The Sanford Underground Research Facility

Jaret Heise, Science Director
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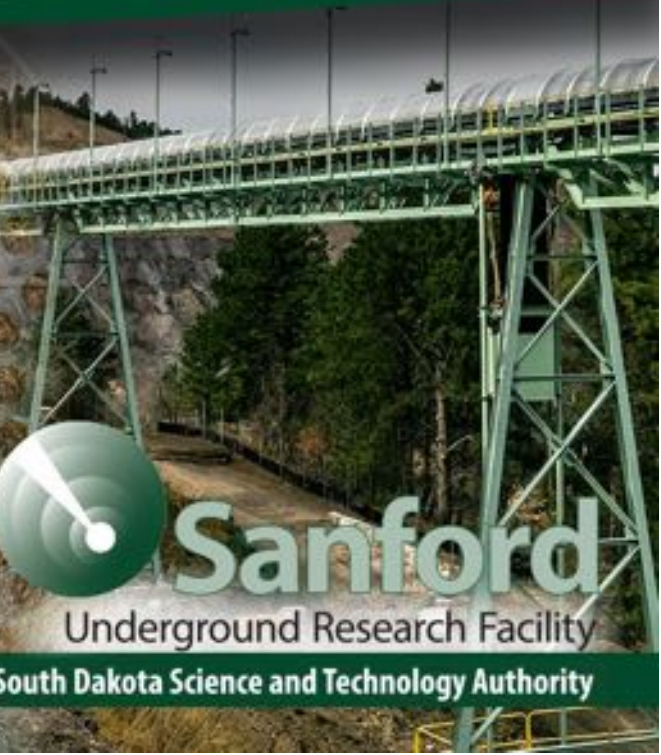
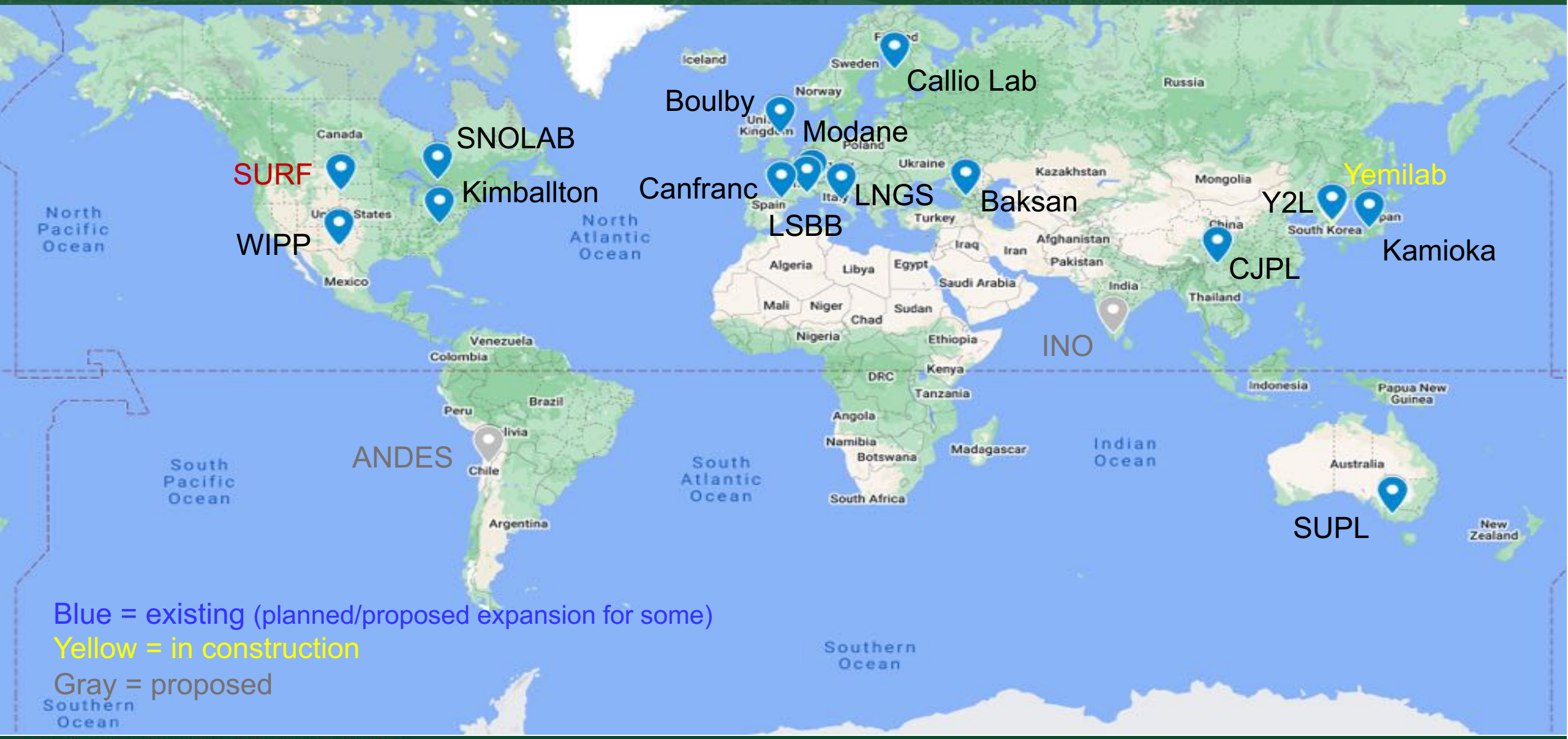


Sanford
Underground Research Facility
South Dakota Science and Technology Authority

CETUP* 2023

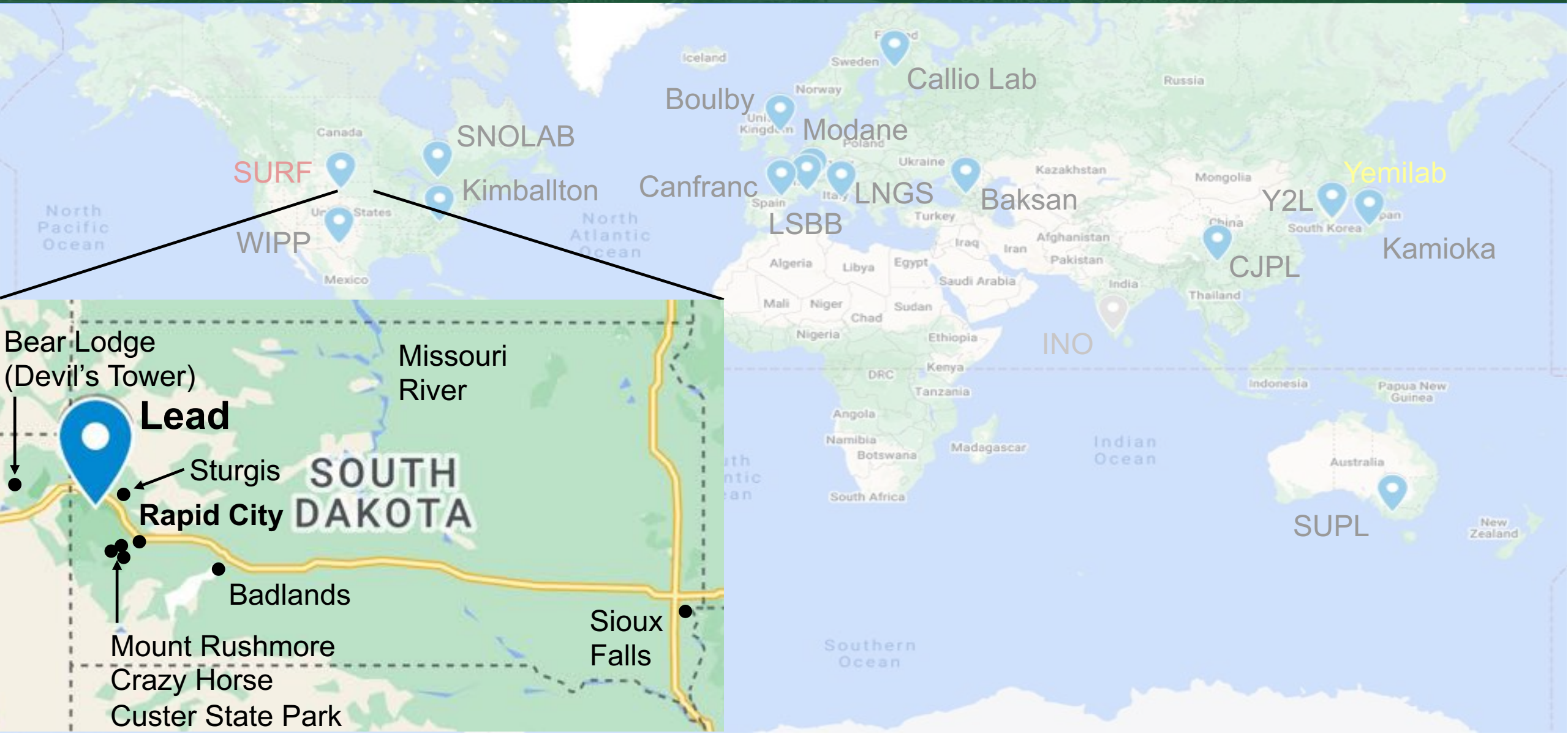
Sanford Underground Research Facility

Where in the world is SURF?



Sanford Underground Research Facility

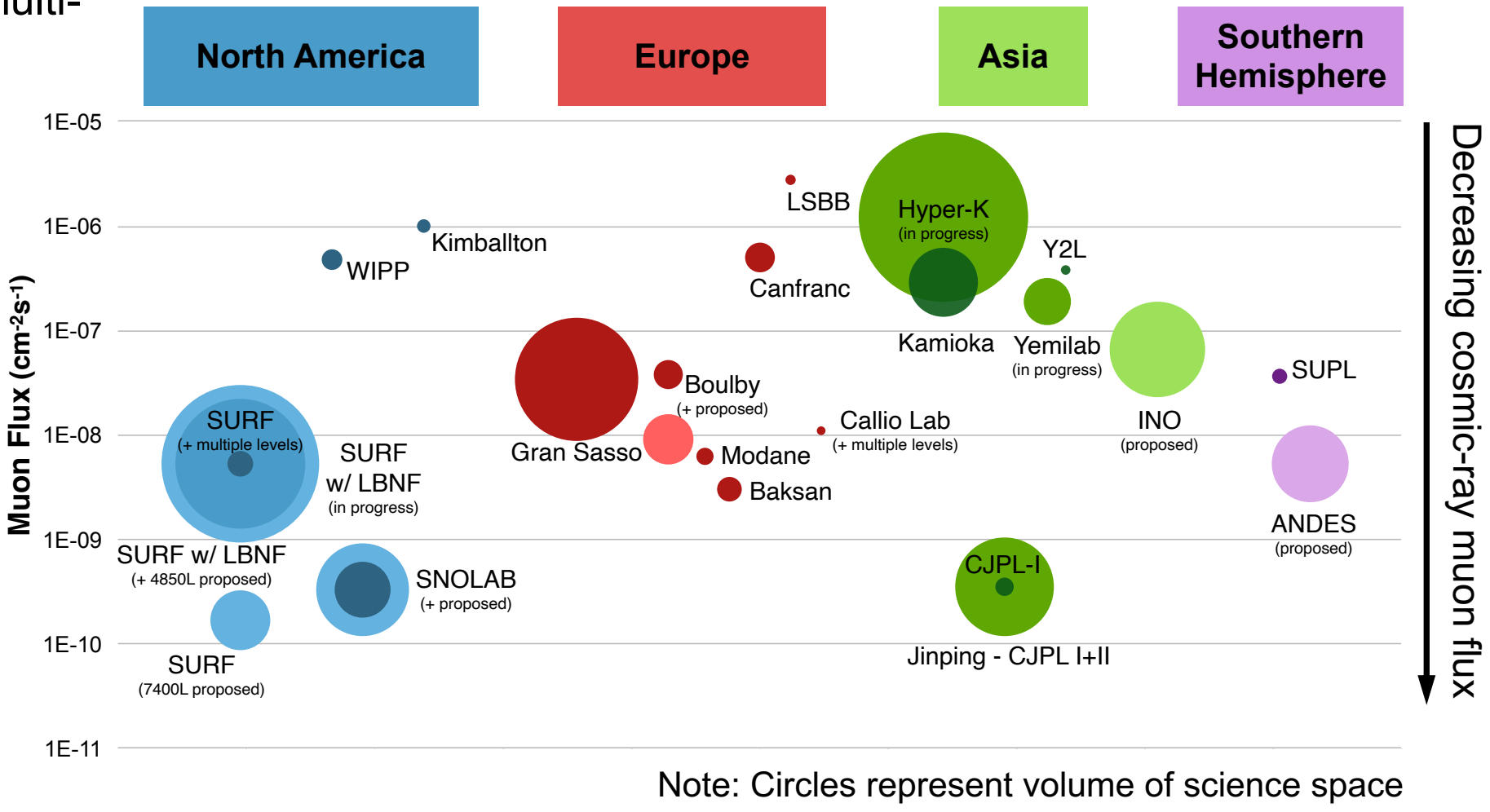
Where in the world is SURF?



Worldwide Underground Facilities

UG Facilities can provide:

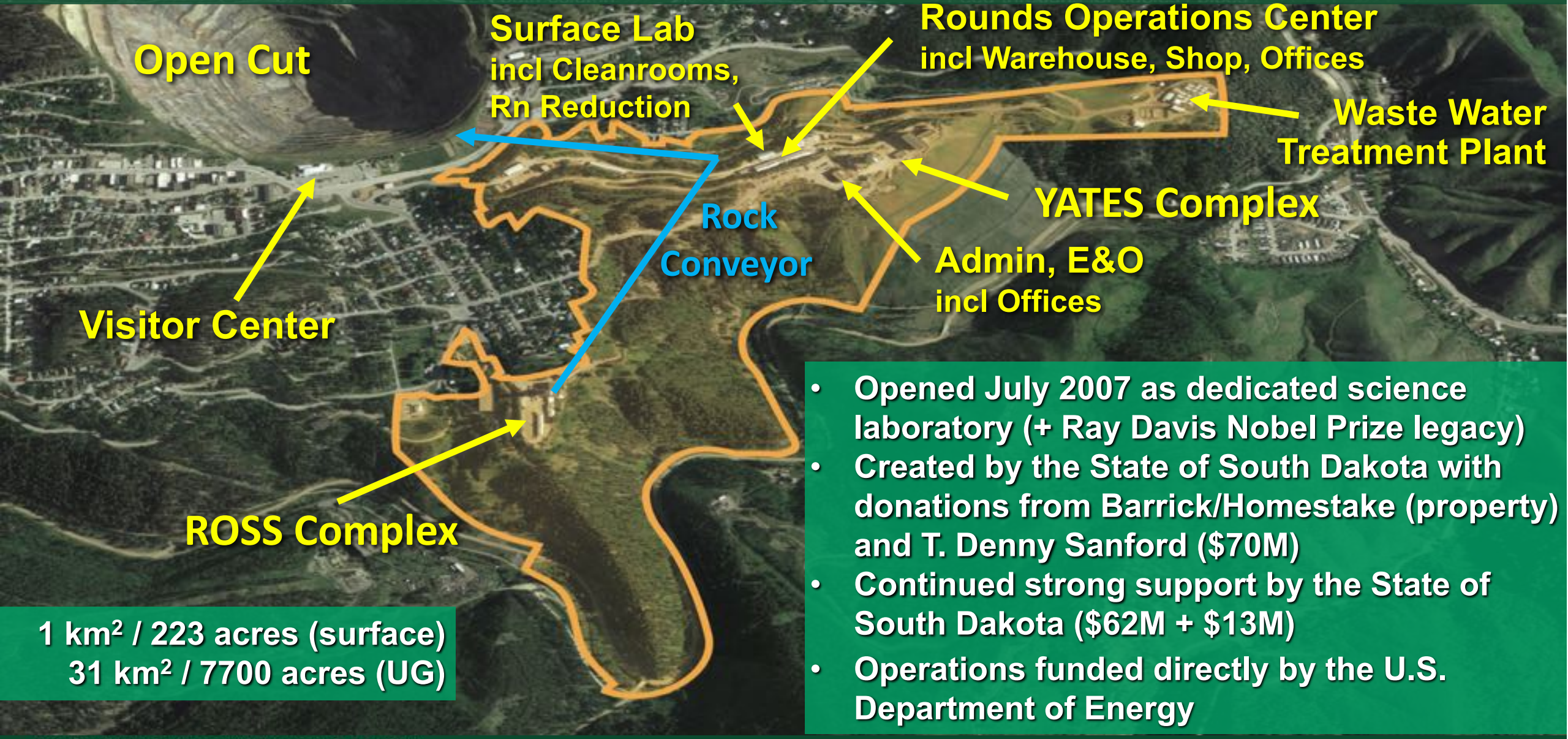
- Unique environments for multi-disciplinary research
  - Overburden protection from cosmic-ray muons
- Local radiation shielding
- Assay capabilities
- Material production/ purification
- Environmental control
- Implementation and operations support
- Community catalyst



