
SURF Science Program
Jaret Heise
SDSTA Science Director
Cultural Advisory Committee
December 5, 2022
Sanford
Underground Research Facility
South Dakota Science and Technology Authority

Underground Facilities

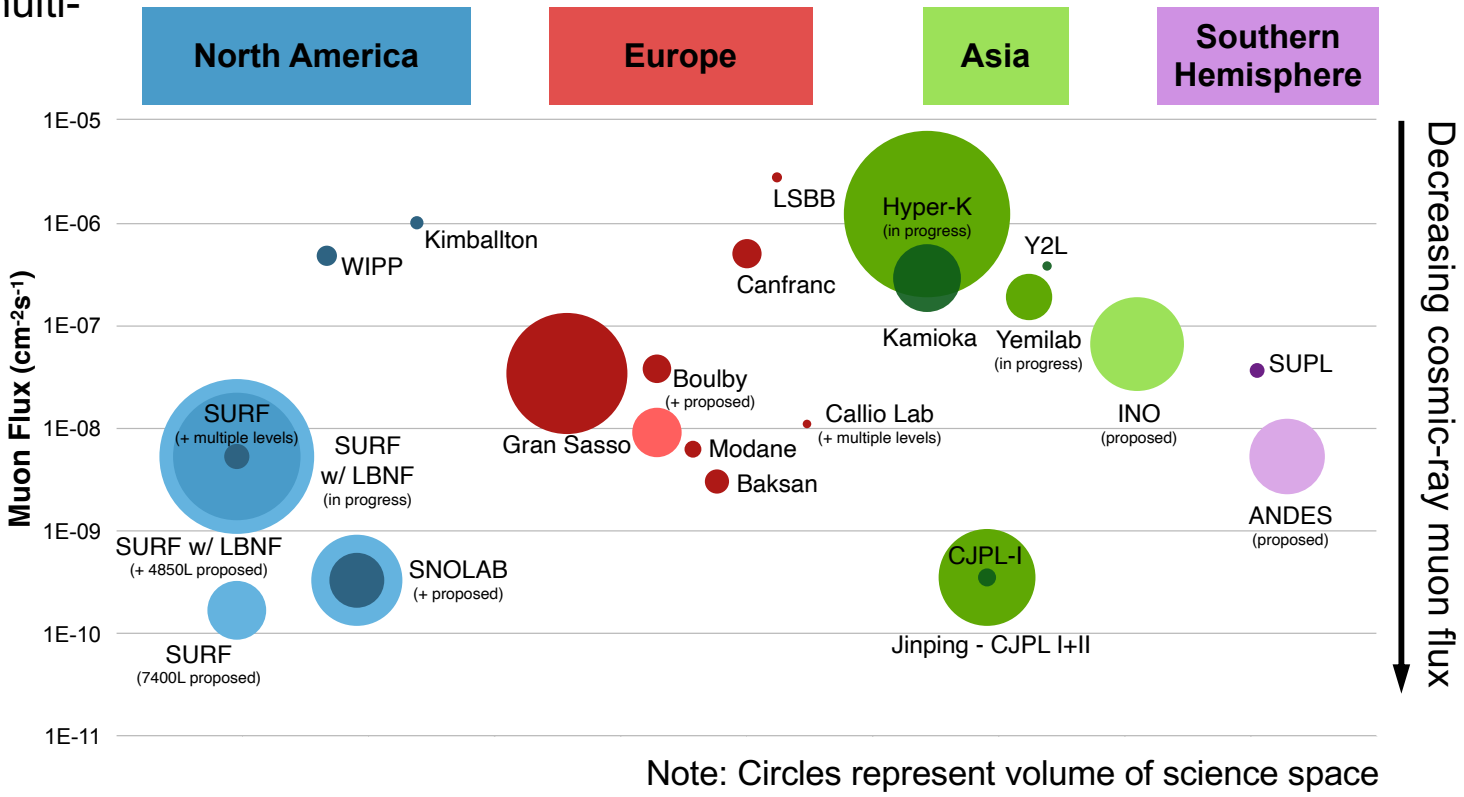
UG Facilities serve a diverse community:

- Physics
  - Low-background environment to study rare processes
- Biology
  - Isolation from surface microorganisms
  - Variety of environmental conditions (temperature, humidity, etc)
  - Variety of niches (materials/rock geochemistry, water from different locations, trace gases, etc)
- Geology
  - Variety of geologic environments / rock formations (permeability, porosity, chemistry); also drill core archive
- Engineering
  - Real-world environments for technology development, mining, etc

Underground Facilities

UG Facilities can provide:

- Unique environments for multi-disciplinary research
  - Overburden protection from cosmic-ray muons
- Local radiation shielding
- Assay capabilities
- Material production/ purification
- Environmental control
- Implementation and operations support
- Community catalyst



Note: Circles represent volume of science space

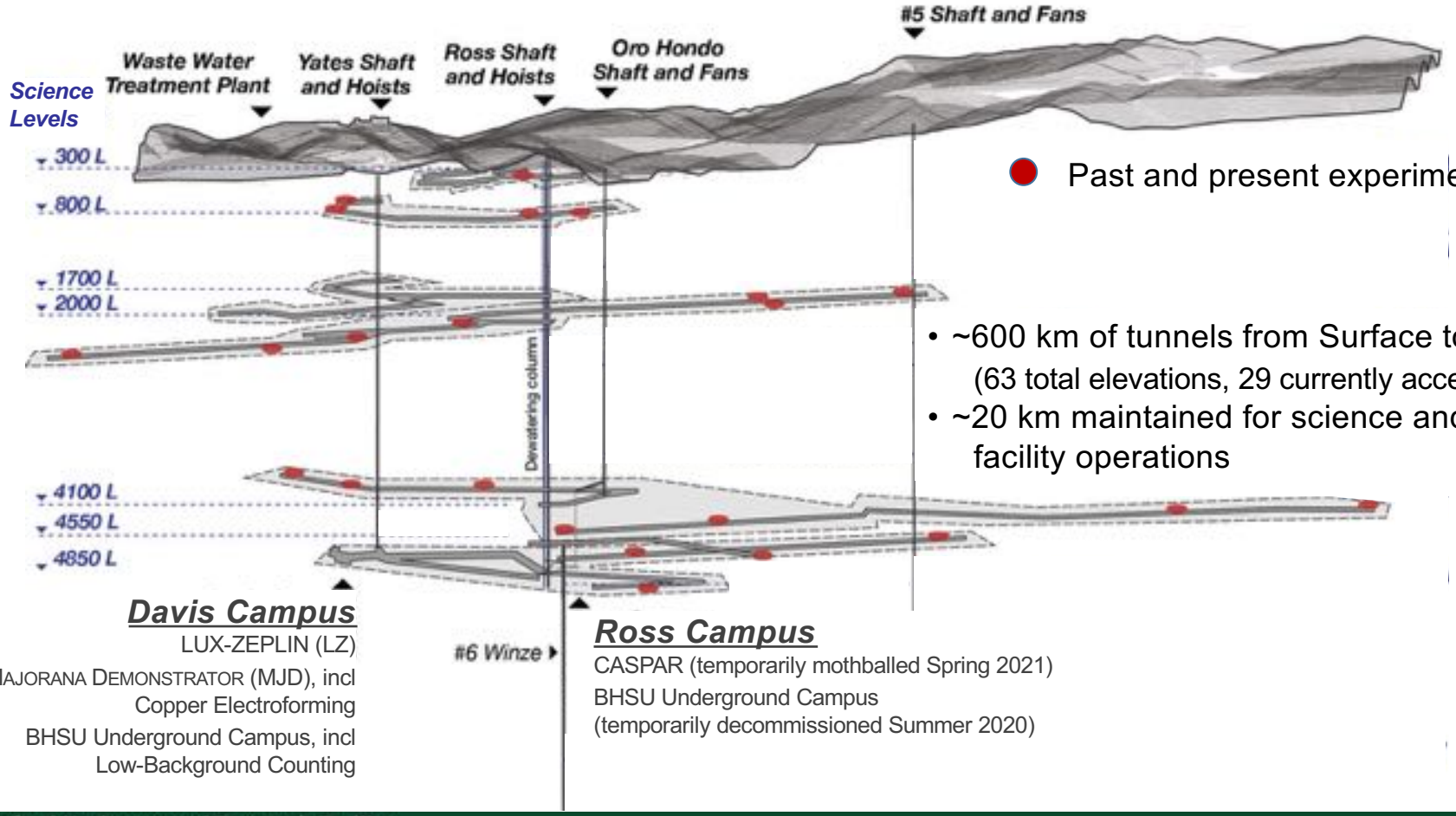
Underground Facilities – SURF

SURF can provide:

- **Unique environments for multi-disciplinary research:** SURF has attracted world-leading experiments and scientists from diverse scientific communities.
  - **Overburden protection from cosmic-ray muons:** SURF is the deepest underground lab in U.S., one of deepest in the world (1500 m, 4300 mwe). SURF has sufficient depth for next-generation experiments, but needs additional space – SURF is exploring options for more 4850L lab space as well as greater depth for the future (2300 m, 6500 mwe)
- **Local radiation shielding:** Water tank and corresponding water purification system, steel shielding; also selection of low-activity facility construction materials (e.g., concrete, shotcrete)
- **Assay capabilities:** Low-background counting serving national & international community
- **Material production/purification:** One of only a few labs where UG Cu electroforming is performed
- **Environmental control:** Cleanrooms with HEPA filtration, dehumidifier and Rn-reduction systems
- **Implementation and operations support:** Robust organization with support for planning, execution and coordination of science program activities both planned and ongoing at facility. SURF has proven track record of delivering successful science.
- **Community catalyst:** User Association, incl Vision Workshop 2021. Science Program Advisory Cmttee. Both groups support upcoming SURF application to become **DOE Office of Science User Facility**

SURF Underground Lab Geography

Yates & Ross Shafts + ventilation shafts, multiple levels for science



- Past and present experiment sites

- ~600 km of tunnels from Surface to 2.4 km deep
  (63 total elevations, 29 currently accessible)
- ~20 km maintained for science and facility operations

Davis Campus

LUX-ZEPLIN (LZ)

MAJORANA DEMONSTRATOR (MJD), incl Copper Electroforming

BHSU Underground Campus, incl Low-Background Counting

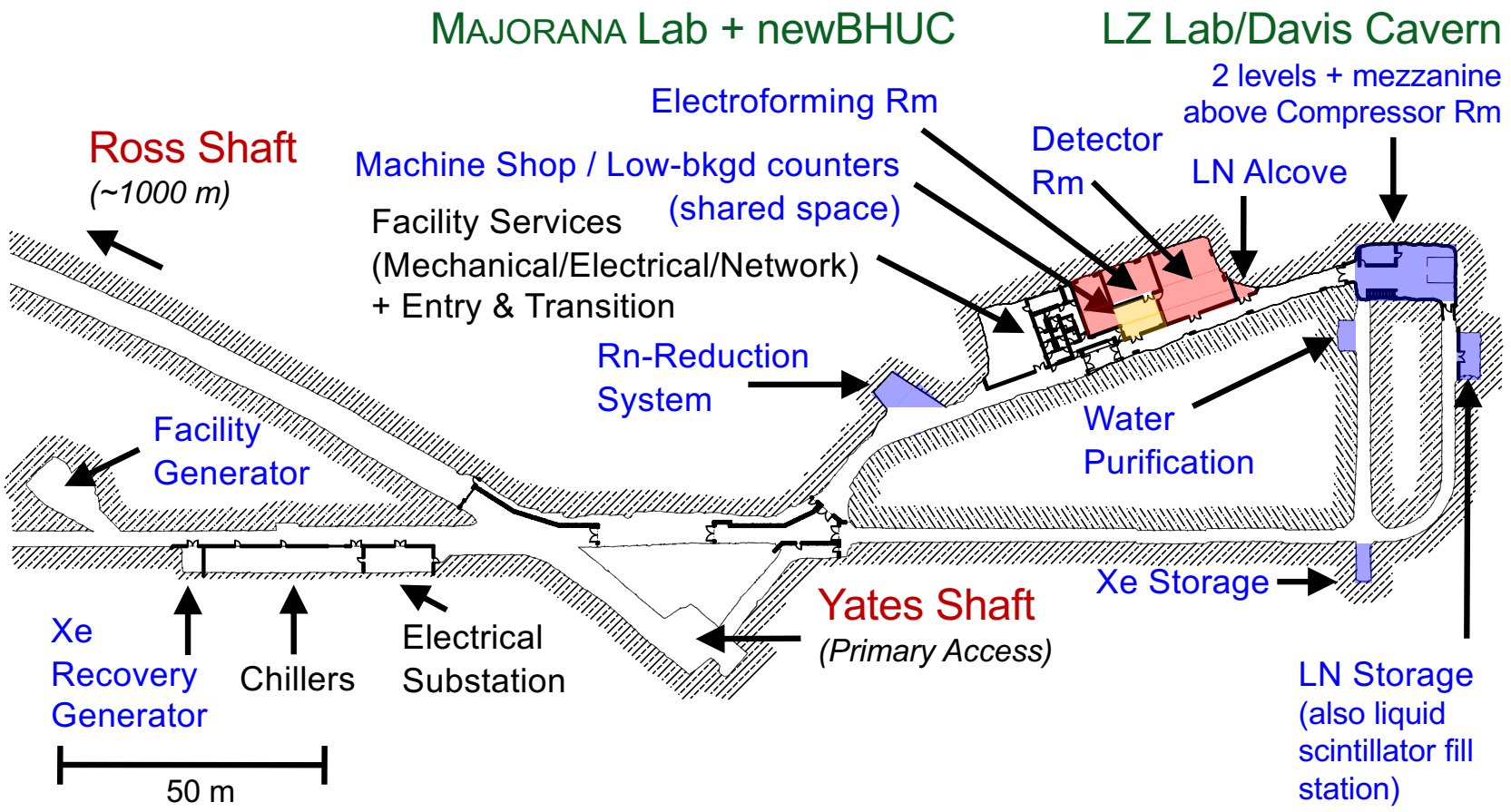
Ross Campus

CASPAR (temporarily mothballed Spring 2021)

BHSU Underground Campus (temporarily decommissioned Summer 2020)

4850L Davis Campus

3,017 m^2 (Total) / 1,018 m^2 (Science)



4850L Davis Campus

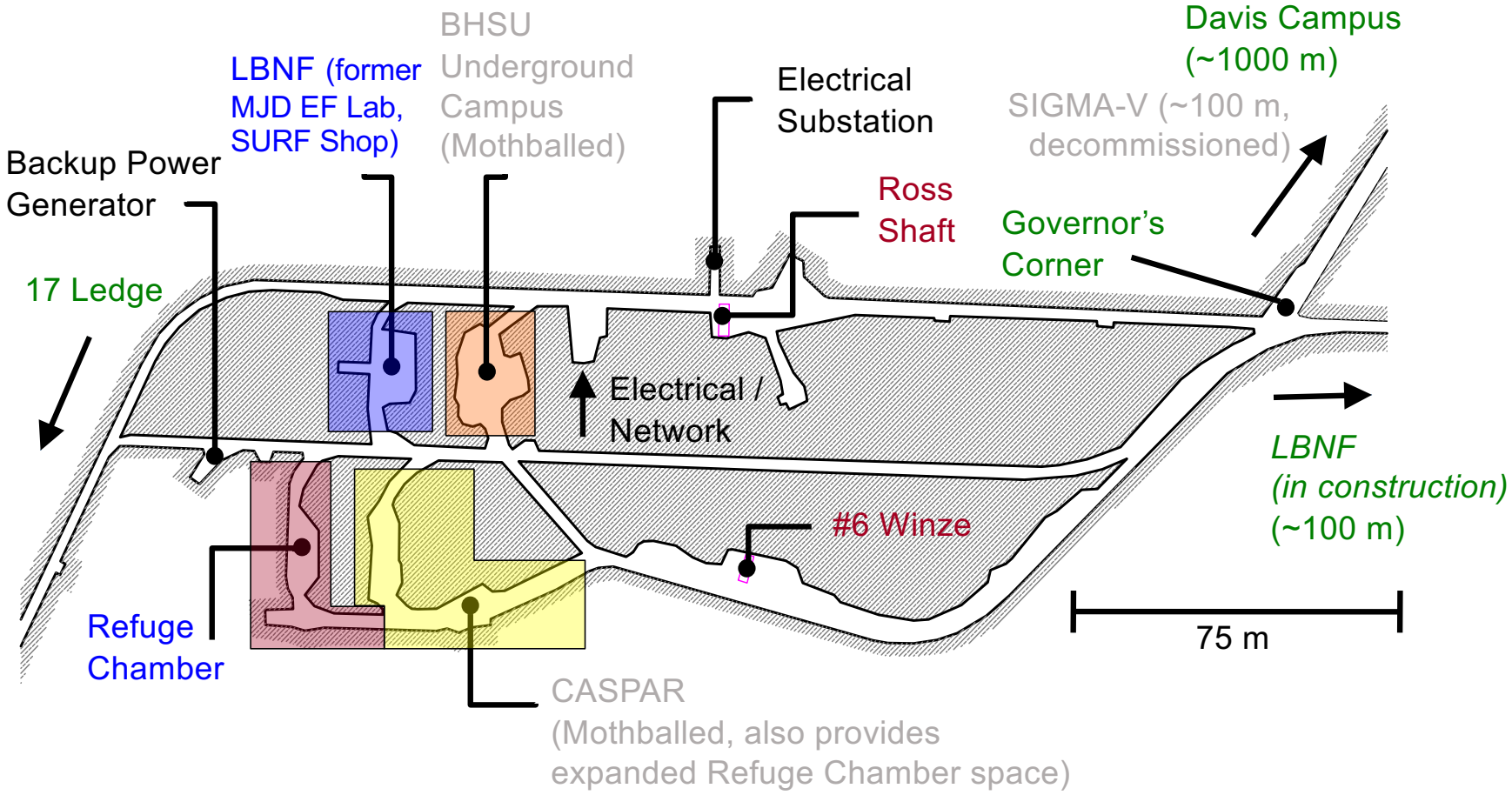
Examples of laboratory space

Detector Room (MJD):
Area =140 m^2, 11 m × 9.8-12.8 m × 2.7 m (H)
(raised section: 5.9 m × 5.8 m × 3.2 m (H))

Lower Davis Cavern (LZ):
Area =142 m^2, 13.7 m × 9.1 m × 6.4 m (H)
(incl tank: 7.6 m diameter × 6.4 m H)

4850L Ross Campus

2,653 m^2 (Total) / 920 m^2 (Science)



4850L Ross Campus

Examples of laboratory space

2010-2017

Former MJD Electroforming:
Area = 228 m^2
(Cleanroom removed, future UG WWTP)

Copper Electroforming

2015-2021, resume FY24

CASPAR Hall:
Area = 236 m^2,
30 m × 3 m (min) × 2.8 m (H)

2015-2020, resume FY24

BHUC Cleanroom:
Cavern Area = 268 m^2,
Cleanroom = 12.1 m × 6.1 m × 2.4 m (H)

SURF Science Program

Research activities ranging from the surface to 1500+m underground

Physics

- LZ – *Dark matter, 2-phase Xe TPC*
- MAJORANA DEMONSTRATOR / LEGEND – *Neutrinoless double-beta decay, Ge-76, Ta-180m, also Cu e-forming*
- CASPAR – *Nuclear astrophysics with 1 MV accelerator*
- LBNF/DUNE – *Neutrino properties, etc*
- BHUC – *BHSU Underground Campus, mainly material screening*
- Berkeley LBF – *Low-bkgd counter (x3);* also CUBED – *Low-bkgd counter (x1)* *(possibly future Crystal Growth)*
- nEXO – *Low-bkgd counter (x1)*
- LLNL – *Low-bkgd counter (x1)*
- SDSMT Bkgds – *Neutron bkgds*

Total = 30 groups
22 Active Projects
61 Total Groups Since 2007

Significant interest from others
(17 groups in 2021)

Biology

- Astrobiology/DeMMO – *In-situ cultivation, DNA isolation*
- 2D Best – *Biofilms*
- Biodiversity – *Microbial communities*
- Biofuels – *Extremophile bioprospecting*
- BuG ReMeDEE – *Methane oxidation*
- Carbon Sequestration – *Biology in core*
- Chemistry – *Env characterization*
- Liberty BioSecurity* – *Extremophiles*

Geology

- SIGMA-V / DEMO-FTES – *Geothermal*
- 3D DAS – *Seismic monitoring using fiber*
- Core Archive* – *Mainly gold deposits*
- Hydro Gravity – *Gravity for water tables*
- BH Seismic – *Global monitoring*
- Transparent Earth – *Seismic arrays*

Engineering

- Xilinx, Inc* – *Chip error testing*
- Thermal Breakout – *In situ stress*
- Shotcrete – *Mining safety*
- GEOX™ – *Env monitoring*
- Caterpillar* – *Mining processes*
- Blast Monitoring – *LBNF-related*

