Opportunities at the Sanford Underground Research Facility

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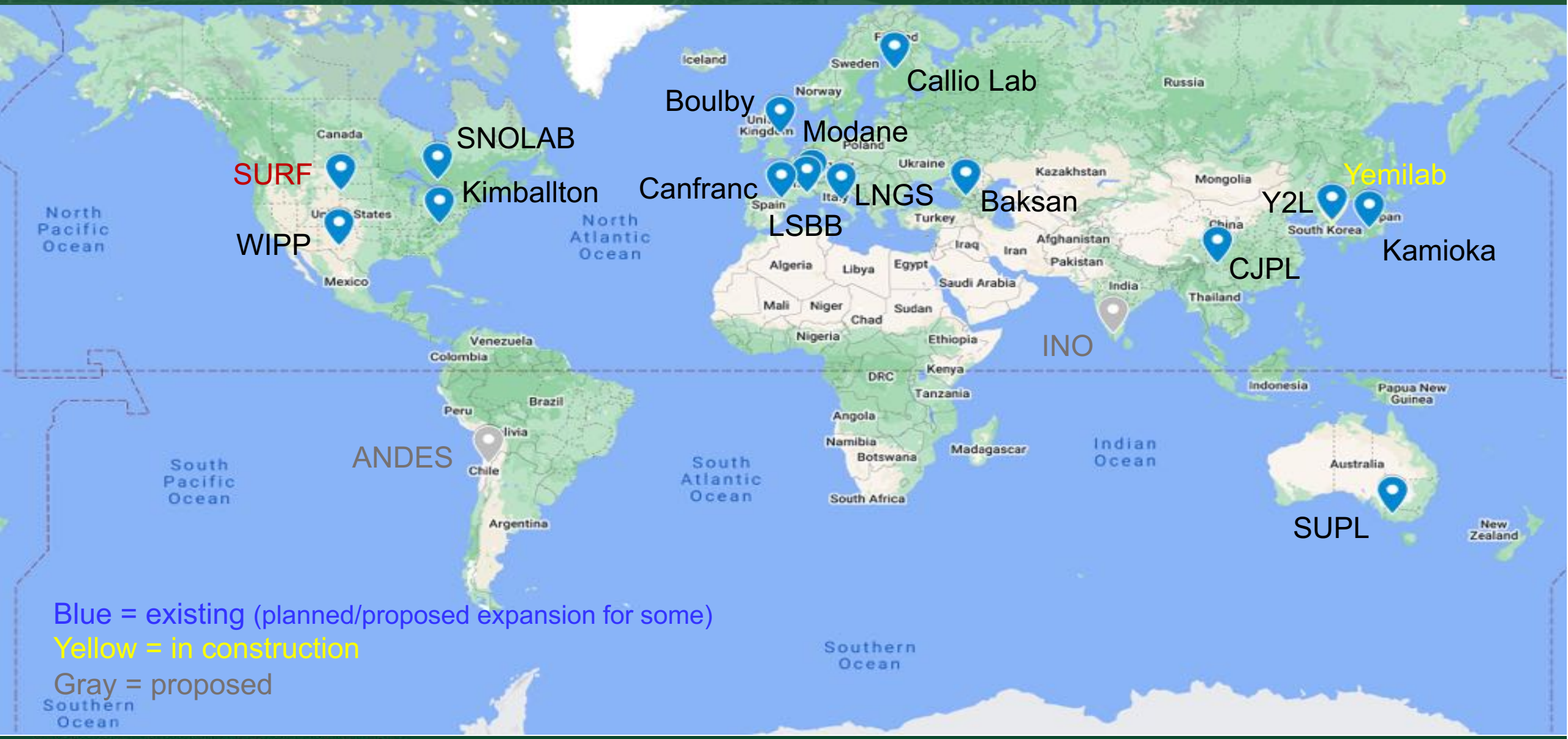
Terrestrial Very-Long-Baseline Atom Interferometry Workshop, CERN, March 13-14, 2023

Sanford Underground Research Facility
South Dakota Science and Technology Authority

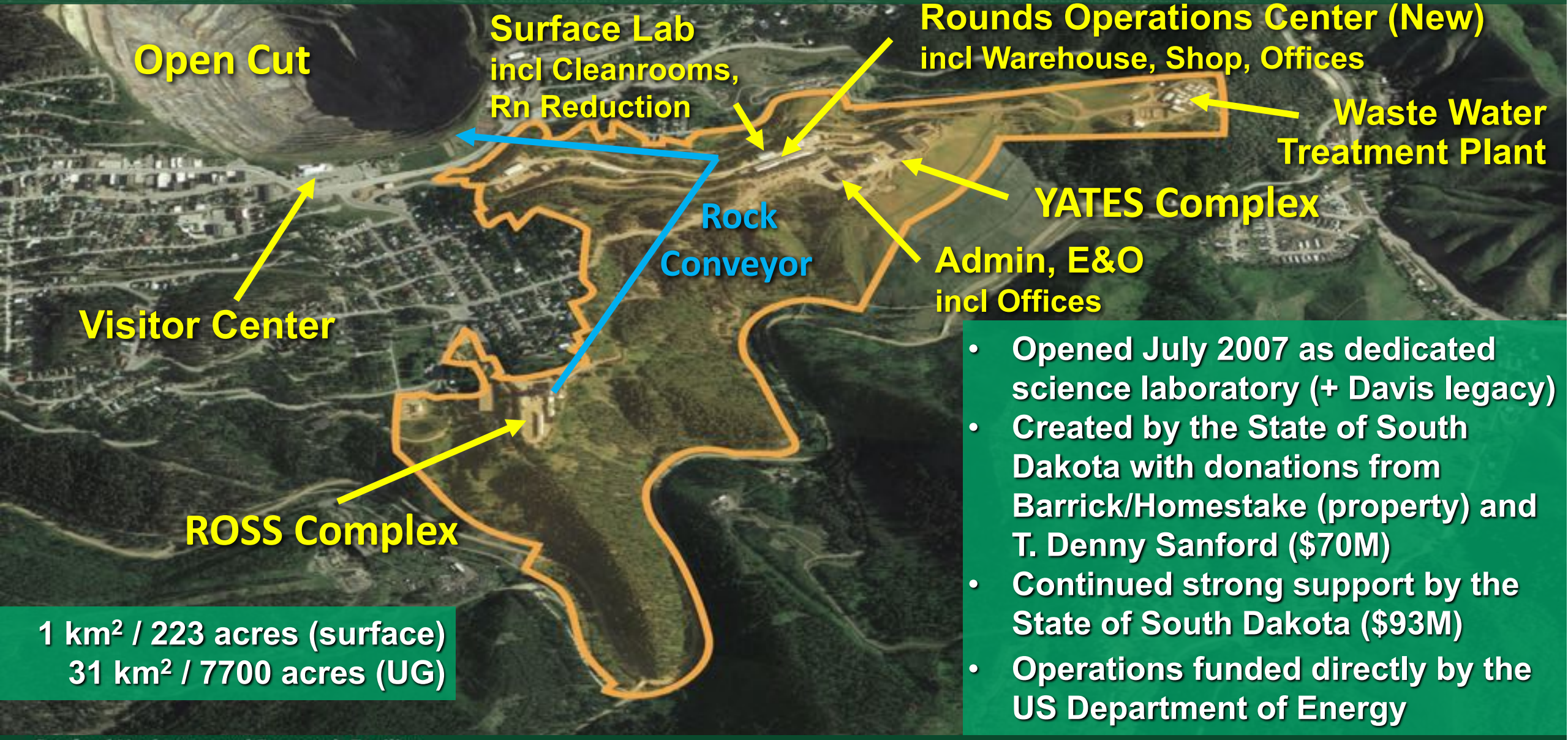
Sanford Underground Research Facility

Where in the world is SURF?



Sanford Underground Research Facility

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

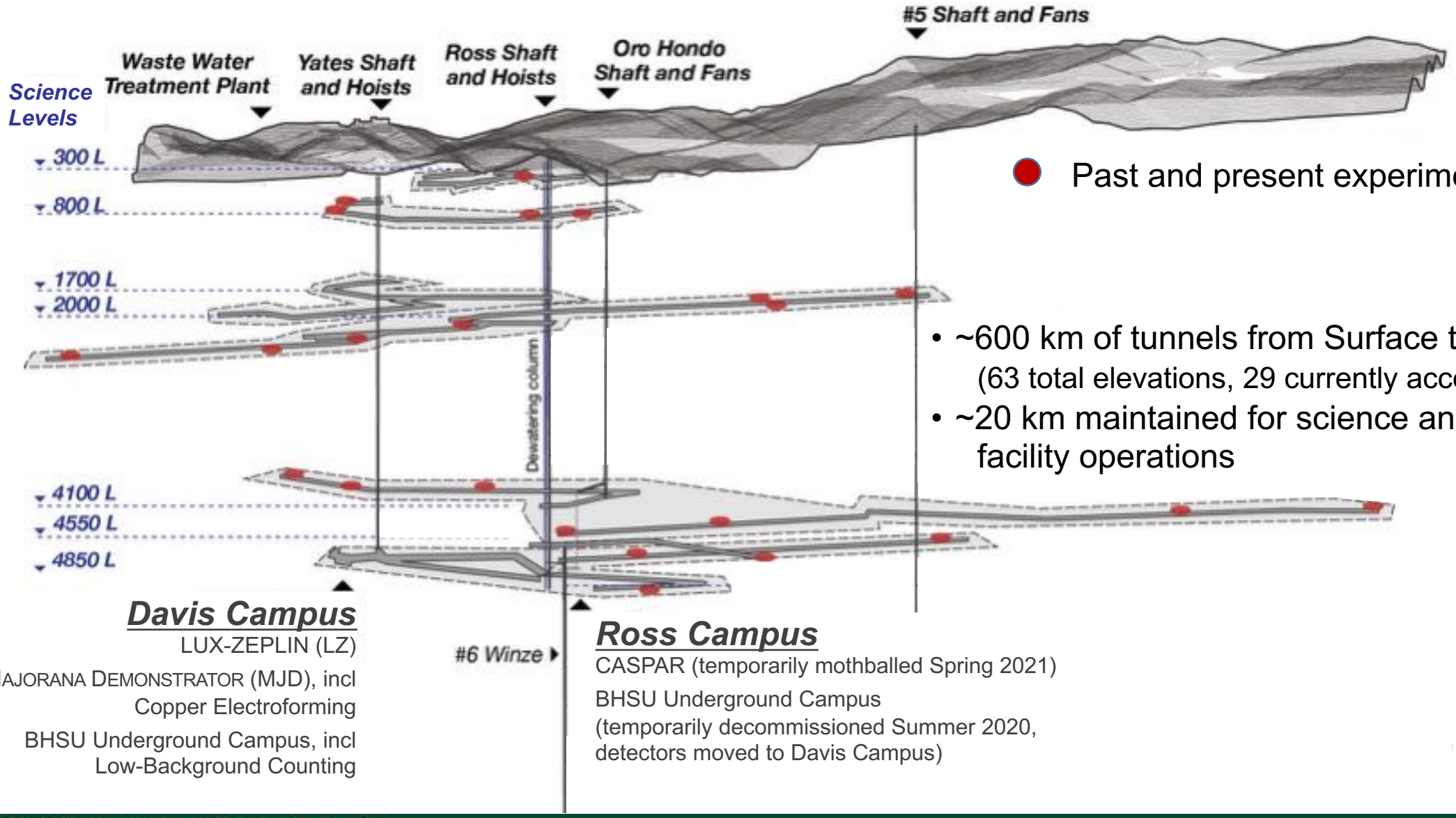


- Opened July 2007 as dedicated science laboratory (+ Davis legacy)
- Created by the State of South Dakota with donations from Barrick/Homestake (property) and T. Denny Sanford ($70M)
- Continued strong support by the State of South Dakota ($93M)
- Operations funded directly by the US Department of Energy

