

Dear SURF Readers,

Welcome to the August 2016 Sanford Underground Research Facility (SURF) monthly newsletter. The newsletter is posted online; a pdf copy is available as well. You can read recent and archived newsletters at our website -- www.sanfordlab.org. We are glad to receive your input on news, links to news articles, upcoming workshops, conference notices, scientific updates, information concerning SURF, employment opportunities, and other highlights relevant to underground science.

Important Dates

September 12-15: DUNE Collaboration Meeting – Fermilab

September 17-18: LUX Collaboration meeting – Lead, SD

KISMET

KISMET is one of several projects supported by DOE under its SubTER (Subsurface Technology and Engineering Research) Crosscut Initiative with LBNL researchers as the lead of a team of scientists and engineers from the University of Wisconsin, South Dakota School of Mines and Technology, Golder Associates, Sandia National Laboratories, Pacific Northwest National Laboratory, Idaho National Laboratory, Stanford University, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory.

SubTER projects are aimed at addressing challenges shared across subsurface energy technologies in the areas of wellbore integrity, stress and induced seismicity, permeability control, and new subsurface signals.

In late July, the Permeability (k) and Induced Seismicity Management for Energy Technologies (KISMET) project completed drilling and coring of a near-vertical array of five boreholes in the SURF 4850 Level West Access Drift (Figures 1 and 2). The group's diverse research team is conducting stress testing and fracturing at the KISMET site with the objective of developing understanding of the relationship between the stress field, hydraulic fractures, and rock fabric. Results of KISMET research will find their most direct application in the

area of Enhanced Geothermal Systems (EGS), a current emphasis for development of geothermal energy technology.

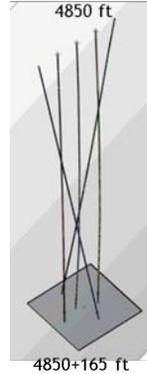


Figure 1: Traces of the near-vertical borehole array that forms a five-spot pattern 50m (165 ft) below the invert



Figure 2: Paul Cook of LBNL logs core from the KISMET boreholes

The first tests of stress, fracturing, and induced seismicity are currently underway in the Poorman phyllite at the KISMET site. The central borehole (100m deep) is being used for fracture stimulation using a straddle packer system and high-pressure pump. Modelling and theoretical analyses suggest the fractures created will be 1-4m in radius. The outer four boreholes (each 50m deep and 3m away from the central borehole) are used for proximal continuous active source seismic monitoring (CASSM) and electrical resistance tomography (ERT). Crosshole CASSM is a monitoring approach based on sending out periodic low-level seismic energy (either a ~1 ms pulse or a swept frequency signal) from multiple sources in a borehole while continuously recording the response in a nearby borehole using hydrophone (pressure) sensors. The source is a small piezoelectric cylinder fluid-coupled to the rock, with bandwidth about 500 to 4000 Hz and peak fluid pressure of about 0.1 bar. In CASSM, seismic travel times and amplitudes, measured

along individual ray paths, can be used to map heterogeneities such as water-filled fractures.

Additional passive monitoring of any detectable microseismicity will be carried out at other locations at SURF. ERT is using multiple electrode pairs distributed along the boreholes, used as either current input or voltage monitors, and recording the changes in resistivity over time, e.g., changes due to creation of water-filled fractures. The ERT data will be sent directly to *Pacific Northwest National Laboratory* (PNNL) for processing with interpretations returned to kISMET in about 15 minutes for near-real time monitoring. The ability of the team creating the fractures to know in near-real time about the character (size, shape, orientation) of the fracture being formed may allow the team to interactively control the fracturing process, and promises to provide unprecedented detail on active fracture growth processes.