Note: Circles represent volume of science space

Sanford Underground Research Facility

Nation's deepest underground lab, advancing multi-disciplinary research



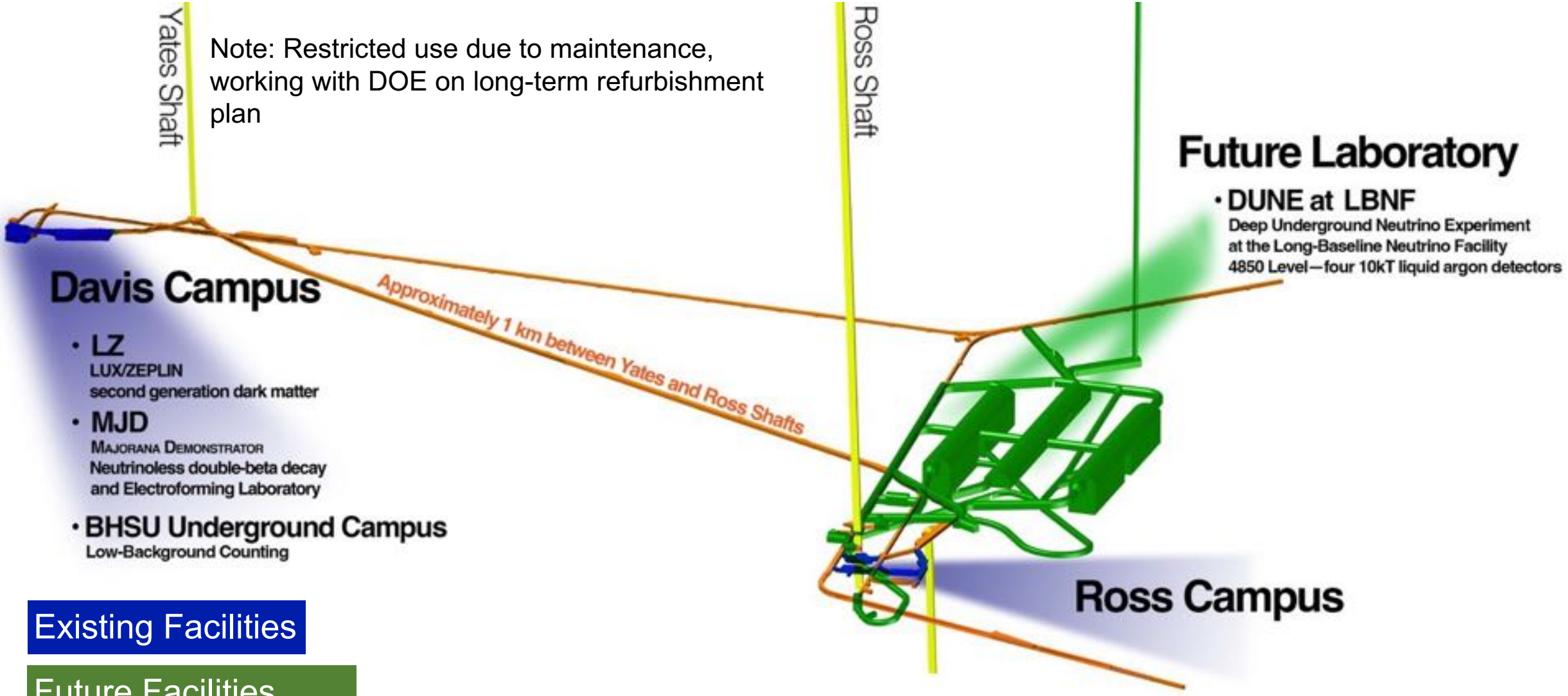
- Opened July 2007 as dedicated science laboratory (+ Ray Davis Nobel Prize legacy)
- Created by the State of South Dakota with donations from Barrick/Homestake (property) and T. Denny Sanford ($70M)
- Continued strong support by the State of South Dakota ($62M + $13M)
- Operations funded directly by the U.S. Department of Energy

1 km² / 223 acres (surface)
31 km² / 7700 acres (UG)

Sanford Underground Research Facility

Nation's deepest underground lab, advancing multi-disciplinary research

4850L Science Facilities



Existing Facilities

Future Facilities


Dark Matter
LUX-ZEPLIN
Neutrinos
MAJORANA DEMONSTRATOR
LBNF /DUNE
Science Program
Biology
Extreme Life
Astrobiology
Geology
Geothermal Energy
Seismic Studies

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*

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*

PDR – *Sensors*

Total = 30 groups

22 Active Projects

62 Total Groups Since 2007

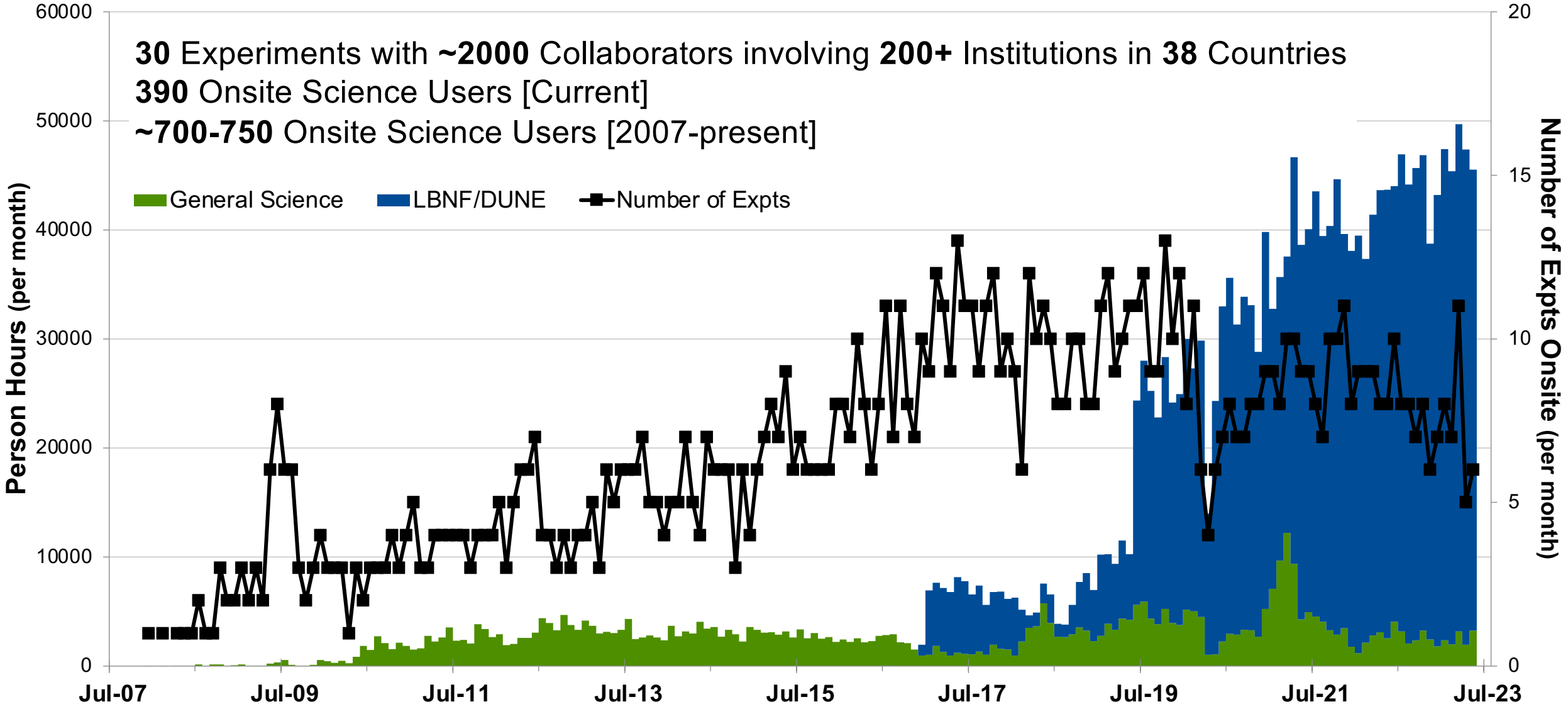
Significant interest from others

(22 groups in 2022)

* Denotes proprietary group

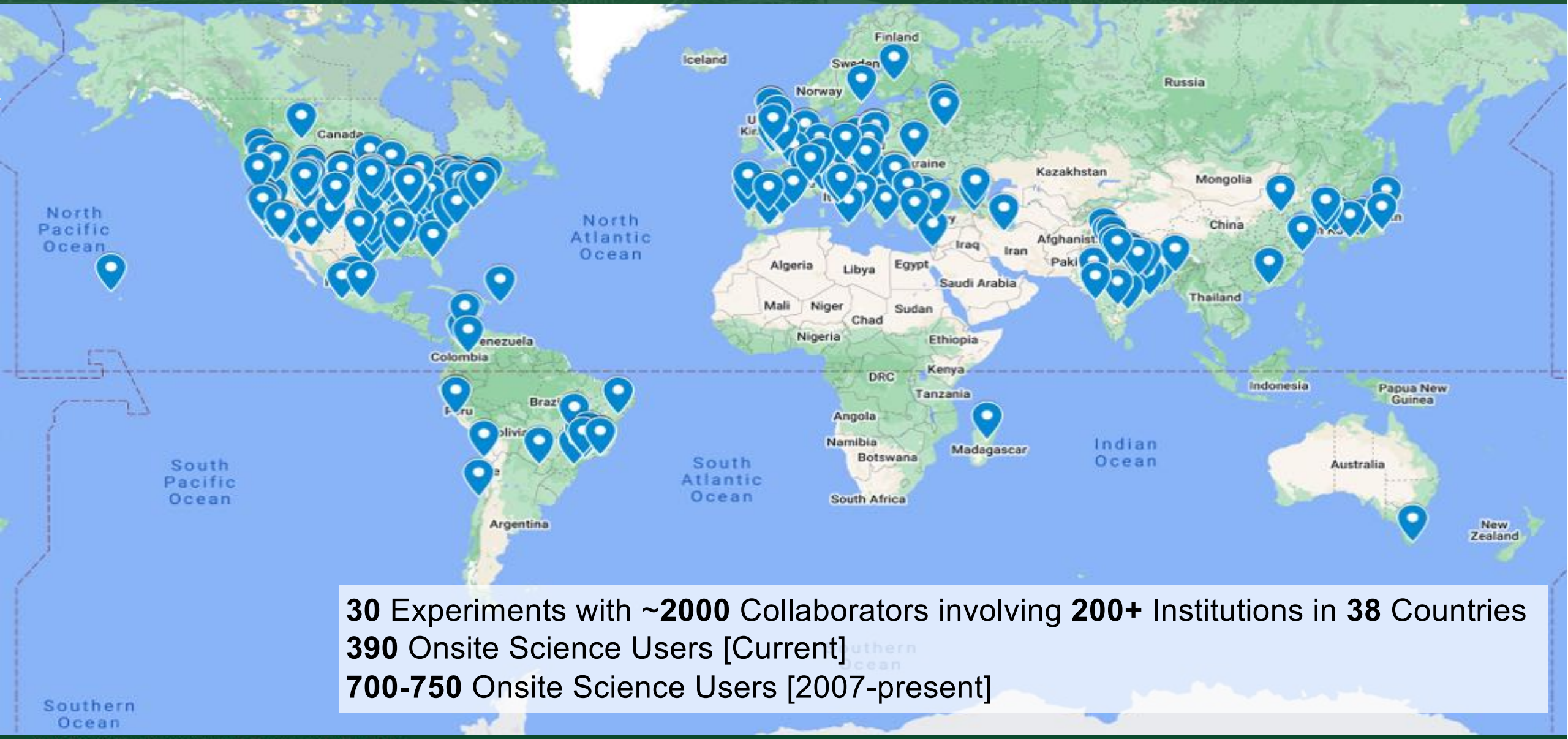
SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



30 Experiments with **~2000** Collaborators involving **200+** Institutions in **38** Countries
390 Onsite Science Users [Current]
700-750 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).
  - Production data started Dec 2021. First WIMP-search results announced Jul 2022 (world-leading), PRL to be published Jun 2023: https://arxiv.org/abs/2207.03764.
  - WIMP-search data taking continuing with run #3 started.
- **Future:**
  - Complete science data 2026/2027, then decommission. SURF Xe inventory available through 2028.
  - Meetings with next-generation liquid Xe collaboration (XLZD): http://arxiv.org/abs/2203.02309. Proposing up to ~100 tonnes Xe, site TBD. SURF expansion would work (size and nominal schedule ~2030); also for Argo (argon).
  - Low-mass dark matter projects potential follow-ons to LZ.

MAJORANA DEMONSTRATOR (MJD)

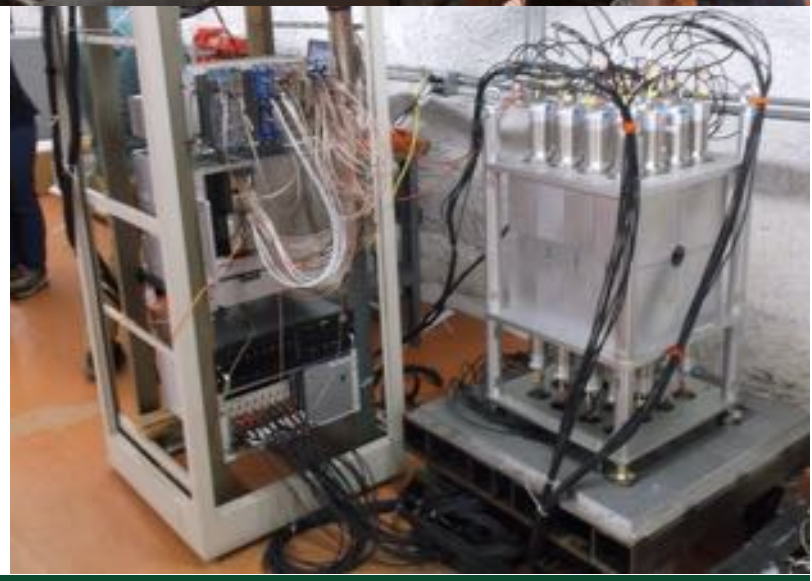
Also Large Enriched Ge Experiment for Neutrinoless ββ Decay (LEGEND)

- **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 published Feb 2023: 10.1103/PhysRevLett.130.062501.
  - Ta-180m rare decay search started May 2022, first results posted Jun 2023: https://arxiv.org/abs/2306.01965.
  - Davis Campus Cu electroforming now has 4 baths.
- **Future:**
  - Ta-180m data taking nominally ends in 2024.
  - 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.
  - 4 scientific papers, incl PRL: 10.1103/PhysRevLett.128.162701.
- **Future:**
  - 5 more papers planned. Also: 4 students graduated, 2 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).