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

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

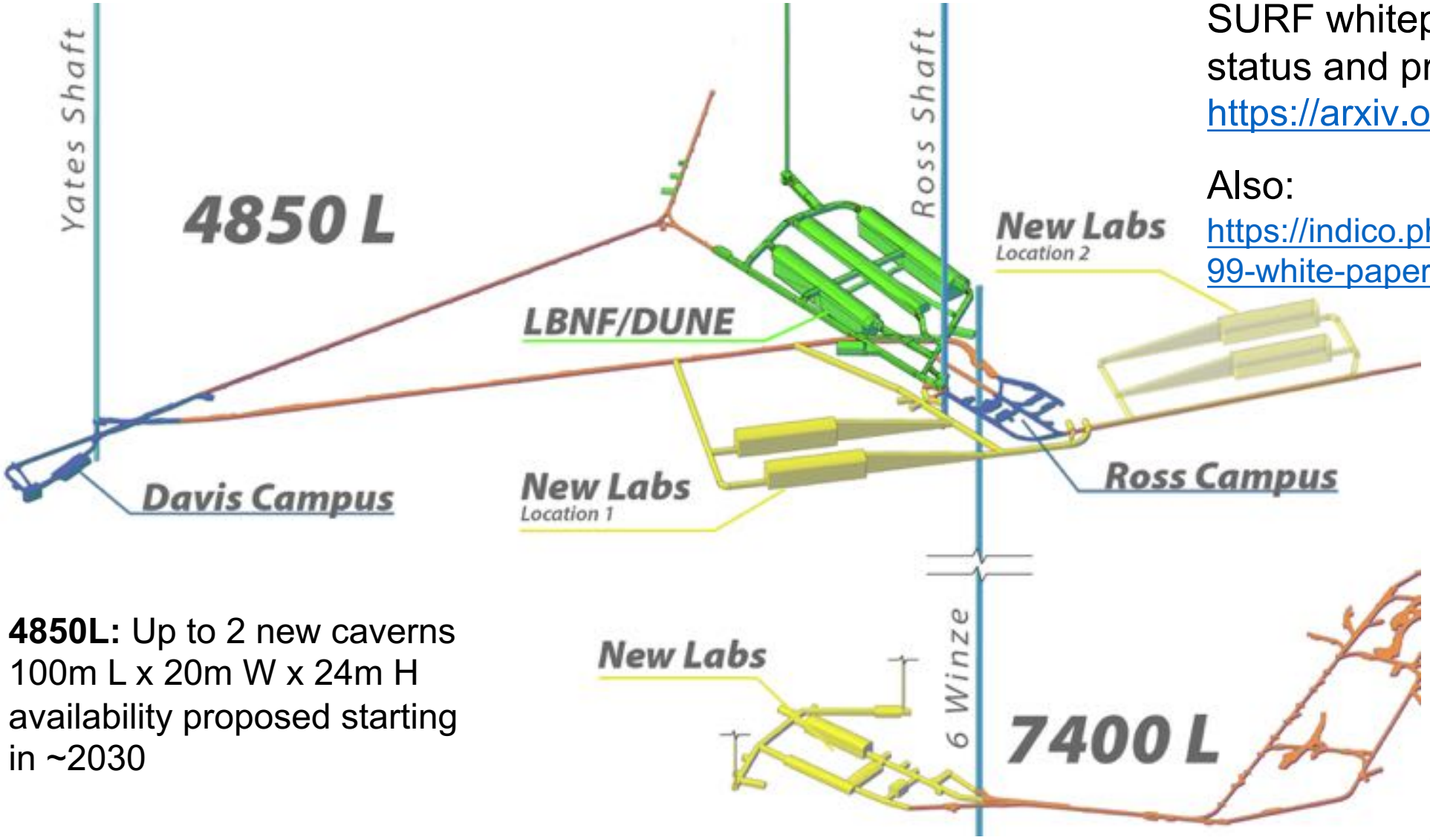
Ross Campus

CASPAR (temporarily mothballed Spring 2021)

BHSU Underground Campus
(temporarily decommissioned Summer 2020, detectors moved to Davis Campus)

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

Also: https://indico.phy.ornl.gov/event/209/page/99-white-papers

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

Snowmass2021: Community Report to DOE/NSF Planning

Community endorses SURF underground laboratory expansion

- Conclusion #1: **Leverage the Long-Baseline Neutrino Facility excavation** enterprise to **increase underground space at SURF** in a timely and cost-effective way to permit siting of next-generation underground 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 and some mid-size and small expts.
- Conclusion #2: Designate SURF as a U.S. DOE **User Facility**.
- Conclusion #3: Provide **full support for the underground facilities hosting LBNF/DUNE**
- Conclusion #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.
- Conclusion #5: To ensure a robust collection of scientific programs in underground facilities, **support the enabling capabilities, technique development, and expertise** required for underground expts.

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*, John L. Orrell, Alexei A. Petrov, Breese Quinn, Fernanda Psihas Ter Rasbeedeirner, Laura Reina, Kate Scholberg, Vladimir Shiltsev, Marcelle Soares-Santos, Sara M. Simon, Tim M. P. Tait, Alessandro Tricoli, Elizabeth E. Worcester, Jinlong Zhang

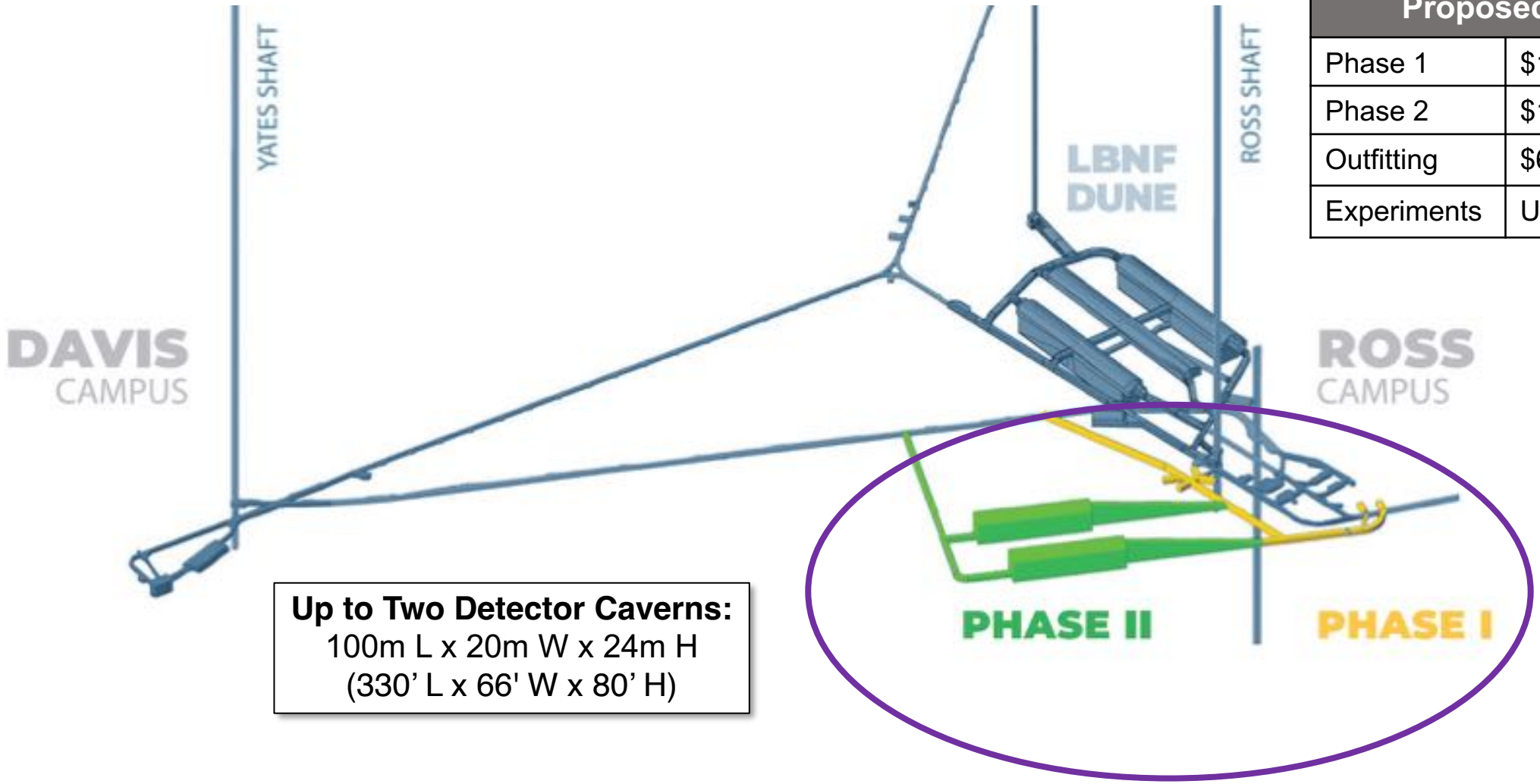
Snowmass 2021 Steering Group: Joel N. Butler, R. Sekhar Chivukula, André de Gouvêa, Tao Han, Young-Kee Kim, Priscilla Cushman, Gleznys R. Farrar, Yury G. Kolomensky, Sergei Nagaitsev, Nicolás Yunes

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

*Deceased, Jan. 5, 2023.

SURF Current & Future Underground Facilities

4850L space needed for next-generation experiments



Proposed Funding Model	
Phase 1	$13M State of SD
Phase 2	$100M Private
Outfitting	$60M Federal
Experiments	Up to $500M ea. - Fed/Intl

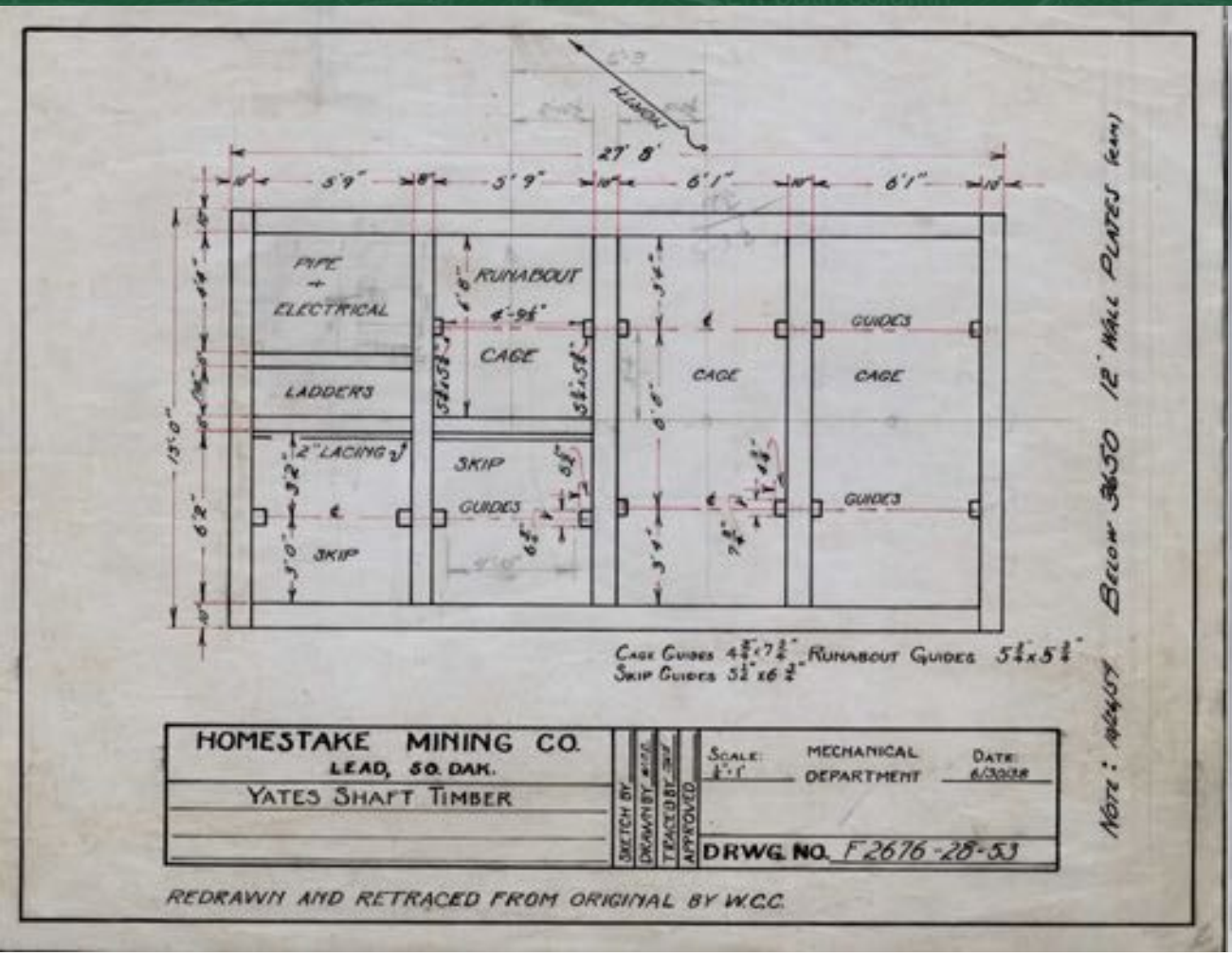
Up to Two Detector Caverns:
100m L x 20m W x 24m H
(330’ L x 66' W x 80’ H)