SubTER funding currently comes from the U.S. DOE offices responsible for Oil & Gas, Carbon Capture and Storage, Nuclear Energy, and Geothermal Energy. To read more: <http://eesa.lbl.gov/subter-kismet/>

CUBED-Mordred Low-Background Counting Station

The CUBED-One (Center for Ultra-low Background Experiments in the Dakotas) low-background detector was recently upgraded successfully by ORTEC. The upgrade detector, CUBED-Mordred, has sensitivity improved from ~700 $\mu\text{Bq/kg}$ to ~200 $\mu\text{Bq/kg}$ of ^{238}U and ^{232}Th . This improvement was achieved mainly by removing a preamp from underneath the detector to outside the shielding.

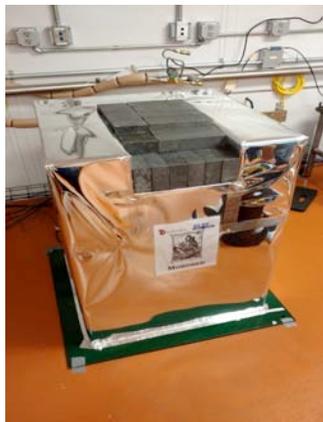


Figure 3:
CUBED-Mordred detector installed at BHUC

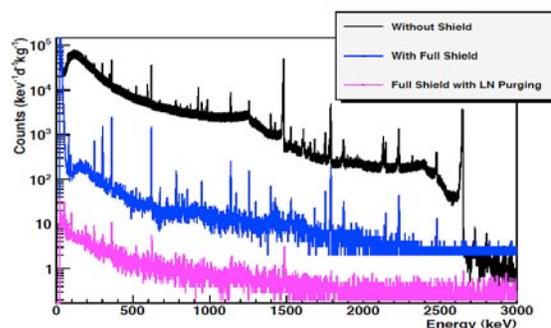


Figure 4: The measured background spectra

Figure 3 shows the installed detector at Black Hills State University Underground Campus (BHUC) at SURF. The analysis of background rates for the detector without shielding, with a full shielding, and the full shielding with LN purging are shown in Figure 4. As can be seen in Figure 4, the shielding reduces the background rates for more than two orders of magnitude, and the purging further reduces the background rates by at least one order of magnitude with the current setup in BHUC at SURF.

CUBED-Mordred is a 1.3 kg *n-type* detector with a threshold of below 20 keV, which is suitable to measure the 46.5 keV gamma ray from ^{210}Pb . Since funding for the upgrade is provided by Lawrence Berkeley National Laboratory (LBNL), this upgraded detector will be fully dedicated to the LZ (LUX-ZEPLIN) assay program under the leadership of the LBNL group for the next two years. Keenan Thomas led the efforts for installation of this detector.

LBNF/DUNE Blasting Designs

Construction of facilities at the Long-Baseline Neutrino Facility and associated Deep Underground Neutrino Experiment (LBNF/DUNE) will take place above and below ground at SURF's 4850 Level. Current work includes excavation of three large caverns: two that will house neutrino detectors filled with 70,000 tons of liquid argon, and one that will house utilities. The LBNF has been conducting a blast vibration study to determine the impact of excavation on existing experiments.

"We were primarily interested in how the blast energy moves through both the rock and the air in existing spaces," said Tracy Lundin, LBNF Conventional Facilities Project Manager.

“The different collaborations, including those with MJD (MAJORANA DEMONSTRATOR), the Black Hills State University Underground Campus, and CASPAR (Compact Accelerator System for Performing Astrophysical Research) had concerns about the excavation and its potential impact on their experiments,” said Mike Headley, SDSTA Executive Director. “The LBNF team has regularly consulted with the other collaborations on the blast vibration study plans and results, as well as approaches that can be taken to reduce the impacts the LBNF excavation might have on other experiments.”



Figure 5: This image illustrates the sequence in which a blast round happens

Preparation for the test blast required drilling a pattern of holes into the rock and filling most of them with explosives, which are then triggered in a specific timed sequence by detonators. A set of holes in the center of the pattern, called the burn cut, is left empty. The pattern is designed so that energy from the blasts in the outer holes propagates radially toward the burn cut. Figure 5 illustrates the sequence in which a round blast takes place. Prior to a blast, the pattern is marked on the face of the rock. The round begins at the center and the hole increases in size with a series of boxes and diamonds. The holes marked in red after the final diamond, called field holes, round out the arch shape of the drift. Production holes along the sides and top of the drift complete the arch. Finally, the lifters on the ground level out the floor of the drift.