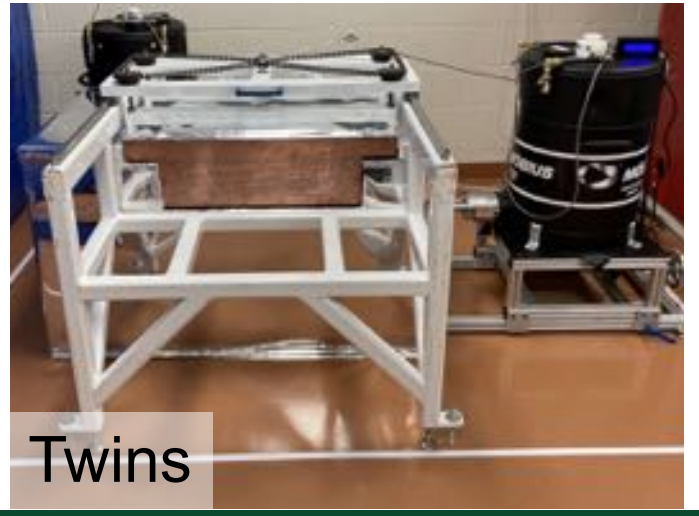


SURF Material Assay at BHUC: Davis Campus

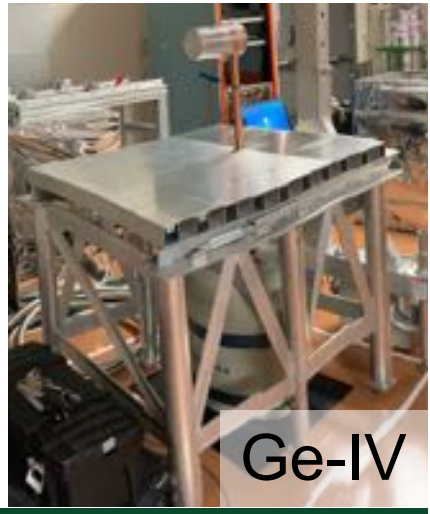
Low-background counting capabilities serving national & international community


Mordred


Maeve & Morgan


Twins


RHYM/RESN

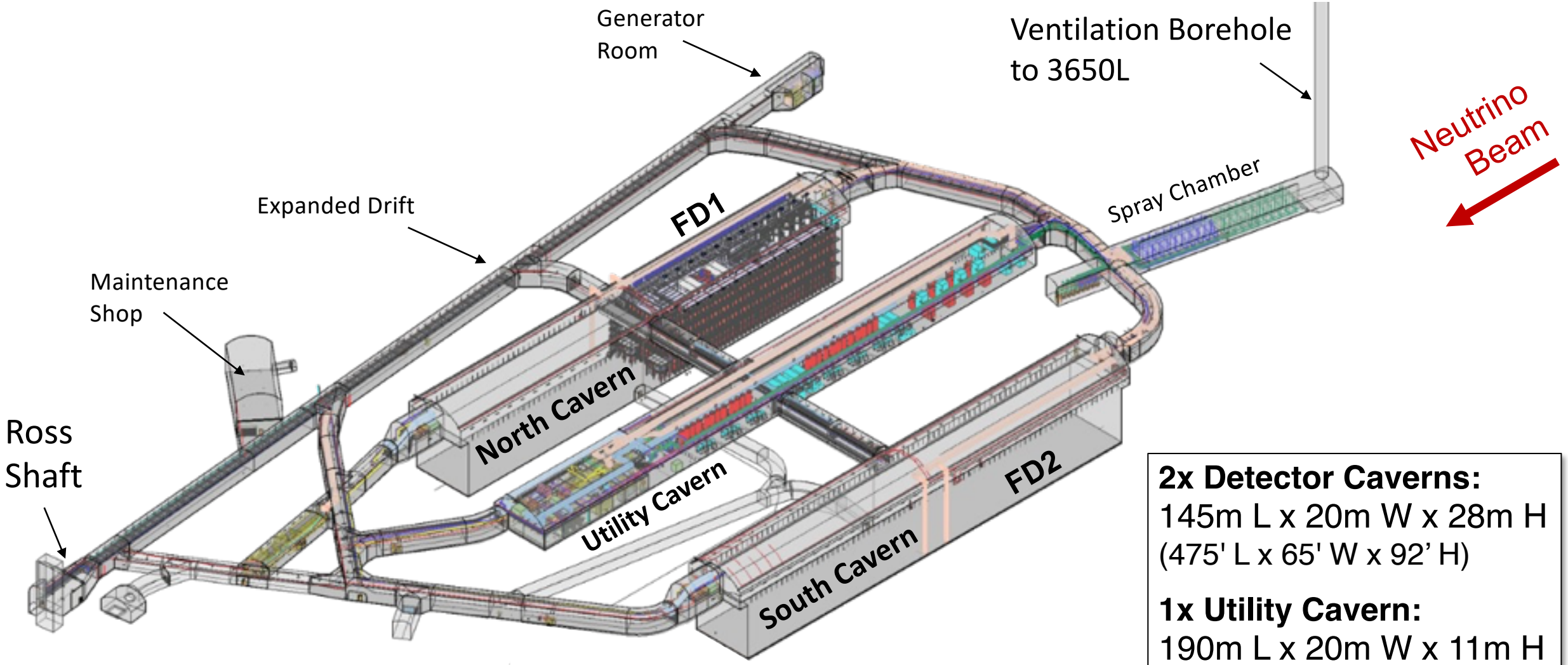

Ge-IV

SURF High-Impact Science

- 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.
- Final Result of the MAJORANA DEMONSTRATOR's Search for Neutrinoless Double-β Decay in ^{76}Ge, I. J. Arnquist *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **130**, 062501 (2023) doi: 10.1103/PhysRevLett.130.062501.
- First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment, J. Aalbers *et al*. (LZ Collaboration) accepted to *Phys. Rev. Lett.*
- Exotic dark matter search with the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration) submitted to *Phys. Rev. Lett.*
- Constraints on the Decay of ^{180m}Ta, I. J. Arnquist *et al*. (MAJORANA Collaboration) submitted to *Phys. Rev. Lett.*

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

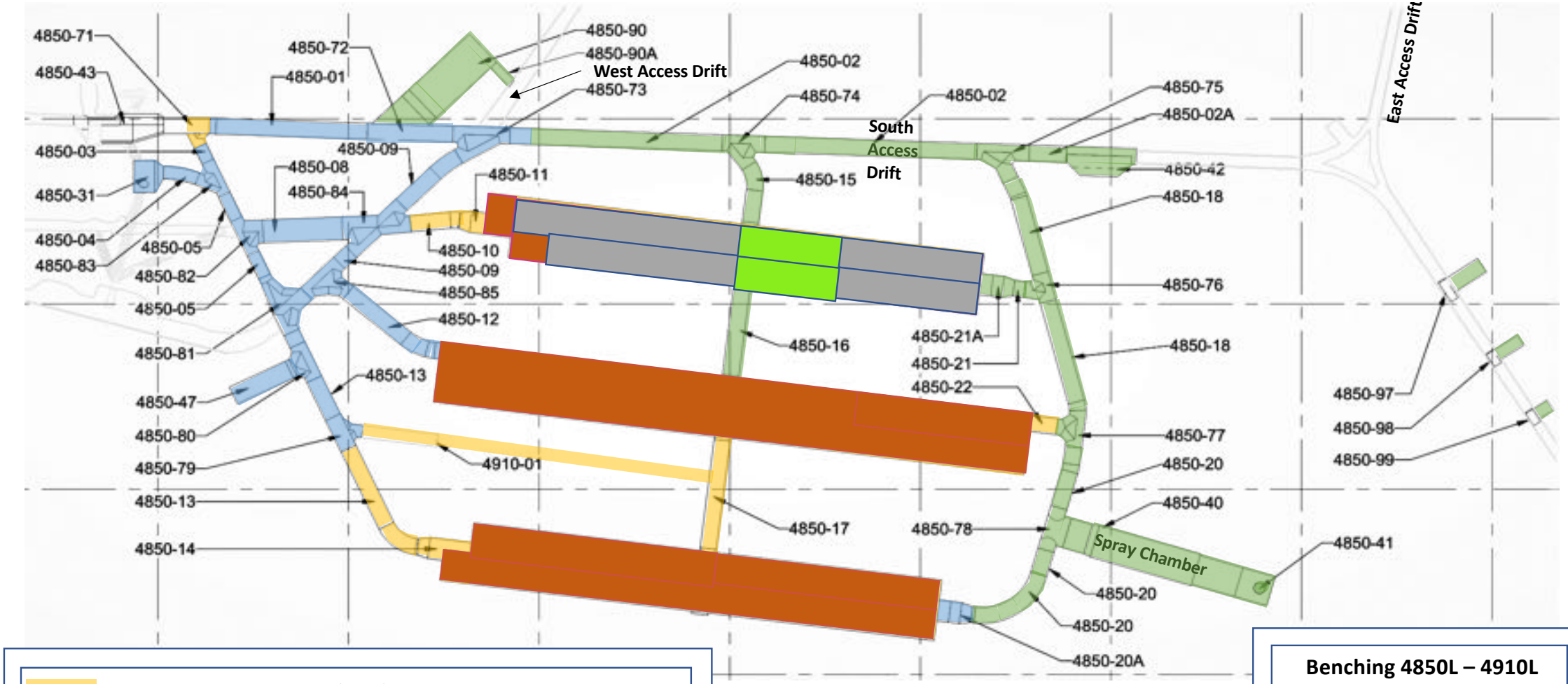


2x Detector Caverns:
145m L x 20m W x 28m H
(475' L x 65' W x 92’ H)

1x Utility Cavern:
190m L x 20m W x 11m H
(624' L x 64' W x 37’ H)

LBNF Excavation Progress

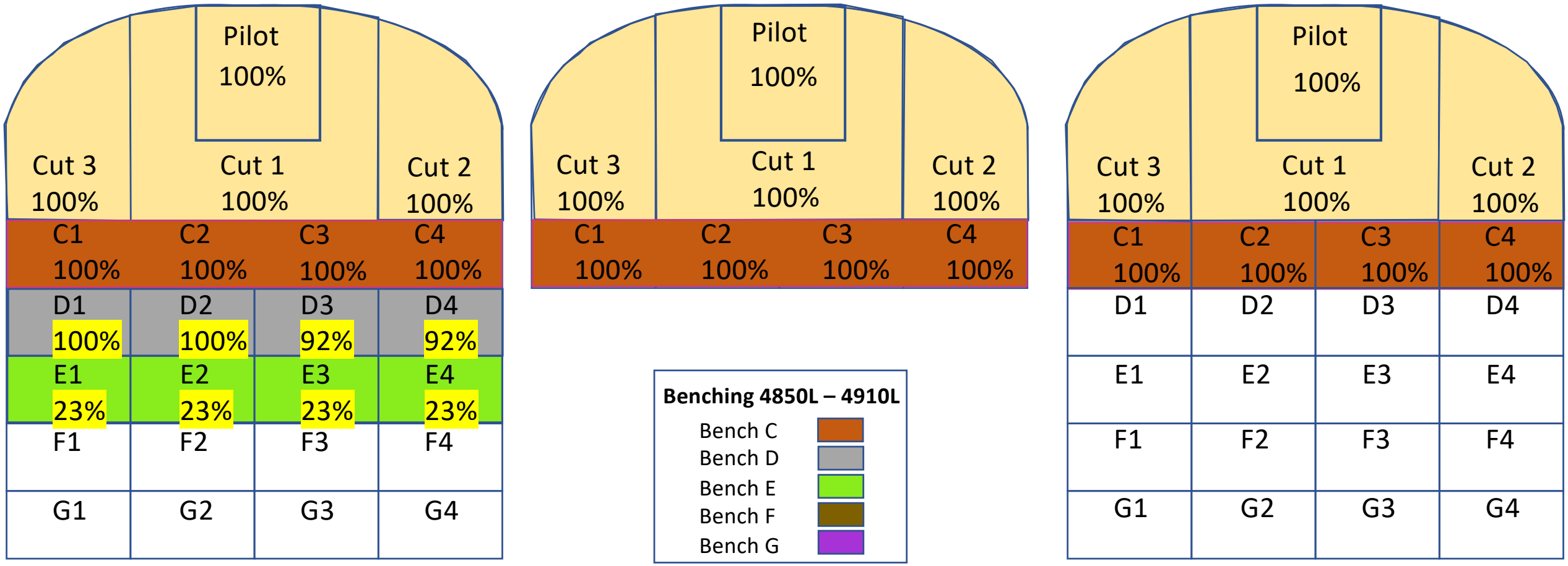
68% completed by volume. Excavation phase continues through mid-2024.



LBNF Excavation Progress

68% completed by volume. Excavation phase continues through mid-2024.