* Denotes proprietary group

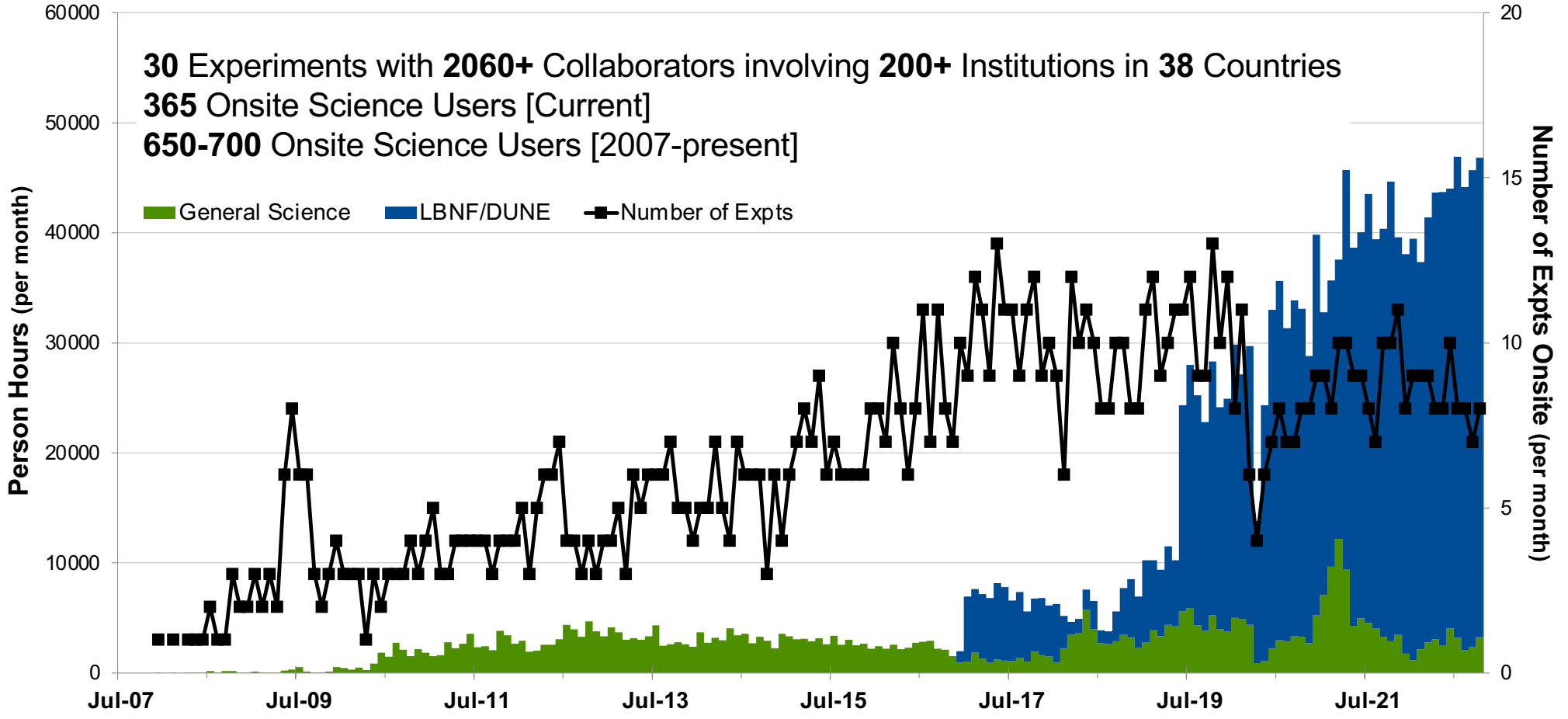
SURF High-Impact Science

https://www.sanfordlab.org/publications-and-reports

- Characterization of thermostable cellulases produced by *Bacillus* and *Geobacillus* strains, G. Rastogi, A. Bhalla, A. Adhikari, K. M. Bischoff, S. R. Hughes, L. P. Christopher, R. K. Sani *Bioresource Technology* **101**, 8798 (2010) doi: 10.1016/j.biortech.2010.06.001.
- Improved Lignocellulose Conversion to Biofuels with Thermophilic Bacteria and Thermostable Enzymes, A. Bhalla, N. Bansal, S. Kumar, K. M. Bischoff, R. K. Sani *Bioresource Technology* **128**, 751 (2013) doi: 10.1016/j.biortech.2012.10.145.
- Insights into the phylogeny and coding potential of microbial dark matter, Rinke C, Schwientek P, Sczyrba A, Ivanova NN, Anderson IJ, Cheng JF, Darling A, Malfatti S, Swan BK, Gies EA, Dodsworth JA, Hedlund BP, Tsiamis G, Sievert SM, Liu WT, Eisen JA, Hallam SJ, Kyrpides NC, Stepanauskas R, Rubin EM, Hugenholtz P, Woyke T. *Nature* **499**:431-437 (2013) doi: 10.1038/nature12352.
- Obtaining genomes from uncultivated environmental microorganisms using FACS-based single-cell genomics, Rinke C, Lee J, Nath N, Goudeau D, Thompson B, Poulton N, Dmitrieff E, Malmstrom R, Stepanauskas R, Woyke T. *Nature Protocols* **9**:1038-1048 (2014) doi: 10.1038/nprot.2014.067.
- First Results from the LUX Dark Matter Experiment at the Sanford Underground Research Facility, D. S. Akerib *et al*. (LUX Collaboration) *Phys. Rev. Lett.* **112**, 091303 (2014) doi: 10.1103/PhysRevLett.112.091303.
- Results on the Spin-Dependent Scattering of Weakly Interacting Massive Particles on Nucleons from the Run 3 Data of the LUX Experiment, D. S. Akerib *et al.* (LUX Collaboration) *Phys. Rev. Lett.* **116**, 161302 (2016) doi: 10.1103/PhysRevLett.116.161302.
- Results from a Search for Dark Matter in the Complete LUX Exposure, D.S. Akerib *et al*. (LUX Collaboration) *Phys. Rev. Lett.* **118**, 021303 (2017) doi: 10.1103/PhysRevLett.118.021303.
- New limits on Bosonic Dark Matter, Solar Axions, Pauli Exclusion Principle Violation, and Electron Decay from the MAJORANA DEMONSTRATOR, N. Abgrall *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **118**, 161801 (2017) doi: 10.1103/PhysRevLett.118.161801.
- First Searches for Axions and Axionlike Particles with the LUX Experiment, D. S. Akerib *et al*. (LUX Collaboration) *Phys. Rev. Lett.* **118**, 261301 (2017) doi: 10.1103/PhysRevLett.118.261301.
- Search for Neutrinoless Double-ß Decay in ^{76}Ge with the MAJORANA DEMONSTRATOR, C. E. Aalseth *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **120**, 132502 (2018) doi: 10.1103/PhysRevLett.120.132502.
- First Limit on the Direct Detection of Lightly Ionizing Particles for Electric Charge as Low as e/1000 with the MAJORANA DEMONSTRATOR, S. I. Alvis *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **120**, 211804 (2018) doi: 10.1103/PhysRevLett.120.211804.
- Measurement of Low-Energy Resonance Strengths in the ^{18}O(α,γ)^{22}Ne Reaction, A.C. Dombos *et al*. (CASPAR Collaboration) *Phys. Rev. Lett.* **128**, 162701 (2022) doi: 10.1103/PhysRevLett.128.162701.
- Search for Spontaneous Radiation from Wave Function Collapse in the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **129**, 080401 (2022) doi: 10.1103/PhysRevLett.129.080401.
- Search for Solar Axions via Axion-Photon Coupling with the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **129**, 081803 (2022) doi: 10.1103/PhysRevLett.129.081803.
- First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment, J. Aalbers *et al*. (LZ Collaboration) submitted to *Phys. Rev. Lett.*
- Final Result of the MAJORANA DEMONSTRATOR's Search for Neutrinoless Double-β Decay in ^{76}Ge, I. J. Arnquist *et al*. (MAJORANA Collaboration) submitted to *Phys. Rev. Lett.*
- Exotic dark matter search with the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration) submitted to *Phys. Rev. Lett.*

SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



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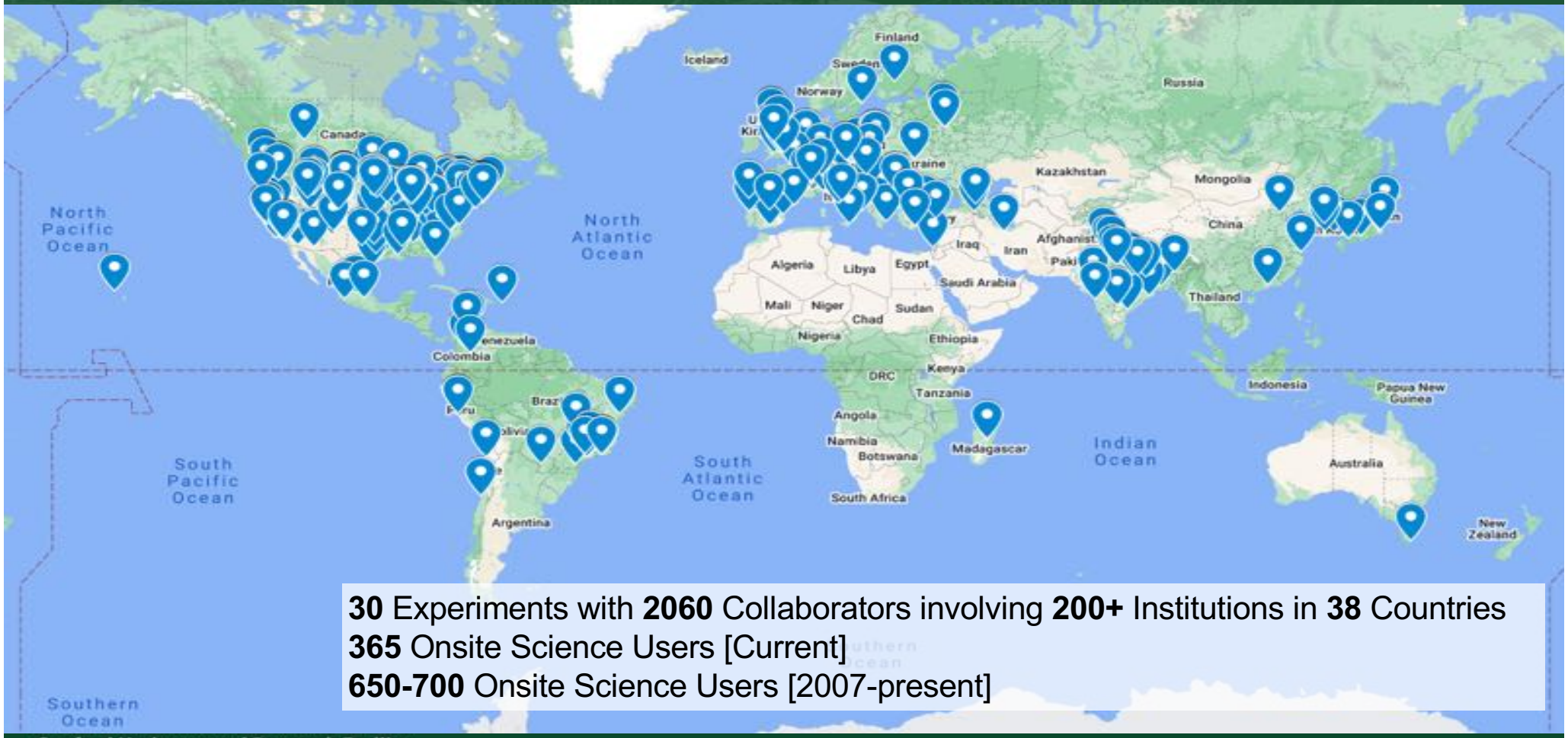


30 Experiments with **2060** Collaborators involving **200+** Institutions in **38** Countries
365 Onsite Science Users [Current]
650-700 Onsite Science Users [2007-present]

LUX-ZEPLIN (LZ)

Large Underground Xenon - ZonEd Proportional scintillation in Liquid Noble gases

- **Science Goal:** Direct dark matter search using dual-phase xenon (10 tonnes) in Ti cryostat surrounded by ultra-pure water and Gd liquid scintillator veto.
- **Collaboration:** 245 members, 35 institutions, lead = LBNL (DOE HEP).
- **Status:**
  - Onsite since Jul 2017 (as LUX since Nov 2009).
  - Commissioning completed in Nov 2021.
  - Production data started Dec 2021. First WIMP-search results announced Jul 2022 (world-leading), run #2 started.
- **Future:**
  - Complete science data ~2026, decommissioning ~2027. SURF ensuring Xe inventory available through 2027.
  - Meetings held with advocates for next-generation liquid Xe observatory for dark matter and neutrino physics (LZ and European) collaborators: http://arxiv.org/abs/2203.02309. Proposing up to ~100 tonnes Xe, site TBD. SURF expansion would work (size and nominal schedule ~2030).
  - Low-mass dark matter projects potential follow-ons to LZ.

MAJORANA DEMONSTRATOR (MJD)

Also Large Enriched Ge Experiment for Neutrinoless ββ Decay (LEGEND)

- **Science Goal:** Neutrinoless double-beta decay using 44 kg Ge in two cryostats, 30 kg enriched ^{76}Ge inside compact shield (poly + Pb + Cu); also LEGEND R&D and more recently rare decays (^{180m}Ta).
- **Collaboration:** 67 members, 20 institutions, lead = ORNL (DOE NP).
- **Status:**
  - Onsite at SURF since Nov 2010.
  - Achieved 65 kg-yr exposure (2015-2021), final 0νββ result posted Jul 2022.
  - Rare decay search Ta-180m underway (started May 2022).
  - Davis Campus Cu electroforming now has 4 baths.
- **Future:**
  - Complete Ta-180m search: nominal plan for data taking was ~1 yr (2023), extension to 2024 recently requested.
  - More discussions needed for decommissioning.
  - Cu e-forming may expand to ~8-10 baths for LEGEND (and UG science community).
  - Ton-scale: 1 North America + 1 Europe, timeframe remains uncertain. SURF options incl LBNF?, expansion ~2030.

CASPAR

Compact Accelerator System for Performing Astrophysical Research

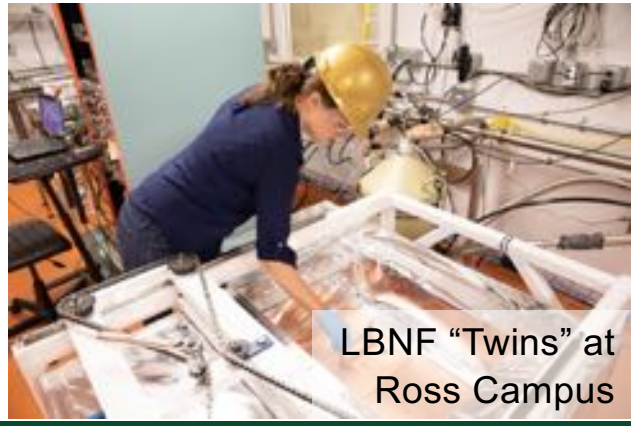
- **Science Goal:** Study of stellar nuclear fusion reactions, esp. neutron production for slow neutron-capture nucleosynthesis using 1-MV electrostatic accelerator for protons or alpha particles.
- **Collaboration:** 16 members, 5 institutions, lead = SD Mines (NSF MPS/PHY).
- **Status:**
  - Onsite at SURF since mid-2015, beam since 2017.
  - Data collected 2017-2021 with targets: ^{7}Li, ^{11}B, ^{14}N, ^{18}O, ^{20}Ne, ^{22}Ne (gas, solid), ^{27}Al.
  - Bkgd characterization, incl liquid scintillator neutron detectors (ORNL), ^{3}He and NaI arrays (Notre Dame).
  - Laboratory mothballed Apr 2021 due to LBNF construction.
- **Future:**
  - 9 scientific papers planned: 3 published (incl PRL), 1 submitted. Also: 3 students graduated, 3 in queue.
  - Planning for next phase of operation starting ~FY24 (4850L Ross Campus lab), targets incl ^{14}N (for CNO solar neutrinos).
  - NSF proposal in 2023 (resume ops with existing UND funds).

SURF Material Assay at BHUC

Black Hills State University Underground Campus

- **Science Support Goal:** Characterize radiopurity of experiment components; also multi-disciplinary science support at Ross Campus.
- **Collaboration:** 14 members, 7 institutions, lead = BHSU (institutional funding, some DOE support via experiments like LZ).
- **Status:**
  - Onsite since Sep 2015 (previous low-bkgd efforts with CUBED starting Apr 2013 at Davis Campus).
  - Ross Campus operations Sep 2015 – Jul 2020. Laboratory mothballed Mar 2021 due to LBNF construction.
  - Initial operations at Davis Campus starting Nov 2020 after SURF-supported cooling upgrades. Samples resumed Mar 2021.
  - Five of six counter systems operating, incl LLNL dual-crystal system. Recent samples incl protoDUNE, also IceCube and CUPID.
- **Schedule:**
  - Operation of all six detector systems. Possible addition of 7th detector (Ge-V).
  - Limited space for expansion at Davis Campus. Return to Ross Campus in ~FY24 following LBNF construction.

LLNL detector commissioning at Davis Campus



LBNF “Twins” at Ross Campus

EGS Collab / SIGMA-V

Stimulation Investigations for Geothermal Modeling Analysis and Validation

- **Science Goal:** Study enhanced geothermal system (EGS) effects on 10-meter scale. Pressure systems used to isolate sections of holes and flow water between holes; also biology sampling.
- **Collaboration:** 128 members, 23 institutions, lead = LBNL (DOE Office of Energy Efficiency and Renewable Energy (EERE), Geothermal Technology Office (GTO)).
- **Status:**
  - Onsite since Oct 2017 (as kISMET since Jun 2016).
  - 4850L: 8x holes drilled (each 60 m), stimulation/flow studies completed, site decommissioned (in future, possibly re-use 2 EGS holes, also 5x kISMET holes).
  - 4100L: 2x initial holes plus 9x holes completed Jan-Aug 2021 (180-265 m long). Some SURF prep (incl modest excavation). Stimulation/flow tests finished Aug 2022.
- **Schedule:**
  - Decommissioning to be complete in Dec 2022.
  - Interest from Earth science community in 4100L site, incl DOE/ Geothermica (Summer 2023). ARPA-E TBD (4100L? Oct 2023).

SIMFIP tool installed on 4100L

DOE-SC BES program manager visit

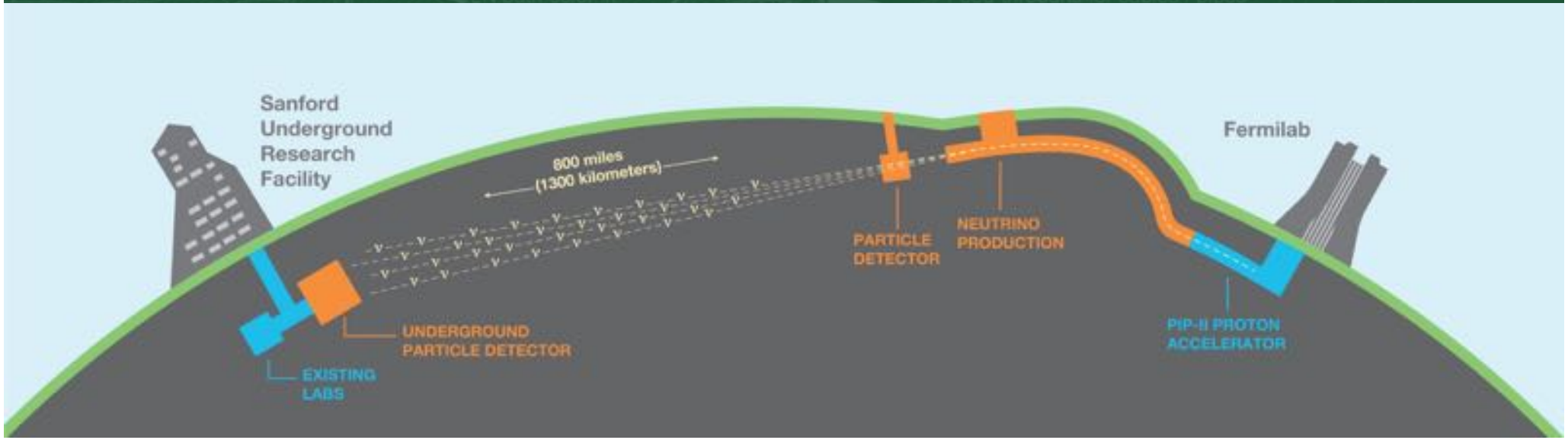
CAT
Caterpillar Underground Research Center (Engineering / Industrial Partnerships)

SURF 1700L/1550L space renovated to support underground R&D and customer experience

- **Renovation:** Former motor & loader barns, 3000-foot ramp. Total of 17,000+ rock bolts, 3000+ welded-wire mesh panels.
- **MineStar tracking technology:**
  - Goal is to validate, demonstrate, and educate how system can integrate with customer facility needs.
  - Over 1 mile of MineStar technology distributed throughout 1700L and 7 Ledge ramp to 1550L.
  - 6 utility vehicles currently UG at SURF using MineStar technology.
  - Site-wide tracking system in development.

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)



Origin of matter: Investigate CP violation. Are neutrinos the reason the universe is made of matter?

Supernova explosions and black hole formation: Ability to observe neutrinos from supernovae events and neutron star (or possibly black hole!) formation in real time.

Unification of forces: Investigate nucleon decay, advance unified theory of energy and matter.

SURF Proposed Near-Term Expts – Physics

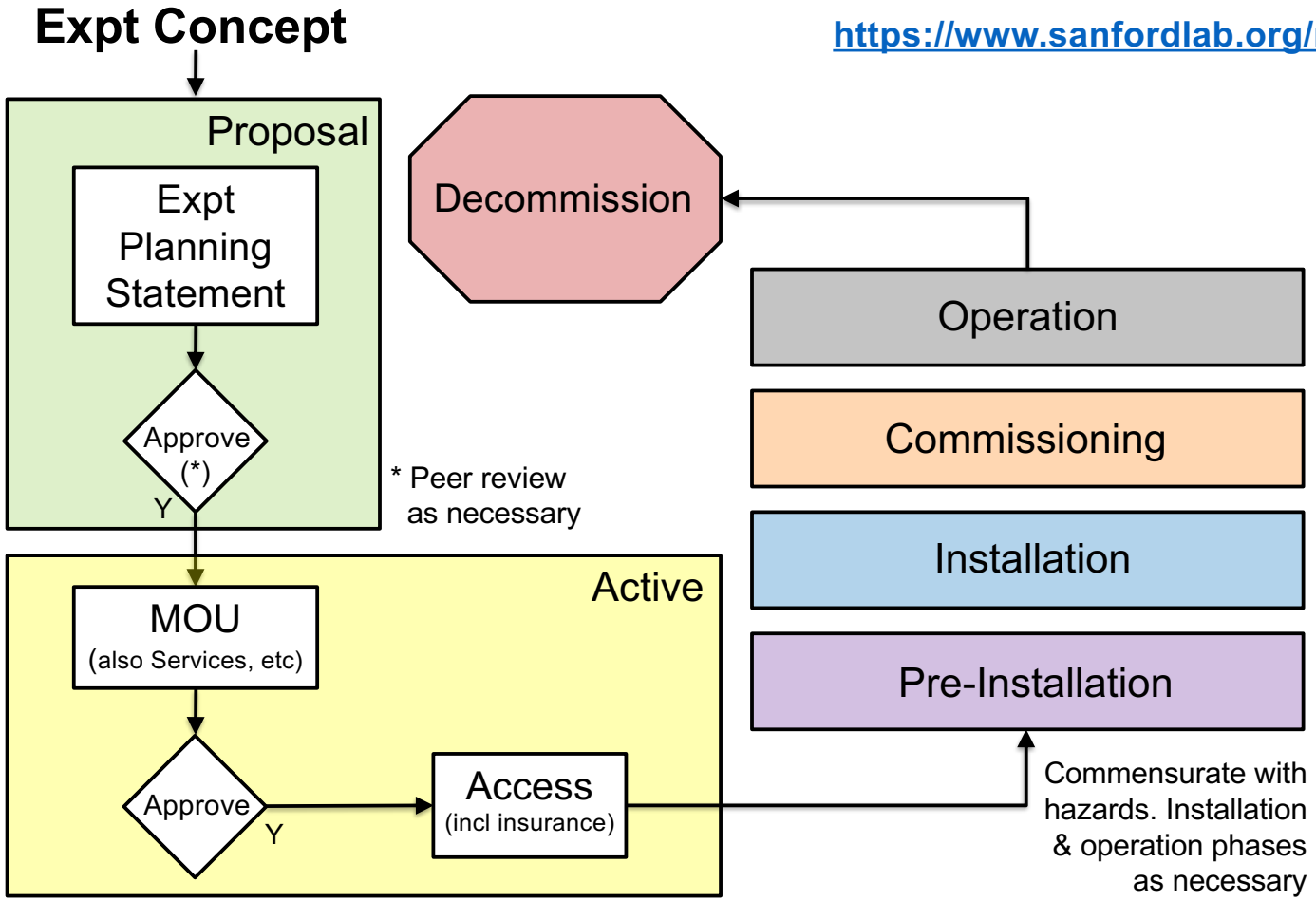
Experiment	Description	Location(s)	Funding Source	Status
Physics: TESSERACT	Low-mass dark matter using Al_2O_3, GaAs, LHe	4850L Davis Campus	DOE HEP, other?	Regular discussions and updates, incl encouraging R&D results. Exploring resources to advance project schedule (DOE funding profile supports FY26 start).
Physics: Scintillating Bubble Chamber	Low-mass dark matter using Ar and CF_4	4850L Davis Campus	DOE HEP, FNAL LDRD	Exploring opportunities for space at SURF (nominal sites are FNAL and SNOLAB), likely timeframe ~2024.
Physics: Theia	Water-based liquid scintillator neutrino studies	4850L	NSF Mid-scale Research Infrastructure-1 (design phase submission Jan 2023)	Interactions regarding site integration and broader impacts.
Physics: Germanium Lab	Laboratory for Ge zone refining, growth, mechanical processing, detector fabrication	Evaluating options: 800L, 2000L, 2300L	NSF Mid-scale Research Infrastructure-1 (design phase submission Jan 2023)	Iterations on documentation, incl requirements, onsite activities ~Fall 2023.
Physics: Rare Backgrounds	Collect alpha, gamma, neutron data using a variety of detectors (incl R&D)	4850L (nominally Davis Campus)	ARPA-E	Onsite activities late 2023 or 2024.
Physics: Cryogenic Test Facility	Dilution refrigerator (dry) to support detector R&D	4850L (nominally Davis Campus)	NSF MRI (submission late 2022)	Onsite activities late 2023 or 2024.
Physics: NEMESIS	Indirect Detection of dark matter using neutron multiplicity spectra	4850L (considering migration from Callio Lab, 210 mwe)	DOE Financial Assistance (submitted Fall 2022)	Expression of interest Sep 2022.
Physics: Various (Texas, Midwest, UNLV/NEMESIS)	Student diversity in STEM	Various	DOE RENEW-HEP (submitted Summer 2022)	Expression of interest Jul/Aug 2022.