The initial study in December 2015, successfully demonstrated how the energy moves through the rock mass. However, it did not provide a complete understanding of air blast overpressures and the

team’s ability to manage impacts on existing facilities and experiments.

Two successive blasts in March 2016 included a redesigned blast pattern, non-electronic detonators, and reinforced air doors throughout the 4850 Level. Both were successful, informing the next LBNF blast designs.

“The new blasting plans will allow LBNF to move forward as planned without harming other experiments,” Headley said.

(To read more on core drilling, see page 5.)

REPORTS/PAPERS AVAILABLE

Special DUNE News: All four volumes of the Deep Underground Neutrino Experiment (DUNE) for Conceptual Design Report DUNE/LBNF are now available on arXiv: Vol. 1. Overview 1601.05471. Vol. 2. Physics 1512.06148, Vol. 3. LBNF 1601.05823, Vol. 4. DUNE detector 1601.02984. <http://arxiv.org/>

The Sanford Underground Research Facility at Homestake. Jaret Heise, J.Phys.Conf.Ser. **606** (2015) no. 1, 012015; [arxiv: 1503.01112](http://arxiv.org/abs/1503.01112) (2015)

Forward Momentum 2025, a 5-year strategic plan based on a 10-year vision for SURF: www.sanfordlab.org/sites/sanfordlab.org/files/.../Forward_Momentum.pdf

The Sanford Underground Research Facility at Homestake (SURF). (K.T. Lesko, Phys Procedia **61** 542 (2015)

P5 report (Print quality) The full Particle Physics Project Prioritization Panel report as accepted by the High Energy Physics Advisory Committee

For news, twitter updates, and other features, see the SURF website: www.sanfordlab.org
Like Sanford Lab Visitor Center on Facebook: <https://www.facebook.com/sanfordlabhomestake/>



SURF IN THE NEWS

ABC News (AP story): [Scientists Looking for Invisible Dark Matter Can't Find Any](#) (Seth Borenstein, July 21)

The New Scientist: [Dark matter no-show puts favoured particles on death row](#) (Jacob Aron, July 21)

Science (NAAS): [Dark matter search comes up empty](#) (Adrian Cho, July 21)

Space.com: [Dark Matter Still a Mystery: Most Sensitive Search Yet Comes Up Empty](#) (Sarah Lewin, July 21) and Scientific American: [Dark Matter Stays Dark](#)

Phys.org: [World's most sensitive dark matter detector completes search](#) (July 21)

Symmetry: [Dark matter evades most sensitive detector](#) (Manuel Gnida, July 21)

Physicsworld.com: [World's most sensitive dark-matter search comes up empty handed](#) (Hamish Johnston, July 22)

Forbes Magazine: [Dark Matter May Be Completely Invisible, Concludes World's Most Sensitive Search](#) (Ethan Siegel, July 21)

LA Times: [LUX: World's most sensitive detector finds no dark matter](#) (Amina Khan, July 22)

Science World Report: [World's Most Sensitive Device Could Not Get Signals 'Coz It's For WIMPS, not Dark Matter](#) Michael Finn, July 25); [Invisible Dark Matter Definitely Can't Be Seen, Scientists Say](#) (Brooke James, July 22)

The Telegraph: [Dark matter more elusive than ever as scientists admit detector has failed to find mystery particle](#) (Sarah Knapton, July 21)

The Daily Mirror.co.uk: [Hunt for mysterious dark matter with £7million detector reports results](#) (John von Radowitz, July 21)

The Register: [Nope, we can't find dark matter either, says LUX](#) (Katyanna Quach, July 21)

The Independent.co.uk: [Huge dark matter experiment finds nothing](#) (Andrew Griffin, July 21)