June 19, 2023



North Cavern **CUC Cavern** **South Cavern**

LBNF Excavation Video

LBNF Excavation Progress

North Detector Cavern

LBNF Excavation Progress

North Detector Cavern

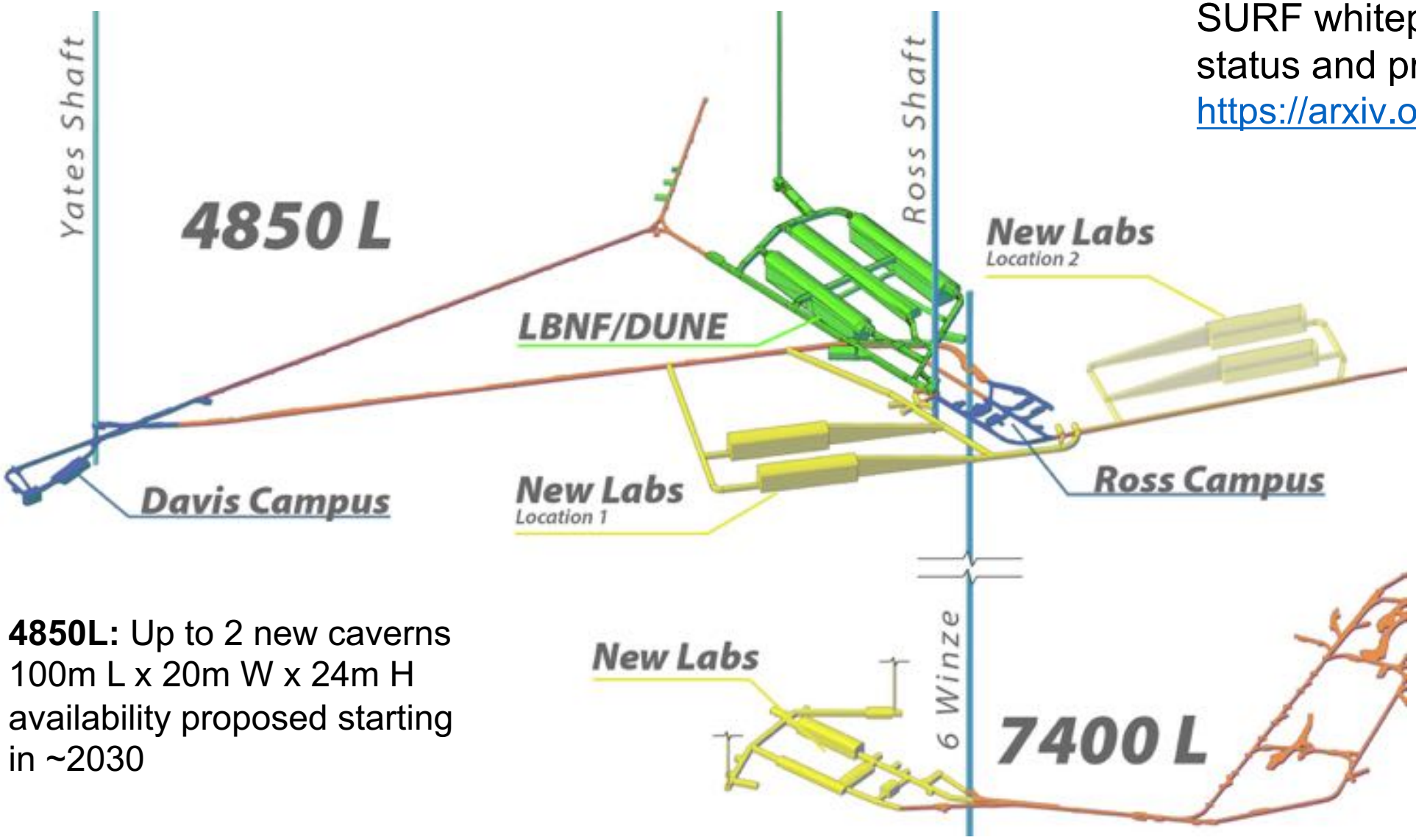
LBNF Excavation Progress

Total of 800,000 tons of excavated rock going to Open Cut

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

Particle Physics Strategic Planning Underway

Establishing a new 10-year vision

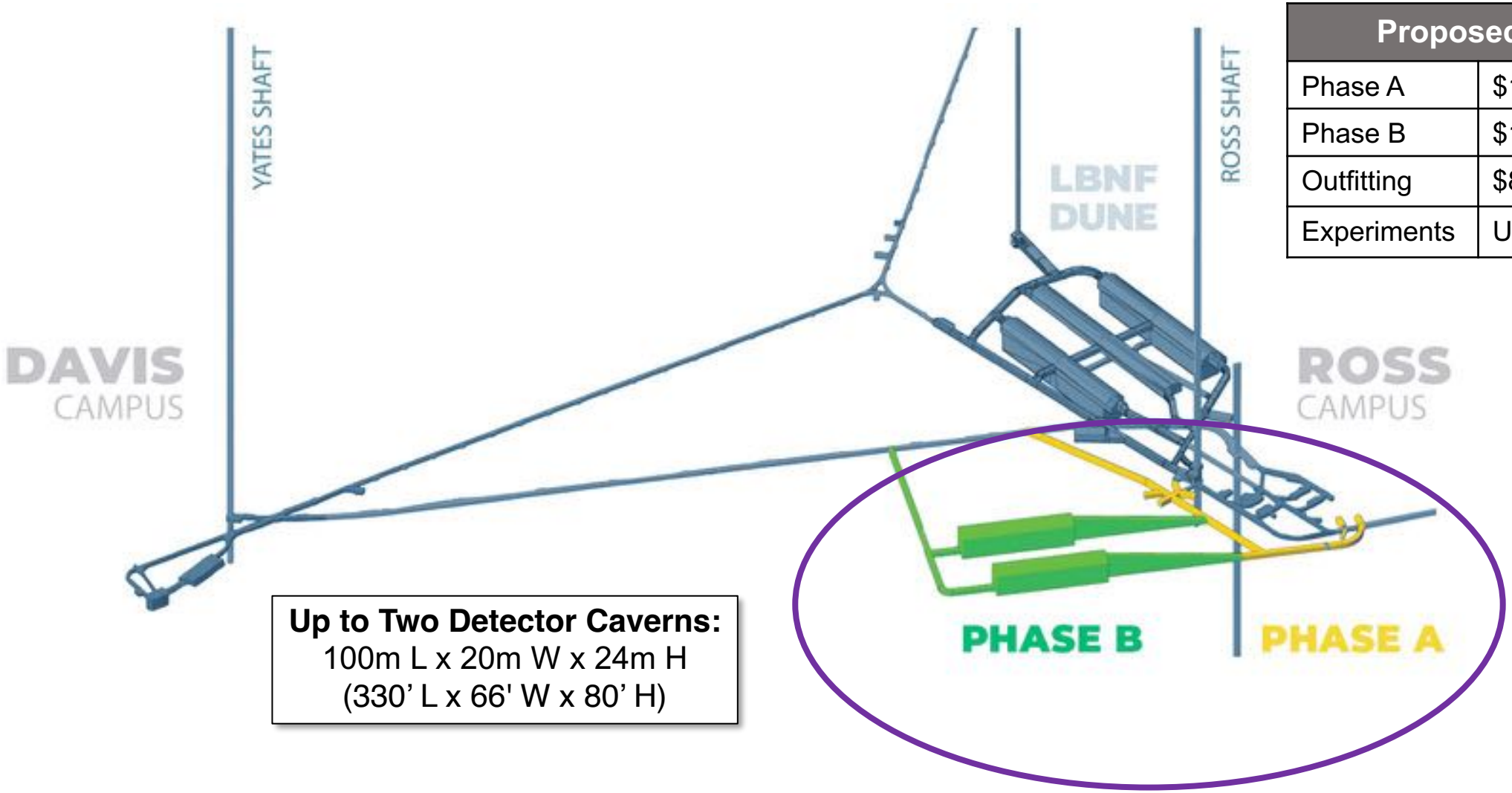
2023 P5

P5 (Particle Physics Projects Prioritization Panel) reports to HEPAP (High-Energy Physics Advisory Panel) that advises High-Energy Physics of DOE Office of Science and Division of Physics of NSF. We will build on the "Snowmass" community study to hash out priorities for the next 10 years within 20-year context.

- Community input process "Snowmass" completed Jul 2022
- Recommendations outlined in Jan 2023 final report to P5:
  - *Construction and operation of LBNF/DUNE Phase I & II and PIP-II*
  - *New experiments and R&D require* ***more underground space***
- SURF-specific recommendations to ensure world-class facility:
  - *Leverage the LBNF excavation enterprise to* ***increase underground space at SURF***
  - *Designate SURF as a formal U.S.* ***DOE User Facility***
- 2023 P5 report expected Fall 2023

4850L Space Needed for Future Experiments

U.S. strategic plan requires more space, community has endorsed expansion.



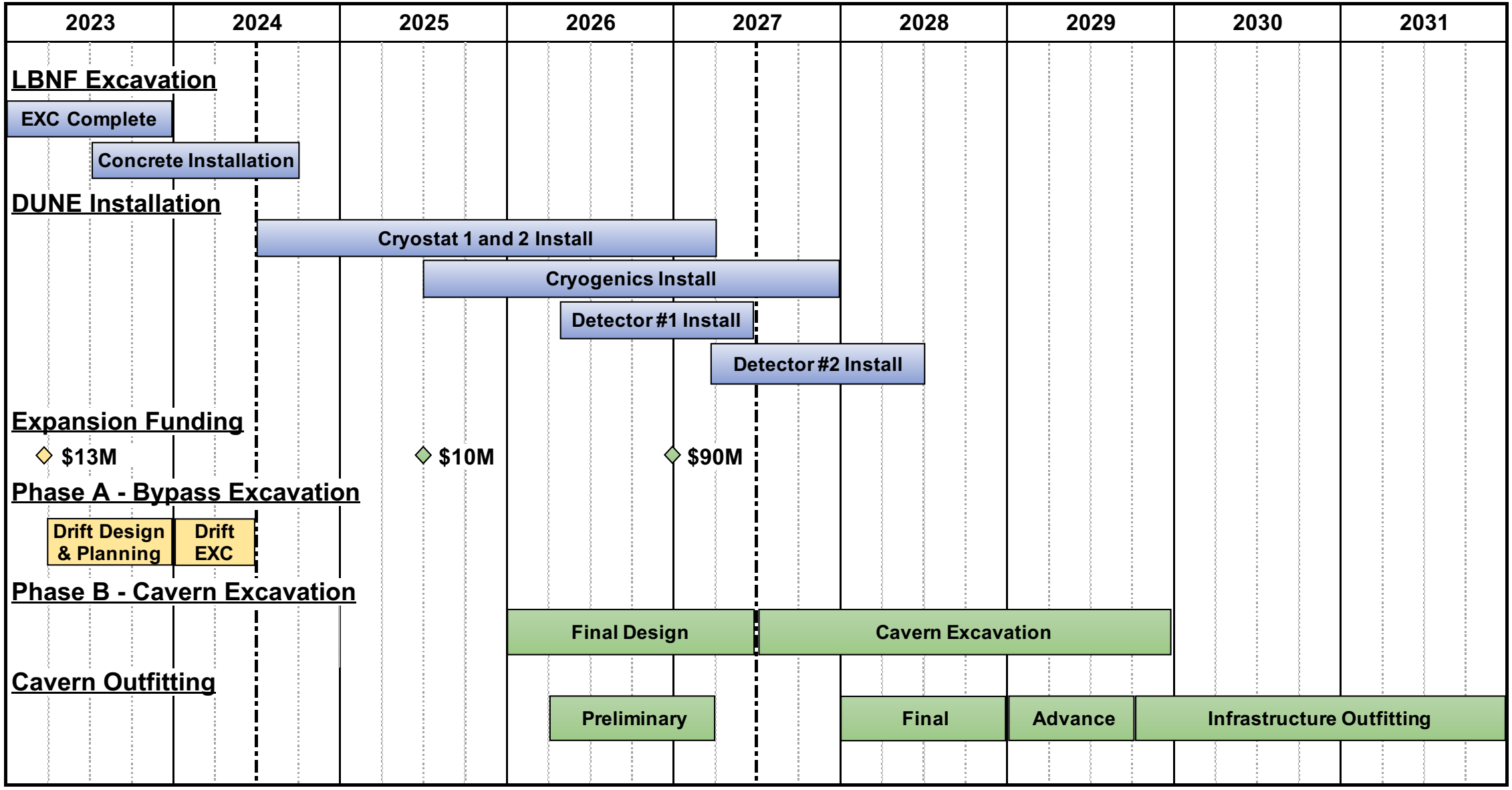
Proposed Funding Model	
Phase A	$13M State of SD ✓
Phase B	$100M Private
Outfitting	$85M Federal
Experiments	Up to $500M ea. - Fed/Intl

SD funding approved
Mar 23, 2023

Up to Two Detector Caverns:
100m L x 20m W x 24m H
(330’ L x 66' W x 80’ H)

SURF 4850L Expansion Schedule

Next-generation experiments need underground space in early 2030s



SURF plans to become DOE User Facility

Benefits:

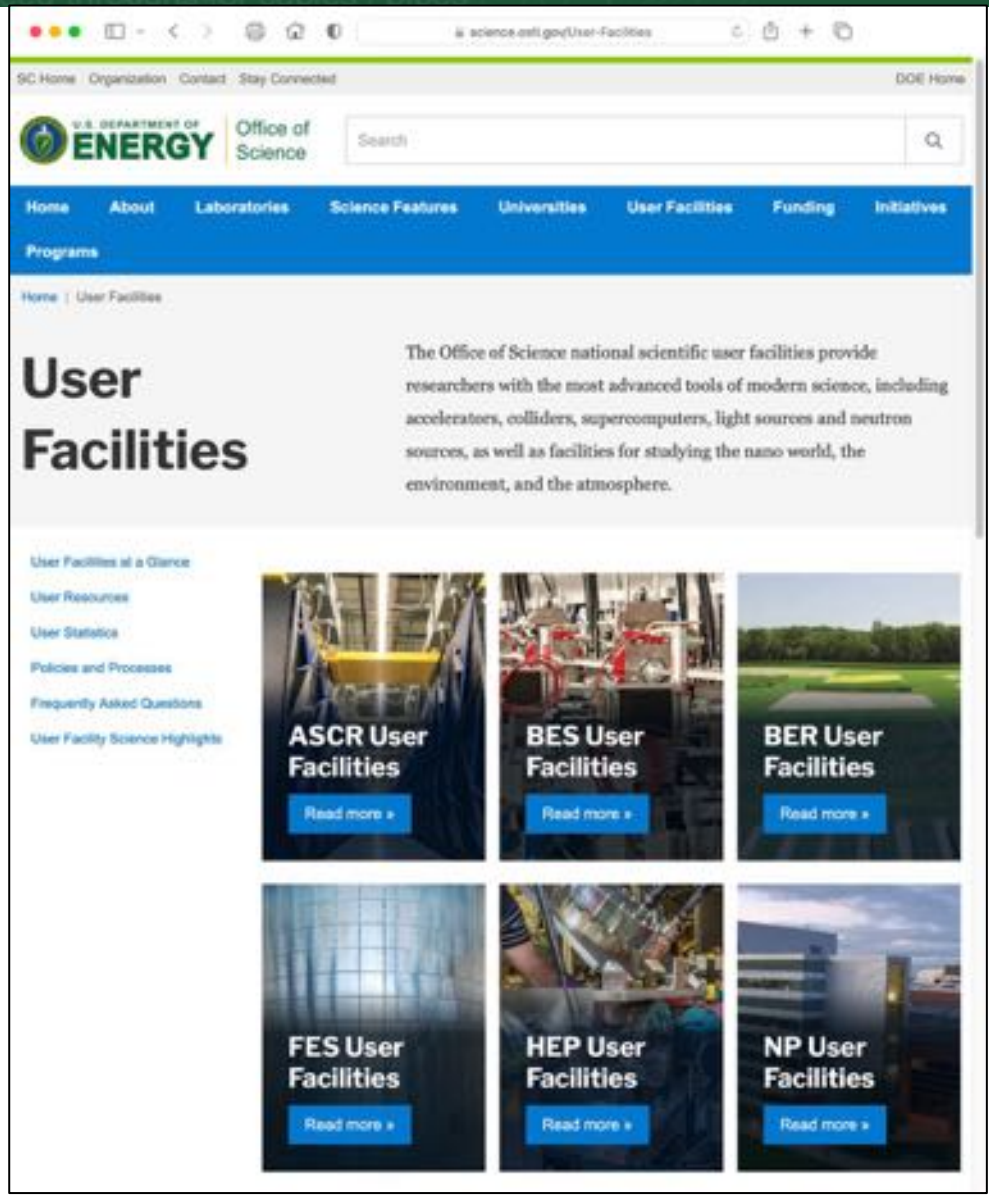
- Expands DOE User Facility portfolio to incl underground lab, raises SURF's stature within DOE community.
- Promotes underground science in U.S., increases funding opportunities.
- Enhances SURF's role in global science community.
- Communicates SURF is open to a broad range of science and users and that we have a standard process, accepted by DOE, for hosting science.

Main Requirements:

- Facility open to users regardless of nationality or institution.
- Allocation of facility resources determined by merit review.
- Facility resources for users to conduct work safely and efficiently.
- The facility supports a formal user organization.

Status:

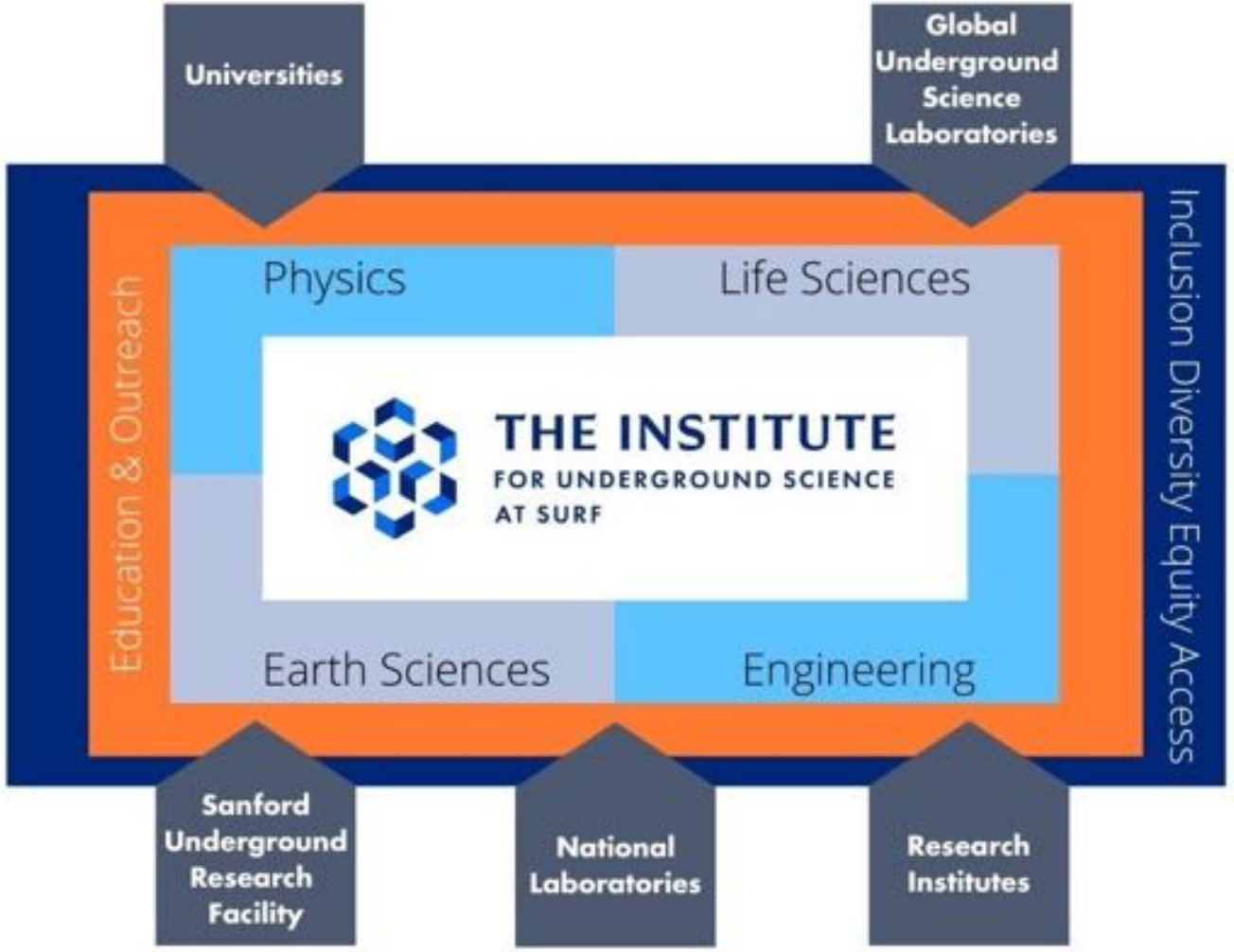
- User Association and Science Program Advisory Cttee established.
- Application draft near final, expect DOE invitation to submit soon.