SURF Proposed Near-Term Expts – BGE

Experiment	Description	Location(s)	Funding Source	Status
Geology: DEMO-FTES	Demonstrate feasibility of fracture thermal energy storage through numerical, laboratory, and small-scale field tests	4100L (re-using EGS/ SIGMA-V infrastructure)	Geothermica (-> DOE EERE-GTO)	Iterations on documentation underway, onsite activities start ~Summer/Fall 2023.
Geology: Eden Geopower	Electro-hydraulic fracturing for enhanced geothermal systems, R&D for FORGE proposals	4850L or 4100L (possibly 2300L or 2000L)	DOE ARPA-E (OPEN, MINER), (also DOE EERE-GTO submission in 2023)	Site visit Oct 2022, iterations on documentation, onsite activities (incl drilling new holes) ~Oct 2023.
Geology: Geochemistry	Black Hills water geochemistry, incl SURF	Possibly some DeMMO sites (800L, 4100L, 2000L, 4850L)	NASA Project Innovation Grant (PIG)	Expression of interest Nov 2022.
Geology: In-Situ Stress	Validation of methods for measuring in-situ stress fields	Surface core archive, Thermal Breakout	Institutional	Expression of interest May 2022.
Biology: Drinkable Water for Space Exploration	In-situ water generation using a stackable reactor design for deep-space exploration	TBD	NASA EPSCoR (submitted early 2022)	Expression of interest Jan 2022.
Biology/ Engineering: Microbe-Assisted Environmental Remediation	Phytoremediation-based ventilation system for removing blast-induced pollutants	4850L	NSF EPSCoR Track 1 (submitted Summer 2022)	Expression of interest Jul 2022.
Biology/ Engineering: SD Biomining Science and Engineering Center	Engineering tools for discovering novel microporganisms, incl extremophiles	TBD	NSF RII Track 1 planning grant (submitted Summer 2022)	Expression of interest Jun 2022.
Engineering: Intelligence Information Systems	Underground sensor technology	TBD	DOD	Expression of interest Nov 2022.

SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework

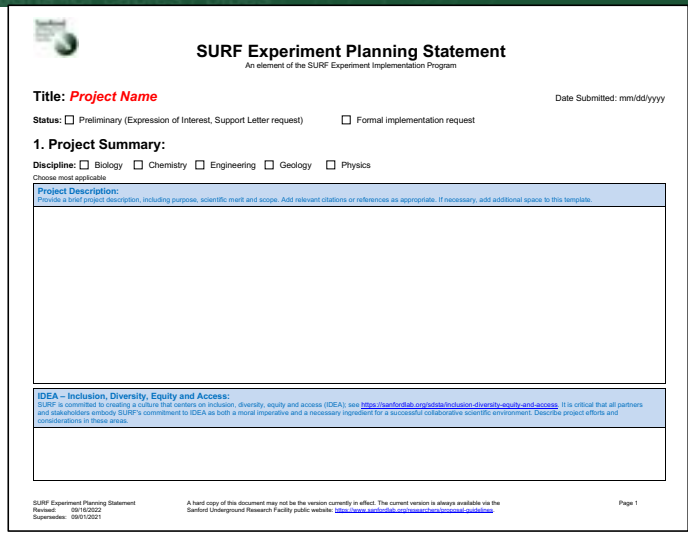


https://www.sanfordlab.org/researchers/proposal-guidelines

Experiment Implementation Program

Experiment Planning Statement: Two-way communication

1. **Project Summary**
   - Discipline, description (purpose, scientific merit), IDEA, funding, personnel
2. **Expt Equipment**
   - General + various categories (chemicals, radioactive materials, etc)
3. **Experiment Area and Infrastructure Needs**
   - Location, space, site preparations/environment/(trip?), services, logistics
   - Guidance on cage dimensions, some electrical
4. **Hazards and Integrated Safety Management**
   - Table of potential risks, identifies special training or permit requirements
5. **Personnel Access:**
   - Personnel schedule and access requirements as function of time (max/min)
   - Guidance on standard cage times
6. **Experiment Schedule**
   - Experiment schedule, incl phase such as installation, commissioning, ops
7. **Experiment Operations**
   - What-If… scenarios (access, ventilation, water, power, cyber, excavation…)
8. **Decommissioning**



SURF Experiment Planning Statement

An element of the SURF Experiment Implementation Program

Title: *Project Name* Date Submitted: mm/dd/yyyy

Status: ☐ Preliminary (Expression of Interest, Support Letter request) ☐ Formal implementation request

1. Project Summary:

Discipline: ☐ Biology ☐ Chemistry ☐ Engineering ☐ Geology ☐ Physics

Choose most applicable

Project Description:

Provide a brief project description, including purpose, scientific merit and scope. Add relevant citations or references as appropriate. If necessary, add additional space to this template.

IDEA – Inclusion, Diversity, Equity and Access:

SURF is committed to creating a culture that centers on inclusion, diversity, equity and access (IDEA); see https://sanfordlab.org/sdsta/inclusion-diversity-equity-and-access. It is critical that all partners and stakeholders embody SURF's commitment to IDEA as both a moral imperative and a necessary ingredient for a successful collaborative scientific environment. Describe project efforts and considerations in these areas.

SURF Experiment Planning Statement
Revised: 09/16/2022
Supersedes: 09/01/2021

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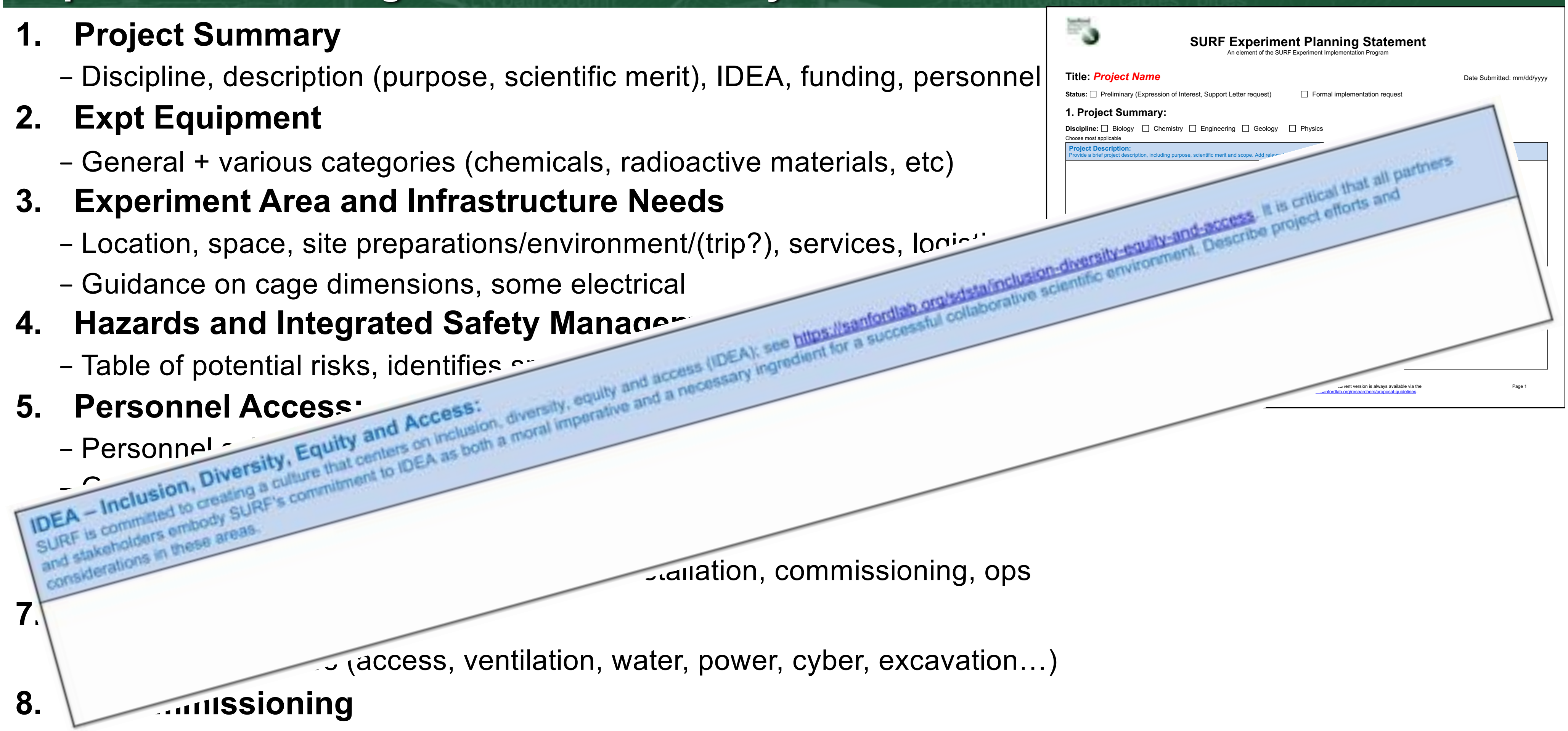

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Status: ☐ Preliminary (Expression of Interest, Support Letter request) ☐ Formal implementation request

1. Project Summary:

Discipline: ☐ Biology ☐ Chemistry ☐ Engineering ☐ Geology ☐ Physics

Choose most applicable

Project Description:

Provide a brief project description, including purpose, scientific merit and scope.

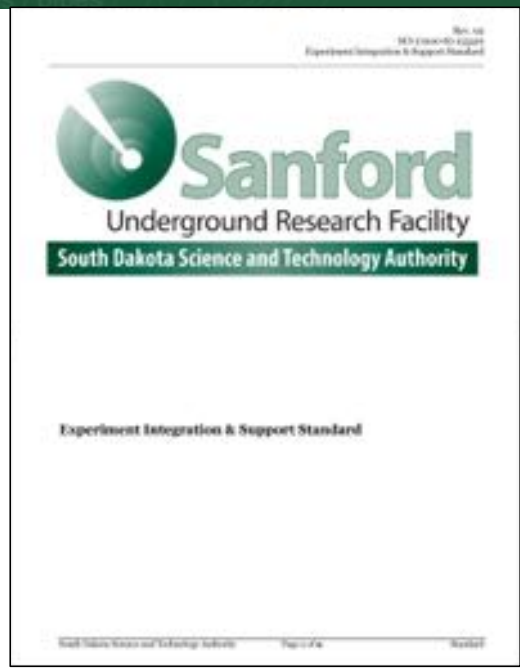
Page 1

IDEA – Inclusion, Diversity, Equity and Access:

SURF is committed to creating a culture that centers on inclusion, diversity, equity and access (IDEA); see https://sanfordlab.org/sdsta/inclusion-diversity-equity-and-access. It is critical that all partners and stakeholders embody SURF's commitment to IDEA as both a moral imperative and a necessary ingredient for a successful collaborative scientific environment. Describe project efforts and considerations in these areas.

Experiment Integration & Support
Overview

- **General:**
  - In partnership with research groups, SDSTA aims to maintain a robust **organization with resources** to promote **safe and successful** experiment operations at SURF
- **Responsibilities:**
  - **Experiment Point of Contact:** Science dept representative assigned to assist in navigating the experiment implementation process and help identify points of contact within other SURF departments as needed
  - **Laboratory Coordinator:** Communication, safety oversight, emergency response
  - **Radiation/Experiment Health & Safety Manager:** ESH dept point of contact for experiment groups (+ support by others)
  - **Operations:** Support for access and facilities (incl engineering, electrical, IT, maintenance, etc); also nominal support for expt installation/integration planning



- **Other Elements:**
  - **Support:** Formalize basic expt support (per DOE guidance), incl safe access, space appropriate for science, communication/network equipment, science/engineering liaison support; also machining services
  - **Facility Access:** Typical schedules, facility guides, emergency access
  - **Planning & Communication:** Shipping & transport, work planning, shift reports, incident reports, evacuation drills

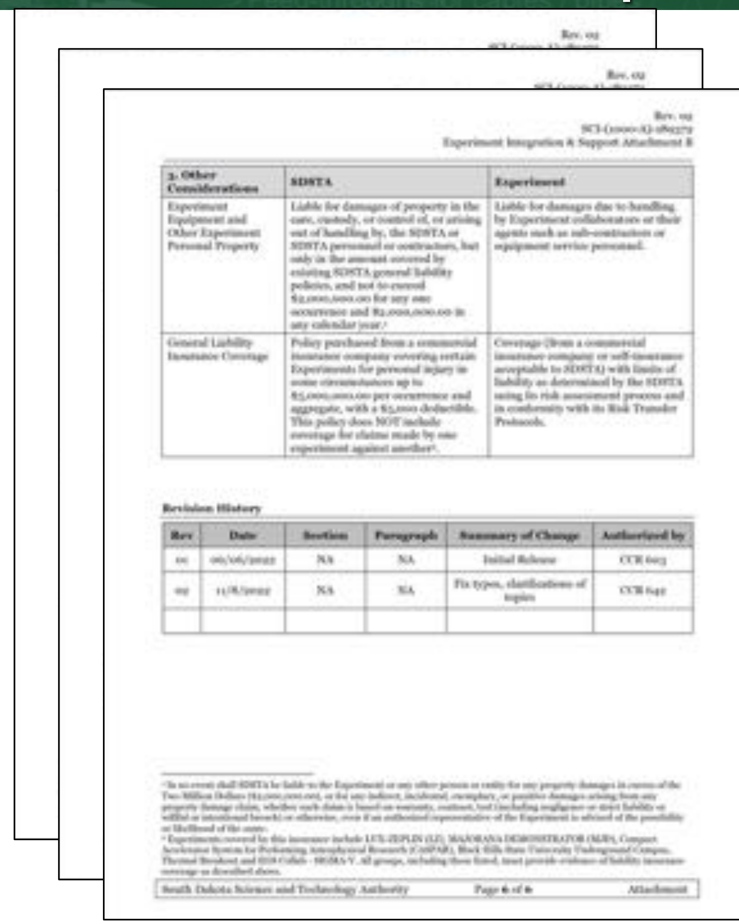
Experiment Integration & Support

Basic support, responsibilities and expectations for SURF and Experiment

Rev. 02
SCI-(0000-A)-189272
Experiment Integration & Support Attachment B

General Staging, Preparation & Storage (Surface)	• Receiving, shipping. • Approval for heated/cold staging, preparation & storage of equipment and materials as appropriate and as space available.	• Costs, packing. • Coordination and advance information on all shipments. • Request approval for staging, preparation & storage space.
General Staging, Preparation & Storage (Underground)	• Receiving (some), shipping arrangements. • Approval for staging, preparation & storage of equipment and materials as appropriate and as space available. • Maintenance of space.	• Costs, packing, specialized storage (except as noted), including maintenance. • Provide advance information on all shipments. • Request approval for storage.
General Transportation	• Shipping arrangements to designated areas using existing transport vehicles. • Regulatory shipping guidance and preparations that can be provided by SDSTA staff.	• Packing (with regulatory exceptions). • Specialized transport vehicles (except as noted). • Provide advance information on all incoming and outgoing shipments. • Costs associated with shipping goods.
Procurement	• As appropriate and as requested (subject to overhead).	• Approved by Experiment PI or designee.
Security	• System maintenance and access management.	• Compliance with SDSTA access requirements and ensuring personnel status updated.
Emergency Support	• Emergency Response Team (ERT) staffing for 24-hour coverage. • Refuge Chamber: equipment, training and capacity, as appropriate. • Standby power (diesel generator) for fire and life safety, as appropriate.	
PPE	Equipment, maintenance, and training as appropriate for: • General underground PPE: cap lamp, hard hat (with cap lamp mounting hardware as required), non-prescription safety glasses with side shields, coveralls, utility belt or small backpack. • Clean PPE: Hard hat (with cap lamp mounting hardware as required). • Self-rescuer. • Self-contained self-rescuer. • Fall arrest and fall restraint equipment.	• Compliance with SDSTA PPE policy and inventory control system. • General underground PPE: safety-toe footwear, prescription safety glasses with side shields. • Clean PPE: all except items provided by SDSTA, including safety-toe footwear. • Self-rescuer: compliance with monitoring program. • Specialized cleanroom PPE: All, including dedicated hard hats for Experiment-specific clean spaces as necessary.

South Dakota Science and Technology Authority | Page 3 of 6 | Attachment



Rev. 02
SCI-(0000-A)-189272
Experiment Integration & Support Attachment B

3. Other Considerations	SDSTA	Experiment
Experiment Equipment and Other Experiment Personal Property	Liable for damages of property in the care, custody, or control of, or arising out of handling by, the SDSTA or SDSTA personnel or contractors, but only in the amount covered by existing SDSTA general liability policies, and not to exceed $2,000,000.00 for any one occurrence and $2,000,000.00 in any calendar year.[1]	Liable for damages due to handling by Experiment collaborators or their agents such as sub-contractors or equipment service personnel.
General Liability Insurance Coverage	Policy purchased from a commercial insurance company covering certain Experiments for personal injury in some circumstances up to $5,000,000.00 per occurrence and aggregate, with a $5,000 deductible. This policy does NOT include coverage for claims made by one experiment against another[2].	Coverage (from a commercial insurance company or self-insurance acceptable to SDSTA) with limits of liability as determined by the SDSTA using its risk assessment process and in conformity with its Risk Transfer Protocols.

Revision History

Rev	Date	Section	Paragraph	Summary of Change	Authorized by
01	06/06/2022	NA	NA	Initial Release	CCR 603
02	11/8/2022	NA	NA	Fix typos, clarifications of topics	CCR 642

[1] In no event shall SDSTA be liable to the Experiment or any other person or entity for any property damages in excess of the Two Million Dollars ($2,000,000.00), or for any indirect, incidental, exemplary, or punitive damages arising from any property damage claim, whether such claim is based on warranty, contract, tort (including negligence or strict liability or willful or intentional breach) or otherwise, even if an authorized representative of the Experiment is advised of the possibility or likelihood of the same.
[2] Experiments covered by this insurance include LUX-ZEPLIN (LZ), MAJORANA DEMONSTRATOR (MJD), Compact Accelerator System for Performing Astrophysical Research (CASPAR), Black Hills State University Underground Campus, Thermal Breakout and SUN Collab - SIGMA-V. All groups, including those listed, must provide evidence of liability insurance coverage as described above.

South Dakota Science and Technology Authority | Page 6 of 6 | Attachment

SURF Organization – Science Staffing

Resources to enable safe and successful implementation of experiments

Markus Horn (PhD)
Research Scientist
- Surface + UG Campuses

Charles Maupin (BSME, PE)
Expt Review Engineer
- Reviews, cryogen safety

Jaret Heise (PhD) – *Director*
- Manage dept and experiment implementation program

+ 1 in FY23

Mark Hanhardt (MS)
Expt Support Scientist
- Surface + UG Campuses

Gavin Cox (MS)
Expt Support Scientist
- LZ Operations

Robyn Varland - *Lab Custodians (Surface + UG)* - Melissa Johnston

Doug Tiedt (PhD)
Research Scientist
- Surface + UG Campuses

Julia Delgaudio (BS)
Expt Support Scientist
- LZ Operations

Recent SURF Conferences

May 11-13, 2022:
Conference on Science at SURF (SD Mines)
https://indico.sanfordlab.org/e/CoSSURF2022

Jun 14-17, 2022:
Low Radioactivity Techniques (SD Mines + SURF)
https://indico.sanfordlab.org/e/LRT2022

SURF User Association

https://www.sanfordlab.org/researchers/surfuserassociation (incl registration)

Purpose

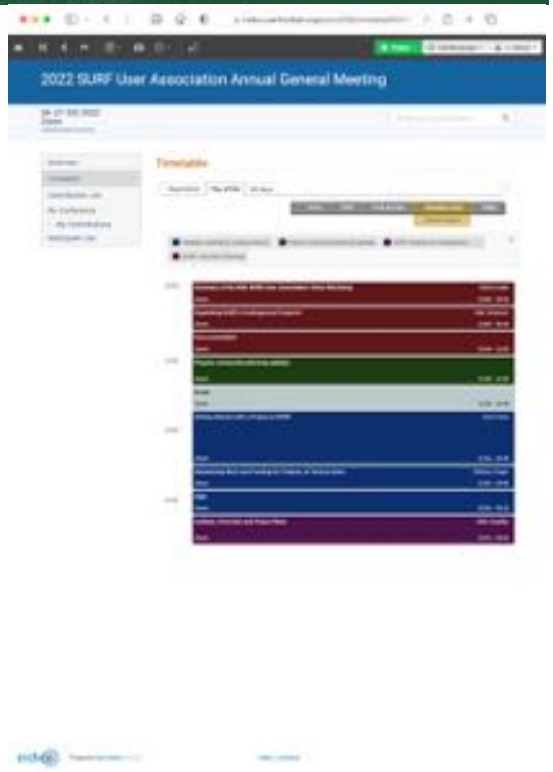
- **Two-way communication** on topics important to researchers.
- Promotes a **sense of community** amongst SURF experiments and researchers.
- Articulates and promotes **scientific case for UG science** and significance to society, provides channel for **advocacy.**

Organization

- **Membership** open to all UG science community.
- **Executive Committee** consists of 9 individuals across scientific disciplines, incl early career. Quarterly meetings with SURF Management.