Express.co.uk: [£7m machine WIMPS out on finding dark matter](#) (July 21)

The Guardian: [Latest results in the hunt for dark matter](#) (Jon Butterworth, July 24)

The Sun: [Super-sensitive £7 million LUX dark matter detector finds... NOTHING](#) (Jasper Hamill, July 22)

UCL (UK): [Dark matter particle remains elusive](#) (Bex Caygill, July 21)

Nature World News: [Dark Matter Still a Mystery](#) (Sky Selrach, July 22)

Christian Science Monitor: [Why dark matter still proves difficult to detect](#) (Rowena Lindsay, July 21)

Wired.com: [It's still proving impossible to find dark matter](#) (Matt Burgess, July 21)

Ars technica: [Dark matter still MIA after most exhaustive search yet](#) (John Timmer, July 21)

Tech Times: [Dark Matter Still Continues To Evade Us, But The Search Is Not Over Yet](#) (Jelani James, July 21)

seeker.com: [No WIMPs Here: Dark Matter Search Draws a Blank](#) (July 21)

Stock News USA: [Dark Matter Still A Mystery To Scientists Despite 20-Month Study](#) (Jeanette Walsh, July 22)

Engadget: [Xenon detector finds no dark matter after 20-month study](#) (David Lumb, July 22)

Morning Ticker: [Huge dark matter discovery ... and it's absolutely depressing](#) (Dan Taylor, July 23)

KOTA TV: [Dark matter slips through scientists' grasp](#) (July 21)

Northern California News: [Even the most sensitive search could not detect dark matter](#) (Natalia Hall, July 24)

Providence Journal: [Dark matter remains elusive for Brown physicist](#) (G. Wayne Miller, July 21)

UC Davis: [LUX Dark Matter Detector Comes Up Empty](#) (July 21)

Cosmos Magazine: [Latest search for dark matter draws a blank](#) (Cathal O'Connell, 7/21)

I4u.com: [Dark Matter is Invisible](#) (Sumayah Aamir, July 21)

Tamil Tech news (video): [LUX Dark Matter Search Completed](#) (Rajamanickam Antonimuthu)

Science 2.0: [LUX Dark Matter Experiment Ends With No WIMPs Found](#) (Staff, July 21)

Science alert: [Scientists' biggest search for dark matter to date just turned up nothing](#) (Peter Dockrill, July 22)

Reddit (670+ comments): [Scientists looking for invisible matter can't find any](#)

Motherboard: [Key Dark Matter Detection Experiment Again Comes Up Empty-Handed](#) (Michael Byrne, July 23)

doggerel.arup.com: [A mile underground, a historic gold mine turns to cutting-edge science](#) (Josh Yacknowitz, July 12) / [Neutrino beams, cosmic rays, and the origins of the universe](#) (6/20)

International Business Times: [Dark Matter Search Draws A Blank As World's Most Sensitive Detector Fails To Find WIMPs](#) (Avaneesh Pandey, July 22)

Gizmodo: [Mysterious Dark Matter Remains Maddeningly Elusive](#) (Jennifer Ouellette, July 21)

Gizmag: [Mile-deep experiment narrows the search for dark matter particles](#) (Dario Borghino, July 21)

Pulse Headlines: [The Large Underground Xenon ends its search with no dark matter detected](#) (Elizabeth de Faria, July 21)

Rapid City Journal: [Scientists: No WIMPs](#) (Tom Griffith, July 22)

[LUX scientists still seeking elusive dark matter](#) (Tom Griffith, July 21)

Black Hills Pioneer: [World's most sensitive dark matter detector completes search for dark matter in Lead's Sanford Lab](#) (John Higgins, July 21)

DURA

To comment on DURA, please contact its chair Richard Gaitskell (Richard.Gaitskell@brown.edu). For Bio-Geo-Engineering matters, contact Bill Roggenthen (William.Roggenthen@sdsmt.edu). For further information on DURA, see: <http://sanfordlab.org/dura>

