SANFORD UNDERGROUND RESEARCH FACILITY



The Sanford Underground Research Facility

Jaret Heise, Science Director
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3rd Higher Education Connections Workshop
Lead, SD
November 1-3, 2026



Geology and Engineering

Enhanced Geothermal Systems
Mining Technology

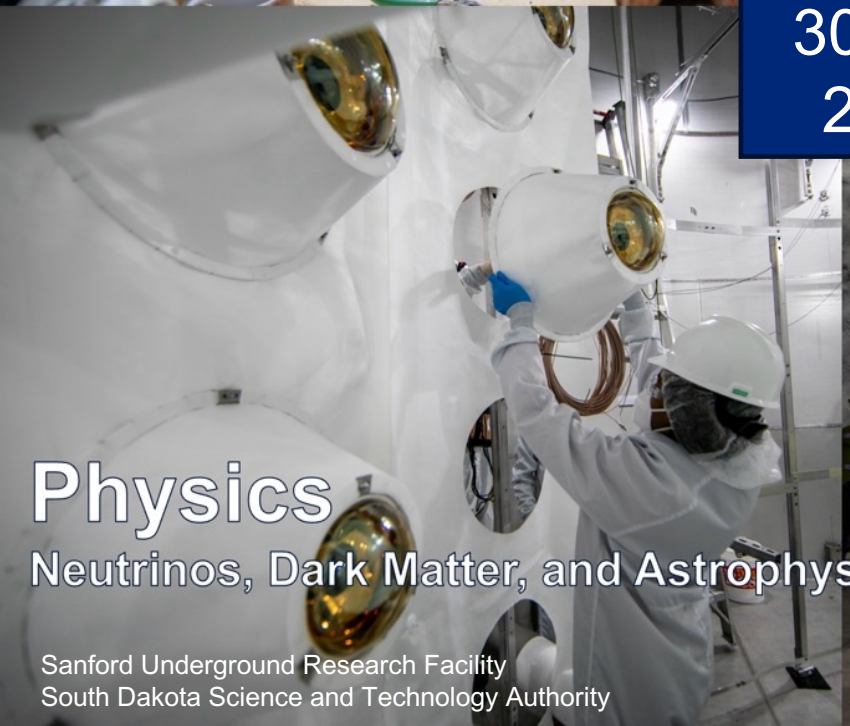


Biology

Extremophiles, Biodiversity

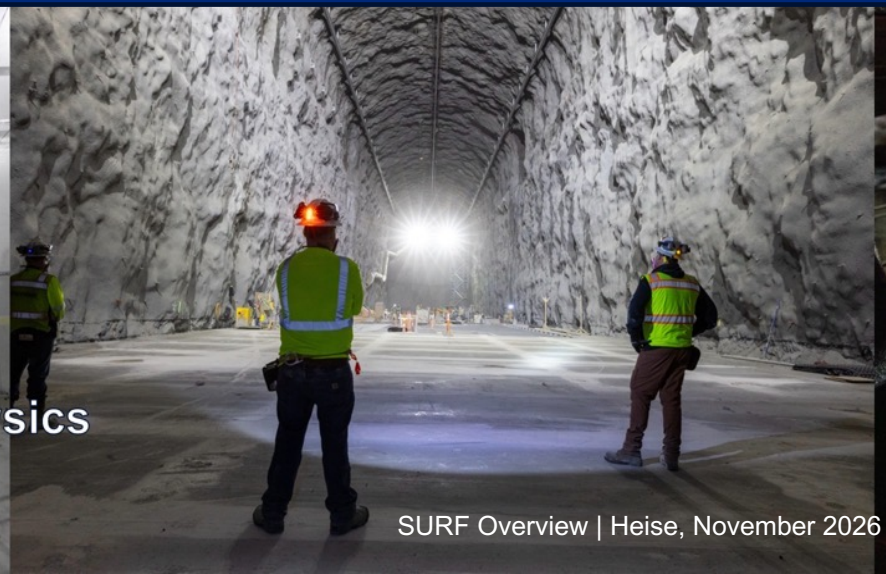
Science Program

30 Expts with 2,250 Collaborators,
280+ Institutions in 47 Countries



Physics

Neutrinos, Dark Matter, and Astrophysics





Partnerships

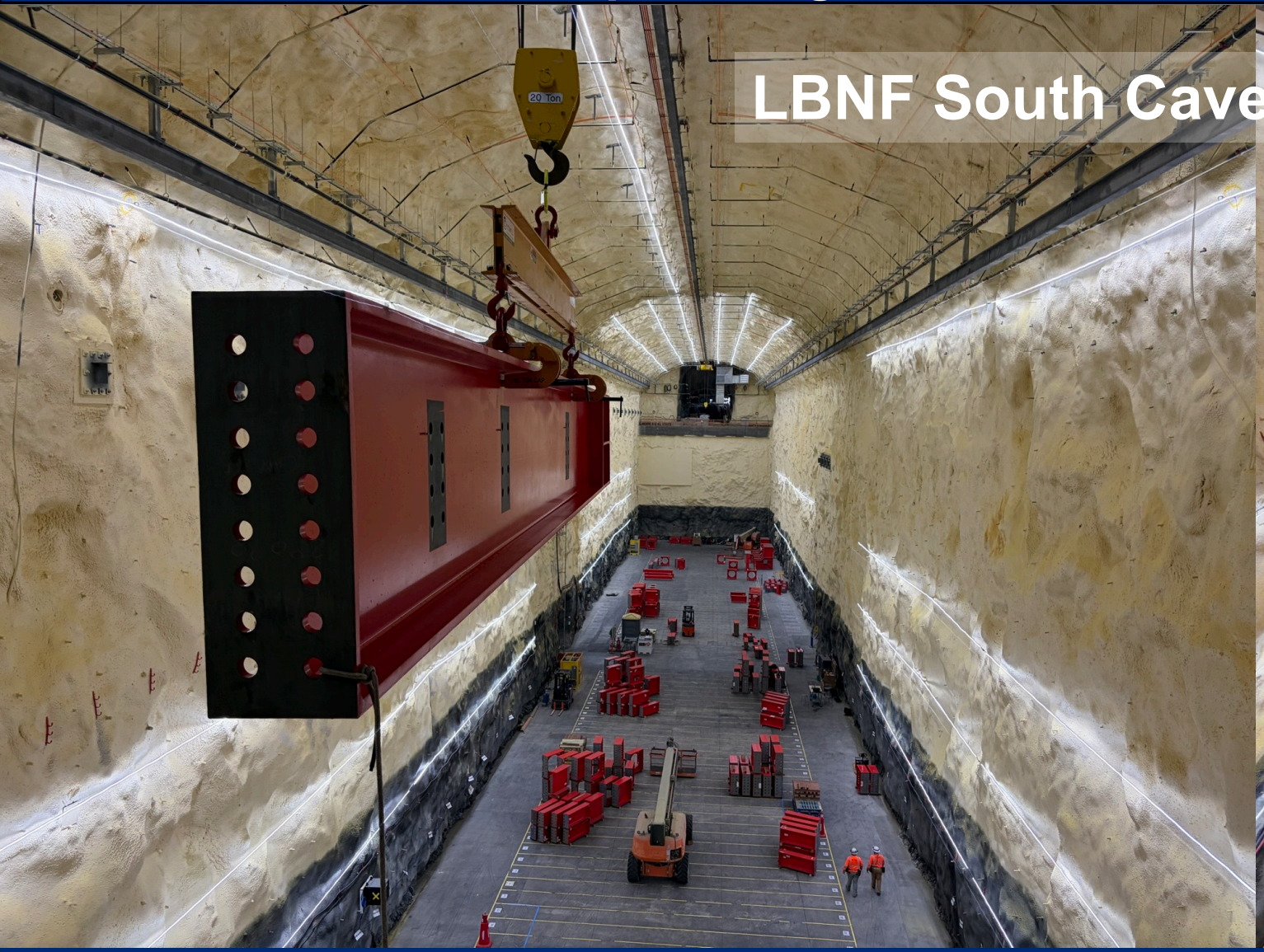
Commercial, Technology,
Industrial, Workforce development

LBNF South Cavern



Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)



LBNF South Cavern



SURF Science Strategic Plan

Long-term vision to ensure SURF continues to serve scientific community

Goals

- **Program:** Attract world-leading scientists and experiments
- **Facilities:** Ensure SURF facilities support science program
- **Support:** Ensure organizational capabilities serve experiments
- **Engagement:** Establish strong SURF role in global UG science community

Physics (closely aligned with top U.S. priorities c. 2023; revisit with SCAC)

- DUNE support (Phase 1 and Phase 2)
- Generation 3 Dark Matter (XLZD and/or ARGO)
- 'Agile' Experiments / Low-Mass Dark Matter
- General R&D facility

Quantum User Facility w/ dilution refrigerator

- Generation 2 Dark Matter upgrade (extend LZ ops + low-mass dark matter)

Non-Physics (based on community expert input)

- SURF is critical hub for innovation and discovery:
  - Geology and geomechanics (geothermal, real-time sensing, etc)
  - Biology and microbial systems (extremophiles, incl CO_2 sequestration)
  - Industrial and academic partnerships (e.g., CAT, NSF REU programs, etc)



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Sanford Underground Research Facility Scientific Strategic Plan
24 June 2024

Executive Summary

The US High Energy Physics and Nuclear Physics communities recently completed their long-range planning exercises: Particle Physics Project Prioritization Panel and Long Range Plan, respectively. Underground physics experiments remain central to the future of the US High Energy Physics program. These plans present opportunities for Sanford Underground Research Facility (SURF) to identify future users and advance plans for hosting their experiments in the coming decade.