Meetings

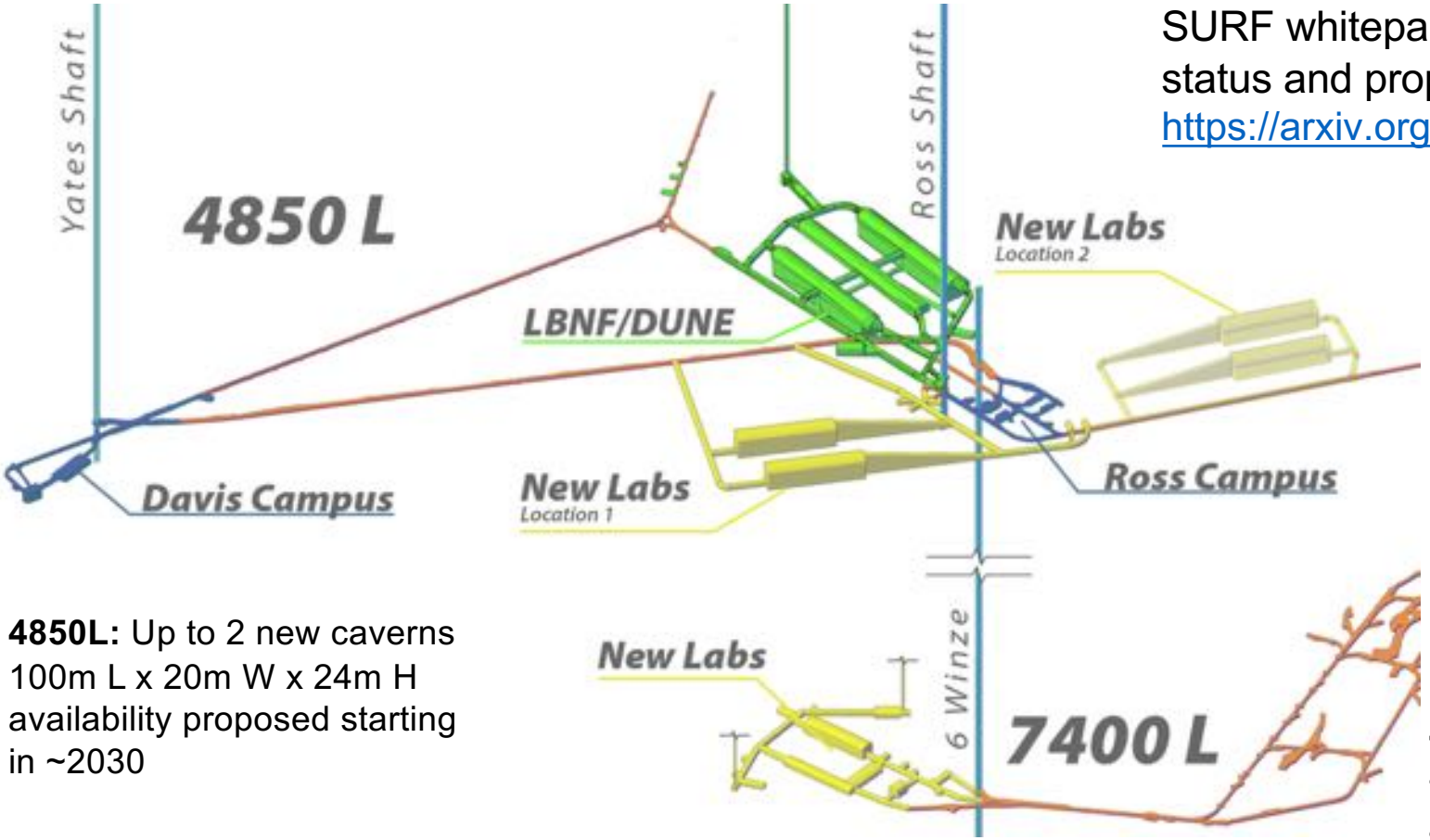
- **General meetings** held annually.
- **Topical workshops**, incl community planning (e.g., Vision Workshop 2021). Next workshops following P5, SURF lab expansion funding.



Oct 26-27, 2022:
SURF User Association General Meeting
https://indico.sanfordlab.org/e/SUA-Oct2022

SURF Current & Future Underground Facilities

Strategic plan incl additional 4850L labs + deeper access



SURF whitepaper describing current status and proposed future facilities: https://arxiv.org/abs/2203.08293

4850L: Up to 2 new caverns 100m L x 20m W x 24m H availability proposed starting in ~2030

7400L: Caverns (nominal) 75m L x 15m W x 15m H schedule TBD

SURF Current & Future Facilities

Summary for various science campuses, including timelines

Location	Laboratory	Existing/*Planned* Space		Available (CY)	Comments
		Area (m^2)	Vol (m^3)		
Surface	Surface Lab (+ RRS)	210	600	2021	LZ use ~complete, allowing use by others
Davis Campus (4850L)	LZ Lab – Davis Cavern (2 levels)	372	1,956	~2027	LZ data complete in ~2026 + decommissioning
	MJD Lab – 2 Rooms + BHUC share	300	1,279	~2024/2026	Initial scope completed 2021, Ta-180m data 2022-2023 + decommissioning; Cu e-forming through 2025+
	Cutout Rooms (4)	100	412	~2027	LZ timeframe for most spaces
Ross Campus (4850L)	Former E-forming	228	742	?	LBNF use now, SURF UG WWTP in next few years
	BHUC (BHSU cleanroom)	266	773	N/A	Mothballed, equip and systems relocated to Davis Campus; re-occupy FY24 after LBNF construction
	CASPAR	395	1,130	2029-2031	Mothballed, equip remains, re-occupy FY24 after LBNF construction. (Also expanded Refuge Chamber)
	Refuge Chamber	258	866	?	Long-term use TBD
LBNF (4850L)	*LBNF*	*9,445*	*191,863*	*~2030?*	*Excavation complete in 2023, temporary use?*
4100L	Geoscience Lab	334	11 drill holes	Fall 2022	Leverage EGS/SIGMA-V infrastructure
4850L	*New Labs (2 proposed)*	*4,022*	*94,608*	*Earliest new: ~2030*	*Each 20m (W) x 24m (H) x 100m (L)*
7400L	*New Labs (2 proposed)*	*4,178*	*42,440*		*Each 15m (W) x 15m (H) x 75m (L) + other supporting*

Summary

- SURF offers world-class service to the UG science community:
  - SURF has **DOE mandate** to support experiments with basic level of support, funding for operations and infrastructure promotes reliability. Anticipating User Facility designation in 2023.
  - SURF has **attracted** world-leading experiments and scientists from diverse scientific communities.
  - SURF has **proven track record** of enabling experiments to deliver high-impact science.
- SURF processes ensure world-class service to the UG science community:
  - **Experiment Implementation Program:** Identifies interfaces and hazards within an approval framework commensurate with experiment hazards.
  - **Experiment Integration & Support:** Partnership with experiments and leveraging organization resources to promote safe and successful experiment operations at SURF.
- In addition to DUNE, SURF wants to host other future world-leading experiments:
  - SURF facility offers opportunities and space for diverse science, incl new proposals
  - Discussions underway with several new groups
  - SURF is actively exploring options to increase underground laboratory space, plans advancing for new large caverns on 4850L (1500 m, 4200 mwe)
- SURF is playing a strong role in the UG science community:
  - In particular, SURF **User Association** is serving as catalyst for discussions, will leverage for future planning

Sanford Underground Research Facility

Thank You!

Jaret Heise – Science Director

- **14 years** SDSTA Science Director
- **19 years** science management experience
- **26 years** experience in underground science

  Participation in Sudbury Neutrino Observatory (SNO) experiment (6800-ft level of active nickel mine, now SNOLAB), which resolved Solar Neutrino Problem first posed by Ray Davis Homestake Chlorine Experiment
  - Univ BC PhD Student at SNO (detector construction, supernova neutrino search)
  - LANL Postdoctoral Researcher at SNO (led neutron detector installation)
  - Queen's Univ SNO Detector Operations Manager (member of onsite management team)

Sanford Underground Research Facility

Where in the world is SURF?

SURF Science Strategic Planning

SURF Snowmass whitepaper reflects UG science community input

- SURF advocates for DOE panel recommendations:
  - Mission need for **additional deep laboratory space** in U.S. (incl depths > 6000 m.w.e.) in U.S. to support compelling future science
  - Mission need for a next-generation (~100 tonne) **dark matter** and **neutrino** observatory in U.S.
  - Establish process to **optimize scientific use of UG spaces** at SURF, incl temporary use of LBNF module as appropriate
  - Endorse value of **multi-disciplinary underground science** at a dedicated laboratory in U.S.
- Additional underground space proposed:
  - **4850L** (1500 m, 4300 m.w.e), **7400L** (2300 m, 6500 m.w.e.)
  - Initial engineering designs completed
  - Excavation for **100-m cavern(s)** could begin as early as 2027, first cavern **complete by ~2030**
- Other:
  - Operational details (incl conveyance specs, storage/staging, etc)
  - Ross Campus occupancy resuming FY24

The Sanford Underground Research Facility

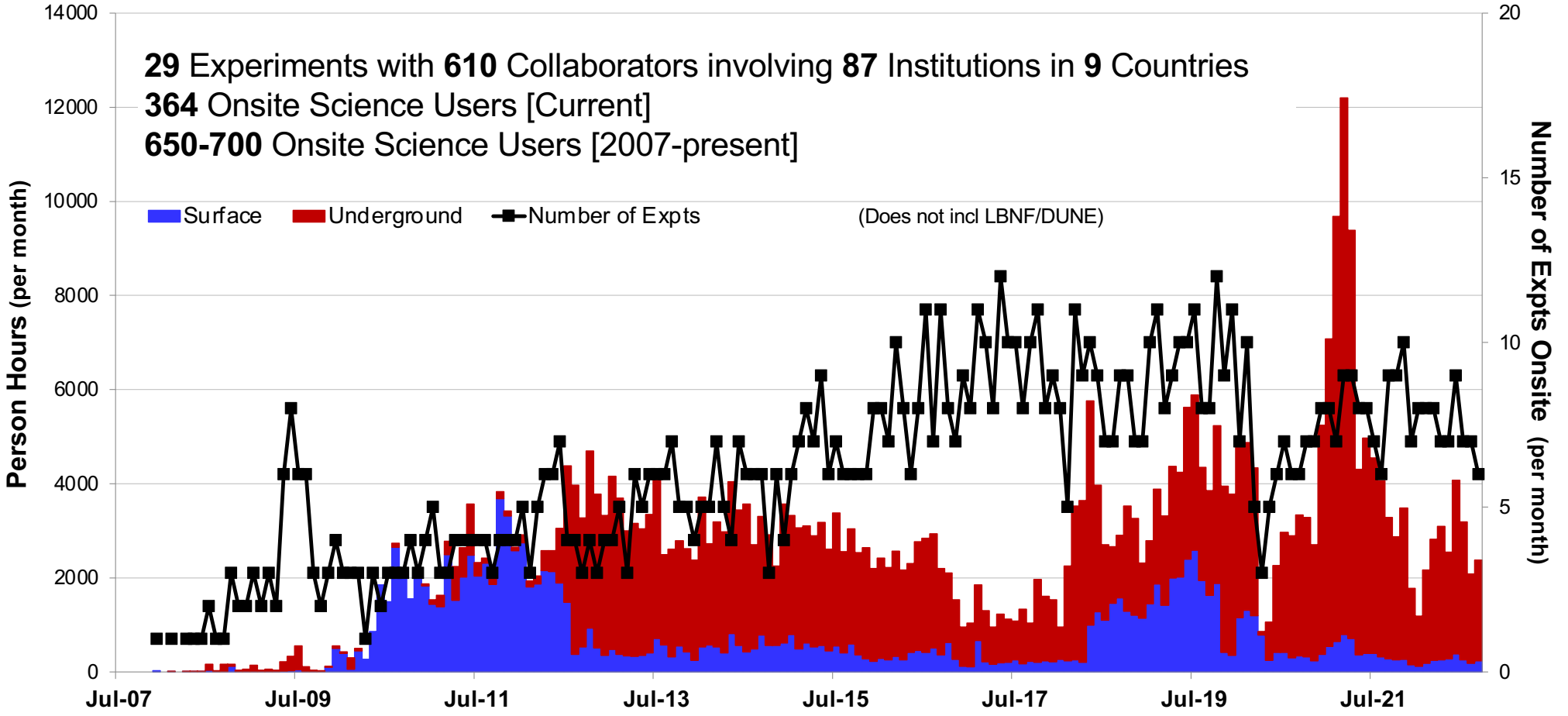
J. Heise

Executive Summary

UG science community input from SURF Vision Workshop held Sep 2021, https://indico.sanfordlab.org/e/Vision2021

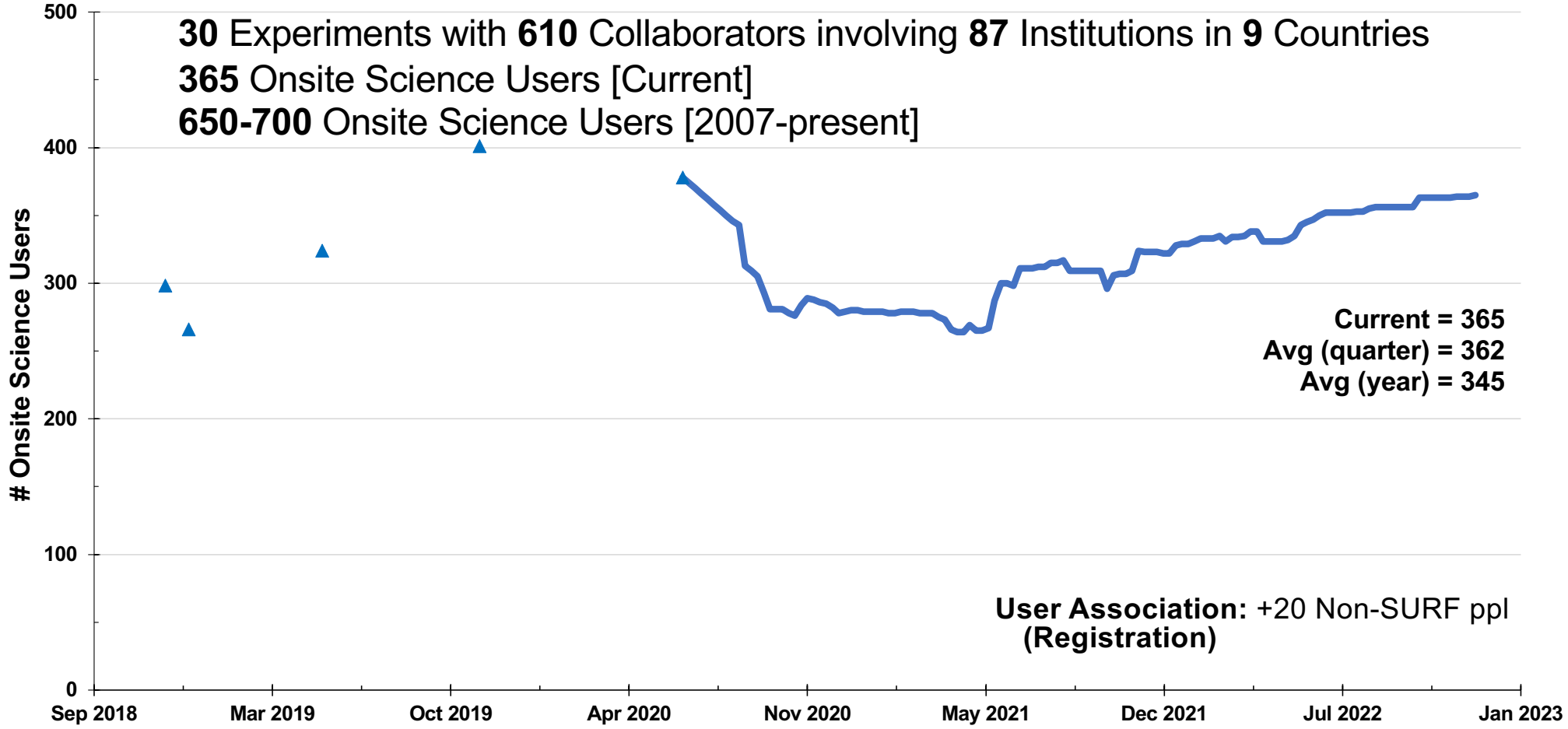
SURF Science Program

Research activities ranging from the surface to 1500+m underground



SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



SURF Science Program

Researchers from 87 institutions (Pre-DUNE), active in bold (61)

United States

- **Black Hills State University, Spearfish, SD**
- **Brandeis University, Waltham, MA**
- **Brookhaven National Laboratory, Upton, NY**
- **Brown University, Providence, RI**
- Caltech, Pasadena, CA
- **Caterpillar Global Mining, LLC, East Peoria, IL**
- Colorado School of Mines, Golden, CO
- **Department of Energy (EERE), Washington, DC**
- **Desert Research Institute, Las Vegas, NV**
- **DTRC, Lead, SD**
- **Duke University / TUNL, Durham, NC**
- **Fermi National Accelerator Lab, Batavia, IL**
- **Golder Associates, Inc., Redmond, WA**
- **Idaho National Laboratory, Idaho Falls, ID**
- **Indiana University, Bloomington, IN**
- Jet Propulsion Laboratory, Pasadena, CA
- **Lawrence Berkeley National Lab, Berkeley, CA**
- **Lawrence Livermore National Lab, Livermore, CA**
- Liberty BioSecurity, LLC, Arlington, VA
- **Los Alamos National Lab, Los Alamos, NM**
- **Mattson Hydrology LLC, Victor, ID**
- McClure Geomechanics, Palo Alto, CA
- **Montana State University, Bozeman, MT**
- National Energy Technology Lab, Albany, OR / Morgantown, WV
- National Renewable Energy Lab, Golden, CO
- **North Carolina State University, Raleigh, NC**
- **Northwestern University, Evanston, IL**
- **Oak Ridge National Lab, Oak Ridge, TN**
- **Pacific Northwest National Lab, Richland, WA**
- **Pennsylvania State University, State College, PA**
- **Primo, Lead, SD**
- **RE/SPEC, Rapid City, SD**
- Rensselaer Polytechnic Institute, Troy, NY
- **Rice University, Houston, TX**
- Rutgers University, Piscataway Township, NJ
- **Sandia National Laboratories, Albuquerque, NM**
- **South Dakota School of Mines & Technology, Rapid City, SD**
- **Spearfish School District, Spearfish, SD**
- **SLAC National Accelerator Lab, Menlo Park, CA**
- **Stanford University, Stanford, CA**
- Tennessee Tech University, Cookeville, TN
- Texas A&M University, College Station, TX
- US Geological Survey, Rapid City, SD / Tucson, AZ

US – continued

- **University at Albany/SUNY, Albany, NY**
- **University of Alabama, Tuscaloosa, AL**
- **University of California Berkeley, Berkeley, CA**
- **University of California Davis, Davis, CA**
- **University of California Los Angeles, Los Angeles, CA**
- **University of California Santa Barbara, Santa Barbara, CA**
- **University of Kentucky, Lexington, KY**
- **University of Maryland, College Park, MD**
- **University of Massachusetts, Amherst, MA**
- **University of Michigan, Ann Arbor, MI**
- **University of North Carolina, Chapel Hill, NC**
- **University of Notre Dame, Notre Dame, IN**
- **University of Oklahoma, Norman, OK**
- **University of South Carolina, Columbia, SC**
- **University of South Dakota, Vermillion, SD**
- **University of Southern California, Los Angeles, CA**
- **University of Rochester, Rochester, NY**
- University of Tennessee, Knoxville, TN
- University of Utah, Salt Lake City, UT
- **University of Wisconsin – Madison / Physical Sciences Lab, Madison, WI**
- **University of Washington, Seattle, WA**
- USDA NCAUR, Peoria, IL
- WD Masonry, Rapid City, SD
- Williams College, Williamstown, MA
- Xilinx, Inc., San Jose, CA
- Yale University, New Haven, CT

World (Non-US)

- **Center for Underground Physics (IBS), Daejeon, Korea**
- Joint Institute for Nuclear Research, Dubna, Russia
- **Imperial College London, London, England**
- **LIP Coimbra, Coimbra, Portugal**
- NRC Institute for Theoretical and Experimental Physics, Moscow, Russia
- Osaka University, Osaka, Japan
- Queen's University, Kingston, Canada
- **Royal Holloway and Bedford New College, Egham, England**
- **Rutherford Appleton Laboratory, Didcot, England**
- Technische Universitat Munchen / Max Planck Institute, Munich, Germany
- **University College London, London, England**
- **University of Bristol, Bristol, England**
- **University of Edinburgh, Edinburgh, Scotland**
- **University of Liverpool, Liverpool, England**
- **University of Oxford, Oxford, England**
- **University of Sheffield, Sheffield, England**

SURF User Association

https://www.sanfordlab.org/researchers/surfuserassociation

Purpose

- **Two-way communication** on topics important to researchers.
- Promotes a **sense of community** amongst SURF experiments and researchers.
- Articulates and promotes **scientific case for UG science** and significance to society, provides channel for **advocacy.**

Organization

- **Membership** open to Underground Science Community (initially was limited to active SURF researchers). General meetings held at least annually.
- **Executive Committee** consists of 9 individuals across scientific disciplines, incl early career. Two-year terms (with term overlap), limits per experiment and institution. Quarterly meetings held with SURF Mgmt.

1. Brittany Kruger (DRI/**Chair**)
2. Megan Smith (LLNL/**Secretary**)
3. Mark Hanhardt (SDSTA)
4. Kevin Lesko (LBNL)
5. Rachel Mannino (LLNL)
6. Ralph Massarczyk (LANL)
7. Sam Meijer (LANL)
8. Brianna Mount (BHSU)
9. Frank Streider (SD Mines)
10. Wenqin Xu (USD)

Status

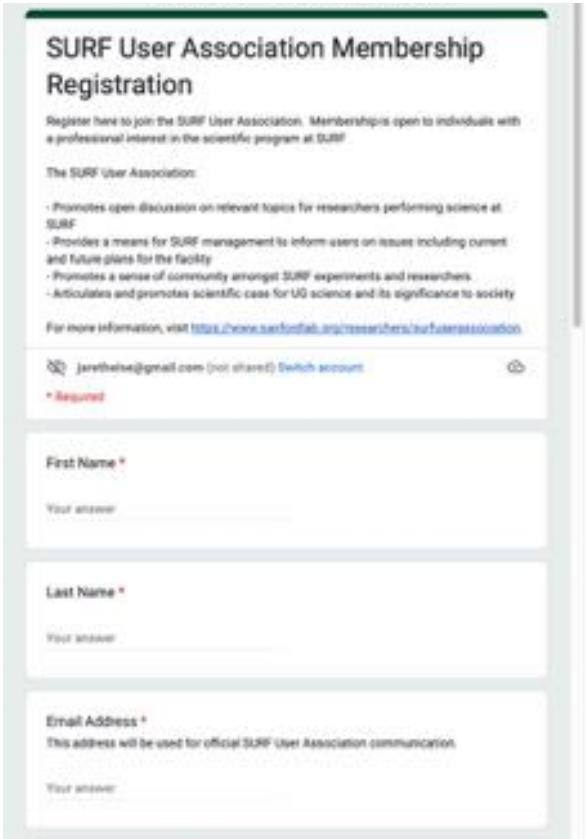
- **Established** Dec 2020, operating well. **Executive Committee** elections conducted successfully (2020, 2021), 2022 soon!
- **Charter** updated in Aug 2021 to broaden membership to **global underground science community**. Subcommittee ratified new registration process in Apr 2022, form linked on SURF website and advertised to community. Expanded membership will increase SURF's prominence and leadership in global UG science community.
- **Charter** updated Oct 2022 to increase **minimum representation** from various disciplines. Charter update in progress to facilitate meetings and clarify institutional restrictions.
- Association organized SURF **Vision Workshop** Sep 2021. **General Meetings** held Sep 2021, Oct 2022.

