td></td>
<td>Mike Sinatra</td>
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<td></td>
<td>Claude Garelik</td>
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<td>David Stewart</td>
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<tr>
<th>EH&amp;S Oversight Committee</th>
<th>Cultural Advisory Committee</th>
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<tbody>
<tr>
<td>Craig Ferguson</td>
<td>K.C. Russell</td>
</tr>
<tr>
<td>Mike Andrews</td>
<td>Jeff Henderson</td>
</tr>
<tr>
<td>Mark Freiberg</td>
<td>Lowell Amiotte</td>
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<tr>
<td>Jim Krebs</td>
<td>Kay Jorgensen</td>
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<tr>
<td>Tony Iannacchione</td>
<td>George Campbell</td>
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<tr>
<td>Jim Tarpinian</td>
<td>Carter Kerk</td>
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<tr>
<td></td>
<td>Kevin Forsch</td>
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<td></td>
<td>Urla Marcus</td>
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<td>Connie Giroux</td>
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<td></td>
<td>Peggy Norris</td>
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<tr>
<td></td>
<td>Bill Harlan</td>
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<td>Design Packages and Design Activities</td>
<td>April</td>
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<td>--------------------------------------</td>
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<tr>
<td>Deep Campus Conceptual Design</td>
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<tr>
<td>Surface Campus Conceptual Design</td>
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<tr>
<td>Underground Laboratories</td>
<td>▲</td>
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<tr>
<td>Underground Infrastructure</td>
<td>▲</td>
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<tr>
<td>Excavation Design</td>
<td>▲</td>
</tr>
</tbody>
</table>

### 2010

- **60% Preliminary Design**
- **90% Preliminary Design**
- **100% PDR**

### Advancing Design Elements and Integrating Experiments

**DUSEL Construction Management and Project Team**
- Proposal FY11 Activities
- Proposal for CA2 Supplement
- S-4 Physics Review
- S-4 BGE Review
- PAC Meeting
- Sanford Lab/DUSEL Safety Review
- NSB Retreat
- Draft Preliminary Design Report
- LBN CD1

**DUSEL and LBNE Project Teams**
- NSF PDR Review
- NSB Meeting

**DUSEL, LBNE, Science Collaboration Reviews, Agency Meetings**
- LCAB IAB
- PAC Meeting
- NSB Retreat
- Internal Review of Preliminary Design
- Internal PDR Reviews
- PDR Assembled
- Creation of New M&O Organization
- NRC Assess

### 2011

Phase 3 Surface Assessment
Comparison of Underground Laboratories around the World

DUSEL Lab Volume assumes:
one 4850 LC and LAr LM at 800L
• We propose an MREFC Project with a scope of $875M (FY09$)
  • this will support the development a dedicated, deep facility capable of supporting 30 to 50 years of multidisciplinary science, engineering, and education and outreach
  • identifies adequate scientific support within the MREFC consistent with the Agency Stewardship Model and assuring the NSF of a leadership role in DUSEL’s science programs
• Scientific support consistent with or exceeding previous MREFC projects

**NSF MREFC Scope**

<table>
<thead>
<tr>
<th>NSF MREFC Scope</th>
<th>Targets including Contingency</th>
</tr>
</thead>
<tbody>
<tr>
<td>DUSEL Project Office</td>
<td>$575M</td>
</tr>
<tr>
<td>Surface Campus (+ $5M from Sanford)</td>
<td></td>
</tr>
<tr>
<td>Underground Infrastructure and Laboratories (+ $7.5M from Sanford)</td>
<td>$300M</td>
</tr>
<tr>
<td>Science Contribution</td>
<td></td>
</tr>
<tr>
<td><strong>Total MREFC</strong></td>
<td>$875M</td>
</tr>
</tbody>
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NB: estimates are $FY09
Establishing the Estimated Cost Range for DUSEL’s Suite of Critical Experiments

- Obtained from the S-4 collaborations, Physics reviews 13-15 July, and interactions with collaborations

<table>
<thead>
<tr>
<th>Science Goal</th>
<th>Total Estimated Experimental Cost Range* ($M)</th>
<th>Proposed MREFC Contribution ($M)</th>
<th>Number of Deployments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Matter</td>
<td>80 - 200</td>
<td></td>
<td>≥1</td>
</tr>
<tr>
<td>0νββ</td>
<td>250 - 350</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Bio/Geo/Eng</td>
<td>60 - 180</td>
<td>175</td>
<td>multiple</td>
</tr>
<tr>
<td>Nuclear Astrophysics</td>
<td>30 - 50</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Advanced low background &amp; assay</td>
<td>10 - 15</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Long Baseline Neutrinos &amp; Proton Decay‡</td>
<td>785 - 1065</td>
<td>125</td>
<td>200 kt WCE</td>
</tr>
</tbody>
</table>

*NB: These Cost Ranges are not to be confused with or substituted for DOE CD estimates, estimates include ~ 50% contingency

‡NB: LBNE CD0 range includes beam, near detector and far detectors, this range includes MREFC contribution
DUSEL’s Milestone Schedule through Construction

Schedule to be updated and optimized with final design reconciliation

NSF-UCB CA1
CA2
PDR Completed
NSB Consideration
Design Transition Funding
Final Design
EIS ROD

MREFC Construction Facility and Experiments

4850 Common Space Excavation
4850 Common Space Outfitting & Commissioning
LM1-4850 Excavation
LM1-4850 Outfitting
LM2-4850 Excavation
LM2-4850 Outfitting
LC1 Excavation
LC1 Outfitting
LM1-7400 Excavation
LM1-7400 Outfitting

SDSTA Funded Facility Operations
Safe Access for Design & Water Pumping
Access to and Maintenance of the Facility during Construction
DUSEL Operations post-Construction

Sanford Laboratory Science Program
DUSEL Science Programs

NRC DUSEL Study 44
Summary of the DUSEL Project

• Well motivated and transformational science driving the facility design
• Facility design & timelines aligned with science requirements
  – Large Community Interest DUSEL science programs, over 700 scientists and engineers
  – NSF-DOE Stewardship Model functioning well
  – Collaborations are conducting essential R&D supporting DUSEL’s Suite of Experiments
  – DUSEL represents strong NSF investment and alignment with NSF programs and activities
• The proposed MREFC Budget provides essential facility and science support, with the facility breaking ground in advance of the experiments, and with the facility and science experiments building on South Dakota’s investments
• Despite aggressive timeline for the PDR, design ready to advance to final design stage
  – Careful oversight and integration of the designs elements and experiments
  – Strong value engineering process - integrating requirements and design optimization
  – Experienced A/E contractors developing design elements
  – Opportunity to develop a world-class Education and Outreach
  – Continued opportunities to develop and advance regional university participation