Institute for Underground Science at SURF

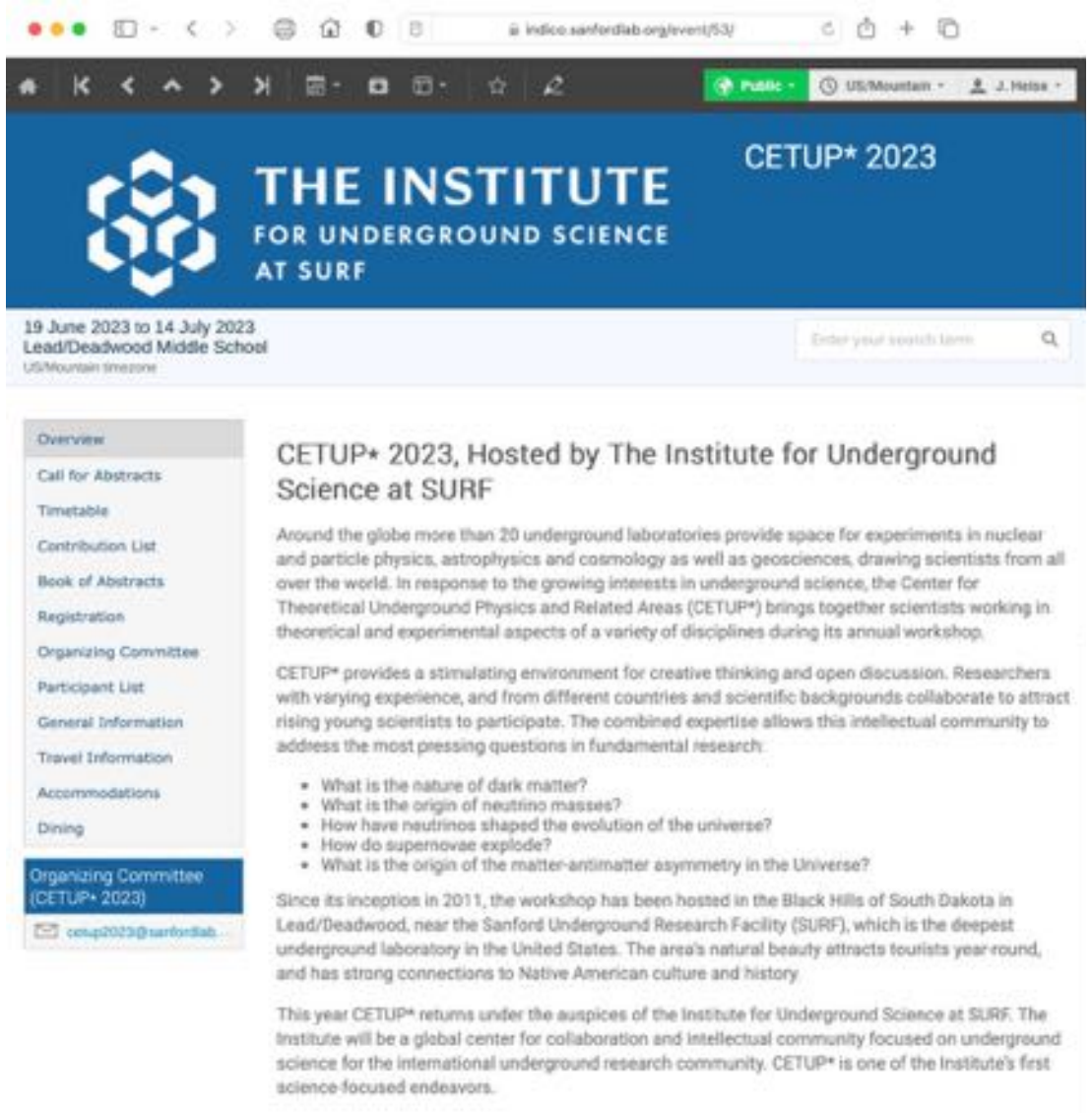
Kick-off planned for later in 2023

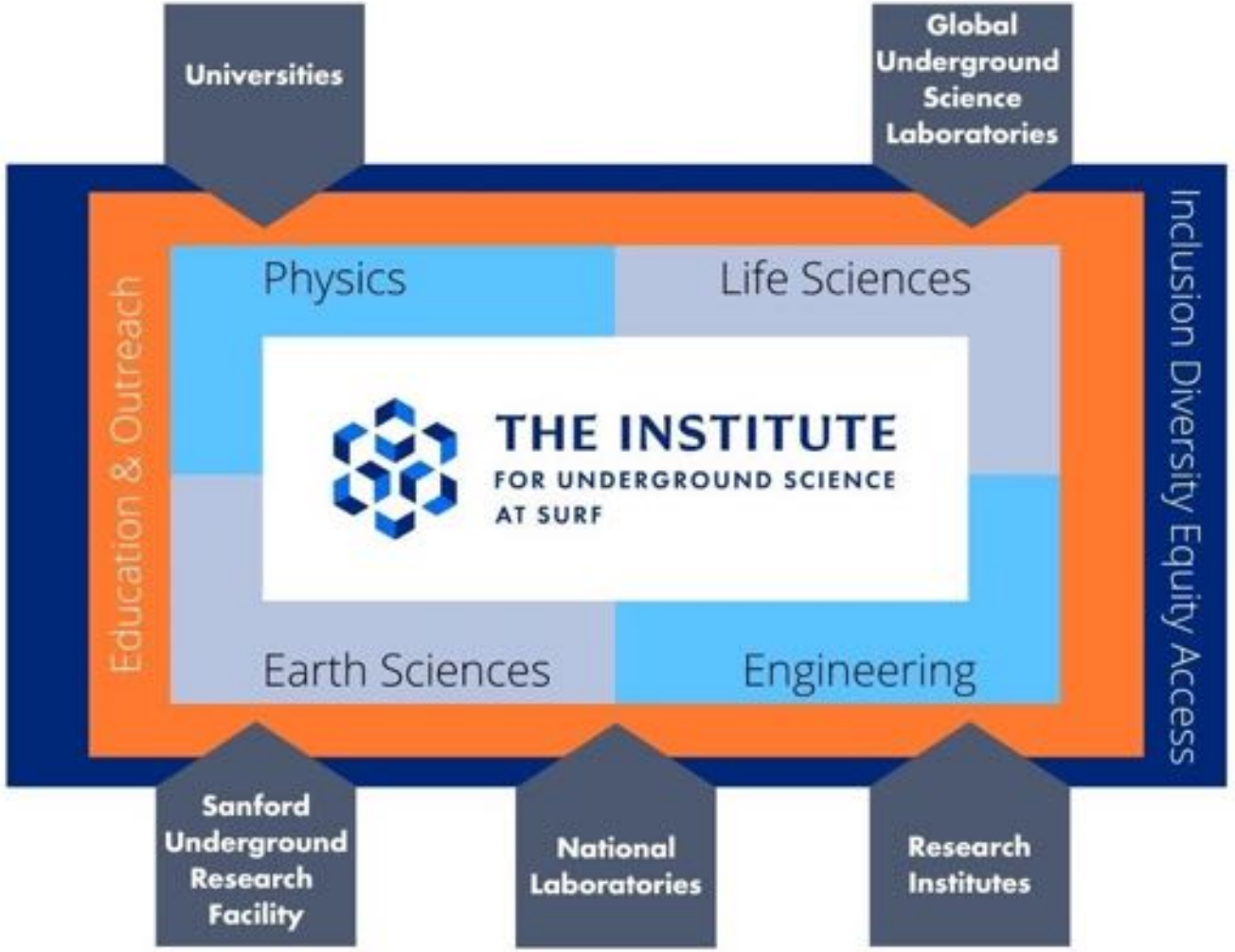
- Establish the world-leading center for underground science collaboration and intellectual community.
- Provide leadership in long-term science community planning.
- Engage with the global community for vision and leadership in a range of disciplines.
- Serve as the “hub” for information on global underground science.
- Foster close collaboration and integration with the science and outreach programs.
- Establish world leadership in K-12 and public E&O programs.



Institute for Underground Science at SURF

CETUP* Topical Workshop started this week!





SURF Summary

- SURF has strong relationship with DOE that benefits UG science community:
  - DOE funding for SURF operations incl **mandate to support experiments**; anticipating DOE User Facility designation.
  - DOE funding for SURF infrastructure ensures **safety and reliability**.
- SURF offers world-class service to the underground science community:
  - SURF breadth and depth enables **diverse and transformational science.**
  - 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 existing science program and LBNF/DUNE remain top priorities**.
- SURF wants to host other future world-leading experiments:
  - All existing and near-term space at SURF is **fully subscribed**.
  - Leveraging LBNF/DUNE excavation contractor offers **significant development advantages**.
  - SURF is preparing to **increase underground laboratory space**, plans advancing for new large caverns on 4850L (1500 m, 4200 mwe) on **timeframe of next-generation experiments (~2030)**.
- SURF is playing a strong role in the UG science community:
  - **User Association** serving as catalyst for community discussions and will leverage for future planning.
  - **Strong community support** endorsing more space at SURF (Vision Workshop 2021, Snowmass 2021).
  - Appropriate to have strong recognition and support for SURF in **P5 report**.

Sanford Underground Research Facility

Thank You!

Sanford Lab Homestake Visitor Center

Acquired January 2022. Greatly expands public outreach opportunities.

SURF User Association

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

Purpose

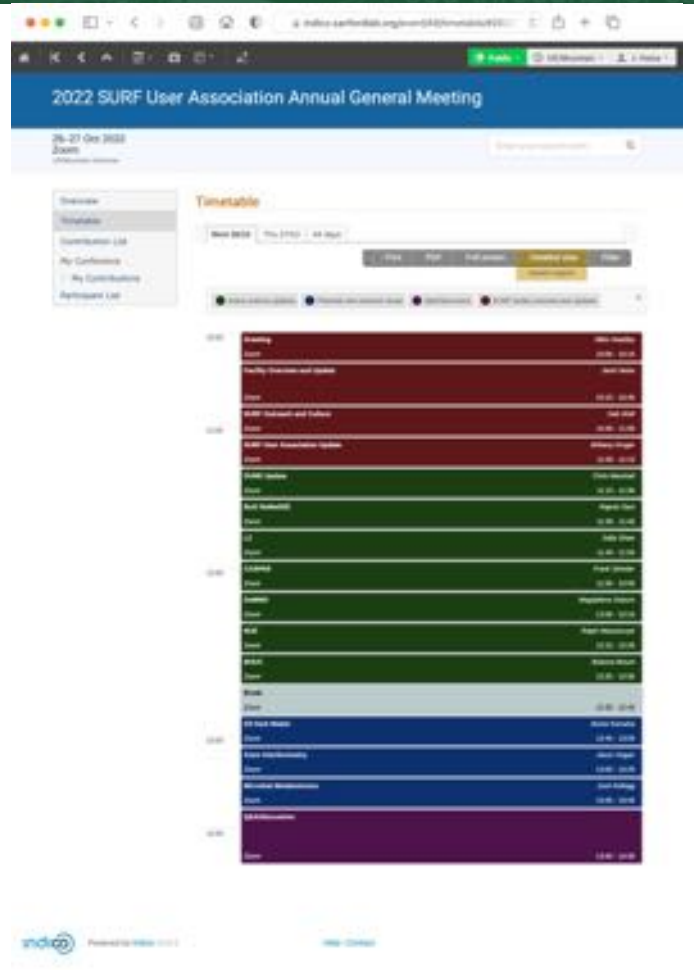
- **Two-way communication** on topics important to researchers.
- Promotes a **sense of community** amongst SURF experiments and researchers.
- Articulates and promotes **scientific case for UG science** and significance to society, provides channel for **advocacy.**

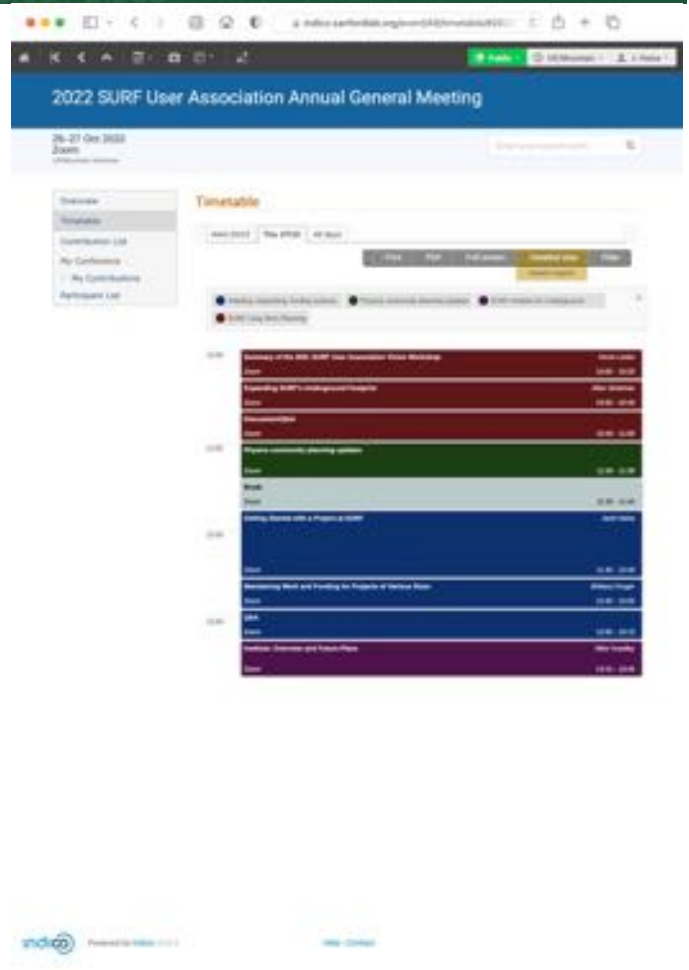
Organization

- **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.