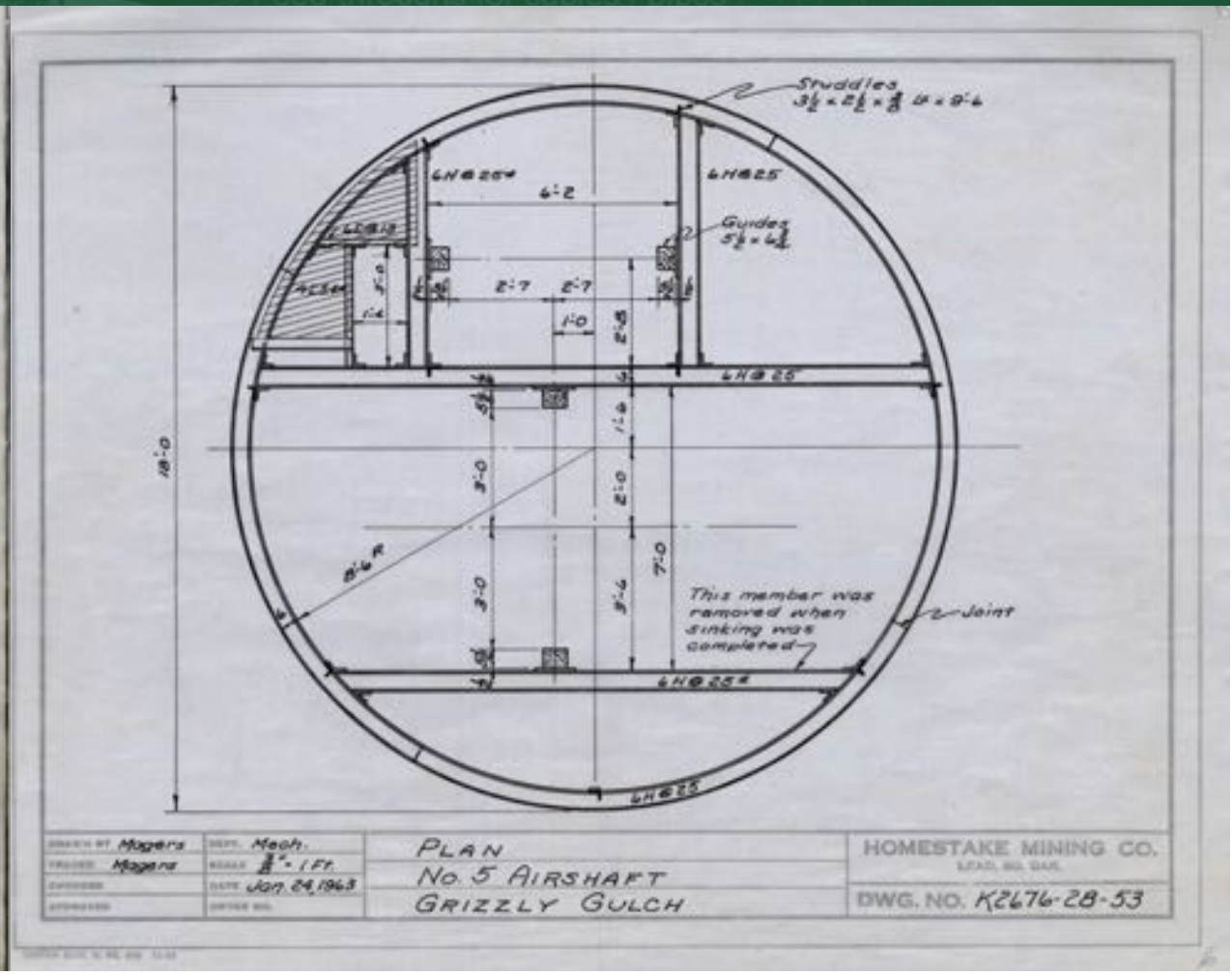
SURF Potential Vertical Facility

- Early efforts:
  - Dec 2008: Workshop held at SDSMT to support DUSEL planning
  - Jul 2009: Shaft magnetic field measurements (UTK, BHSU)
- Renewed interest in vertical facility during SURF Vision Workshop 2021: https://indico.sanfordlab.org/e/Vision2021
- Initial SURF study completed Mar 2022:
  - Vertical Facility design assumptions:
    - Significant length: Medium scale (100 m), large scale (1000 m)
    - Cross-section: 2.4 – 5 m
    - Access required to top and bottom
    - Surface (or near surface) access preferred (for constructability and cost considerations)
    - Availability of existing supporting infrastructure and utilities
  - Evaluation:
    - 12 shafts/winzes/raises
    - 6 areas feasible for further study (SDSTA property)
    - 2 areas need more information (Barrick property)

SURF Potential Vertical Facility

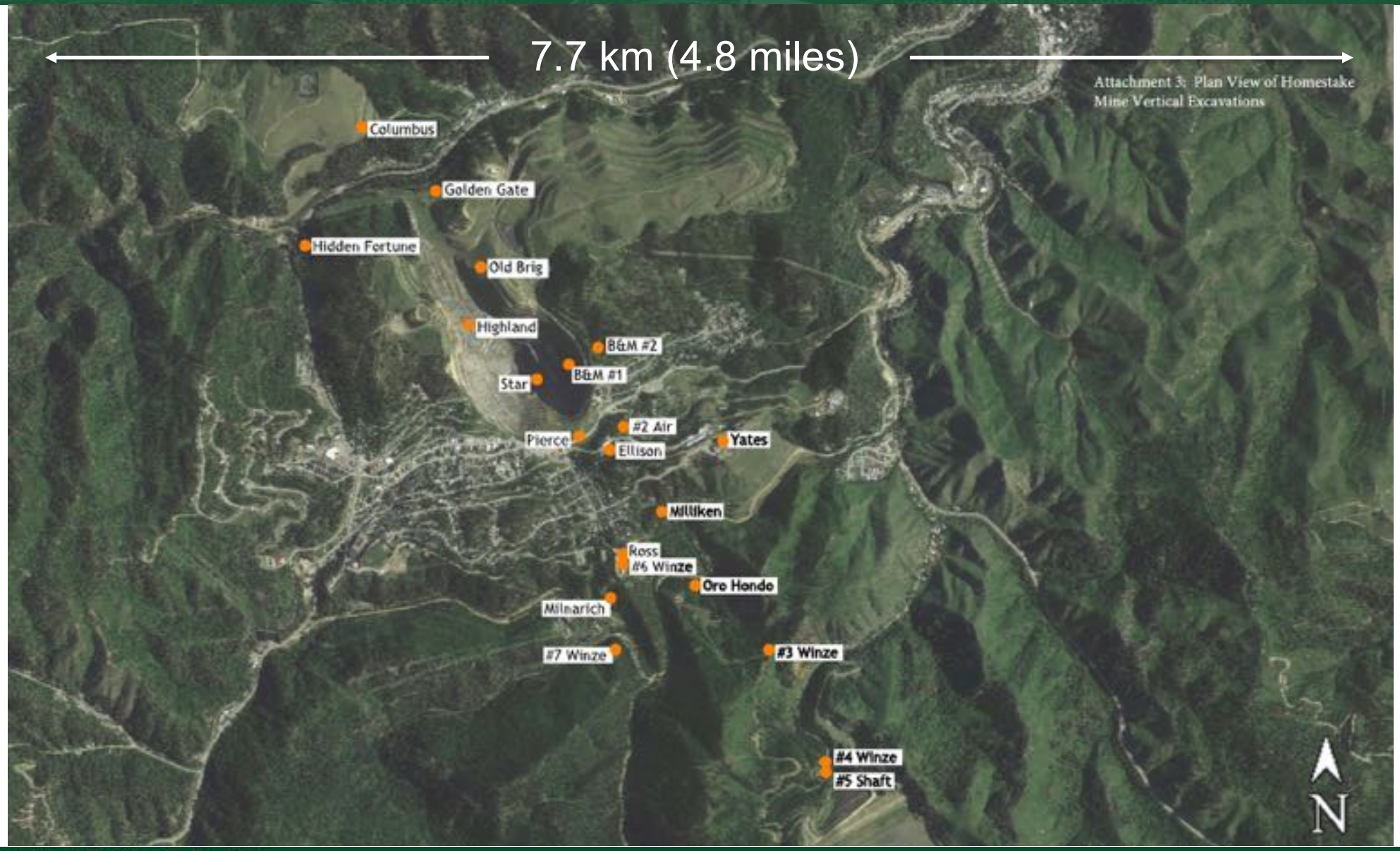
Examples showing shaft geometries and compartments