SURF User Association Executive Committee

Name	Field	Experiment	Institution	Notes	Term Expiry
Mark Hanhardt	Physics	CASPAR	SURF	Early Career	Dec 2022
Brittany Kruger	Biology	DeMMO	Desert Research Institute	**Chair**	Dec 2023
Kevin Lesko	Physics	LZ	Lawrence Berkeley Natl Lab		Dec 2022
Rachel Mannino	Physics	LZ	Univ of Wisconsin-Madison	Early Career	Dec 2022
Ralph Massarczyk	Physics	MJD/LEGEND	Los Alamos Natl Lab	Post-Chair	Dec 2022
Sam Meijer	Physics	MJD/LEGEND	Los Alamos Natl Lab		Dec 2023
Brianna Mount	Physics	BHUC	Black Hills State University		Dec 2022
Megan Smith	Geology	EGS Collab	Lawrence Livermore Natl Lab	**Secretary**	Dec 2023
Frank Strieder	Physics	CASPAR	South Dakota Mines		Dec 2023
Wenqin Xu	Physics	MJD	University of South Dakota		Dec 2022

SURF User Association

Expanded membership registration (incl some demographics)


SURF User Association Membership Registration

Register here to join the SURF User Association. Membership is open to individuals with a professional interest in the scientific program at SURF.

The SURF User Association:

- Promotes open discussion on relevant topics for researchers performing science at SURF
- Provides a means for SURF management to inform users on issues including current and future plans for the facility
- Promotes a sense of community amongst SURF experiments and researchers
- Articulates and promotes scientific case for UG science and its significance to society

For more information, visit https://www.sanfordlab.org/researchers/surfuserassociation

jarettheise@gmail.com (not shared) Switch account

* Required

First Name *

Your answer

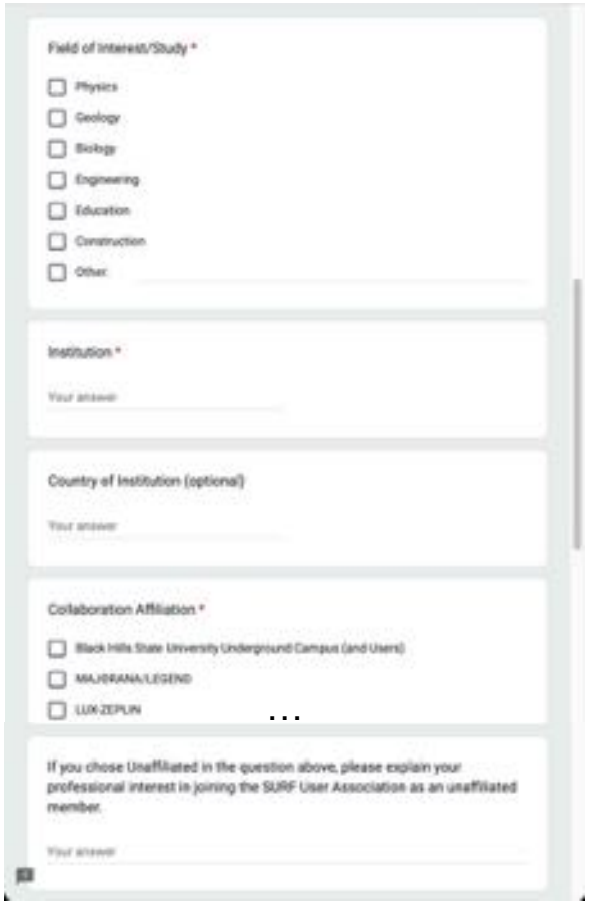
Last Name *

Your answer

Email Address *

This address will be used for official SURF User Association communication.

Your answer


Field of Interest/Study *

- Physics
- Geology
- Biology
- Engineering
- Education
- Construction
- Other

Institution *

Your answer

Country of Institution (optional)

Your answer

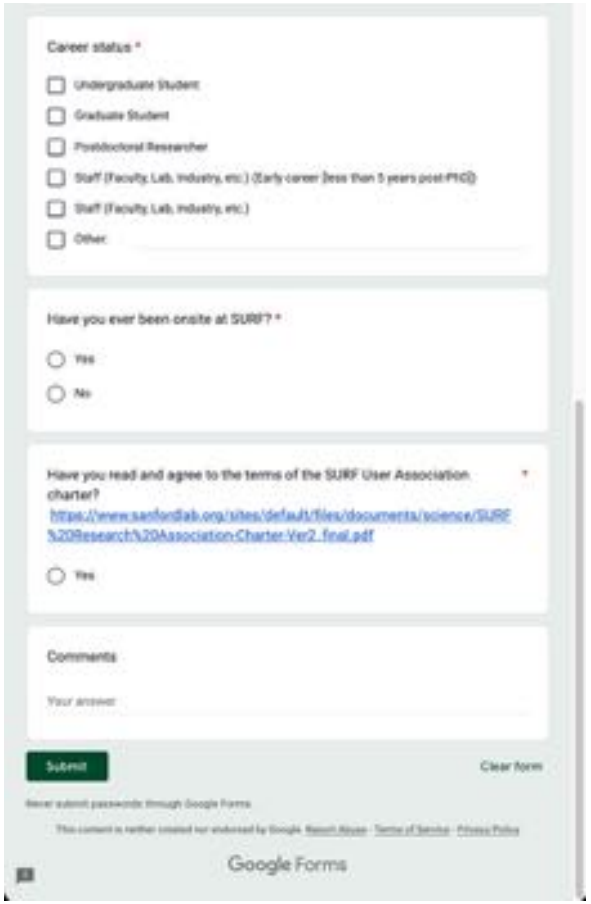
Collaboration Affiliation *

- Black Hills State University Underground Campus (and Users)
- MAJORANA/LEGEND
- LUX ZEPLIN

...

If you chose Unaffiliated in the question above, please explain your professional interest in joining the SURF User Association as an unaffiliated member.

Your answer


Career status *

- Undergraduate Student
- Graduate Student
- Postdoctoral Researcher
- Staff (Faculty, Lab, Industry, etc.) (Early career [less than 5 years post PhD])
- Staff (Faculty, Lab, Industry, etc.)
- Other

Have you ever been onsite at SURF? *

- Yes
- No

Have you read and agree to the terms of the SURF User Association charter? *

https://www.sanfordlab.org/sites/default/files/documents/science/SURF%20Research%20Association-Charter-Ver2_final.pdf

- Yes

Comments

Your answer

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SURF Science Program Advisory Committee

Purpose

- **Science Program:** Provide guidance on overall SURF scientific program (incl current, planned/proposed experiments), as well as direction and breadth of program. Peer review per DOE User Facility.
- **Science Support:** Advise on SURF experiment implementation program and organizational capacity to support experiments.
- **Science Facilities:** Advise on capability and capacity of the SURF facility necessary to support the SURF scientific program.

Organization

- SPAC consists of up to **14 members,** representing breadth of SURF research disciplines with strategic and synergistic influences (SDSTA Laboratory and Science Directors *ex-officio*).
- Members: **Two-year** terms (extendable). Chair: **One-year** term (extendable).
- Selection of new members made by SDSTA Laboratory + Science Directors in consultation with SDSTA IDEA Office.

1. David MacFarlane (SLAC/**Chair**)
2. Ed Blucher (Chicago)
3. Derek Elsworth (Penn State)
4. Joseph Formaggio (MIT)
5. Hunter Knox (PNNL)
6. Magdalena Osburn (Northwestern)
7. Federica Petricca (Max Planck)
8. Lance Roberts (SD Mines)
9. Hamish Robertson (Washington)
10. William Roggenthen (SD Mines)
11. Kate Scholberg (Duke)
12. Barbara Szczerbinska (TAMU-CC)
13. Mary Voytek (NASA)
14. TBD

Status

- **Established** Sep 2021, operating well.
- **First meeting held** (remote) Jan 2022, tracking 17 recommendations (incl conducting planning workshops to strengthen SURF's posture for attracting new science). Second meeting held Nov 9-10, 2022 (hybrid), expect report in Dec.

Getting Started with a Project at SURF

https://www.sanfordlab.org/researchers/proposal-guidelines

Resources for researchers

- Lab access and training
- ▸ Proposal Guidelines
- Upcoming workshops and meetings
- Science Liaison Office
- SURF User Association

Proposal Guidelines

All proposals must follow these guidelines

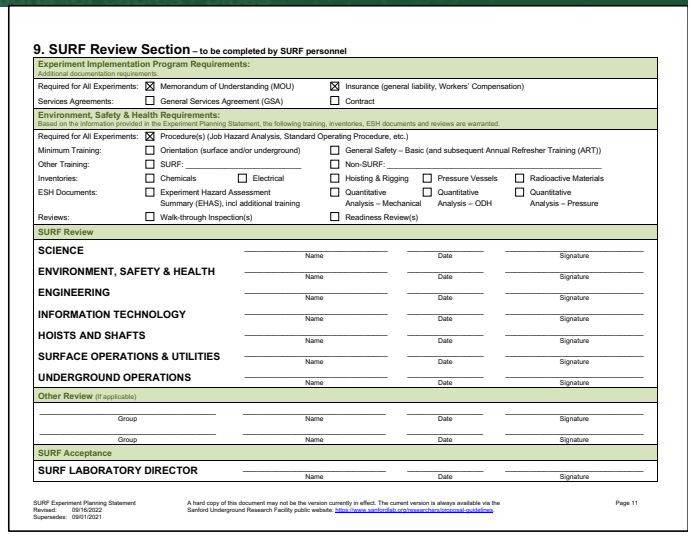
We are excited at Sanford Lab to contribute to cutting-edge science by providing the best environment for experiments that require unique underground facilities. We are glad to work with you to get your experiment running. To begin the process of approval and installation, follow the steps in the order listed below:

1. Read the Experiment Implementation Program.
2. Read the Experiment Integration and Support document.
3. Complete a draft of the Experiment Planning Statement describing your project.
4. Contact the SURF Science Director.
5. Complete the Memorandum of Understanding (MOU). The MOU references the SURF waiver required for underground access, the SURF ESH Manual and the SURF Publication Policy.

Experiment Implementation Program

Experiment Planning Statement: Two-way communication

1. **Project Summary**
   - Discipline, description (purpose, scientific merit), IDEA, funding, personnel
2. **Expt Equipment**
   - General + various categories (chemicals, radioactive materials, etc)
3. **Experiment Area and Infrastructure Needs**
   - Location, space, site preparations/environment/(trip?), services, logistics
   - Guidance on cage dimensions, some electrical
4. **Hazards and Integrated Safety Management**
   - Table of potential risks, identifies special training or permit requirements
5. **Personnel Access:**
   - Personnel schedule and access requirements as function of time (max/min)
   - Guidance on standard cage times
6. **Experiment Schedule**
   - Experiment schedule, incl phase such as installation, commissioning, ops
7. **Experiment Operations**
   - What-If… scenarios (access, ventilation, water, power, cyber, excavation…)
8. **Decommissioning**



9. SURF Review Section – to be completed by SURF personnel

Experiment Implementation Program Requirements:
Additional documentation requirements.

Required for All Experiments:	☒ Memorandum of Understanding (MOU)	☒ Insurance (general liability, Workers' Compensation)
Services Agreements:	☐ General Services Agreement (GSA)	☐ Contract

Environment, Safety & Health Requirements:
Based on the information provided in the Experiment Planning Statement, the following training, inventories, ESH documents and reviews are warranted.

Required for All Experiments:	☒ Procedure(s) (Job Hazard Analysis, Standard Operating Procedure, etc.)				
Minimum Training:	☐ Orientation (surface and/or underground)	☐ General Safety – Basic (and subsequent Annual Refresher Training (ART))			
Other Training:	☐ SURF: _____	☐ Non-SURF: _____			
Inventories:	☐ Chemicals	☐ Electrical	☐ Hoisting & Rigging	☐ Pressure Vessels	☐ Radioactive Materials
ESH Documents:	☐ Experiment Hazard Assessment Summary (EHAS), incl additional training		☐ Quantitative Analysis – Mechanical	☐ Quantitative Analysis – ODH	☐ Quantitative Analysis – Pressure
Reviews:	☐ Walk-through Inspection(s)		☐ Readiness Review(s)		

SURF Review

	Name	Date	Signature
SCIENCE			
ENVIRONMENT, SAFETY & HEALTH			
ENGINEERING			
INFORMATION TECHNOLOGY			
HOISTS AND SHAFTS			
SURFACE OPERATIONS & UTILITIES			
UNDERGROUND OPERATIONS			

Other Review (If applicable)

Group	Name	Date	Signature

SURF Acceptance

	Name	Date	Signature
SURF LABORATORY DIRECTOR			

SURF Experiment Planning Statement
Revised: 09/16/2022
Supersedes: 09/01/2021

A hard copy of this document may not be the version currently in effect. The current version is always available via the Sanford Underground Research Facility public website: https://www.sanfordlab.org/researchers/proposal-guidelines

Page 11

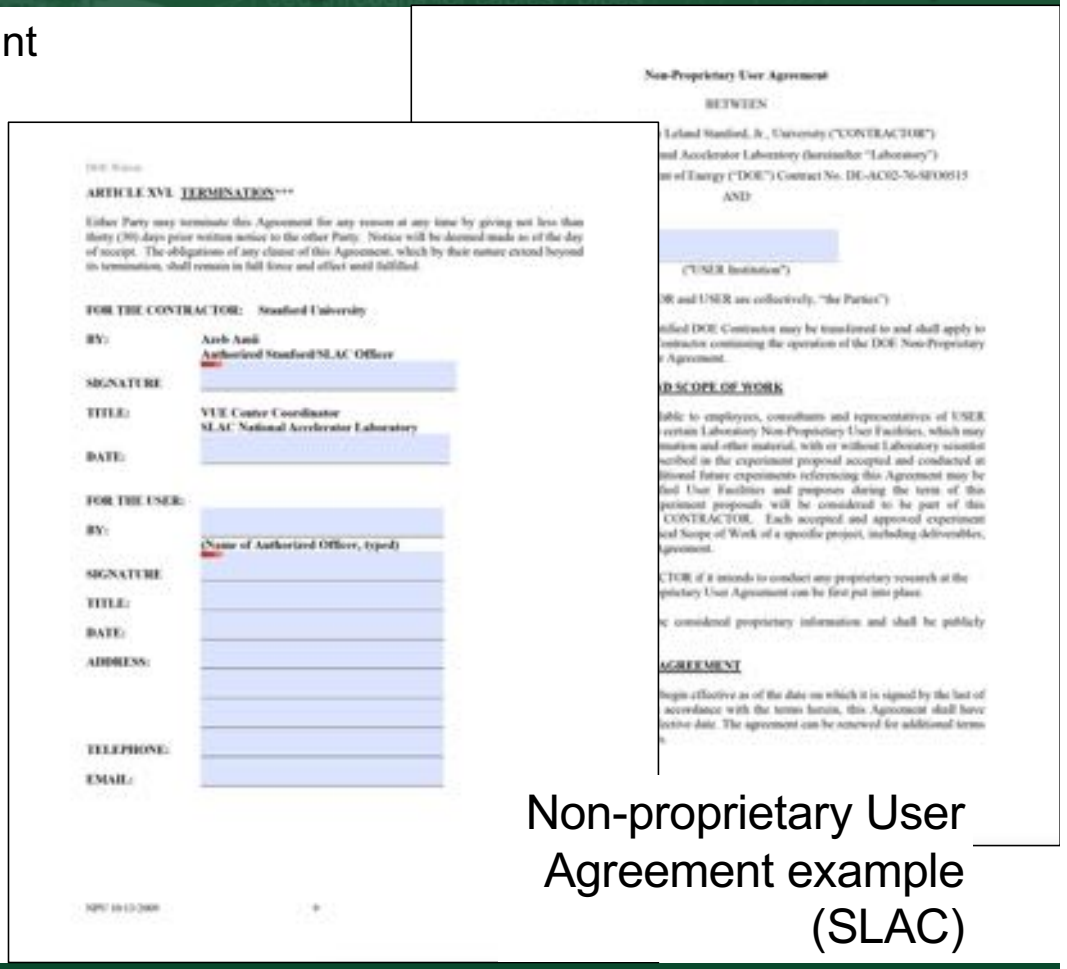
9. **SURF Review**
   - MOU, insurance pre-checked
   - ESH guidance
   - SURF review, other review
   - SURF Lab Director sign-off

Experiment Implementation Program – Future

DOE User Facility User Agreement (similar to existing SURF MOU & GSA docs)

DOE template promotes best practices in agreement composition and consistency across user facilities:

- Facilities and Scope of Work
- Term of Agreement (5 years for some)
- Cost, Billing and Payment of Expenses
- Admission Requirements
- Property and Materials
- Scheduling
- Indemnity and Liability
- Patent Rights
- Rights in Technical Data
- Lab Site Access, Safety and Health
- Personnel Relationships
- Export Controls
- Publications
- Disputes
- Conflict of Terms
- Termination



Non-proprietary User Agreement example (SLAC)

SURF Science Program – Current Physics Highlights

Strong and diverse program with exciting future

- **LZ:** Direct search for **dark matter** using 10 tonnes xenon within ultra-pure water shield + Gd liquid scintillator veto

  Status: Production data started Dec 2021. Detector working well, robust calibration program underway (incl DD generator). First WIMP-search results announced Jul 2022, run for 5 years.

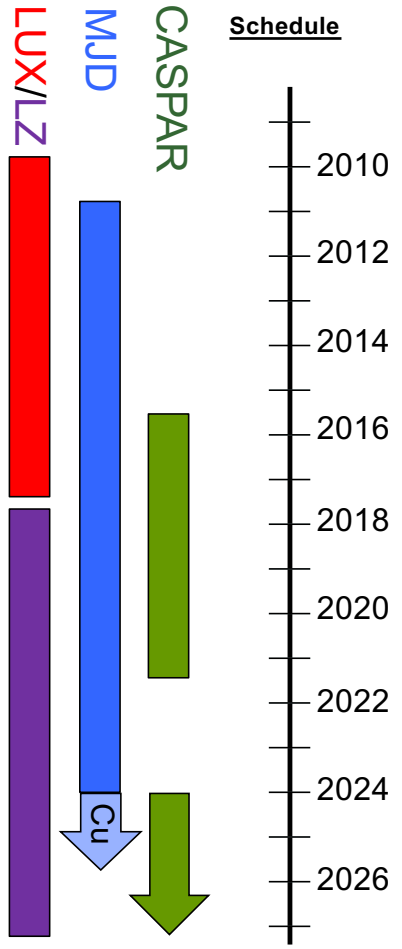
- **MAJORANA DEMONSTRATOR:** Investigate **neutrinoless double-beta decay** using 44 kg Ge in two cryostats, 30 kg enriched ^{76}Ge inside multi-layer compact shield

  Status: Data 2015-2021 (exposure goal achieved), final 0νββ result posted Jul 2022. Ultra-pure electroformed Cu production continues, also LEGEND detector characterization and R&D. Rare decay search ^{180m}Ta underway, complete in 2023/2024.

- **CASPAR:** Study of stellar nuclear fusion reactions, esp. neutron production for **slow neutron-capture nucleosynthesis** using 1-MV accelerator

  Status: Beam operation 2017-2021, targets incl ^{7}Li, ^{11}B, ^{14}N, ^{18}O, ^{20}Ne, ^{22}Ne (gas, solid), ^{27}Al. ^{18}O(α,γ)^{22}Ne PRL Apr 2022. Next phase starting FY24, incl ^{14}N (relevant for CNO solar neutrinos).

- **BHUC:** 5x **low-bkgd assay** counters operating (~10s ppt sensitivity)