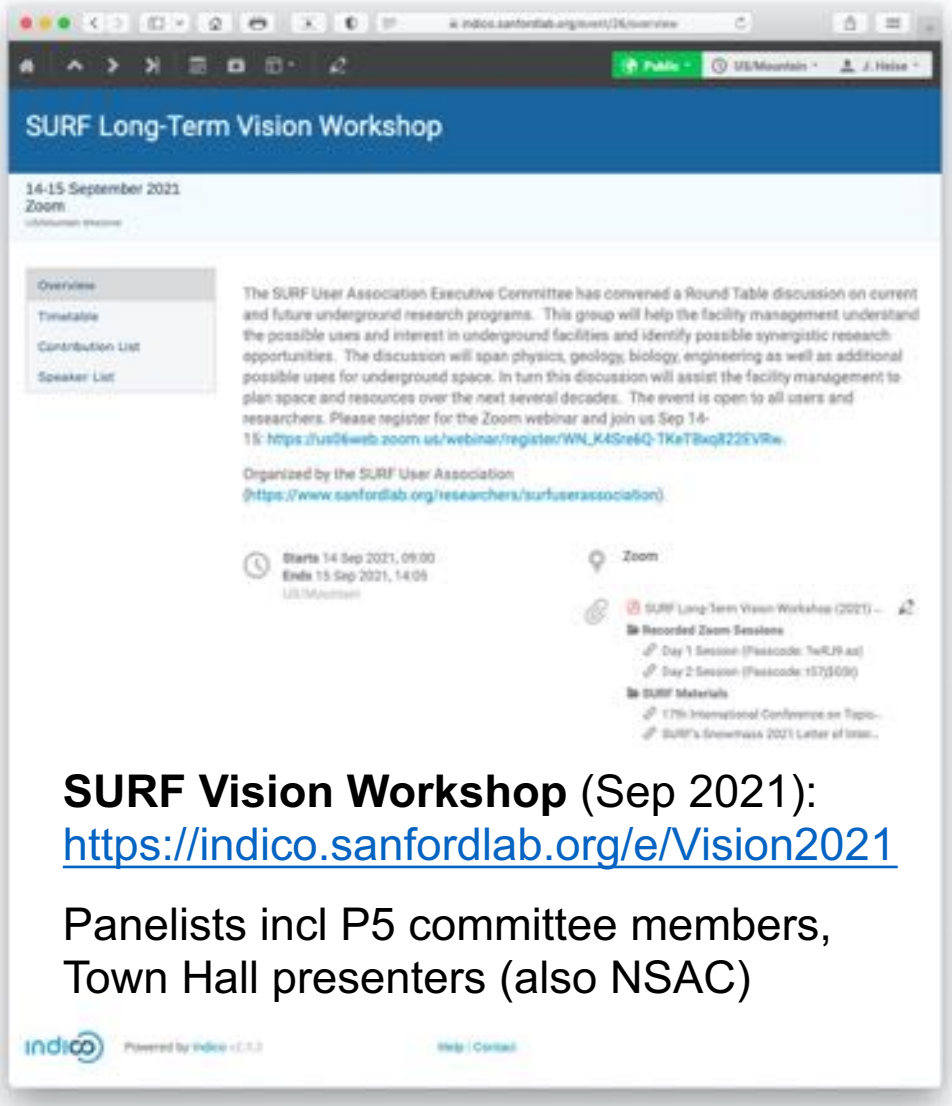


Oct 26-27, 2022:
SURF User Association General Meeting
https://indico.sanfordlab.org/e/SUA-Oct2022

SURF Community Engagement

SURF Long-Term Vision Workshop

- **All Science Disciplines:** Significant interest in additional underground space. Additional excavation both scientifically motivated and cost effective (if following LBNF/DUNE) even if precise details re: specific experiments not worked out yet
- **Physics:**
  - **LBNF/DUNE:**
    - Community interest in “Module of Opportunity” (now Phase 2)
    - Other expts benefit from LBNF/DUNE neutrino beam at SURF
    - Prediction of DUNE+ (follow-on expt to DUNE) beyond 2050
  - **Dark Matter:** Generation-3 detector for direct WIMP search
  - **Neutrinoless Double-Beta Decay:** Prediction of generation beyond ton-scale
  - **QIS:** Quantum sensors (dark matter, gravitational waves, etc), quantum computing
  - **Nuclear Astrophysics:** Physics niche complementing other UG accelerators
- **Science Support:** Long-term access, assay, materials, etc
- **Misc:** UG labs promote synergies, advocacy for diversity of projects



SURF Vision Workshop (Sep 2021): https://indico.sanfordlab.org/e/Vision2021

Panelists incl P5 committee members, Town Hall presenters (also NSAC)

SURF at Snowmass

SURF contributions reflect UG science community input and engagement

- SURF documents submitted for UG Facilities Frontier:
  - LOI: https://www.snowmass21.org/docs/files/?dir=summaries/UF/
  - Whitepaper: https://arxiv.org/abs/2203.08293

- Additional underground space proposed at SURF:
  - **4850L** (1500 m, 4200 m.w.e), **7400L** (2300 m, 6500 m.w.e.)
  - Initial engineering designs completed
  - Excavation for **100-m caverns** could begin as early as 2027, **complete by ~2030**

- SURF advocated for recommendations, including:
  - Mission need for **additional deep laboratory space** in U.S. in U.S. to support compelling future science
  - Establish process to **optimize scientific use of UG spaces** at SURF (i.e., LBNF/DUNE)
  - Endorse value of **multi-disciplinary underground science** at a dedicated laboratory in U.S.

The Sanford Underground Research Facility

J. Heise

630 East Summit Street, Lead, SD 57754 USA

Submitted to the Proceedings of the US Community Study on the Future of Particle Physics (Snowmass 2021)

Executive Summary

The Sanford Underground Research Facility (SURF) has been operating since 2007 as a dedicated scientific laboratory supporting underground research in rare-process physics, as well as offering research opportunities in other disciplines. SURF laboratory facilities include a Surface Campus as well as campuses at the 4850-foot level (1500 m, 4200 m.w.e.) that host a range of significant physics experiments, including those studying dark matter, neutrino properties, and nuclear astrophysics topics. SURF is also home to the Long-Baseline Neutrino Facility (LBNF) that will host the international Deep Underground Neutrino Experiment (DUNE).

SURF's capabilities are well-matched to attributes that define a world-class underground facility:

- Unique environments for multi-disciplinary research: SURF is the deepest underground lab in U.S. and one of deepest laboratories in the world, attracting world-leading experiments and scientists from diverse scientific communities. SURF has sufficient depth for next-generation neutrino, rare process and dark matter experiments and is actively exploring expansion opportunities as indicated in Figure 1.
- Local radiation shielding: SURF provides a water tank at the Davis Campus and corresponding water purification system. Low-activity facility construction materials were employed in specific areas (e.g., concrete, shotcrete), and in the Davis Cavern additional steel shielding was embedded in the floor below the water tank.
- Assay capabilities: Low and ultra-low background counting services are available for SURF experiments as well as the international scientific community.
- Material production/purification: SURF is one of only a few laboratories in the world where underground copper electroforming is currently performed.
- Environmental control: Cleanrooms with HEPA filtration and dehumidification systems as well as radon-reduction systems (on the surface and underground); some locations have coatings that inhibit radon emanation.
- Implementation and operations support: SURF has a robust organization with support for experiment planning, installation and operations, with a proven track record of delivering successful science, leveraging and augmented by U.S. national laboratory resources as appropriate.

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

Snowmass Underground Facilities Frontier

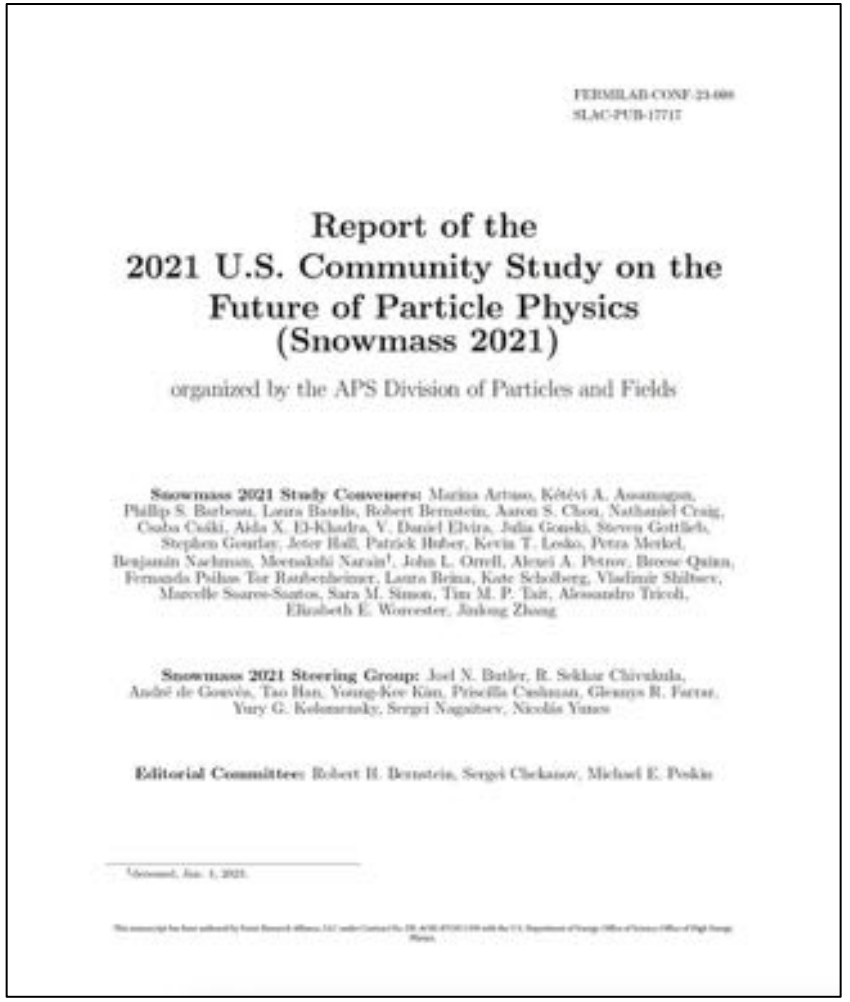
Strong community support for SURF and UG experiments

Executive Summary:

- New experiments and enabling R&D require **more UG space**.
- Endorsed **SURF 4850L expansion** (and possible future 7400L) for next-generation dark matter, neutrinoless double-beta decay expts

Recommendations:

1. Leverage **LBNF excavation** enterprise to **increase underground space at SURF** in timely and cost-effective way to permit siting of next-generation UG high energy physics research experiments.
   - **Excavate and outfit one or more new underground caverns at SURF 4850'** to house at least one large next-generation expt plus mid-size & small expts.
2. Designate SURF as a U.S. **DOE User Facility**.
3. Provide full support for **LBNF/DUNE UG facilities**.
4. R&D and decision making for a **third-generation direct-detection dark matter program** should commence immediately to enable a construction start in the late 2020s.
5. To ensure a robust collection of scientific programs in underground facilities, support the **enabling capabilities, technique development, and expertise** required for UG experiments.



FERMILAB-CONF-23-000
SLAC-PUB-17717

Report of the
2021 U.S. Community Study on the
Future of Particle Physics
(Snowmass 2021)

organized by the APS Division of Particles and Fields

Snowmass 2021 Study Conveners: Marina Artuso, Kétévi A. Assamagan, Phillip S. Barbeau, Laura Baudis, Robert Bernstein, Aaron S. Chou, Nathaniel Craig, Csaba Csáki, Aida X. El-Khadra, V. Daniel Elvira, Julia Gonski, Steven Gottlieb, Stephen Gourlay, Jeter Hall, Patrick Huber, Kevin T. Lesko, Petra Merkel, Benjamin Nachman, Meenakshi Narain[1], John L. Orrell, Alexei A. Petrov, Breese Quinn, Fernanda Psihas Ter Rantzenheimer, Laura Reina, Kate Scholberg, Vladimir Shiltsev, Marcelle Soares-Santos, Sara M. Simon, Tim M. P. Tait, Alessandro Tricoli, Elizabeth E. Worcester, Jinlong Zhang

Snowmass 2021 Steering Group: Joel N. Butler, R. Sekhar Chivukula, André de Gouvêa, Tao Han, Young-Kee Kim, Priscilla Cushman, Gleanys R. Farrar, Yury G. Kolomensky, Sergei Nagaitsev, Nicolás Yunes

Editorial Committee: Robert H. Bernstein, Sergei Chekanov, Michael E. Peskin

[1]deceased, Jan. 1, 2021.

SURF 4850L Expansion – South Dakota Support

4850L space needed for next-generation experiments

United States Senate
WASHINGTON, DC 20510

February 18, 2023

South Dakota State Legislators
c/o Joint Committee on Appropriations
500 East Capitol Avenue
Pierre, SD 57501

Dear Members of the South Dakota State Legislature,

We write to emphasize our strong and continued commitment to support ongoing and additional federal funding for the Sanford Underground Research Facility (SURF).

We understand the South Dakota State Legislature is considering a $13 million appropriation for the South Dakota Science and Technology Authority (SDSTA), owner and operator of SURF. This is a significant investment of state resources, and we appreciate the thoughtfulness and due diligence required in your deliberations.

SURF is the deepest underground research facility in the United States, which makes it uniquely positioned to conduct cutting-edge research in a range of fields, including physics, biology, and engineering. The facility has attracted internationally-leading researchers and has made significant contributions to our understanding of the universe and the advancement of science. SURF is only a reality due to past support, including the bold, historic support of the State of South Dakota.

In 2004, the South Dakota State Legislature appropriated $14.3 million to create the SDSTA and cover expenses incurred in the agreement with Barrick Mining Corporation and the Homestake Mining Company to donate the mine. Then, in an October 2005 special session, the State of South Dakota appropriated $19,887,630 to begin facility operations, which included pumping water out of the mine. At that time, the South Dakota delegation secured federal resources in the form of a $10 million grant. This combined funding was matched by a generous $70 million donation from philanthropist T. Denny Sanford, who believed in the dream of converting the mine into a world-class research facility.

The legacy of SURF is a story of South Dakotans investing in South Dakota, and the investments have paid off. To date, South Dakota has cumulatively spent $62 million in support of SURF; that money has yielded $932 million in direct federal and private investment, a 15:1 return. SURF provides good jobs and state-wide economic benefits. Between federal fiscal year 2007 and 2022, SURF has spent over $135 million in South Dakota payroll and over $170 million in contracts with South Dakota vendors.

Now, South Dakota is again at a crossroads. Our state leaders will determine whether or not the current appropriation request is a merited and wise use of our citizens' tax dollars. Likewise, we will need to make the case to our federal counterparts that further investment in this facility is a wise use of federal taxpayer dollars.

Phase I of the expansion will be used to fund the design and construction of a drift (a tunnel) at the 4850-foot level, necessary to facilitate the later construction in 2027 of two caverns to house future experiments. The timing of the state appropriation for phase I is critical to eliminate the need to demobilize and remobilize the excavation contractor that is already on site (a savings of $15 million) and to avoid interference with the over $1 billion LBNF/DUNE Project currently being undertaken at SURF.

For phase II of the expansion, the SDSTA has been working diligently to raise private funds to cover the cost of the excavation of the two caverns. We are committed to working to secure federal funding as needed to resolve any unexpected shortfalls in private funding and to cover the cost of outfitting the caverns to make them suitable to house future experiments.

SURF's future objectives are supported by national academic partners and federal agency stakeholders. Those entities are well aware of SURF's expansion plans. The U.S. Department of Energy recently commissioned a panel of experts from other national laboratories to perform an independent review of SDSTA's operations. In June 2022, the panel found SDSTA's planning and management of operations to be excellent. SURF has sound management and strong business-minded board members.

SURF's partners are eagerly anticipating this expansion because there is nowhere else in the United States capable of conducting this research. Our nation recently lost two U.S.-funded research projects to underground labs in Canada and Italy. Without the new caverns, future experiments funded by U.S. taxpayers will continue to go to underground laboratories in other countries.

SURF's potential is tremendous. With additional space to house more research projects, more federal funding opportunities will exist. The newly-excavated spaces could attract experiments with investments of up to $1 billion or more per cavern. Equally important, additional research capacity increases opportunities to keep our next generation, the best and the brightest in the world, at home.

This is again a historic time for SURF. The actions the state and the federal government take will have long-lasting effects for South Dakota. We hope this additional information is helpful as you consider this budget request.