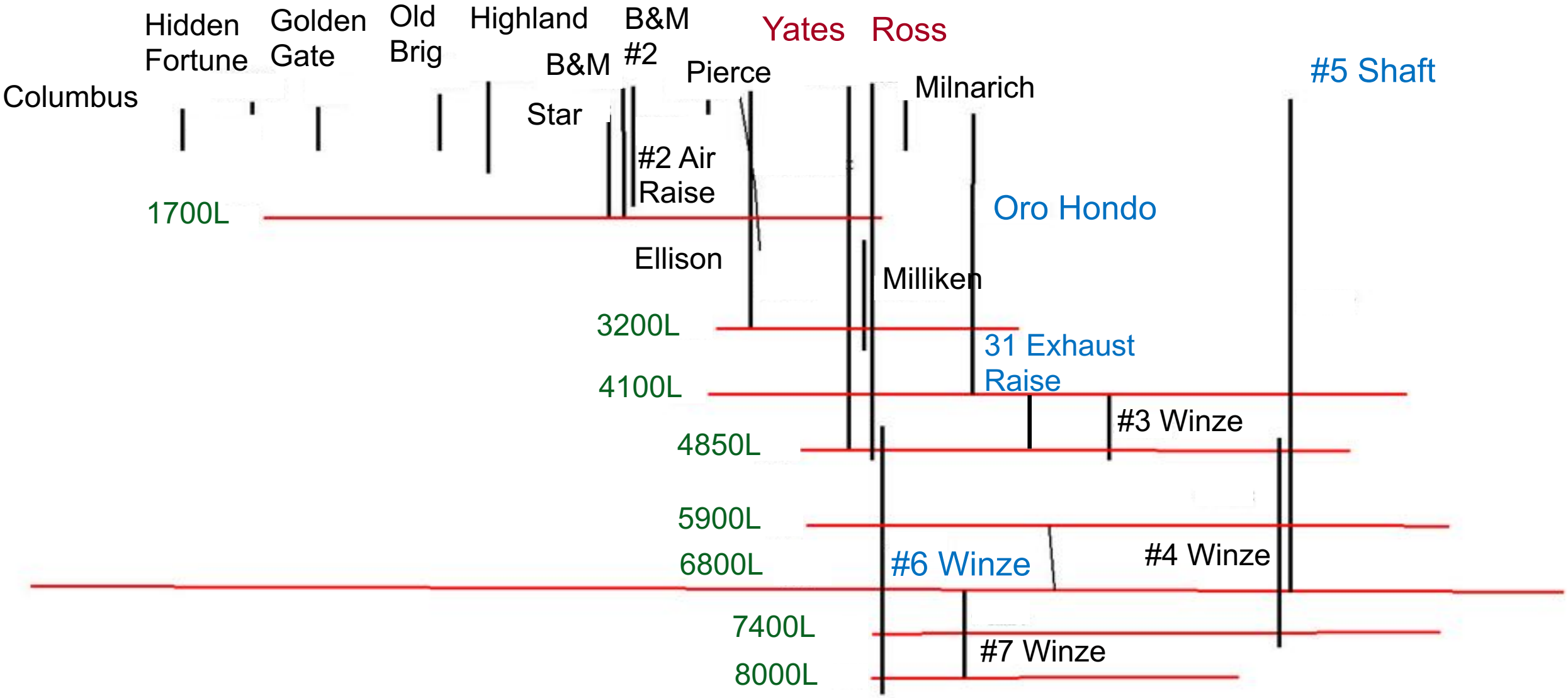
SURF Potential Vertical Facility

Surface layout



SURF Potential Vertical Facility

Depth layout



SURF Potential Vertical Facility

Feasibility based on requirement assumptions

Name	Current Use	Length	Cross Section/ Diameter	Ownership	Feasible? (Y/N)	Comment
Ross Shaft	Main Lab Access/ Ventilation Pathway	1582 m (5189 ft)	5.8 m x 4.3 m (19 ft x 14 ft)	SDSTA	No	Construction would impact current use (access, ventilation)
Yates Shaft	Main Lab Access/ Ventilation Pathway	1563 m (5128 ft)	8.5 m x 4.6 m (28 ft x 15 ft)	SDSTA	No	Construction would impact current use (access, ventilation)
#5 Shaft	Secondary Lab Ventilation Pathway	2103 m (6900 ft)	5.2 m diameter (17 ft diameter)	SDSTA	Yes	Rehabilitation required (debris at 208 m/683 ft), sustain current use
Oro Hondo Shaft	Main Lab Ventilation Pathway	1117 m (3664 ft)	1.5 m x 4.6 m (5 ft x 15 ft)	SDSTA	No	Limited cross section does not support use as vertical facility
Ellison Shaft	None	985 m (3233 ft)	6.1 m x 3.7 m (20 ft x 12 ft)	SDSTA	Yes	Limited access, concrete plug at 90 m/ 300 ft
#6 Winze	Dewatering column to deep pool (future access to 7400L?)	1083 m (3552 ft)	5.2 m x 4.3 m (17 ft x 14 ft)	SDSTA	Yes	Rehabilitation required, currently 137 m / 450 ft useable

SURF Potential Vertical Facility

Feasibility based on requirement assumptions

Name	Current Use	Length	Cross Section/ Diameter	Ownership	Feasible? (Y/N)	Comment
#3 Winze	None	191 m (626 ft)	3.4 m x 1.8 m (11 ft x 6 ft)	SDSTA	No	UG access, poor ground, travel distance for access
Milliken Winze	None	459 m (1505 ft)	3.7 m x 3.7 m (12 ft x 12 ft)	SDSTA	Yes	UG access, travel distance for access, 2000L to 3500L
Milnarich Shaft	None	182 m (596 ft)	Unknown	SDSTA	Yes	Surface access, surface to 800L (concrete plug)
Star Shaft	None	183 m (600 ft)	2.1 m x 6.4 m (7 ft x 21 ft)	Barrick	Marginal	Useable section between 1100L and 1700L. Rehabilitation required, surface is in Open Cut
B&M #2 Shaft	None	492 m (1614 ft)	5.8 m x 2.1 m (19 ft x 7 ft)	Barrick	Marginal	Surface access, surface to 1700L (concrete plug)
31 Exhaust Raise	Connection to primary ventilation	229 m (750 ft)	5.5 m diameter (18 ft diameter)	SDSTA	Yes	UG access, long travel but both ends accessible

SURF Potential Vertical Facility

Initial evaluation results

Large Scale (1000-m Candidates):

- **#5 Shaft –** Available from surface to 4850L (1500m) and extends to 6900L
- **Ellison Shaft –** Available from surface to 3200L (need to remove top ~100 m concrete plug)

Medium Scale (100-m Candidates):

- **#6 Winze –** Available from 4550L to 5000L (extends further to 8000L)
- **Milliken Winze –** Available from 2000L to 3500L
- **Milnarich Shaft –** Available from surface to 800L (if top concrete plug removed), also need to verify dimensions
- **31 Exhaust Raise –** Available from 4100L to 4850L, need to verify dimensions

SURF Potential Vertical Facility

Summary and next steps

- Initial evaluation completed for vertical facility at SURF:
  - Candidate areas identified based on preliminary requirements
  - Options with nominal feasibility exist for medium scale (100-m) and large scale (1000-m) facilities
- Pre-conceptual design for vertical facility at SURF:
  - O ($100k) needed to refine requirements and initial evaluation
  - Need funding source. Endorsement from U.S. federal funding agency (esp. DOE) would motivate near-term efforts

SURF Summary

- SURF offers world-class service to the underground science community:
  - SURF has **U.S. DOE mandate** to support experiments with basic level of support, funding for operations and infrastructure promotes safety and reliability. Anticipating **User Facility** designation.
  - 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.

- 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.
  - SURF is playing a strong role in the UG science community. User Association serving as catalyst for discussions and will leverage for future planning.
  - SURF is actively exploring options to **increase underground laboratory space**, plans advancing for new large caverns on 4850L (1500 m, 4200 mwe) on timeframe of next-generation experiments (~2030):
    - Strong community support endorsing more space at SURF, Snowmass report (Jan 2023): https://inspirehep.net/literature/2627711.
    - Anticipate strong support for SURF in DOE/NSF P5 strategic plan.

  - **SURF recognizes compelling atom interferometry science motivating vertical facility:**
    - **Need community support and endorsement from U.S. federal funding agency (esp. DOE) to motivate near-term efforts**

Sanford Underground Research Facility

Thank You!

SURF Potential Vertical Facility

Definitions

- **Shaft:** A surface-based, vertical excavation into a mine that is/was previously outfitted with a hoist plant and conveyanaces to deliver personnel and materials to various underground levels.
- **Winze:** An underground-based, vertical excavation into a mine that is/was outfitted with a hoist plant and conveyances to deliver personnel and materials to various underground levels. A winze does NOT extend to the surface of the mine (does not daylight at the surface).
- **Raise:** A vertical excavation into a mine that is not fitted with a hoist plant. A raise is typically installed for ventilation, sand (slurry backfill piping), or manway foot traffic purposes. A raise may come to the surface but is typically an underground feature that connects multiple underground levels to support facility operations.

SURF Science Strategic Planning

SURF Snowmass whitepaper reflects UG science community input

- SURF advocates for P5 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, 4200 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

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

Snowmass2021: Community Report to DOE/NSF Planning

Community endorses SURF underground laboratory expansion

The Underground Facilities and Infrastructure Frontier: Experiments that require low backgrounds from cosmic radiation, typically needed by CF and NF experiments, often must be performed underground. Underground experiments address some of the most important questions of particle physics, including the study of dark matter, neutrino physics including neutrinoless double-beta decay and atmospheric neutrinos, cosmic ray physics, and proton decay experiments.

The UF concluded that new experiments and enabling R&D require more space than is currently available worldwide. They proposed a possible addition of the underground space at a depth of 4850 feet at SURF in South Dakota and possible additional space at a depth of 7400 feet. These would open up space to develop additional experiments and would provide the opportunity for SURF to host next-generation dark matter or $0\nu\beta\beta$ experiments.

As underground experiments become larger, they will increasingly have stricter radiation requirements and the need for larger and higher quality clean rooms, radon-reduction systems, and improved monitoring. These issues are discussed in the Underground Facilities Frontier report and information was presented on the needs of upcoming experiments.

FERMILAB-CONF-23-008
SLAC-PUB-17717

Report of the
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(Snowmass 2021)

organized by the APS Division of Particles and Fields

SURF Plans to Become DOE User Facility

Benefits:

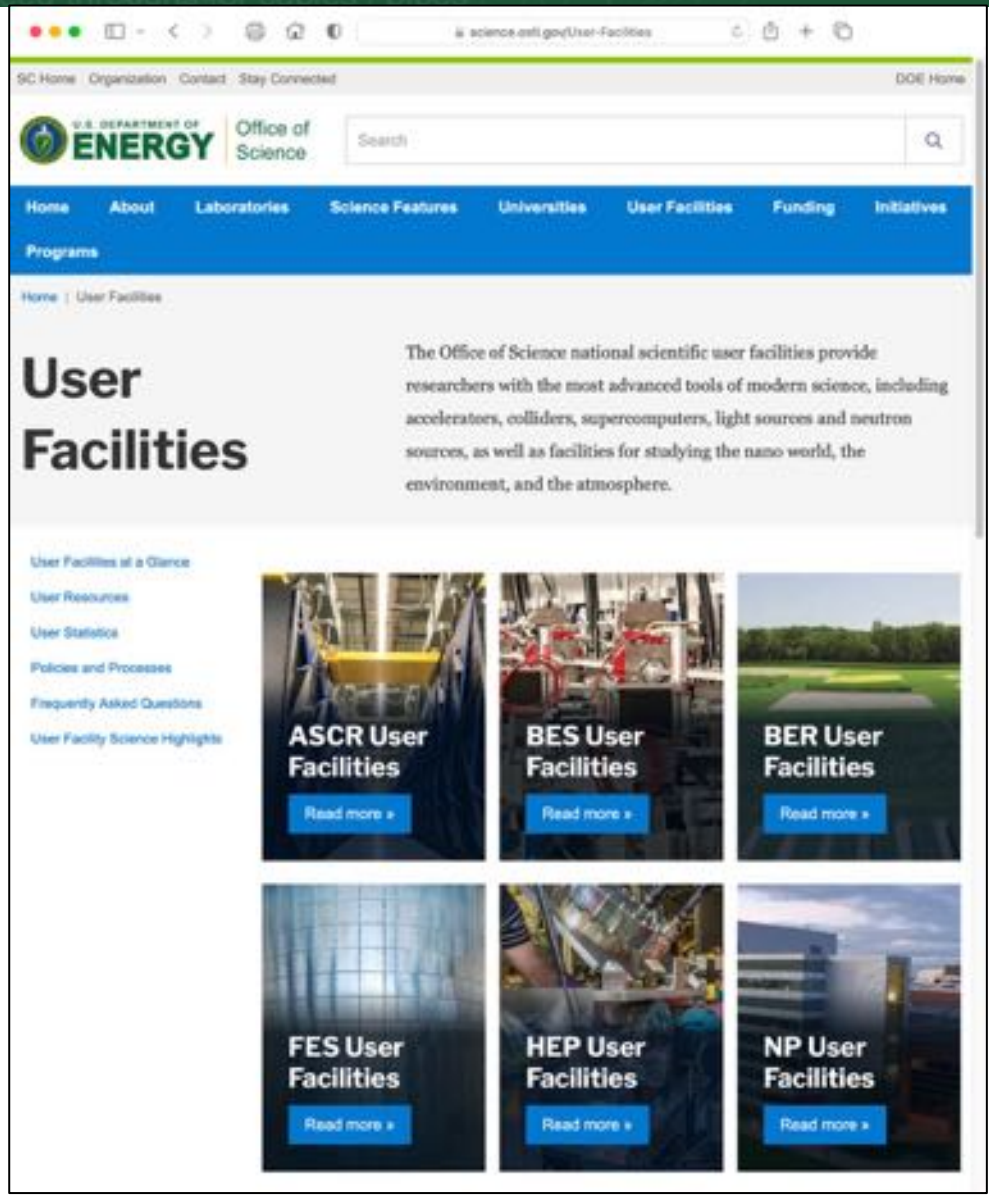
- Expands DOE User Facility portfolio to incl underground lab, raises SURF's stature within DOE community.
- Promotes underground science in U.S., increases funding opportunities.
- Enhances SURF's role in global science community.
- Communicates SURF is open to a broad range of science and users and 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:

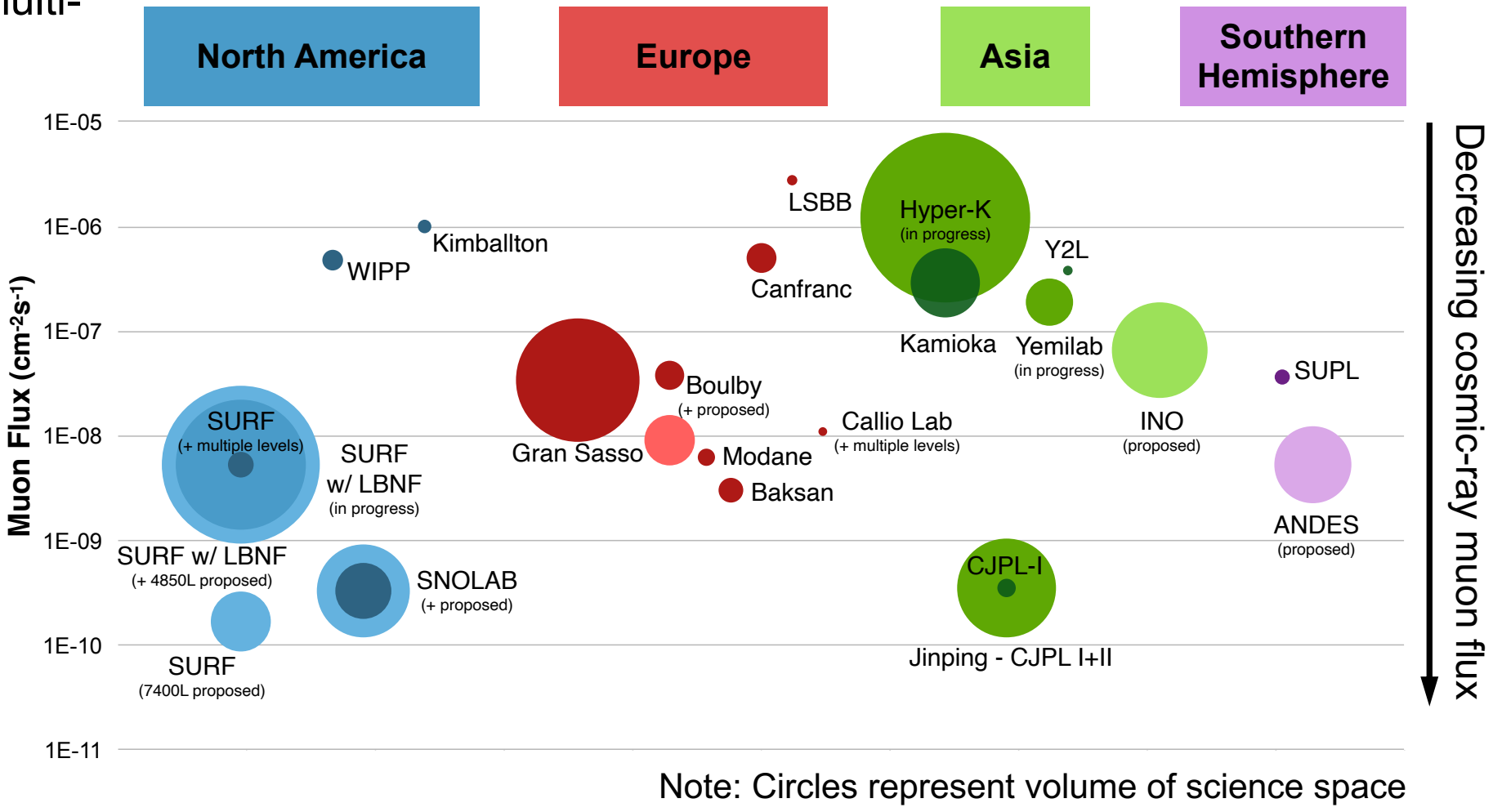
- User Association and Science Program Advisory Cttee established.
- Application draft near final, expect DOE invitation to submit soon.



Underground Facilities

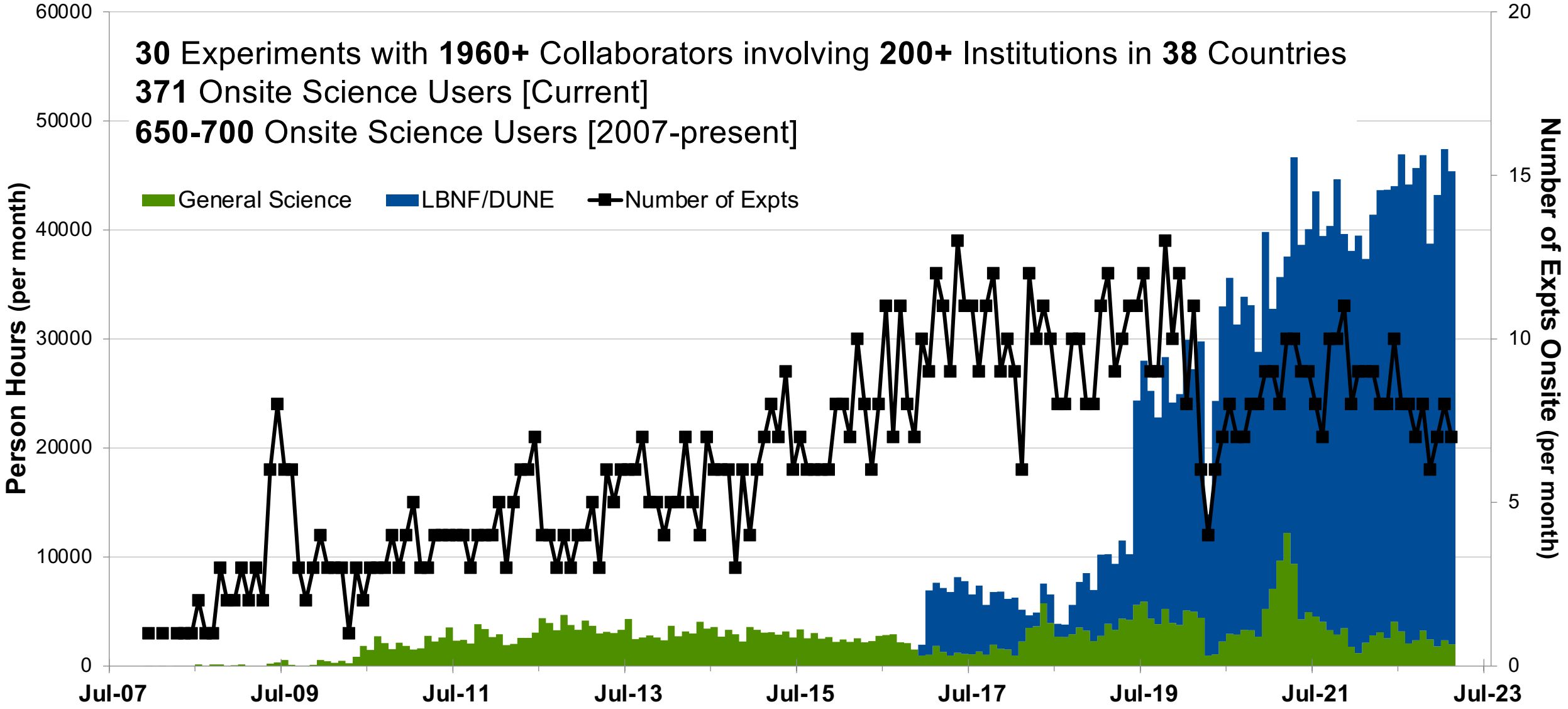
UG Facilities can provide:

- 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



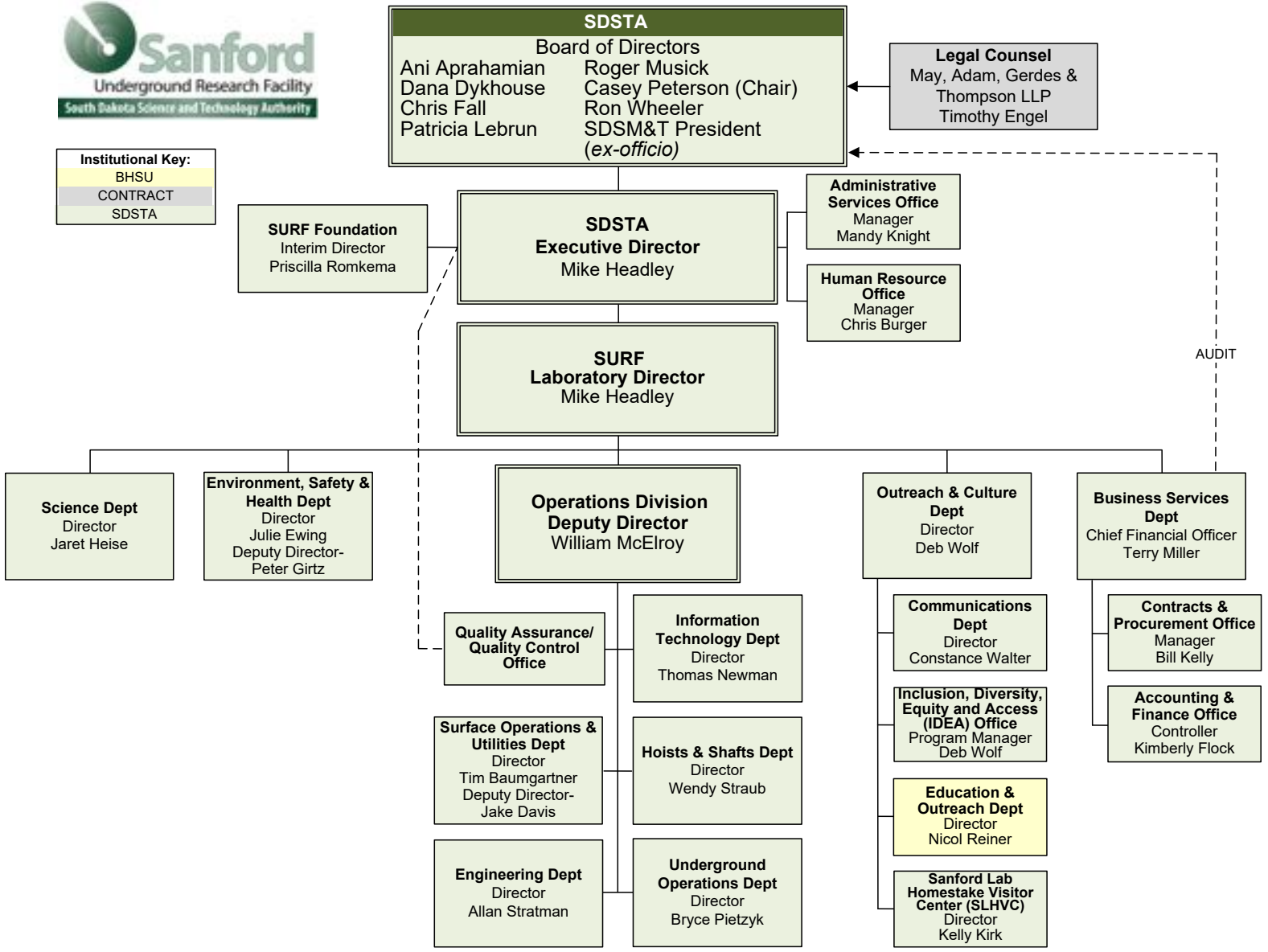
SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