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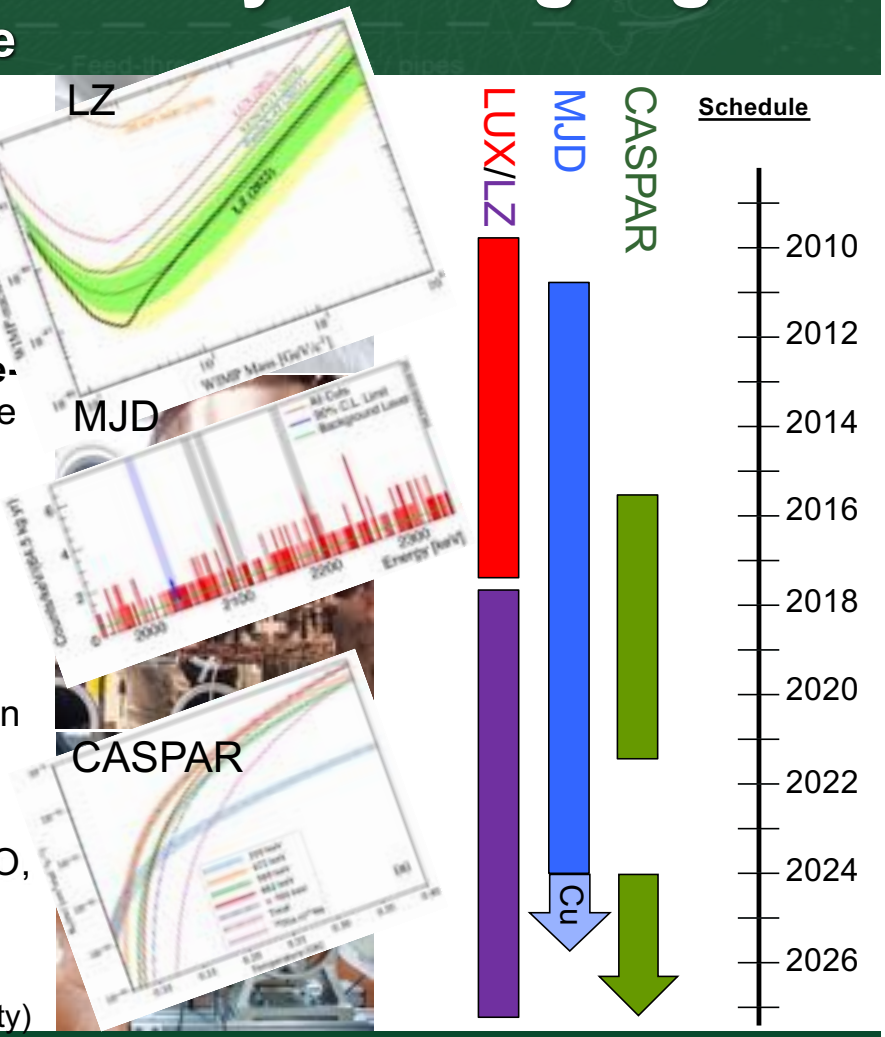
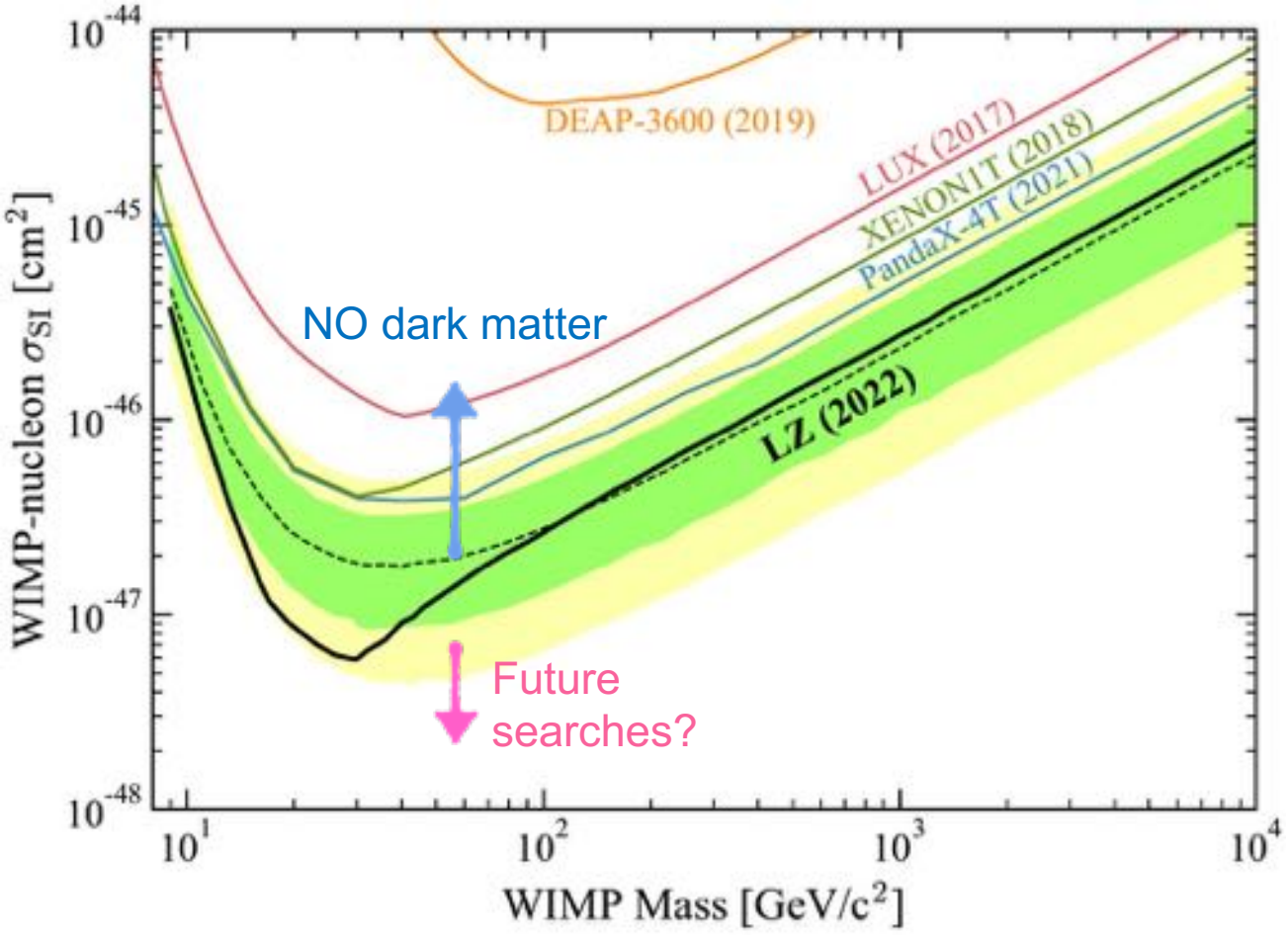
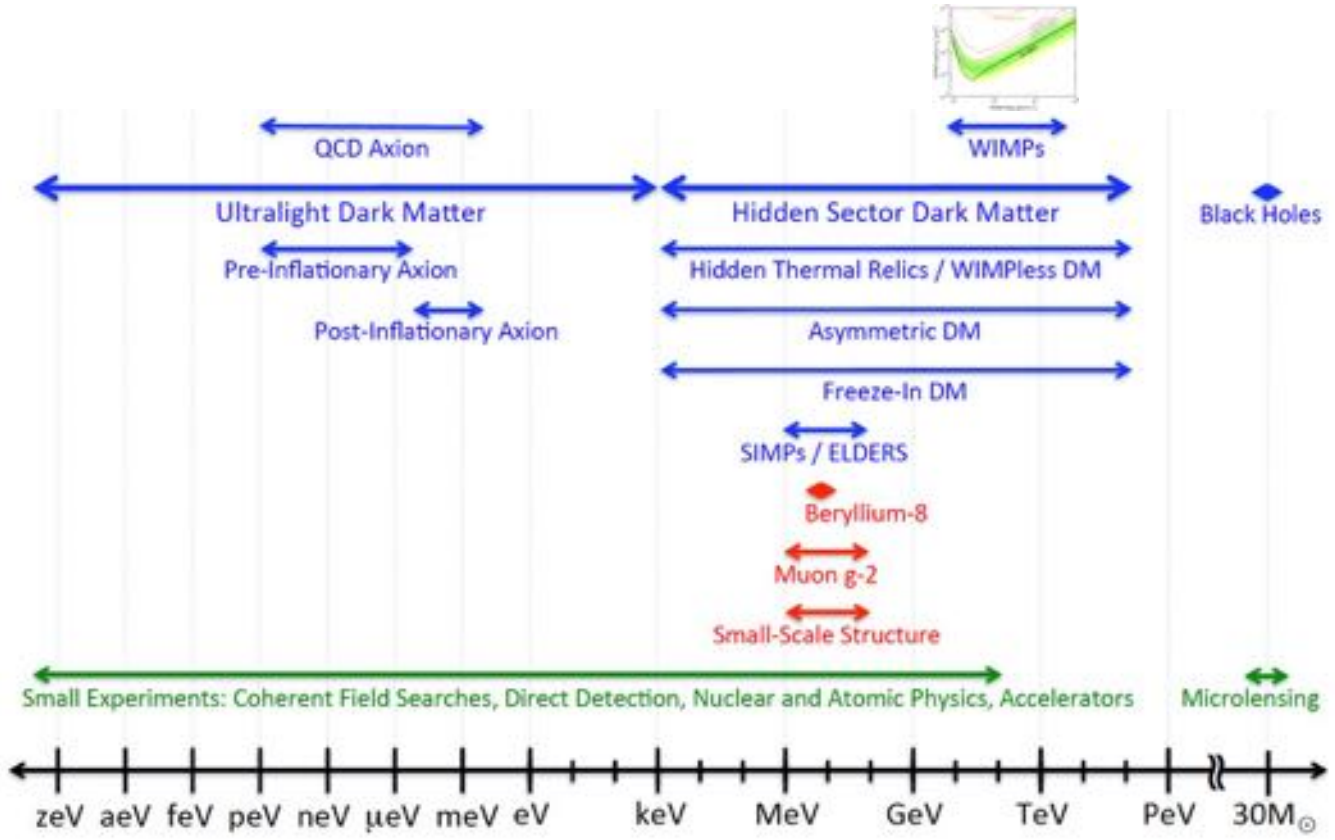


LUX-ZEPLIN (LZ)

How to Look for Dark Matter



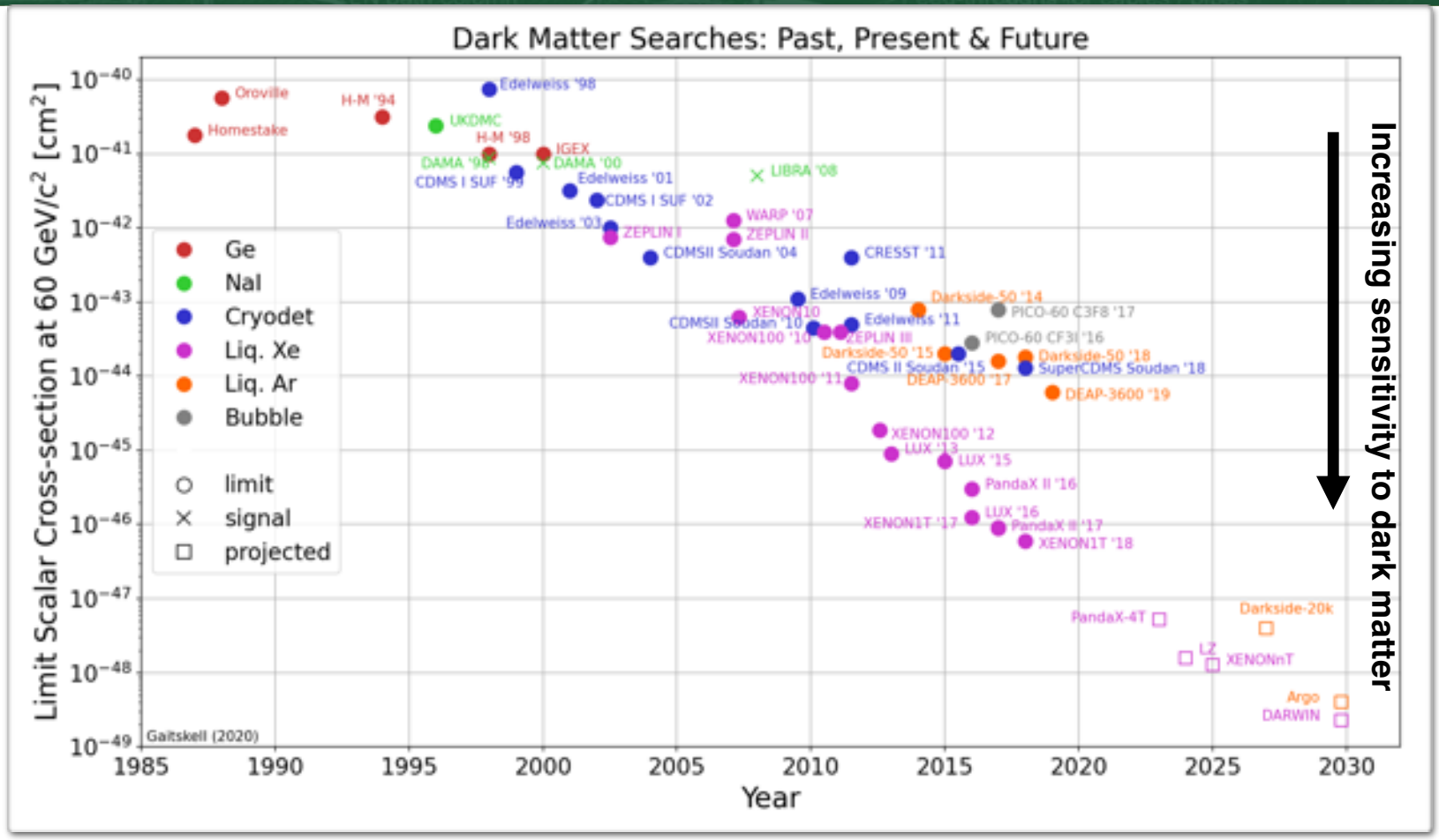
LUX-ZEPLIN (LZ)
How to Look for Dark Matter



1 zeV = 10^{-30} x M_{proton} 1 GeV = M_{proton}

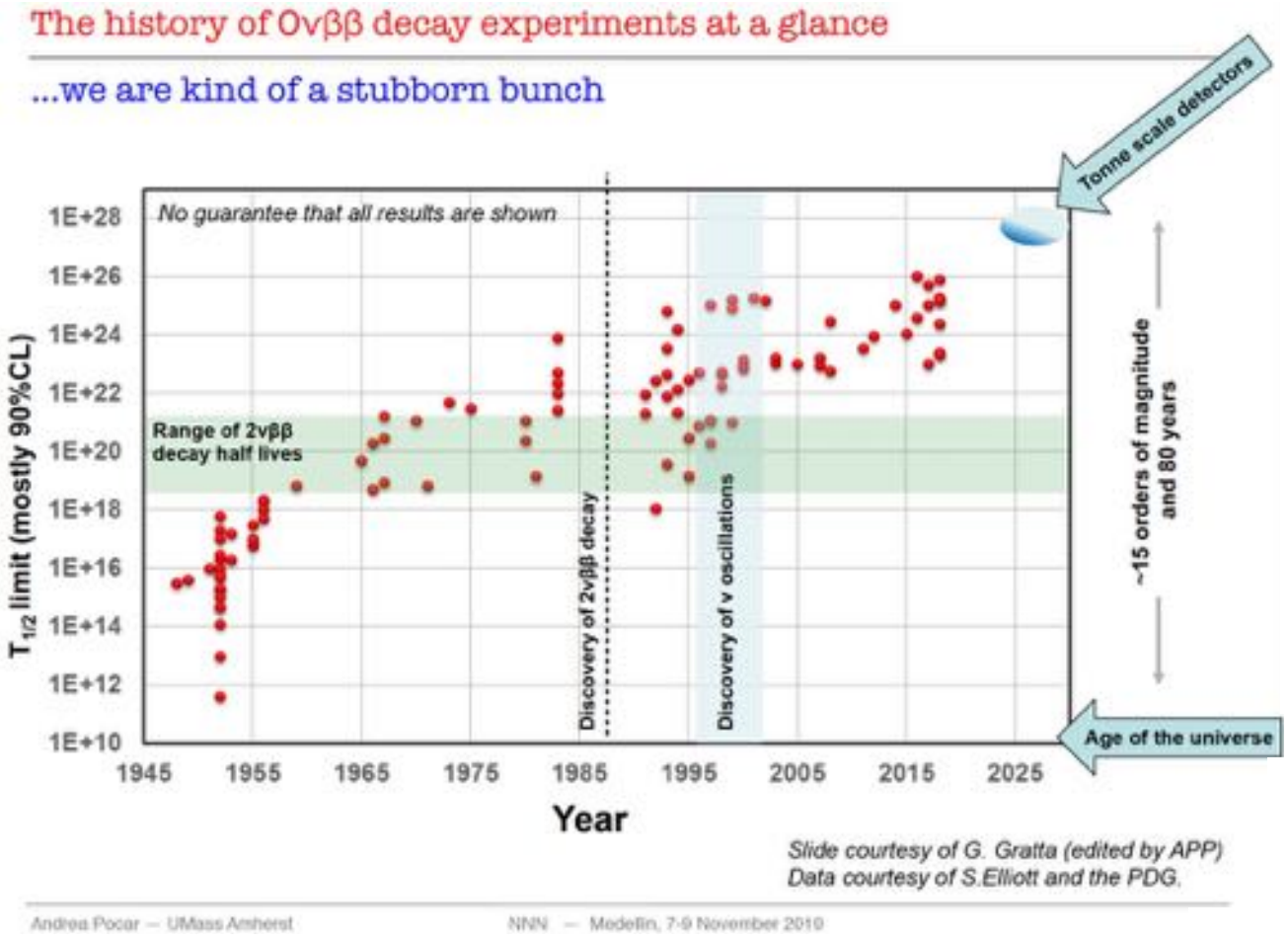
LUX-ZEPLIN (LZ)

How to Look for Dark Matter



MAJORANA DEMONSTRATOR (MJD)

How to Study Neutrino Properties

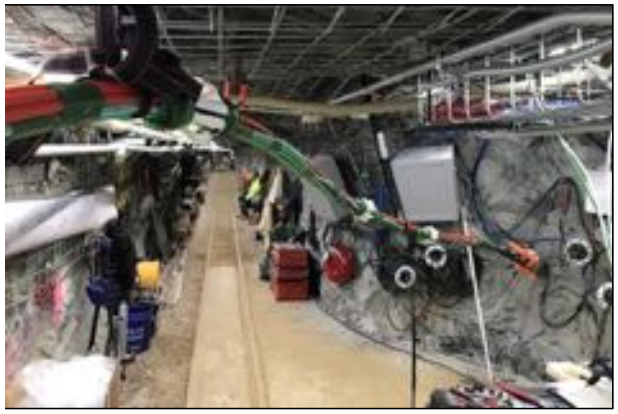


SURF Science Program

Biology / Geology / Engineering (Multiple Levels)

Life Science:

- Explorations into the diversity and extent of life, practical applications such as biofuels. Testing equipment for future Mars mission.
- **Status:** 800L, 1700L, 2000L, 4100L, 4850L.



Earth Science:

- Topics include seismic studies, UG monitoring, geothermal testing, mineral deposit studies
- **Status:** Surface, 800L, 1700L, 2000L, 4100L, 4850L.

Engineering:

- Topics include soft error rate chip testing, thermal applications, UG hazard monitoring, reinforced shotcrete, technology R&D
- **Status:** Surface, 1700L, 4100L, 4850L.

SURF Current Experiments – Physics

Experiment	Description	Location(s)	Funding Source	Status
LUX-ZEPLIN (LZ)	Direct dark matter search using Xe (10 tonnes)	4850L Davis Campus; also Surface	DOE HEP, SDSTA (+ modest NSF)	Active: Data taking started in Dec 2021, first results Jul 2022. Expt to run 5 yrs.
MAJORANA DEMONSTRATOR (MJD)	Neutrinoless double-beta decay using Ge (45 kg)	4850L Davis Campus; also Surface	DOE NP, LANL LDRD (+ modest NSF)	Active: DBD exposure goal achieved (2015-2021). Ta-180m studies started May 2022 continue for 1+ years.
LEGEND	DBD phased detector ultimately consisting of 1000 kg enriched Ge (~200 kg detector operating at LNGS)	4850L Davis Campus	DOE NP (+ NSF)	Active*: Testing new detectors, producing ultra-pure electroformed Cu. (*) Managed under MJD relationship.
CASPAR	Nucleosynthesis reactions using 1-MV accelerator	4850L Ross Campus (mothballed)	NSF MPS/PHY, SDSTA, institutional	Inactive: Resume operations in FY24.
BHUC	Low-background assays (also biology and chemistry)	4850L Davis Campus (Ross Campus mothballed)	SD, institutional, SDSTA	Active: Assay operations ongoing. Return to Ross Campus in FY24.
Users below:				
BLBF	Low-bkgd assays (mainly for LZ)	BHUC	DOE HEP	Active: 3x HPGe operating.
CUBED	Low-bkgd assays (mainly for LZ)	BHUC	NSF (capital), DOE HEP (via LZ)	Active*: 1x HPGe operating. (*) Managed by BLBF.
Kentucky/Alabama (nEXO)	Low-bkgd assays (mainly for nEXO)	BHUC	DOE NP	Active: 1x HPGe installation underway.
LLNL	Low-bkgd assays (incl AIT/NEO)	BHUC	Institutional	Active: 1x HPGe operating.
SDSMT	Neutron bkgds	BHUC	Institutional	Inactive: May resume in conjunction with LZ.
DUNE	Precision neutrino measurements	4850L LBNF	DOE HEP + intl (+ modest NSF)	Active: Construction underway.

SURF Current Experiments – Geology

Experiment	Description	Location(s)	Funding Source	Status
EGS Collab - SIGMA-V	Geothermal energy R&D	4100L (previously 4850L)	DOE EERE-GTO	Active: Stimulations and water flow tests finished. Decommissioning to be completed in Nov 2022.
3D DAS	Seismic monitoring using optical fiber (3100 m) leveraging 3D topology in underground environment	Ramp between 4100L-4850L	Air Force Research Lab	Active: Initial data in May 2022 (fiber from 4550L up ~760 m toward 4100L, down ~610 m toward 4850L). Exploring options for better coupling to rock.
Dakota Gold [Proprietary]	Drill core studies	Surface	Institutional	Inactive: Surface Core Archive, last visit Apr 2022.
Hydrogravity	Black Hills hydrology	Surface, 300L, 4100L, 4850L	USGS	Inactive: Last visit in 2014, but still interest.
Transparent Earth	Underground seismic array	2000L, 4100L	Institutional (previously NSF)	Inactive: Equipment onsite.
Black Hills Seismic Network	Ground motion monitoring (connects to citizen science network)	4100L	Institutional	Active: Data since Dec 2021.

SURF Current Experiments – Biology

Experiment	Description	Location(s)	Funding Source	Status
DeMMO	Water sampling using drill holes	Surface, 800L, 4100L, 2000L, 4850L	Institutional (previously NASA)	Active: Regular sampling since 2013.
Biodiversity (BHSU)	Characterize UG microbial communities	Mainly 4850L; also 1700L, 4100L	SD, NASA EPSCoR, institutional; also NSF REU	Active: Regular sampling since 2008.
Chemistry (BHSU)	Characterize chemical composition of various UG microenvironments	1700L, 4850L	NSF	Active: Sampling since 2016.
BuG ReMeDEE	Explore mechanisms of methane oxidation	Mainly 4850L; also 1700L, 4100L	NSF EPSCoR RII Track-2	Active: Regular sampling since 2017.
Liberty BioSecurity [Proprietary]	Identify novel functional proteins	4850L	Institutional	Inactive: Last visit Mar 2019; future trips possible.
Biofuels (SDSMT)	Explore extremophile microorganisms	4850L	NSF, SD, other non-DOE	Inactive: Infrequent sampling.
2D BEST	2D materials for biofilm applications	TBD	NSF EPSCoR RII Track-1	Inactive: Sampling planned (also use existing samples).
Carbon Sequestration	Microbial catalysts for carbon sequestration	4100L	NSF	Inactive: Samples collected, may access surface Core Archive.

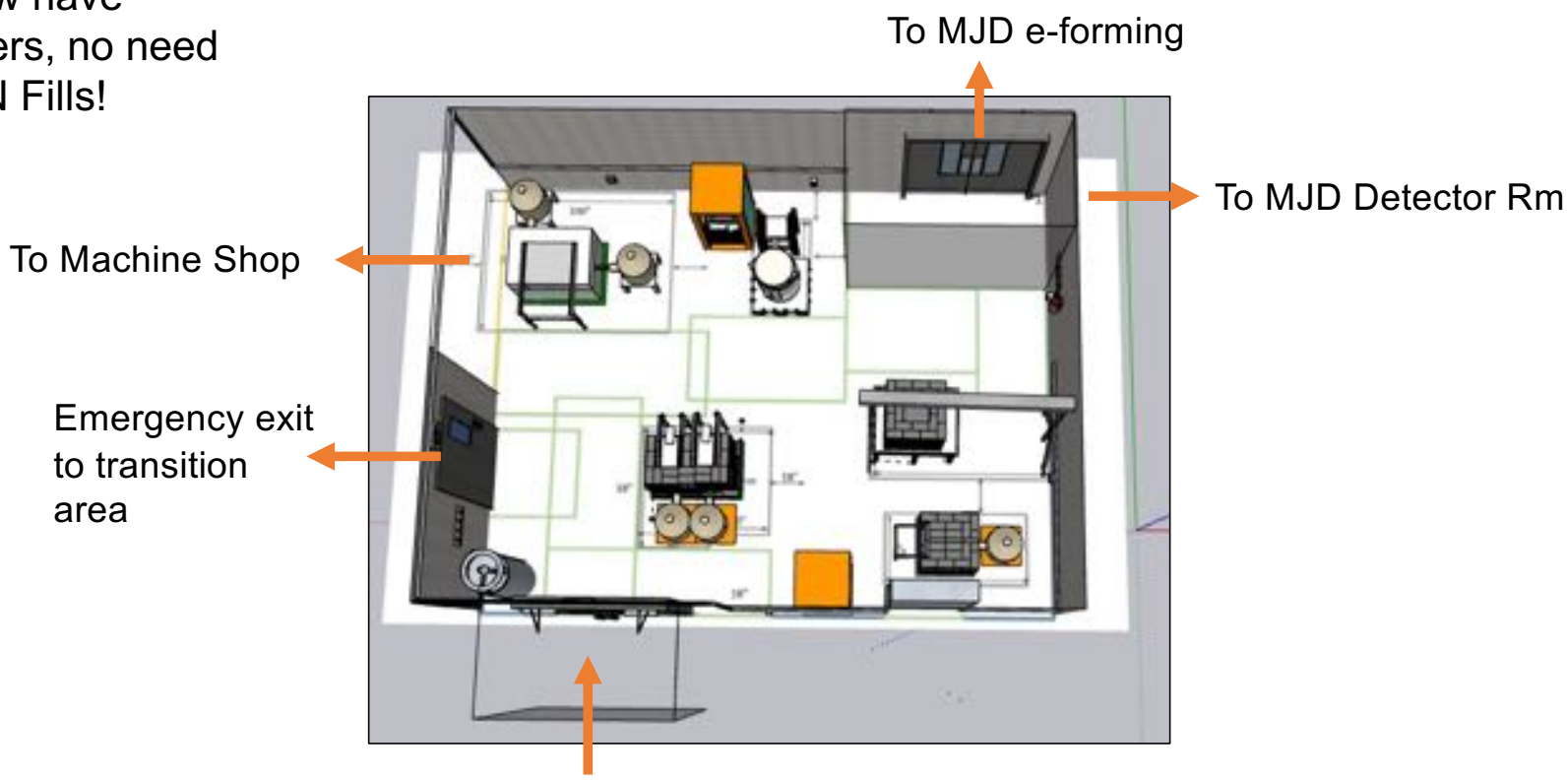
SURF Current Experiments – Engineering

Experiment	Description	Location(s)	Funding Source	Status
Caterpillar [Proprietary]	Field test mining equipment	1550L, 1700L	Institutional	Active: Product demonstrations underway, space outfitting and configuration ongoing.
Thermal Breakout	Technology to determine stress properties	4100L	DOE Fossil Energy & Carbon Mgmt	Active: Heater testing planned in 2023.
Xilinx [Proprietary]	Chip error testing	4850L Davis Campus	Institutional	Inactive: New chip arrays expected.
Shotcrete (SDSMT)	Fiber-reinforced shotcrete	Surface	SD	Inactive: Infrequent LIDAR measurements.
Flow Meter Environmental Monitoring		800L, 1700L, 2000L, 4100L, 4850L (5), 5000L	SD, Institutional, SDSTA	Active: Monitor airflow in conjunction with SURF.
Post-Blast Monitoring	Biofilm-based scrubber for mine ventilation air treatment	4850L	Institutional	Inactive: Initial monitoring complete.