Sincerely,

M. Michael Rounds
United States Senator

John Thune
United States Senator

SURF 4850L Expansion – South Dakota Funding

4850L space needed for next-generation experiments

sdlegislature.gov/Session/Bill/23993

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Senate Bill 35

BACK TO FULL LIST

SHARE TWEET

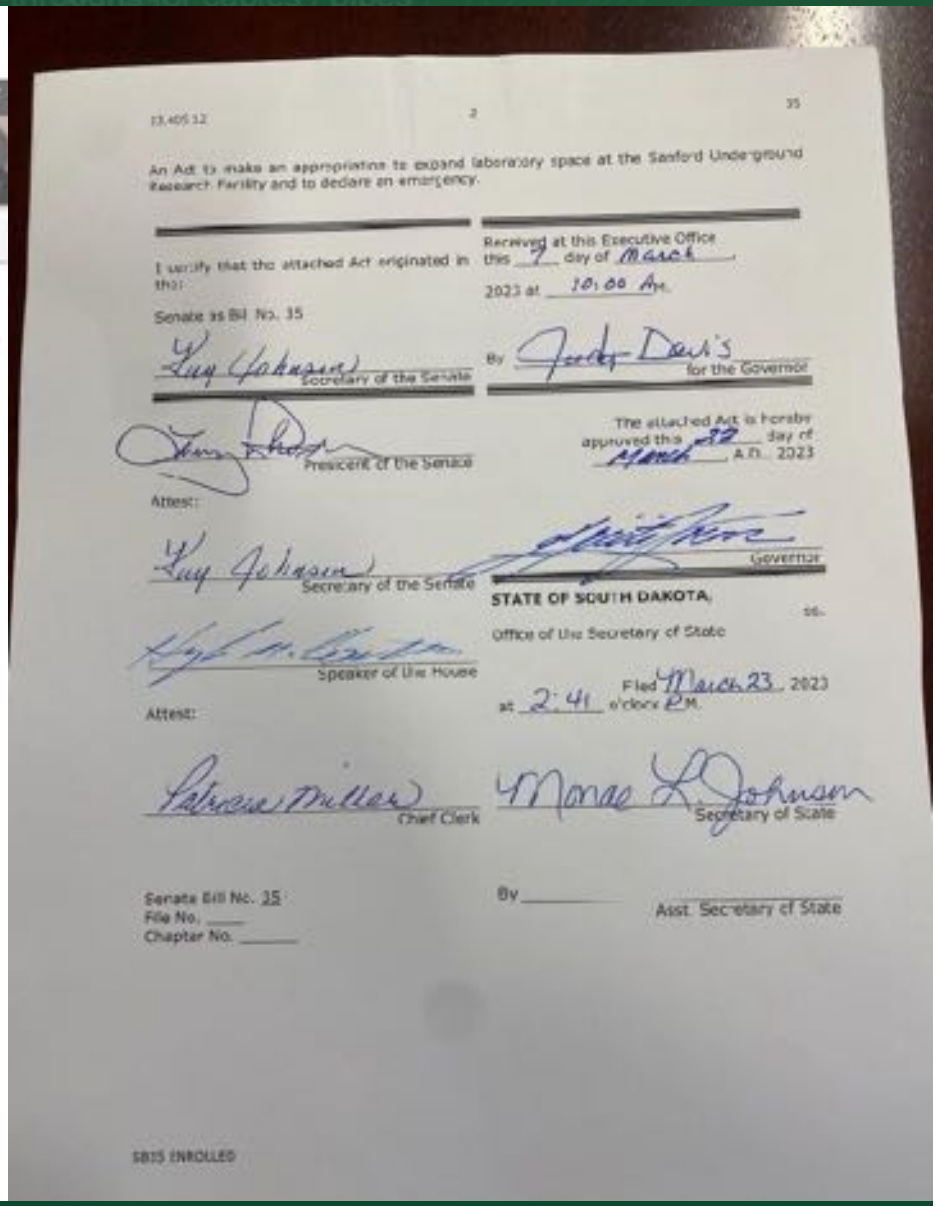
Title: make an appropriation to expand laboratory space at the Sanford Underground Research Facility and to declare an emergency.

Sponsors: Senators Maher (prime), Castleberry, Crabtree, Davis, Diedrich, Duhamel, Foster, Johnson, Kolbeck (Steve), Larson, Nesiba, Novstrup, Otten (Herman), Rohl, Schoenbeck, Stalzer, Tobin, and Zikmund and Representatives Reimer (prime), Blare, Cammack, Chaffee, Chase, Donnell, Drury, Duba, Duffy, Emery, Fitzgerald, Kassin, Krull, Kull, Lesmeister, Massie, Moore, Nelson, Olson, Peterson (Drew), Schneider, Shorma, St. John, Tordsen, and Venhuizen

Subjects: Appropriation, Emergency Clause, Procurement of Public Improvements, State Affairs and Government

Want to add this bill to one of your tracking lists? Logon to MyLRC

Date	Action	Audio	Location
01/10/2023	First read in Senate and referred to Senate Commerce and Energy S.J. 13	N/A	
01/17/2023	Scheduled for hearing		1:19:31
01/17/2023	Referred to Joint Committee on Appropriations, Passed, YEAS 9, NAYS 0.		1:19:31
02/22/2023	Scheduled for hearing		1:19:11
02/22/2023	Joint Committee on Appropriations Do Pass, Passed, YEAS 15, NAYS 3.		1:19:11
02/24/2023	Senate Deferred to another day, Passed S.J. 338	N/A	
02/27/2023	Senate Do Pass, Passed, YEAS 29, NAYS 4. S.J. 353		1:03:45
02/28/2023	First read in House and referral to committee waived pursuant to JR 6D-1 H.J. 400	N/A	
03/01/2023	House of Representatives Do Pass, Passed, YEAS 55, NAYS 13. H.J. 442		2:52:16
03/02/2023	Signed by the President S.J. 417	N/A	
03/06/2023	Signed by the Speaker H.J. 491	N/A	
03/07/2023	Delivered to the Governor on Tuesday, March 07, 2023 S.J. 442	N/A	
03/27/2023	Signed by the Governor on Thursday, March 23, 2023	N/A	



An Act to make an appropriation to expand laboratory space at the Sanford Underground Research Facility and to declare an emergency.

I certify that the attached Act originated in the: Senate as Bill No. 35

Secretary of the Senate

Received at this Executive Office this 7 day of March 2023 at 10:00 A.M.

By for the Governor

President of the Senate

The attached Act is hereby approved this 23 day of March A.D. 2023

Attest: Secretary of the Senate

Governor

STATE OF SOUTH DAKOTA, ss. Office of the Secretary of State

Speaker of the House

Filed March 23, 2023 at 2:41 o'clock P.M.

Attest: Chief Clerk

Secretary of State

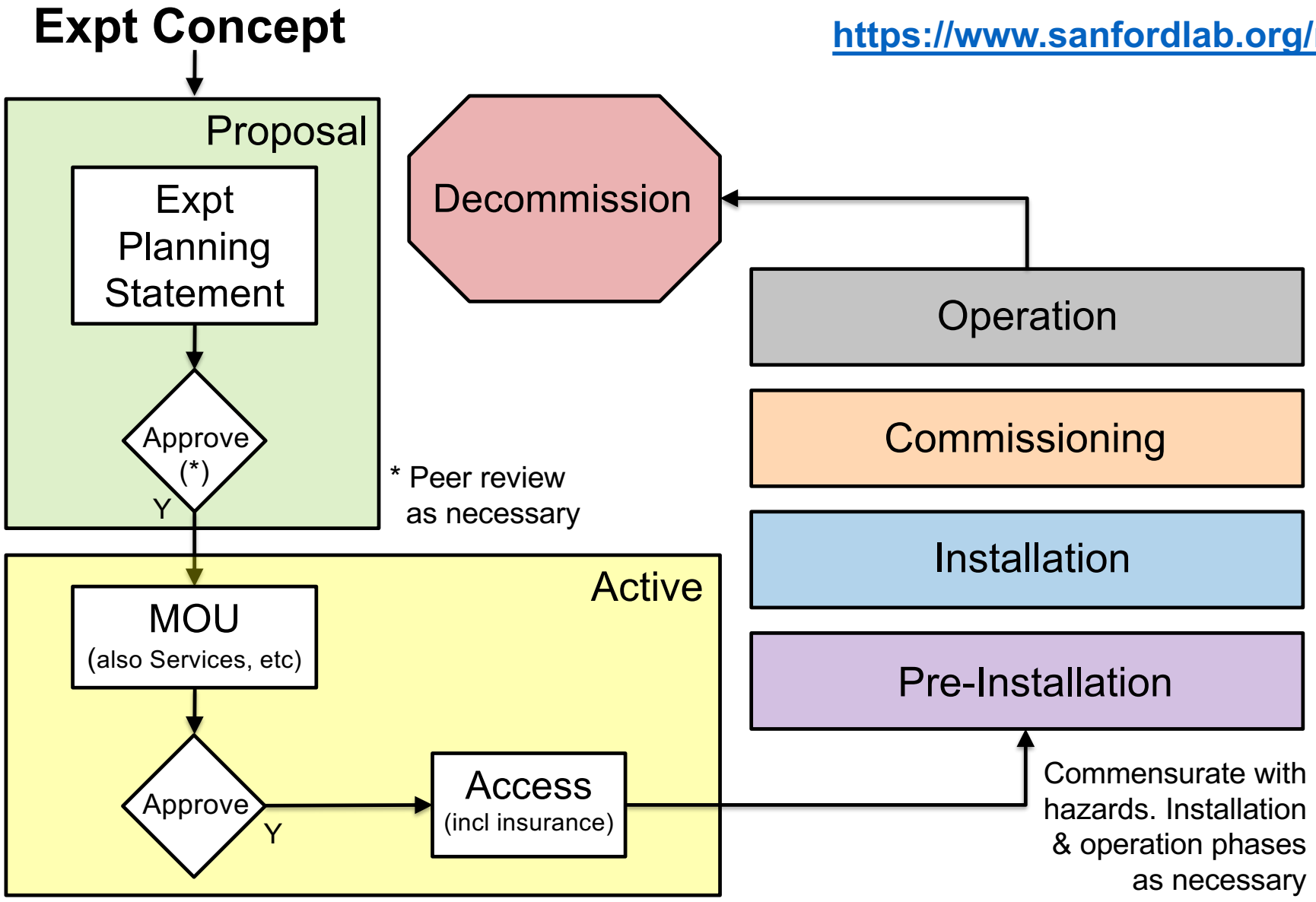
Senate Bill No. 35
File No. ____
Chapter No. ____

By ____ Asst. Secretary of State

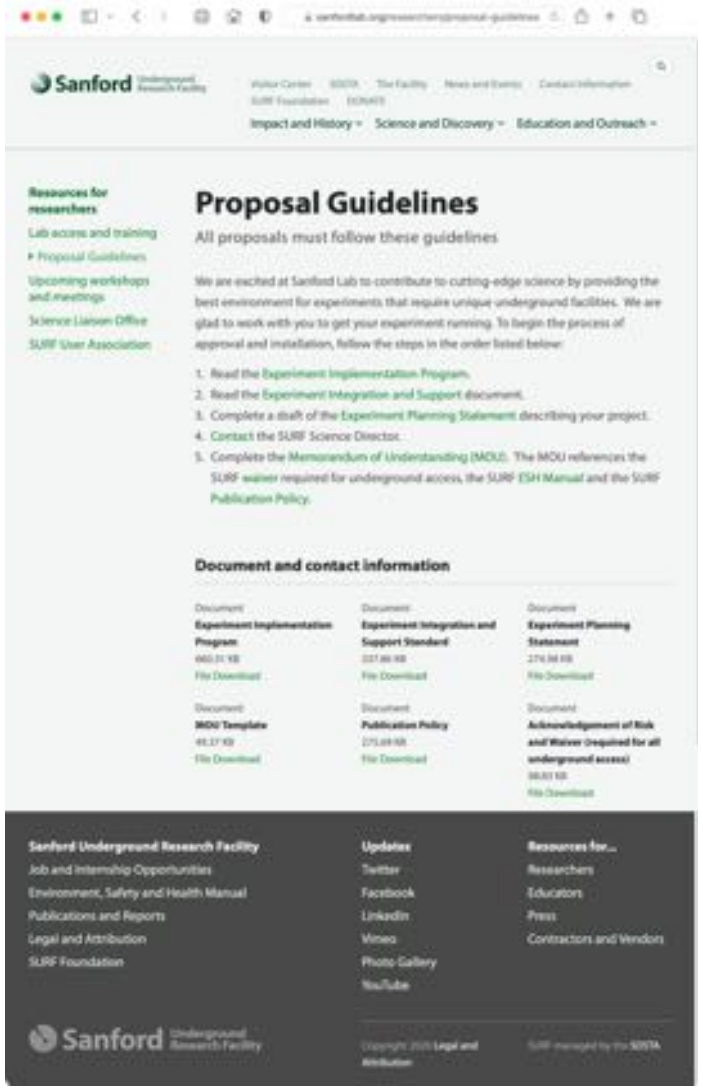
SB35 ENROLLED

SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework

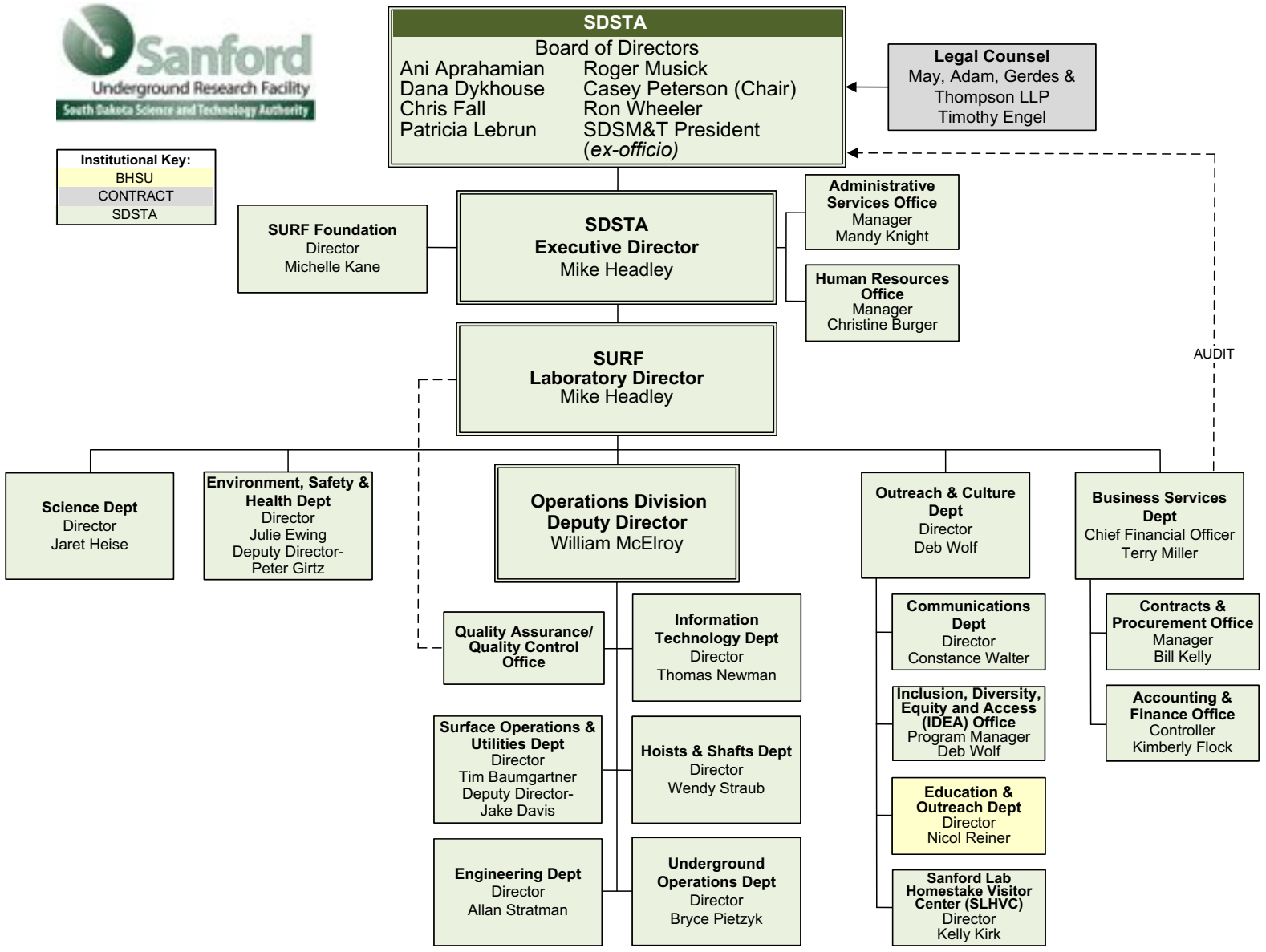


https://www.sanfordlab.org/researchers/proposal-guidelines



SURF Organization

Resources to advance world class science and inspire learning across generations



Staffing Area	FY22 FTE (%)	FY27 FTE (%)
Admin / Mgmt	21 (10%)	22 (10%)
Engineering	12 (6%)	13 (6%)
ESH	21 (10%)	21 (9%)
Outreach	20 (10%)	21 (9%)
Scientific	6 (3%)	11 (5%)
Technical / Operations	123 (61%)	137 (61%)
TOTAL	**203**	**225**