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 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*

SURF User Association

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

Purpose

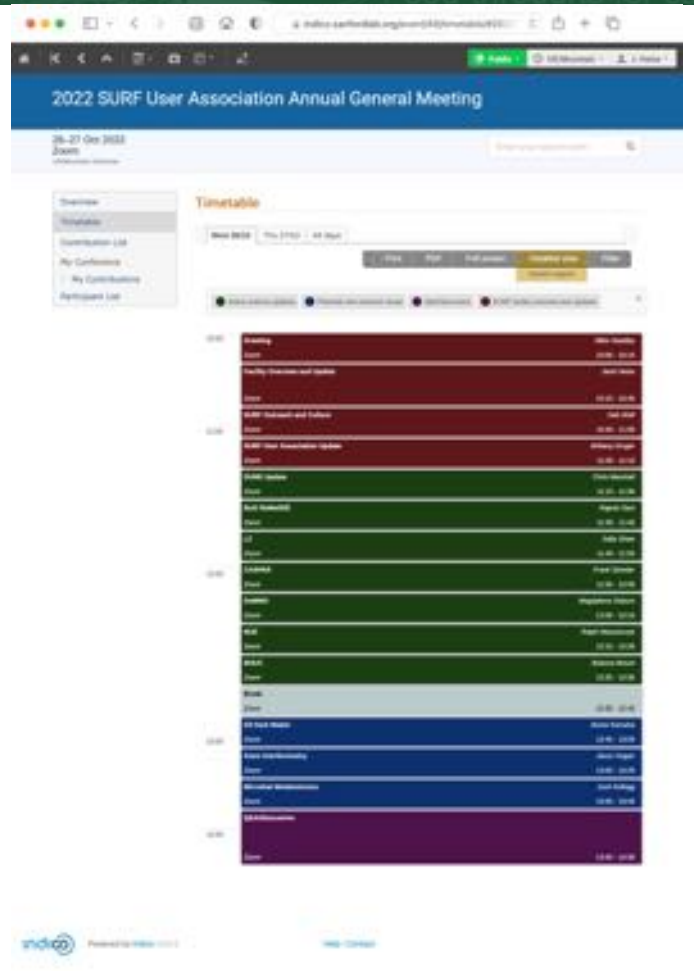
- **Two-way communication** on topics important to researchers.
- Promotes a **sense of community** amongst SURF experiments and researchers.
- Articulates and promotes **scientific case for UG science** and significance to society, provides channel for **advocacy.**

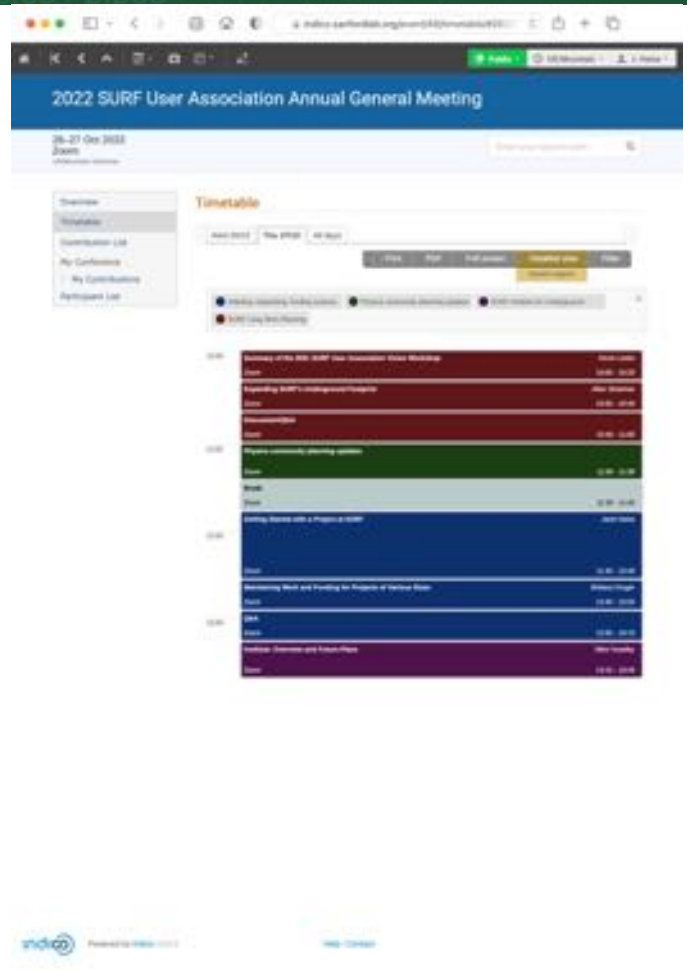
Organization

- **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 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.
- 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) 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

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

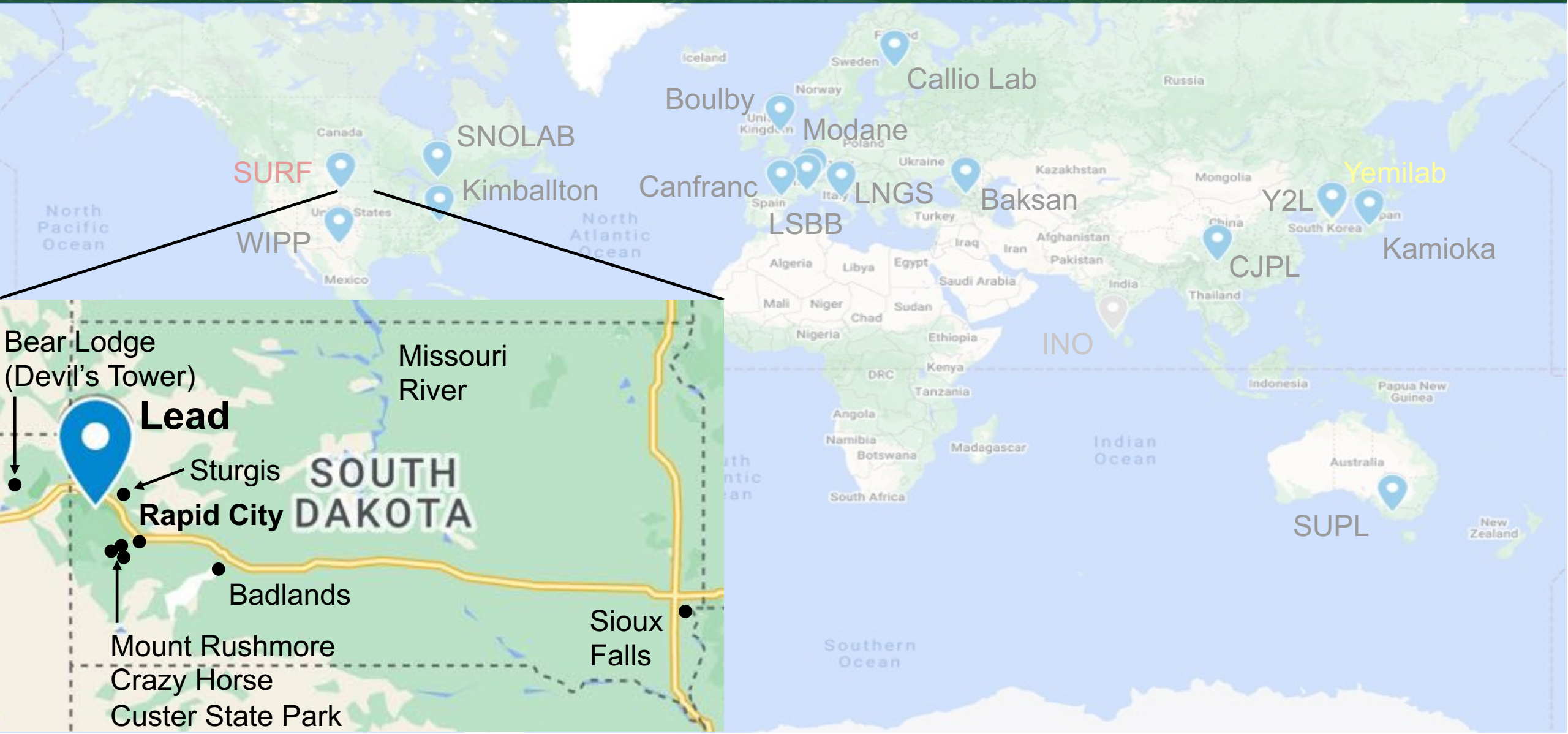
Significant interest from others

(17 groups in 2021)

* Denotes proprietary group

Sanford Underground Research Facility

Where in the world is SURF?