SURF Material Assay at BHUC: Davis Campus

Low-background counting capabilities serving national & international community

Detectors now have Mobius Coolers, no need for regular LN Fills!



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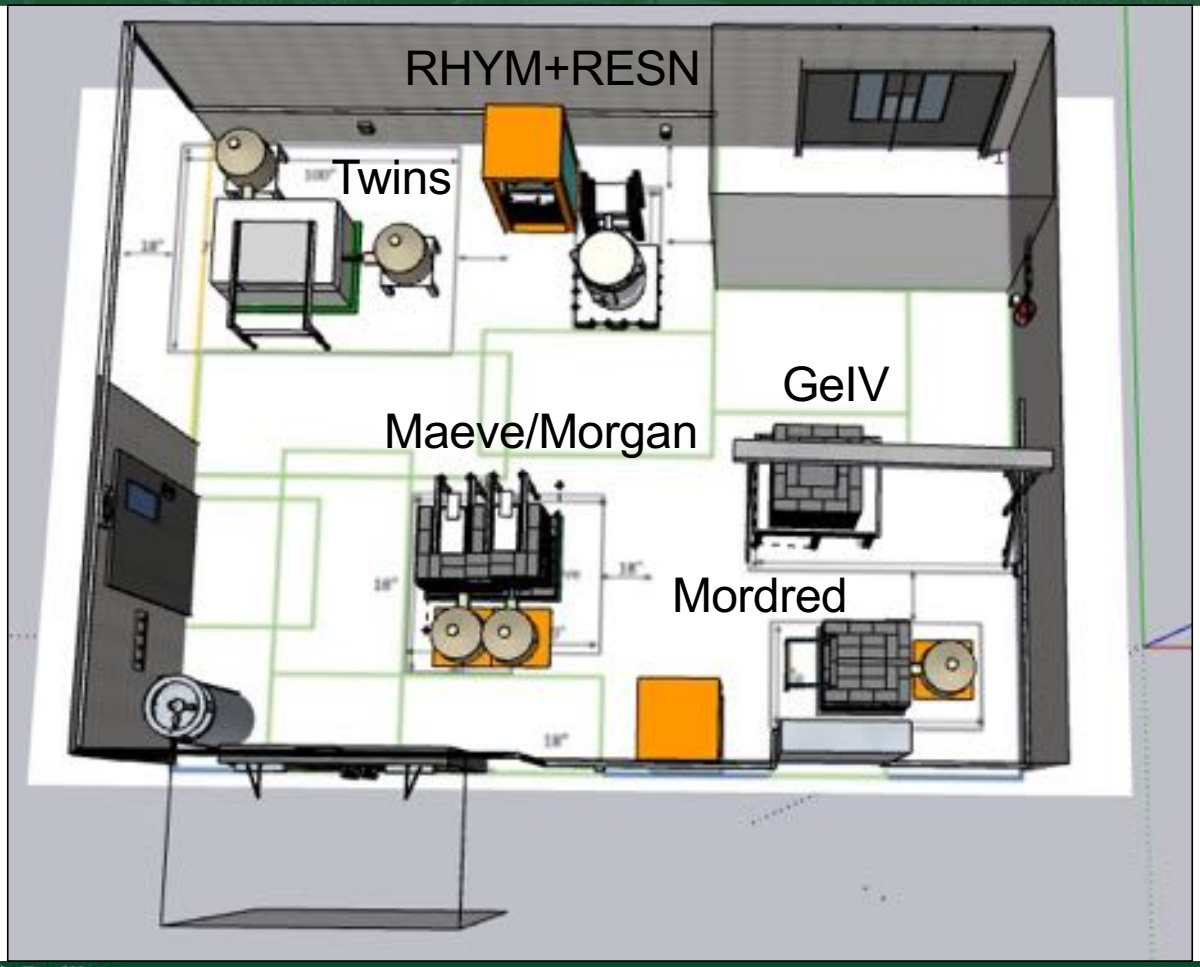

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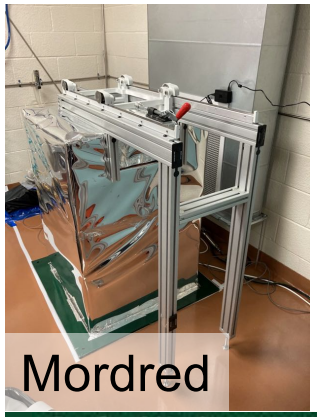
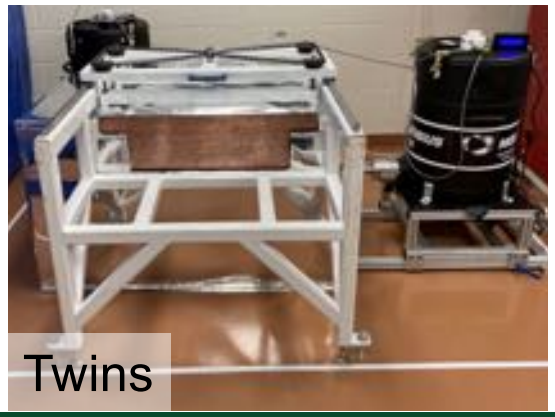

Mordred


Maeve & Morgan


Twins


RHYM/RESN


Ge-IV

SURF Material Assay at BHUC

Low-background counting capabilities serving national & international community

Detector	Crystal		[U] mBq/kg	[Th] mBq/kg	Install Date	Status	Comments
	Type	Size					
Maeve (BLBF)	p-type (85%)	2.2 kg	**0.1** (10 ppt)	**0.1** (25 ppt)	Davis Campus: Nov 2020 (Ross Campus: Nov 2015; Davis Campus: May 2014)	Production assays	Relocated from Oroville. Old Pb (200-yr old) inner shielding. Cooling system upgrade 2020.
Morgan (BLBF)	p-type (85%)	2.1 kg	**0.2** (20 ppt)	**0.2** (50 ppt)	Davis Campus: Nov 2020 (Ross Campus: Nov 2015; Davis Campus: May 2015)	Production assays	Low-bkgd upgrade 2015. Cooling system upgrades 2020.
Mordred (USD/CUBED, BLBF)	n-type (60%)	1.3 kg	**0.7** (60 ppt)	**0.7** (175 ppt)	Davis Campus: Nov 2020 (Ross Campus: Jul 2016; Davis Campus: Apr 2013)	Production assays	Low-bkgd upgrade 2015-2016, shield access upgrade. Cooling system upgrades 2020.
Dual HPGe ("Twins") (BLBF, BHSU, UCSB)	p-type (2x120%)	2x 2.1 kg	**~0.01** (~1 ppt)	**~0.01** (~1 ppt)	Davis Campus: Sep 2020 (Ross Campus: Mar 2018, Jul 2017 (initial))	Operating	Low-bkgd upgrades 2016-2017; flexible shield. Cooling system upgrades 2020.
Ge-IV *(Alabama, Kentucky)*	*p-type (111%)*	*2 kg*	***0.04*** *(3 ppt)*	***0.03*** *(8 ppt)*	*Davis Campus: Summer 2022?, Nov 2020 (initial) (Ross Campus: Jul 2018, Oct 2017 (initial))*	*Installation underway*	*Vertical design, requires gantry + hoist. Cooling system upgrades 2020.*
Dual HPGe ("RHYM+RESN") (LLNL)	p-type (2x65%)	2x 1.1 kg	**<0.1** (<10 ppt)	**<0.1** (<25 ppt)	Davis Campus: Feb 2022, Sep 2020 (initial)	Operating	Cryocooler, low-E ^{210}Pb (<2 mBq/kg).

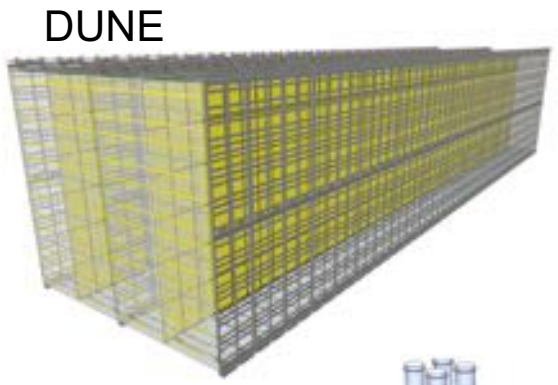
Also see: LZ Assay Paper https://arxiv.org/pdf/2006.02506

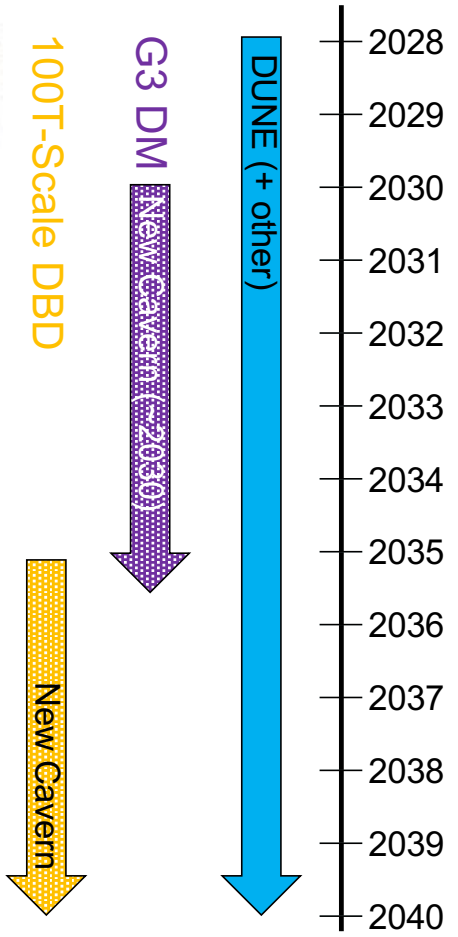
Local universities have some additional material screening capabilities: **HPGe** (SOLO [0.6 kg]/BHSU, [0.2-0.4 kg]/SD Mines), **ICP-MS** (BHSU), **Rn emanation** characterization (0.1 mBq/SD Mines), **Alpha** (1 mBq/m^2 ^{210}Po/SD Mines; XIA UltraLo-1800/LZ purchased)

SURF Science Program – Planned / Future

Strong and diverse program with exciting future possibilities

- **DUNE:** 4x 10 kT LAr detectors with horizontal/vertical drift for **neutrinos** (**CPV, MH, SN, proton decay**, etc). Excavation complete in 2024, science starts **2028.** Renewed discussions for "**Module of Opportunity**"
- Neutrinoless Double-Beta Decay (Ton+ Scale): Investigate **neutrino properties** using ~1-100-tonne enriched isotope, inverted hierarchy coverage
- Dark Matter (Generation-3): Search for WIMP **dark matter** to neutrino background "floor/fog" using ~50-100 tonne Xe (e.g., XLZD) or other target
- THEIA: Water-based liquid scintillator (25-100 kT) using LBNF beam to investigate **neutrino** properties (**CPV, MH, CNO, DSNB**, etc)
- Low-Bkgd Module: **SoLAr** (nu), **SLoMo** (nu+DM), etc, targeting the "Module of Opportunity"
- Other:
  - Low-mass dark matter: **TESSERACT** (Al_2O_3, GaAs, LHe), **Scintillating Bubble Chamber** (Ar), Xe-based detectors (**Hydro-X)**
  - Ge lab, Low-bkgd Xe DM (**CrystaLiZe**), Quantum; *Vertical facility?*
  - Non-physics, incl geothermal (DEMO-FTES, Eden)





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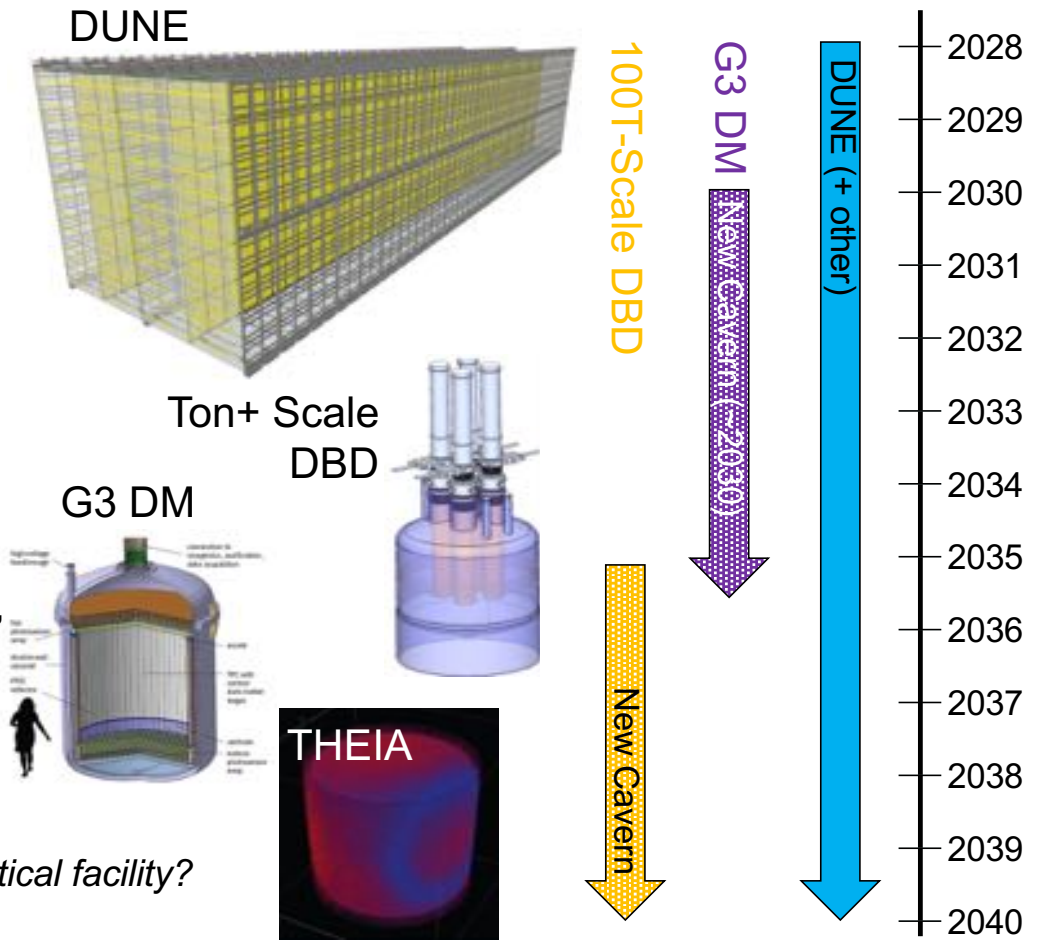
- Dark Matter (Generation 2) [illegible] WIMP **dark matter** [illegible] using [illegible] target
- [illegible] liquid scintillator (25-100 kT) using [illegible] beam to investigate **neutrino** properties (**CPV, MH, CNO, DSNB**, etc)
- Low-Bkgd Module: **SoLAr** (nu), **SLoMo** (nu+DM), etc, targeting the "Module of Opportunity"
- Other:
  - Low-mass [illegible] GaAs, [illegible] (Ar), Xe-based [illegible]
  - [illegible] lab; Low-bkgd Xe DM (**CrystaLiZe**), Quantum; *Vertical facility?*
  - Non-physics, incl geothermal (DEMO-FTES, Eden)

Non-DUNE Projects Require New Cavern (and/or "Module of Opportunity")

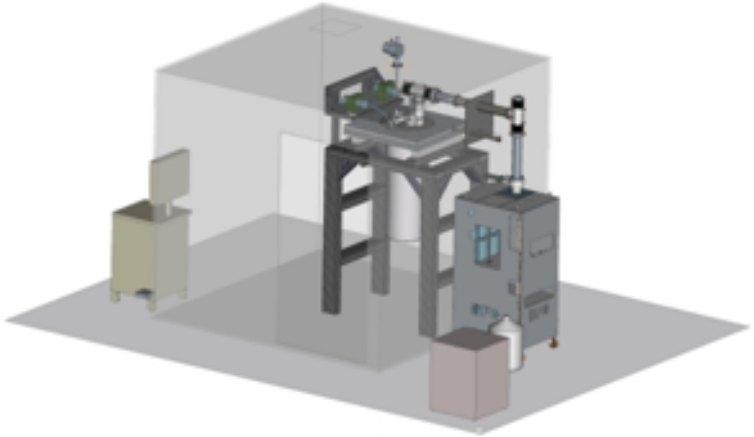
Vertical Facility Requires Feasibility Study (and design/development)



Experiment Integration & Support
TESSERACT

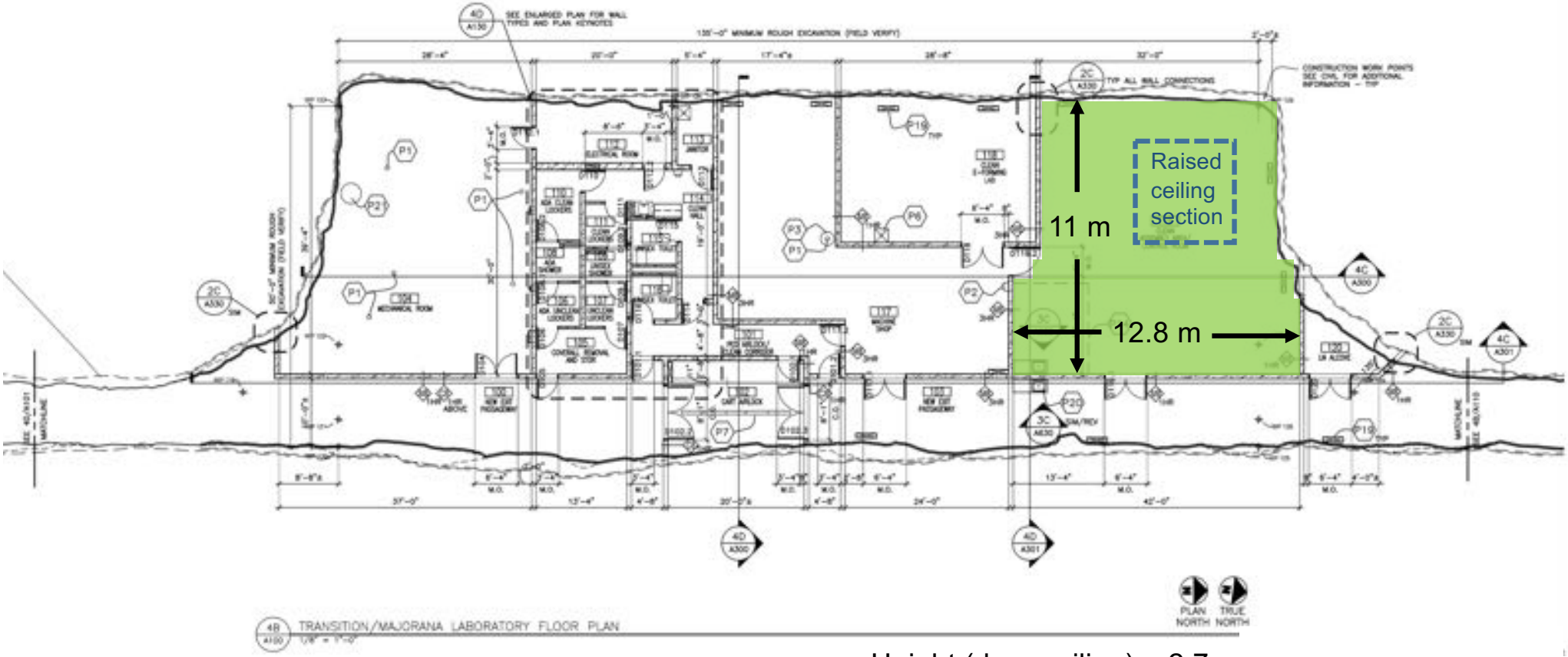
- **Experiment Comments** (based on discussions since mid-2020):
  - DOE funding profile does not capitalize on rate of technical progress
  - Opportunities to advance schedule incl equipment and personnel:
    - Dilution refridgerator (Bluefors XLD400)
    - Engineering support mainly for facility integration

- **Status**
  - Feb 2021: Davis Campus CAD files shared (Cline *et al*.)
  - May 2021: Information re: onsite Ti shared
  - TESSERACT working on SURF Experiment Planning Statement, captures key interfaces between experiment and facility
  - SURF exploring opportunity for “test cryostat facility”:
    - Supporting NSF MRI proposal for Bluefors XLD1000 (invited to submit full proposal). FY25 timeframe given ~1 year delivery
    - Additional funding avenues once SURF designated DOE User Facility? (Also ~FY25 timeframe given ~1 year delivery)
  - SURF arranging for dedicated engineering support for preliminary design / facility integration work



4850L Davis Campus

MJD Detector Room: Area = 140 m^2, Volume = 603 m^3



Height (drop ceiling) = 2.7 m

Height (raised section, 5.9 m x 5.8 m) = 3.2 m

Long-Baseline Neutrino Facility (LBNF)