SANFORD UNDERGROUND LABORATORY NEWS

Visitors at Sanford Lab



Figure 6: Tour of the 4850 Level (from left): Nigel Lockyer, Chris Mossey, Hema Ramamoorthi, Mike Weis, Franklin Orr, Mike Headley, David Vardiman, James Symons, and Casey Peterson

On July 5, Sanford Lab was proud to host Dr. Franklin Orr, Under Secretary for Science and Energy at the Department of Energy. The purpose of his trip was to visit the proposed site of the LBNF far site facilities and tour the Davis Campus 4850 Level (Figure 6). While at SURF, he met with various people associated with the project: Mike Headley (SDSTA Executive Director and Far Site Facilities Division Head), Nigel Lockyer (Fermilab Director),

Hema Ramamoorthi (Fermilab Directorate Chief of Staff), Mike Weis (Fermi Site Office Manager), Chris Mossey (LBNF Project Director), James Symons (LBNL Associate Lab Director for Physical Sciences), Casey Peterson (SDSTA Board Chair), and David Vardiman (SDSTA Senior Geotechnical Engineer).

Core Drilling

A core drilling team recently began collecting core samples for the LBNF/DUNE experiment at SURF. Core drilling is an essential function of any civil or geotechnical project, especially when building in a large underground site such as the Davis Campus. David Vardiman, Geotechnical Project Engineer at Sanford Lab, says, “Extreme loads require drilling deep to understand the bedrock.”

At Sanford Lab, engineers characterize the rock mass to ensure that it will support the large caverns that house experiments. The core samples will indicate the strength and geologic composition of the rock, and reveal the orientation of folds and other imperfections in the rock mass, which can influence the design of the excavation.



Figure 7: Joel Carr (First Drilling) at left operates the controls of a drill rig in the west drift of the 4850 Level; Brad Burnett (right) reads the latch mechanism used to retrieve the core from the drill hole

The proposed experiment will be housed on the 4850 Level, near the Ross Shaft. The caverns that will house the detectors will be 65 feet wide, 94 feet tall, and 505 feet long. Since approximately 800,000 tons of rock will be excavated, evaluating the rock strength is crucial.

“Through drilling, we’ve determined that the rock at the LBNF/DUNE site is of very high quality,” Vardiman said. “One of the things that makes the Black Hills such an ideal location for these caverns, is that you can go down a mile and the stresses the rocks experience are very close to being in balance—both vertically and horizontally.”

To get the core samples, *First Drilling* of Colorado set up a Conner 208h core rig, which uses a hollow diamond-tipped bit that cuts through the hard rock and leaves a solid rock core sample (Figure 7). All of the core is logged and packaged for testing at a geotechnical lab. The latter work was completed by *Arup*, the architectural and engineering firm for LBNF/DUNE.

The data will be used to create mathematical models that run analyses on the structural integrity of the rock and to determine what kind of ground support will be needed. "We take great care in the analysis of every core sample, because the whole design hinges on that," Vardiman said. "We have to be very knowledgeable about the strengths and weaknesses of the rock, and the best way to excavate within it. We have to know how to preserve and augment that strength to get the cavern life span we need in a highly variable-condition environment."

EDUCATION AND OUTREACH

New Education Specialists

The Education and Outreach Department at Sanford Lab has added two new Science Education Specialists to the group, as of August 15.



Becky Bundy was born and raised in Northern Virginia, but she comes to SURF from Georgia, where she spent the past 10 years teaching high school physics, AP physics, and chemistry. She has a Ph.D. in Microbiology, and spent her last three summers developing high school science lessons based on cutting-edge nanotechnology research being performed at the University of Georgia. Becky is excited to be here at SURF where she can combine her passions for science and education; she can't wait to further support the education and outreach efforts of Sanford Lab. She comes to South Dakota with her husband, John, 3-year old son, Owen, and 13-year old kitty, Kudzu. Becky will be working with the E&O department full-time.