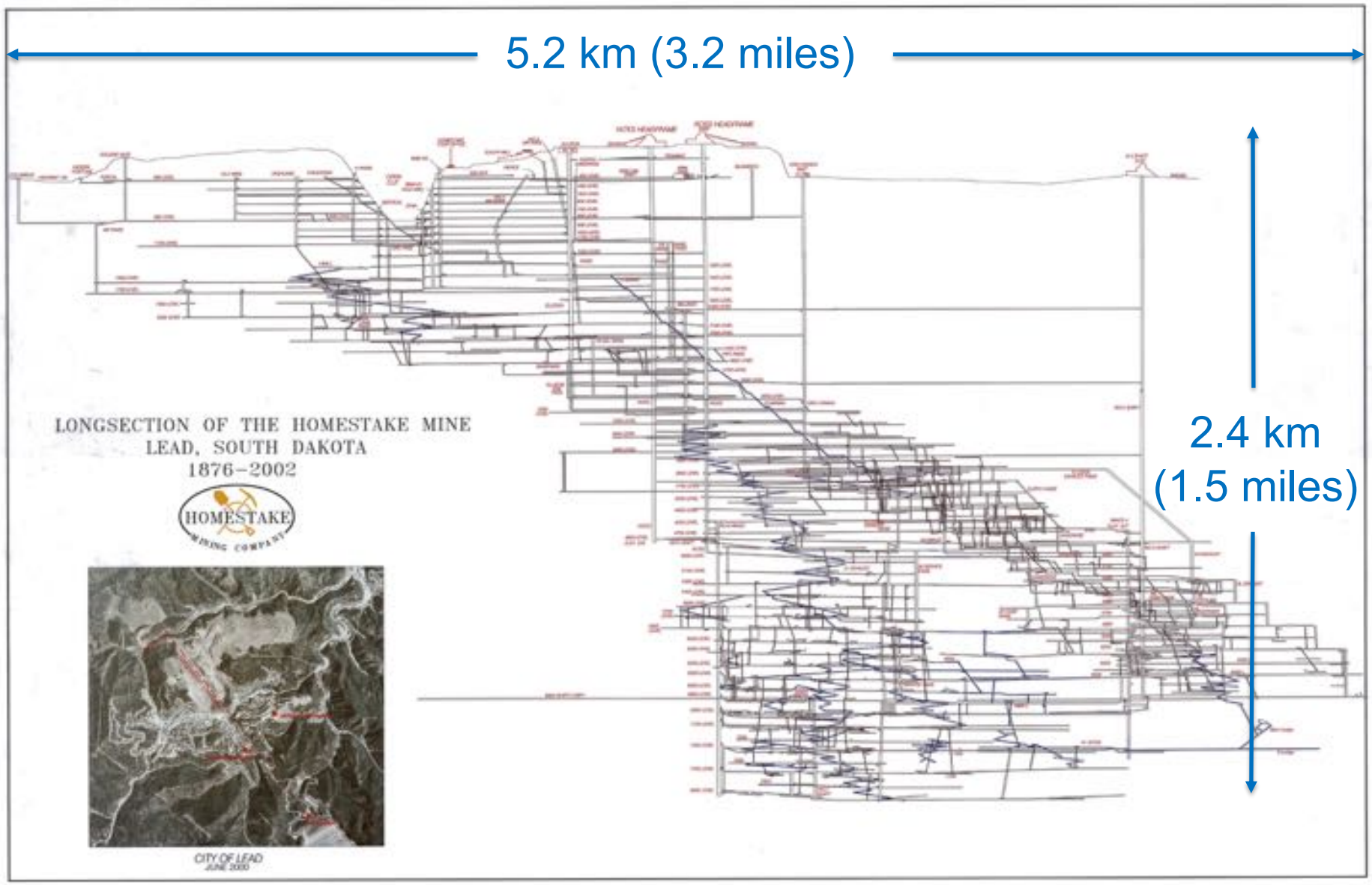


Sanford Underground Research Facility

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

SURF Underground Lab Geography

Significant underground footprint for science



SURF Current & Future Facilities

Summary for various science campuses, including timelines

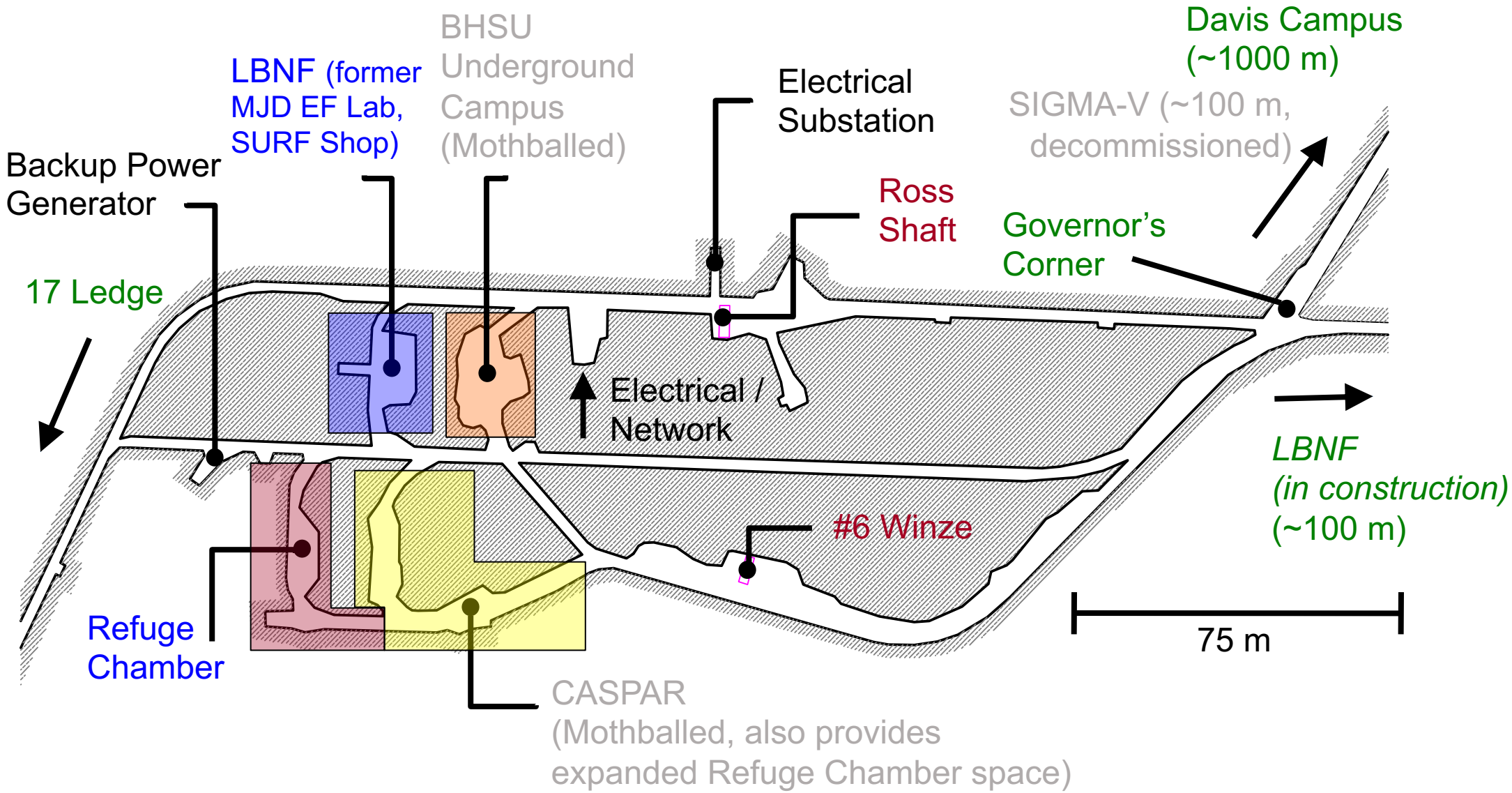
Location	Laboratory	Existing/*Planned* Space		Available (CY)	Comments
		Area (m^2)	Vol (m^3)		
Surface	Surface Lab (+ RRS)	210	600	2021	LZ use ~complete, allowing use by others
Davis Campus (4850L)	LZ Lab – Davis Cavern (2 levels)	372	1,956	~2027	LZ data complete in ~2026 + decommissioning
	MJD Lab – 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*

SURF Infrastructure Improvement Projects

- **FY20** ($9.5M)
  - Refuge Chamber
  - Headframe Security
  - Yates Cage MG Set
  - Davis Campus Chillers
  - Ross Complex Waterlines
  - Water Inflow System Replacement (Phase I)
- **FY21** ($5.4M)
  - Water Inflow System Replacement (Phase II)
  - Yates Shaft Concept Study
  - Industrial and Potable Water to Yates Complex (Phase II)
  - WWTP Gravity Flow Upgrades
  - Upgrade Oro Hondo Backup Ventilation System
- **FY22** ($5.3M)
  - 3650L Pumproom Rehabilitation (Phase I)
  - Ross/Yates Hoistroom Roof Drains, Repointing
  - Replace Power Cables East Switchyard
  - WWTP RBC Replacement (Phase I)
- **FY23** ($4.2M)
  - 3650L Pumproom Rehabilitation (Phase II)
  - Replace Yates Hoistroom Roof
- ***FY24*** *(TBD)*
  - *4850L refuge chamber headcount to 250 ppl and Ross Campus bathrooms*
- ***FY25-31*** *(TBD)*
  - *Yates hoists and shaft refurbishment*

4850L Ross Campus

2,653 m² (Total) / 920 m² (Science)



SURF 4850L Ross Campus

Examples of laboratory space

2010-2017

Copper Electroforming

2015-2020, resume FY24

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

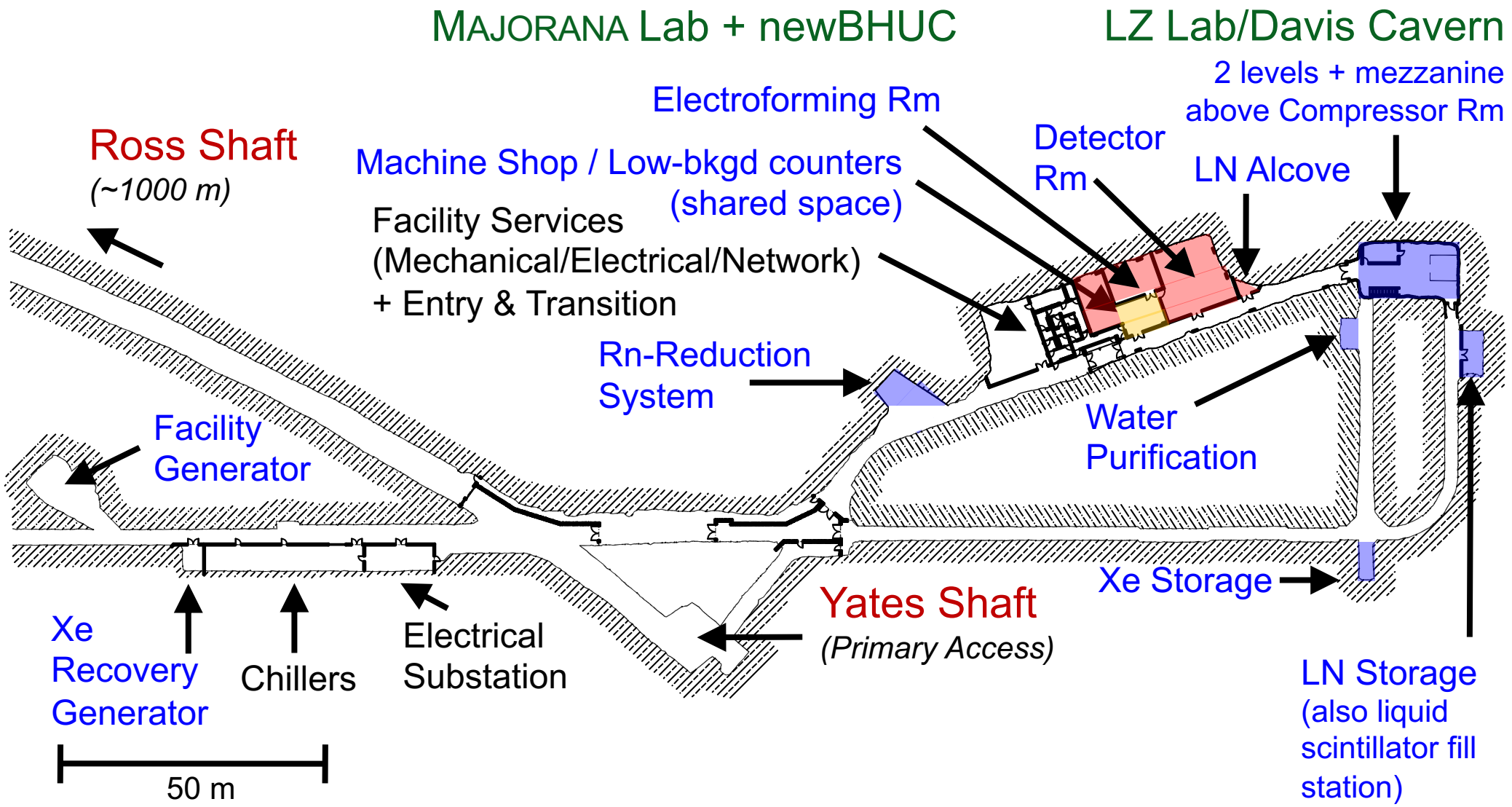
2015-2021, resume FY24

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

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

DATE ISSUED:
September 14th, 2020

SOURCE:
Sanford Underground Research Facility

CONTENT:
Press Release

CONTACT:
Constance Walter
Communications Director
cwalter@sanfordlab.org

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).