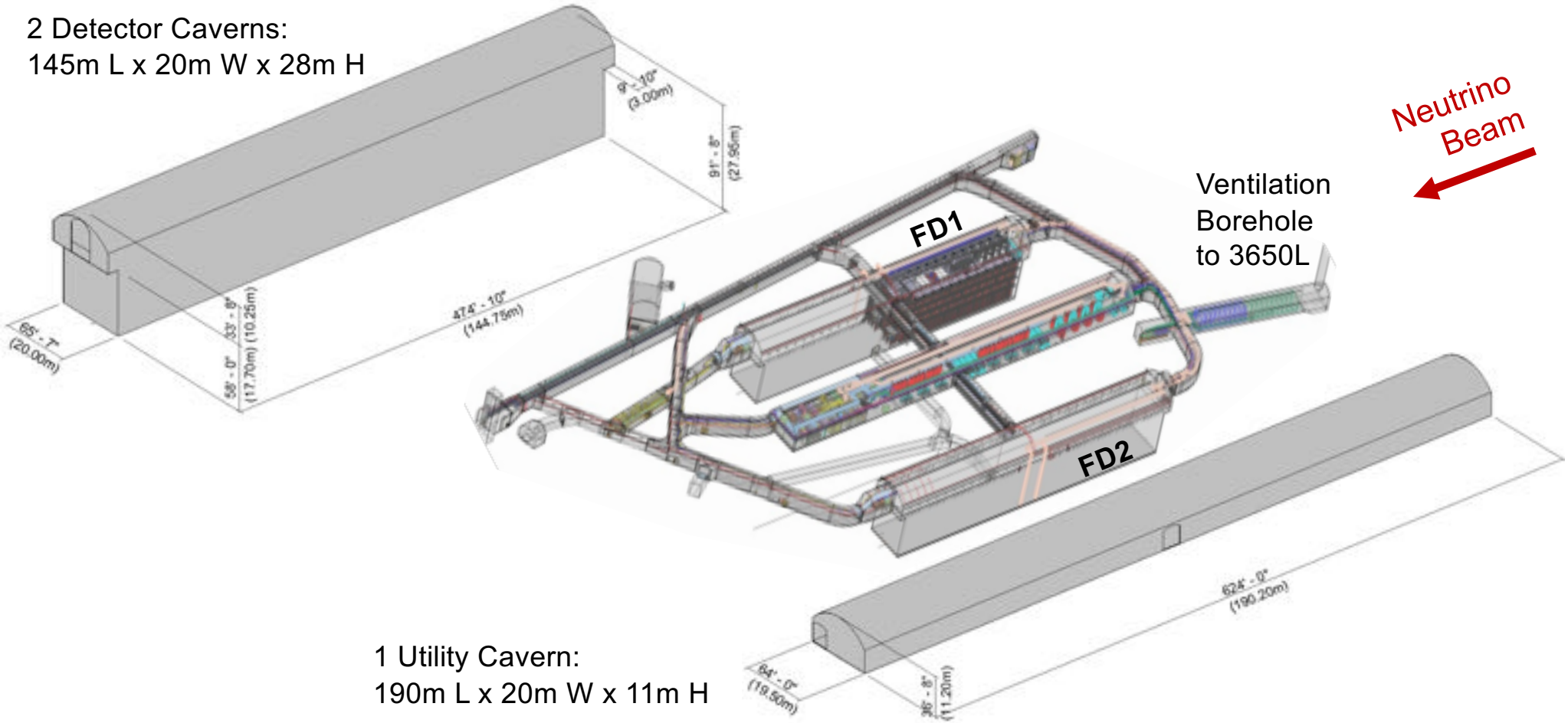
LBNF will host the Deep Underground Neutrino Experiment (DUNE)

- First internationally conceived, constructed, and operated project hosted by the Department of Energy in the United States. Significant **international** contributions (incl CERN).
- Two detector caverns to host 4 detectors (total of 70 kT/50M liter liquid argon) + utility cavern.
- **Reliability projects** rehabilitated some key SURF infrastructure 2016 – 2020.
- **Pre-excavation construction** at SURF in Jan 2019 – Feb 2021. Transportation system for excavated rock operational (first rock to Open Cut May 2021).
- **Excavation** initial phase started Jun 2020, focused on ventilation. Main excavation phase (caverns, access) started Apr 2021 and will last ~3 years (drill & blast expected to complete by Fall 2023).
- **Infrastructure outfitting** and **cryostat construction** expected 2024-2027, **science starts 2028**.

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

2 Detector Caverns:
145m L x 20m W x 28m H

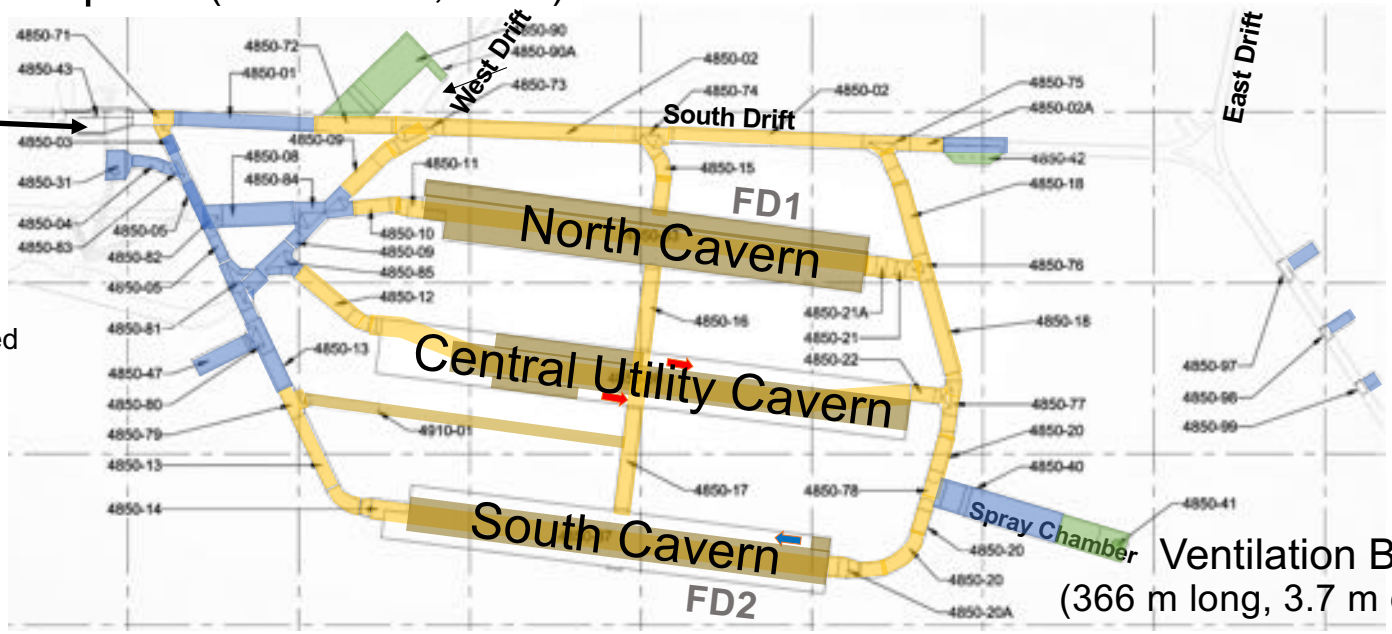


1 Utility Cavern:
190m L x 20m W x 11m H

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

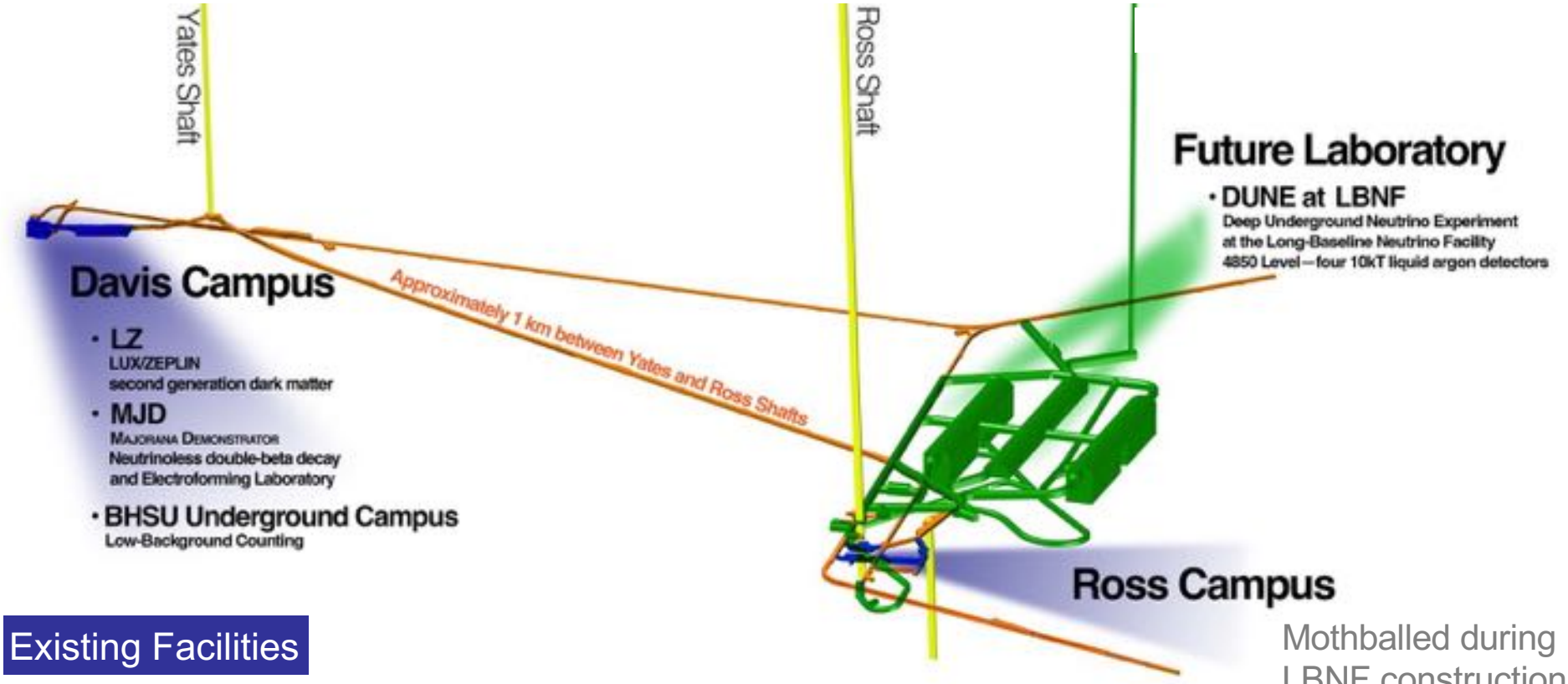
Excavation 42% complete (October 17, 2022)



- Aug 2023: North Cavern excavation complete
- Mar 2023: Central Utility Cavern excavation complete
- Oct 2023: South Cavern excavation complete
- Mar 2024: All concrete complete
- May 2024: Infrastructure outfitting (~18 mths), cryostat construction starts (warm ~11 mths + cold ~12 mths)

Current & Future Underground Facilities

SURF research through 2050 and beyond



Existing Facilities

Future Facilities

SURF Designated APS Historical Site

Announcement Sep 2020, Dedication May 2022

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A communication resource from the **world's particle physics laboratories.**

APS designates Sanford Lab, Morgan State University as historic physics sites

14 September 2020 - Sanford Underground Research Facility

The pioneering neutrino research done by Ray Davis over nearly three decades forever changed our understanding of the Standard Model of Physics

The American Physical Society (APS) today announced it has designated SURF one of two Historic Sites in physics. The other, Morgan State University in Baltimore, Maryland, is recognized as the birthplace of the National Society of Black Physicists (NSBP).

DATE ISSUED:
September 14th, 2020

SOURCE:
Sanford Underground Research Facility

CONTENT:
Press Release

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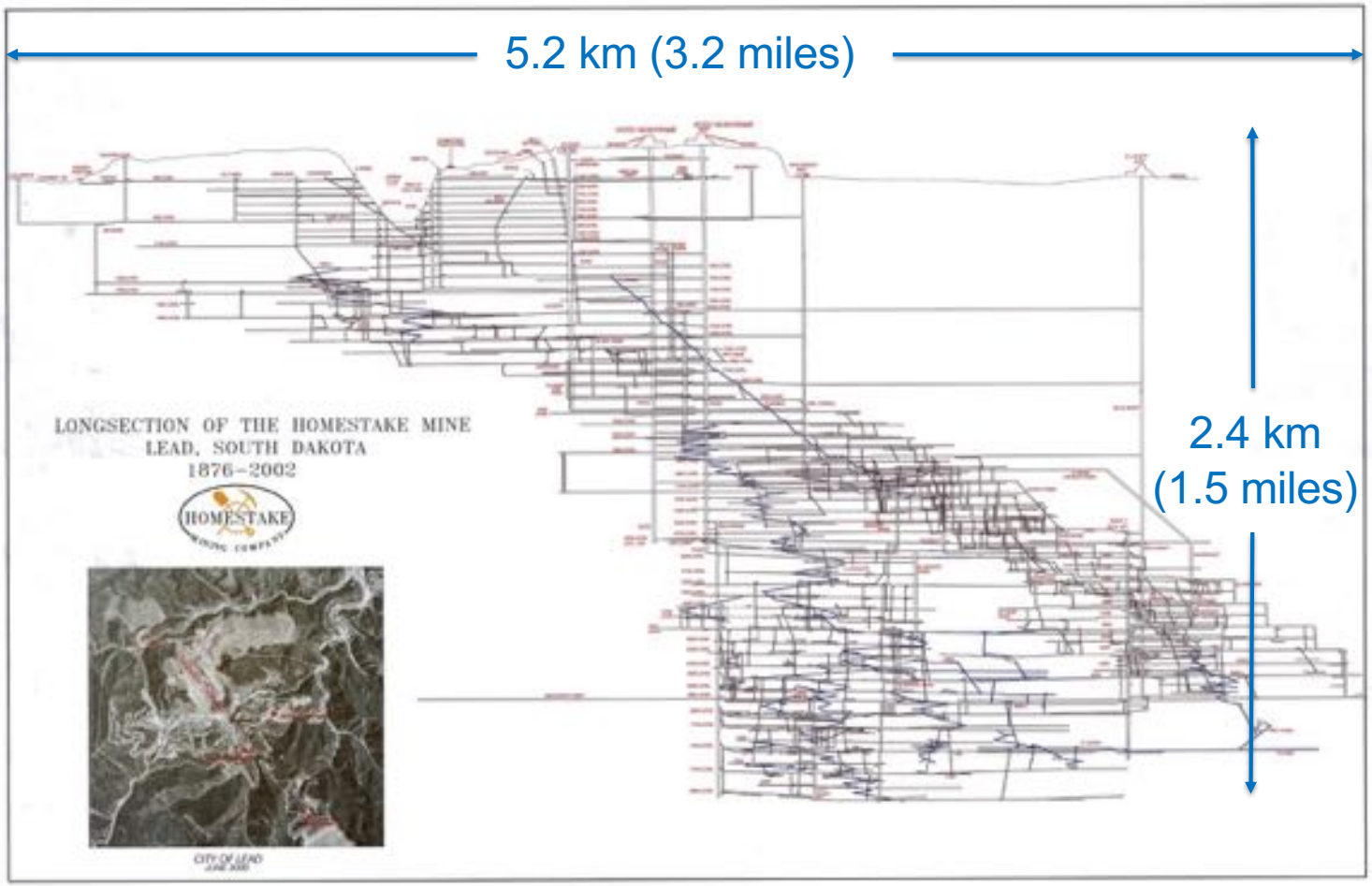
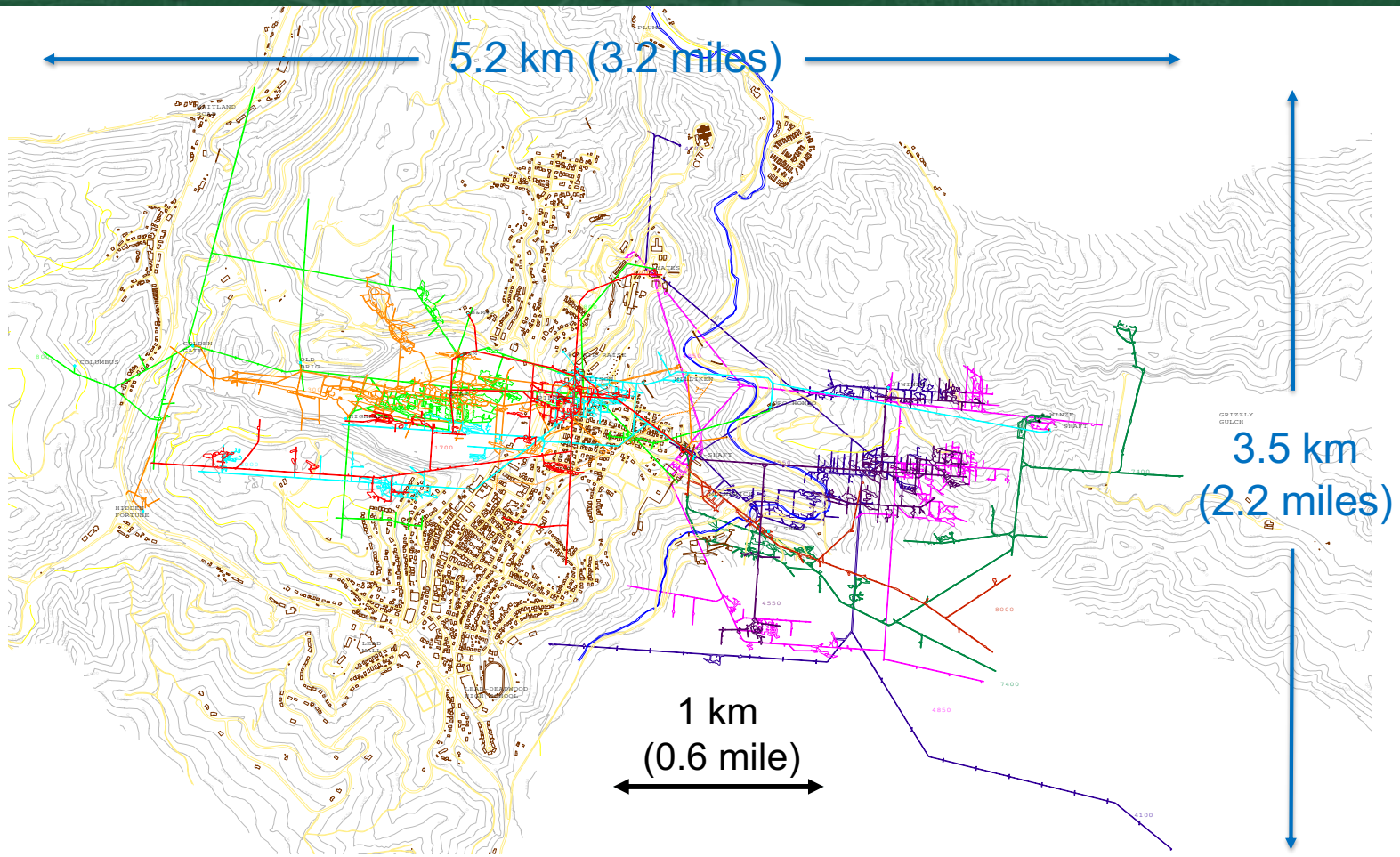
SURF Underground Lab Geography

Significant underground science footprint



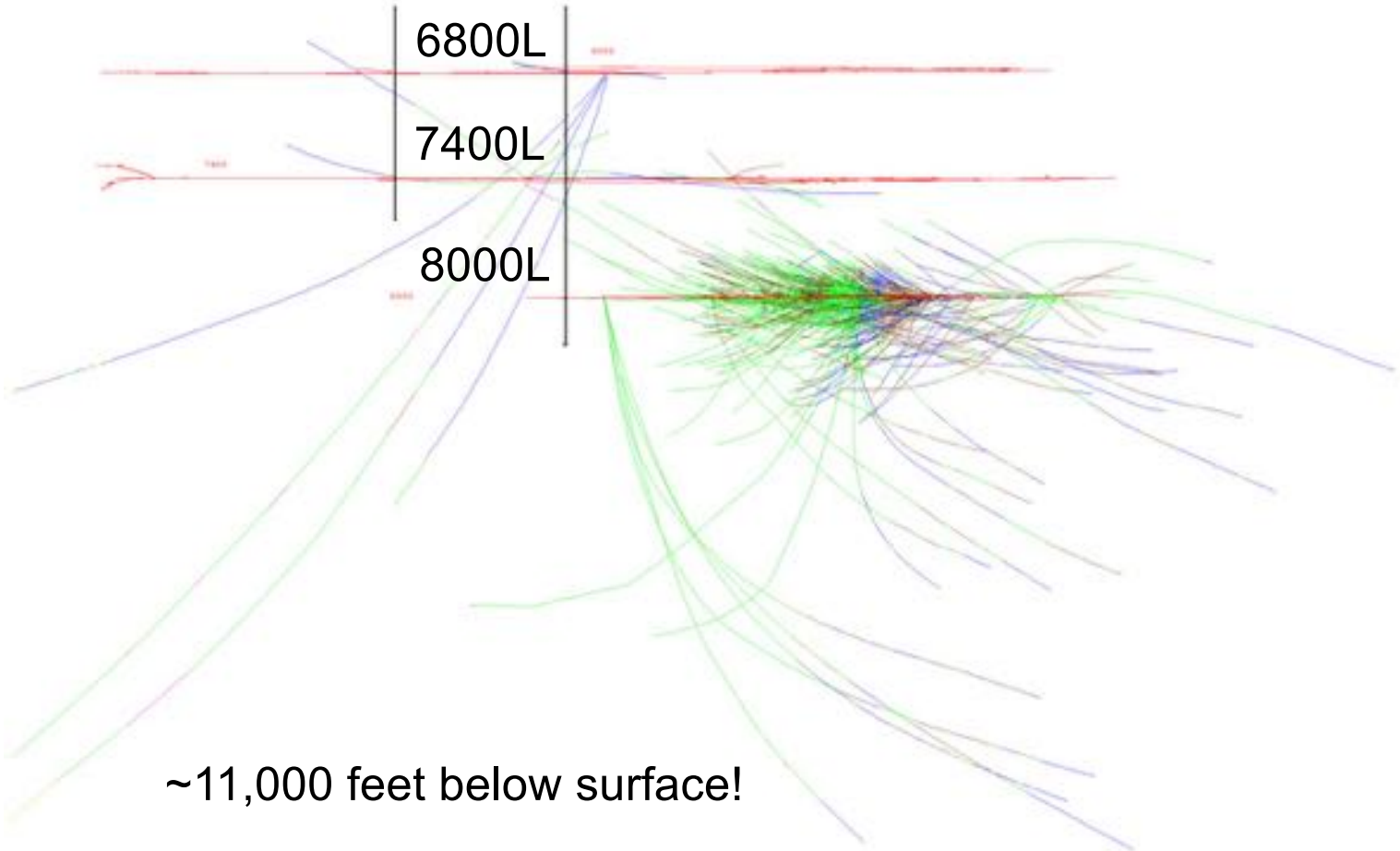
SURF Underground Lab Geography

Significant underground science footprint



SURF Underground Lab Geography

Future Possibilities to Access Existing Deep Holes?



~11,000 feet below surface!