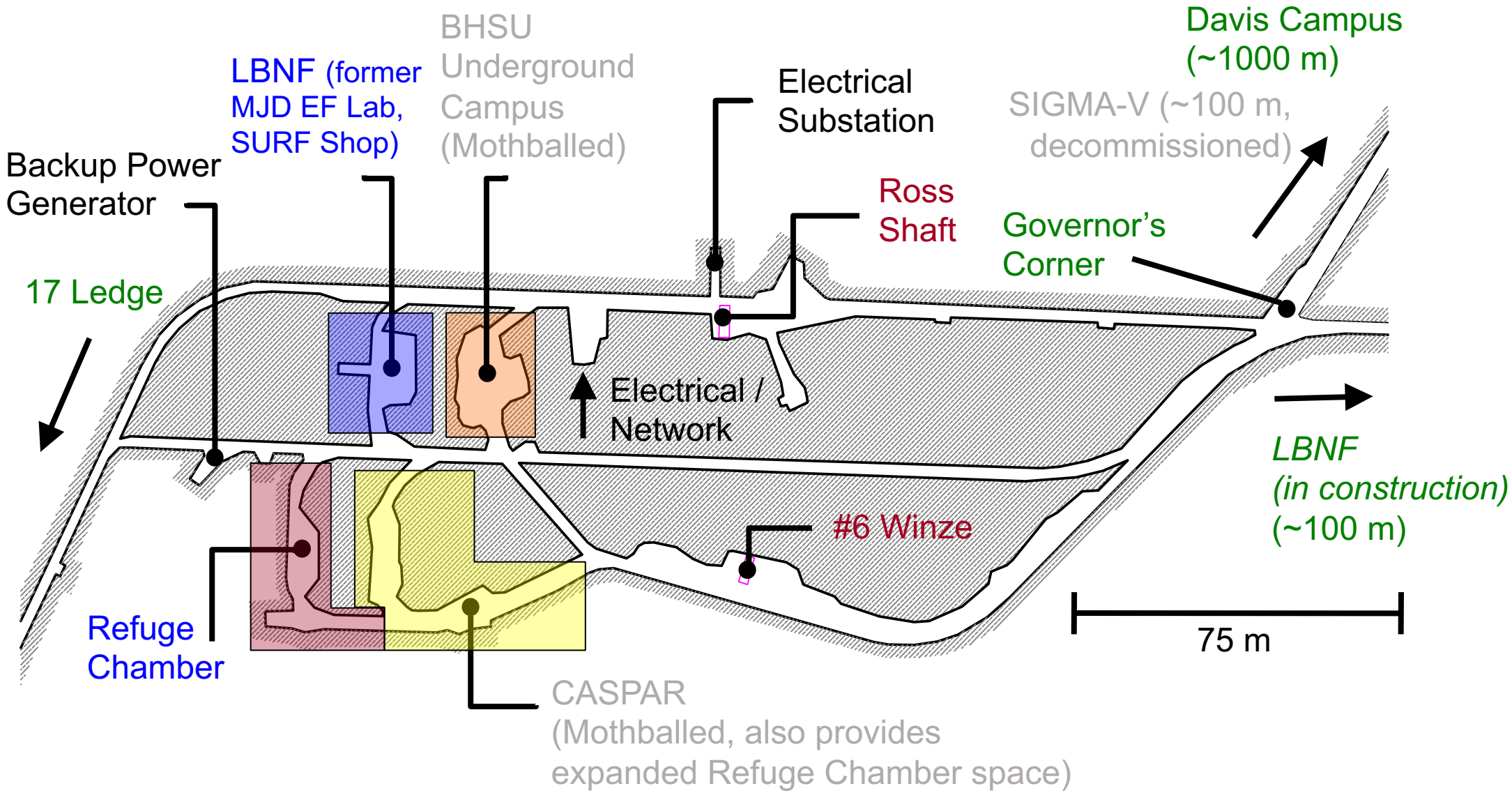
SURF Current & Future Facilities

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 2022-23+ + 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*	*~2024*	*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: excavation 2027, complete ~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*

4850L Ross Campus

2,653 m² (Total) / 920 m² (Science)



SURF 4850L Ross Campus

Examples of laboratory space

2010-2017

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

Copper Electroforming

2015-2020, resume FY24

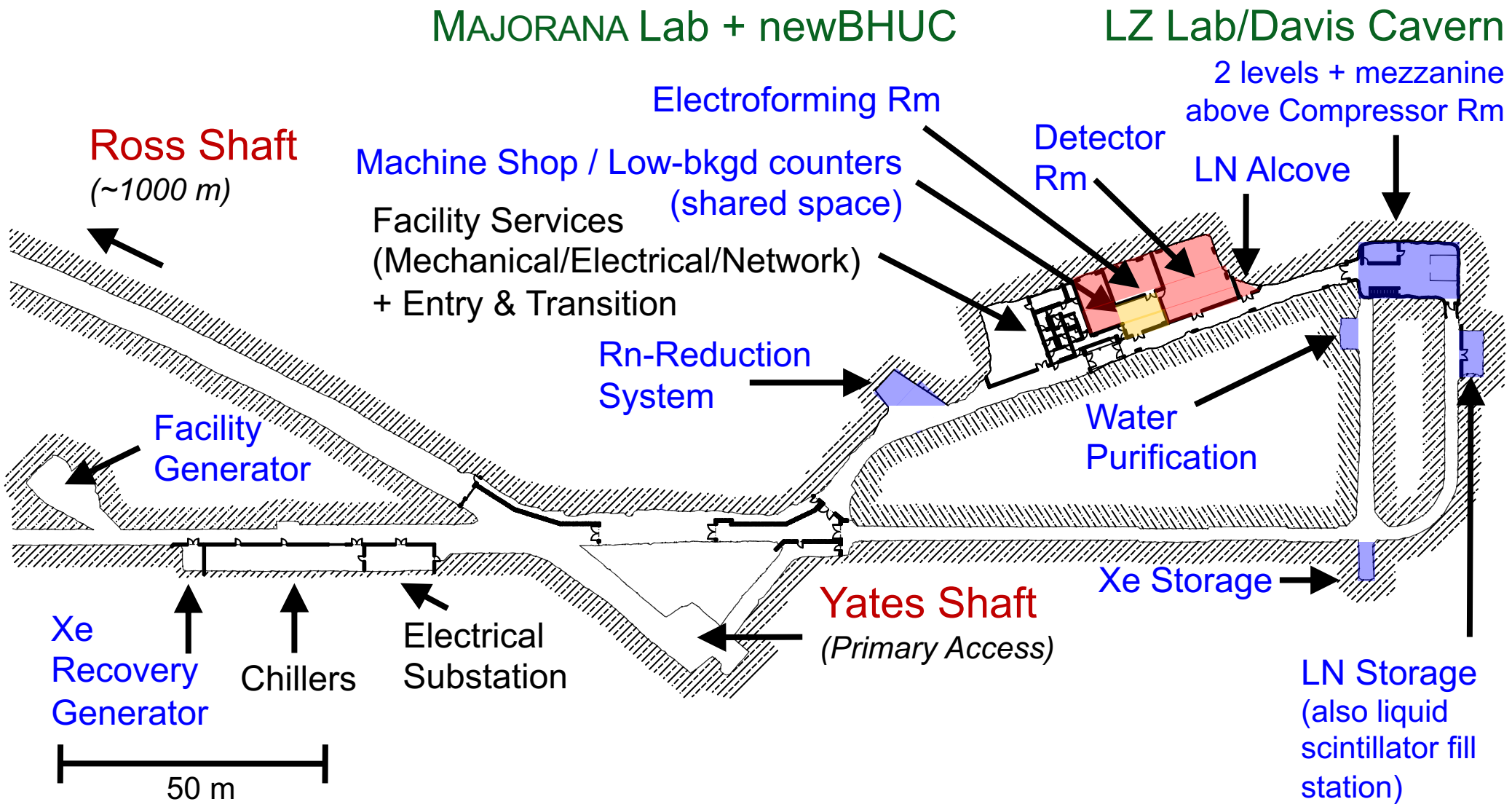
BHUC Cleanroom:
Cavern Area = 268 m^2,
Cleanroom = 12.1 m × 6.1 m × 2.4 m (H)

2015-2021, resume FY24

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

4850L Davis Campus

3,017 m² (Total) / 1,018 m² (Science)



SURF 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))

Davis Cavern, Lower (LZ):
Area =142 m^2, 13.7 m × 9.1 m × 6.4 m (H)
(incl tank: 7.6 m dia. × 6.4 m H). Total Cavern H = 10.8 m

SURF Designated APS Historical Site

Announcement Sep 2020, Dedication May 2022

www.interactions.org/press-release/aps-designates-sanford-lab-morg

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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

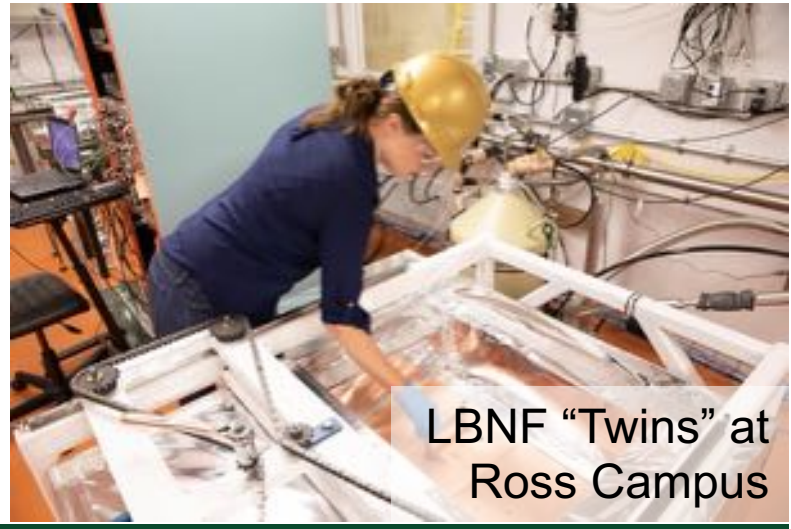
CONTACT:
Constance Walter
Communications Director
cwalter@sanfordlab.org

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.
  - All six counter systems operating, incl LLNL dual-crystal system. Recent samples incl protoDUNE, also IceCube, CUPID, NEXT-100.
- **Schedule:**
  - Fully commission LBNL dual-crystal system. 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

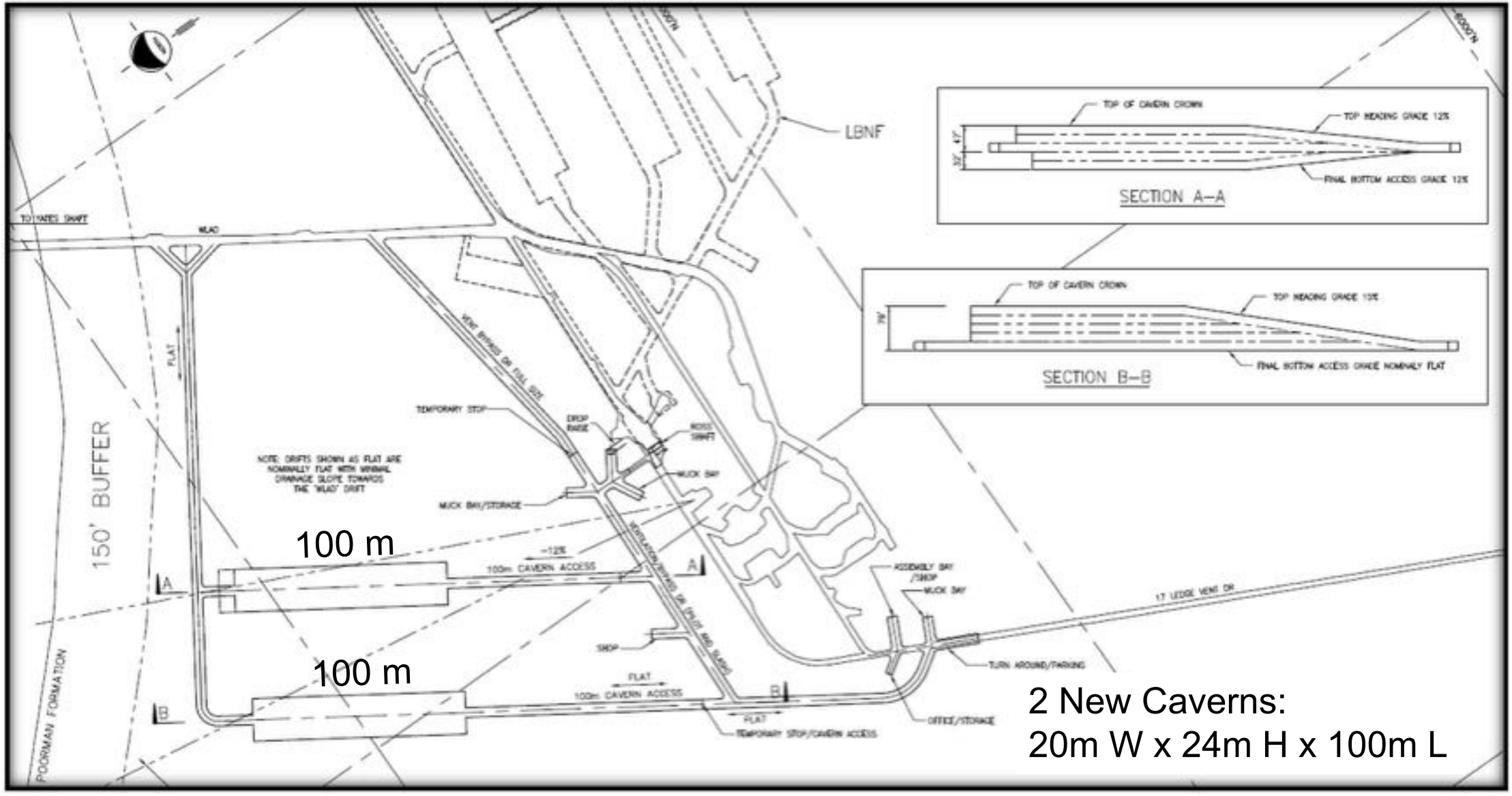
SURF Underground Facility Expansion

Feasibility study for new 4850L caverns

- Feasibility considerations:
  - Space (up to 100 m long), geotechnical conditions
  - Ventilation for excavation, outfitting, and operation
  - Waste rock handling
  - Access to and separation from existing operations
  - Ability to excavate, construct, and expand in phases
- Assessment results:
  - Current **ventilation** plan adequate for proposed expansion
  - Proposed laboratory expansion locations provide adequate **isolation and separation** from existing Science operations
    - Access to Ross waste dump, blast isolation doors for excavation
  - Positive **geotechnical** site locations based on preliminary info
    - Suggest additional geotechnical study at specific site locations to verify
  - Cost and schedule provided for **phased construction**
    - Excavation for **two 100-m caverns ~2.5 years**, incl mobilization & de-mob

SURF Underground Facility Expansion

Feasibility study for new 4850L caverns



SDSTA Overview

- SURF has 400 full-time staff, including SDSTA, partners, and contractors.
- SDSTA programs and services:
  - We own, operate and maintain the SURF facility in support of scientific research.
  - We host world-leading science experiments in a range of disciplines.
  - We support the construction of the Long-Baseline Neutrino Facility (LBNF) to host the Deep Underground Neutrino Experiment (DUNE) at SURF.
  - We provide leadership in K-12 and public STEM education and outreach.
- SURF operations are federally funded through a five-year Cooperative Agreement (CA) between U.S Dept of Energy (DOE) and SDSTA.