Long-Baseline Neutrino Facility (LBNF)

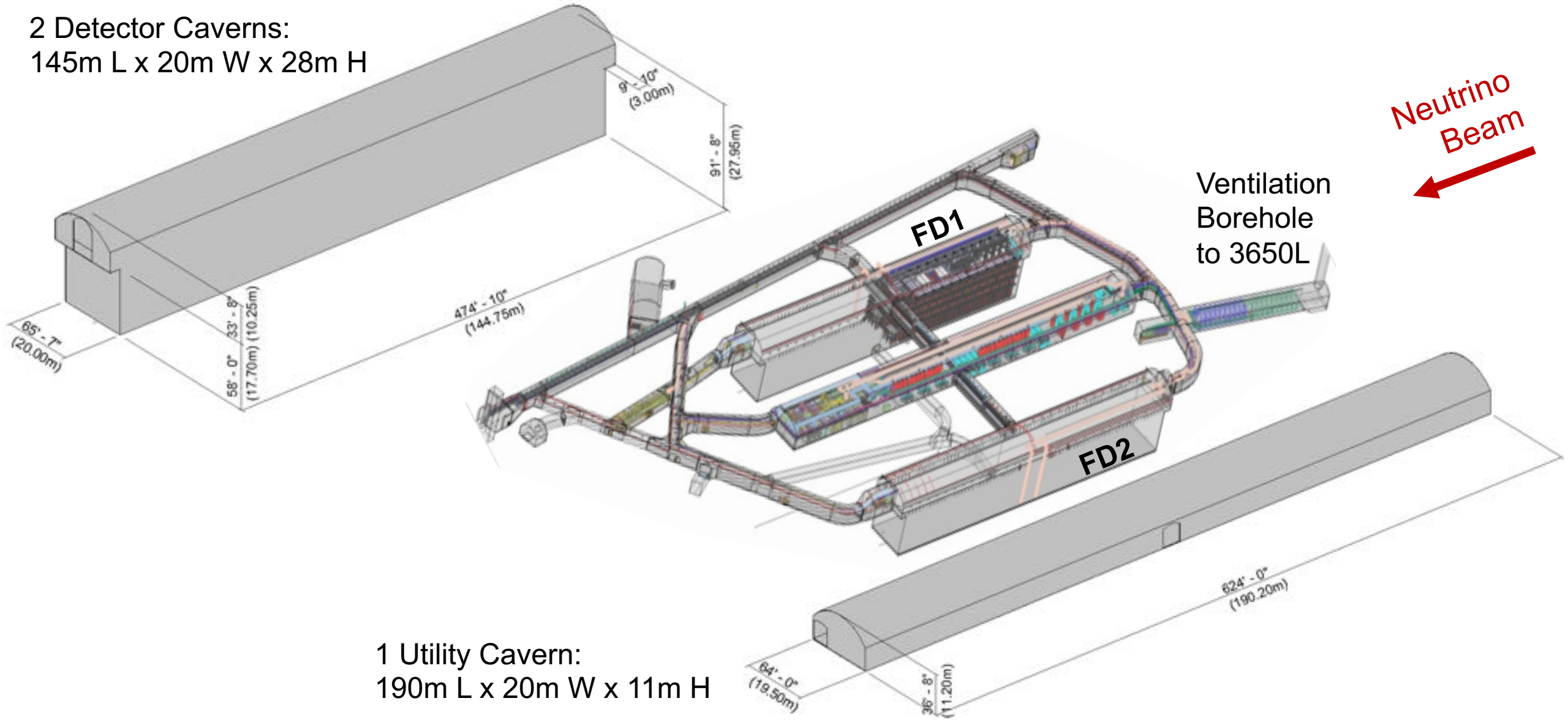
LBNF will host the Deep Underground Neutrino Experiment (DUNE)

- 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 ~Dec 2023).
- **Infrastructure outfitting** and **cryostat construction** expected 2024-2027, **science starts 2029**.

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)

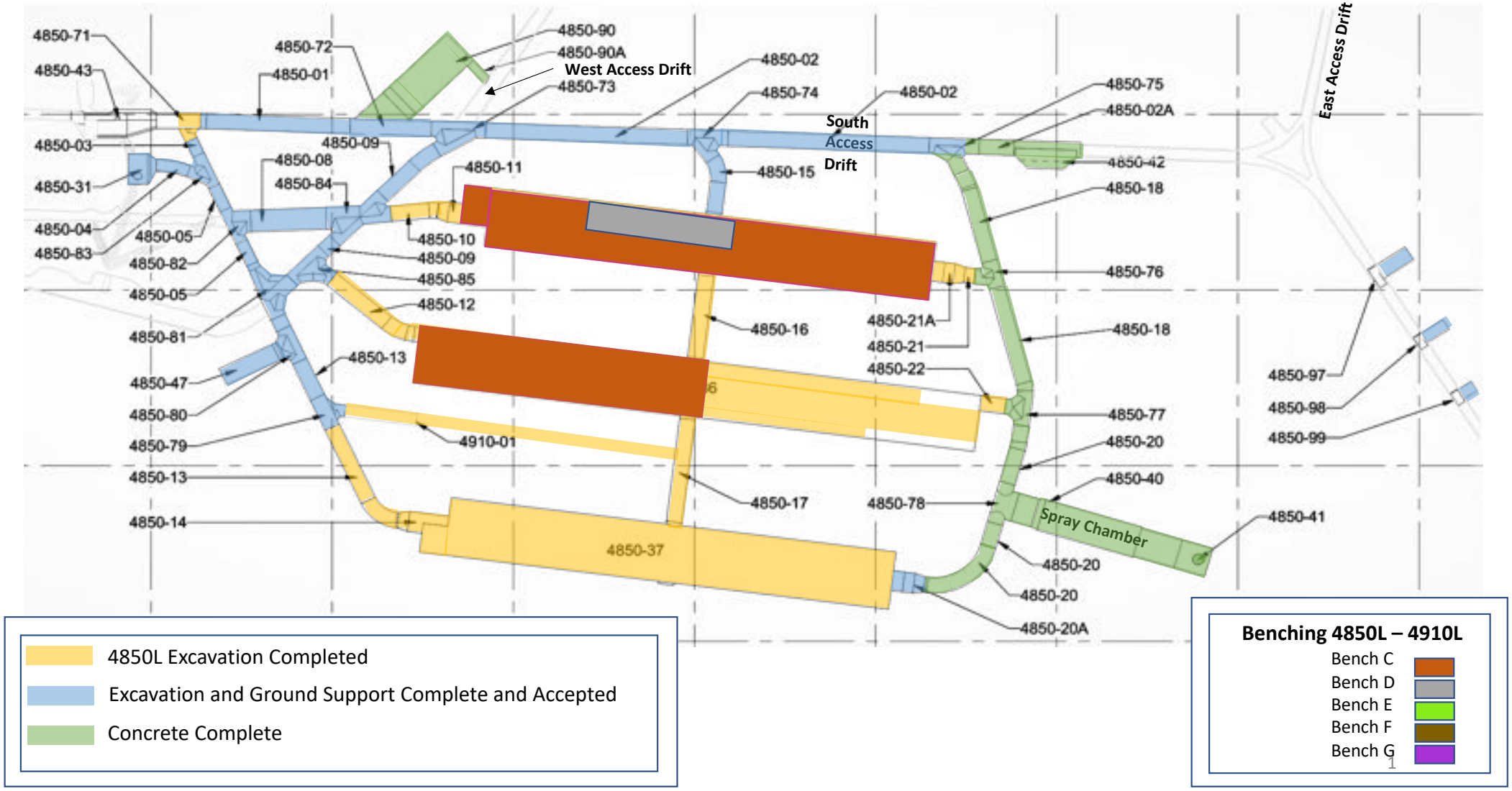
LBNF/DUNE at SURF Animation
(https://www.youtube.com/watch?v=zoxjRsIzd4k)

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

Total Excavation Completed to Date = 56.8%

March 6, 2023



4850L Excavation Completed

Excavation and Ground Support Complete and Accepted

Concrete Complete

Benching 4850L – 4910L

Bench C

Bench D

Bench E

Bench F

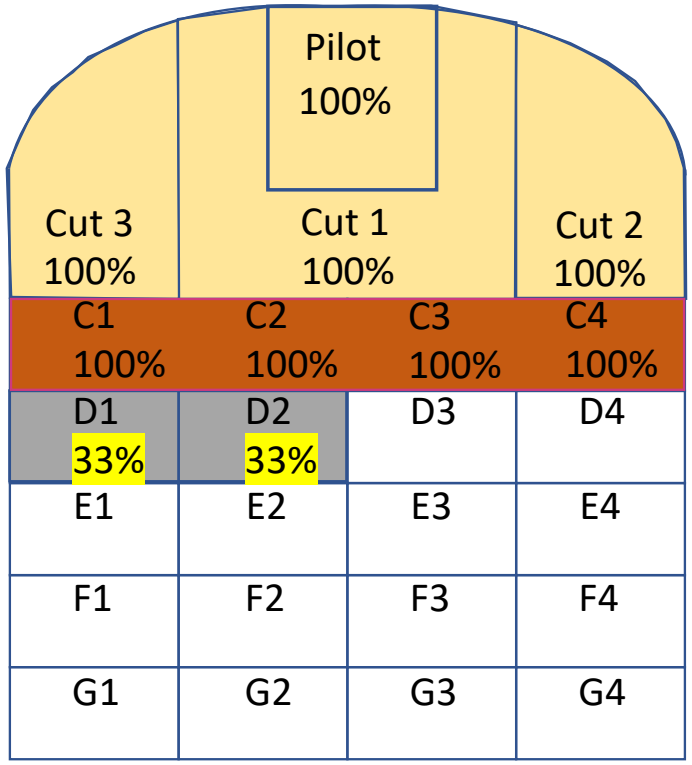
Bench G

Long-Baseline Neutrino Facility (LBNF)

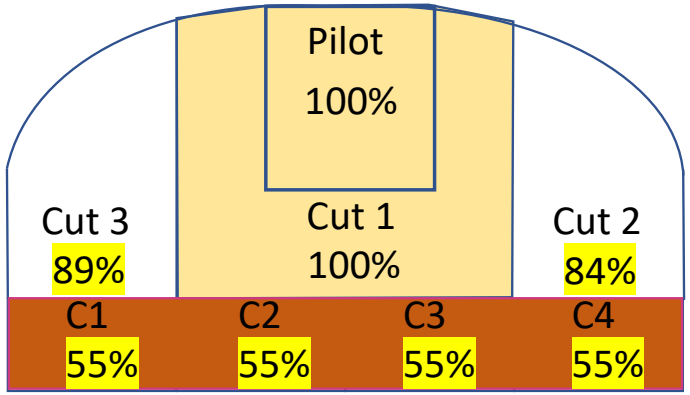
LBNF will host the Deep Underground Neutrino Experiment (DUNE)

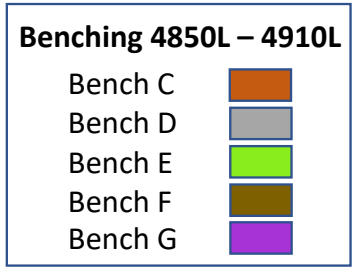
Cavern Excavation Completion Percentage

March 6, 2023

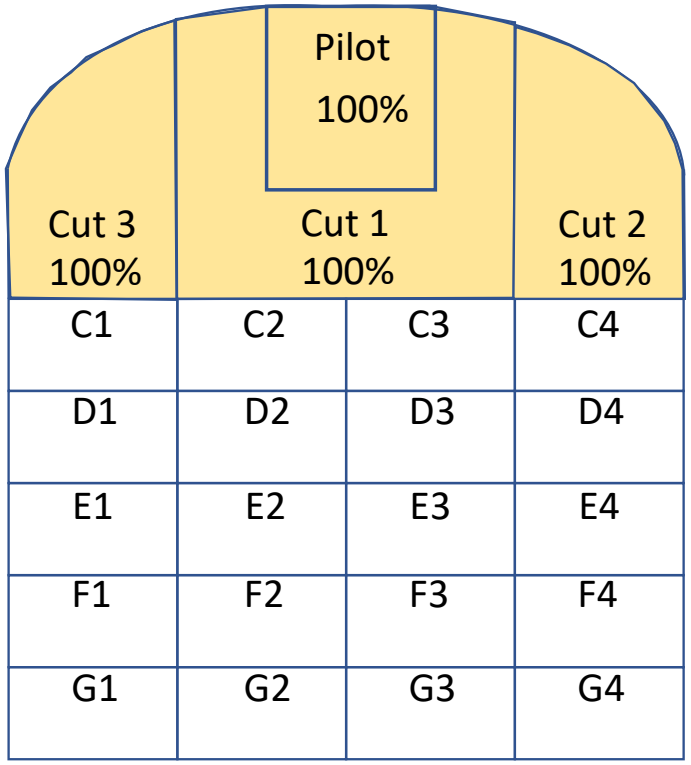


North Cavern





CUC Cavern



South Cavern

LBNF Excavation Progress

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

LBNF Excavation Progress

North Cavern reaches full width

LBNF Excavation Progress

North Cavern reaches full width

LBNF Excavation Progress

North Cavern reaches full width