Kari Webb joins SURF from Northwest Iowa. Most recently, she served as the Director of Curriculum, Instruction and Assessment for the Sioux City Community School District. Her responsibilities included the development and management of curriculum for nearly 15,000 students in grades TK-12 in all content areas, and working on a balanced system of assessments to support teachers in the use of student achievement data to drive instruction. Her favorite part of the job was the design and delivery of professional development for over 1000 certified teachers.

Kari's previous employment included work for the Iowa Governor's STEM Initiative. The goal of the initiative is to increase student engagement and achievement in the STEM fields for Iowa students, and to promote best practices in STEM teaching and learning in Iowa's preK-12 classrooms. Kari studied chemistry at the University of South Dakota, and Education Policy and Leadership at the University of Iowa. Kari and her husband, James, have three grown daughters. They enjoy finding new trails for hiking and cycling, and are happy to be living in South Dakota again! Kari will be working with the E&O department 70% time.

Becky and Kari are hitting the ground running by taking over the development of two new curriculum units for the 2016-2017 school year. Kari will be working on a *Science and Measurement* unit for elementary schools, and Becky will be working on a *Waterworks* unit for middle schools. The current staff of the E&O Department--June, Julie and Peggy--invite you to drop by the Yates Education Building when you are next on-site and meet Becky and Kari. They are anxious to connect with everyone associated with Sanford Lab so they can fully understand all aspects of our facility and the science and engineering happening at SURF.

ENVIRONMENT, HEALTH & SAFETY



Water conservation

- Check faucets, pipes, etc. for leaks. Install water-saving low-flow shower heads and low-flow faucet aerators.
- Turn off the water after you wet your toothbrush.
- Use your dishwasher or clothes washer only for full loads.
- Water your lawn only when necessary. Don't run the hose while washing your car. Use a spray nozzle for efficient water usage.

UPCOMING CONFERENCES AND WORKSHOPS

INPC2016, International Nuclear Physics Conference, September 11-16, 2016, Adelaide, Australia.
<http://inpc2016.com/>

Perspectives of GPU Computing in Science, September 26-28, 2016, Sapienza Università di Roma. Discuss and assess impacts and perspectives of GPU and many-core computing.
<http://www.roma1.infn.it/conference/GPU2016/index.html>

WIN2017, Workshop on Weak Interactions and Neutrinos, June 19-24, 2017, Irvine, CA.
<http://www.physics.uci.edu/WIN2017/>



JOBS

Postdoctoral researchers, Yale. Two openings in Experimental Nuclear and Particle Physics. David Moore, david.c.moore@yale.edu. Closing: 11/18/16.
<http://inspirehep.net/record/1481910>

NERSC Data Postdoctoral Fellow, LBNL. Support high-energy experiments, esp. LUX-ZEPLIN (LZ) software development/deployment. Closing: 9/1/16.
<https://lbl.taleo.net/careersection/2/jobdetail.ftl?lang=en&job=82724>

Two postdoctoral positions, University of Alabama. Research in Nuclear Physics group on EXO-200 neutrinoless double-beta-decay. Andreas Piepke, andreas@ua.edu. Indicate "EXO" in the subject line. Closing: 10/1/16.

<https://facultyjobs.ua.edu/postings/38770>

Research Associate Physics, Brookhaven National Lab. Research with Electronic Detector Group (EDG) on DUNE, ProtoDUNE, Daya Bay and other experiments. Job ID: 771
<https://jobs.bnl.gov/job/upton/research-associate-physics/3437/2658641>

Postdoctoral Researcher positions, LLNL. Research focus on R&D on nEXO neutrinoless double beta decay experiment (Job # 101011). Research on fission TPC project in Nuclear and Particle Physics Group (Job # 100894). Samuele Sangiorgio, sangiorgio1@llnl.gov.
<http://careers-ext.llnl.gov/jobs/5386296-postdoctoral-research-staff-member>
<http://careers-ext.llnl.gov/jobs/search?q=100894>

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