For the High Energy Physics community, SURF is a critical host for the future of multiple highest priority experiments for the coming decades. The **DUNE Phase I** and **Phase II** are recommended as the highest priority and present an opportunity for the US HEP program to host a world-class, international, neutrino program at SURF. Under all budgetary scenarios considered in the P5 report, dark matter experiments are recommended in the coming decades. The **G3 dark matter experiment XLZD or ARGO** represents an important opportunity for SURF to host experiments in their planned expansion or in DUNE's *Module of Opportunity*. It is imperative that SURF engineering and physics staff actively engage with these collaborations in the coming year to develop conceptual plans, requirements, and installation plans. These plans can be matured to Memoranda-Of-Understanding (or other vehicles) with additional work by the experimental

Strategic Assessment of Research and Collaborative Opportunities Beyond Physics at the Sanford Underground Research Facility

October 5, 2026 (Draft submitted January 31, 2026)

Executive Summary:

The Sanford Underground Research Facility (SURF) has successfully transitioned from its history as a gold mine into a leading international hub for deep underground science and technology. SURF offers a suite of environmental conditions well-suited for a variety of geology, biology, and engineering research, unlike physics labs that use the subsurface mainly for radiation shielding. The facility's primary value comes from its four unique attributes: its depth, its breadth, varied geochemical composition, and its long-term access that facilitates investigations of the subsurface requiring longer periods of time. SURF offers access to a rock mass volume of ~35 km^3 and, with approximately 34 km maintained for access on 29 underground levels reaching up to 1.5 km deep, provides the largest geography for scientific purposes of any global underground laboratory.

Research and Partnerships

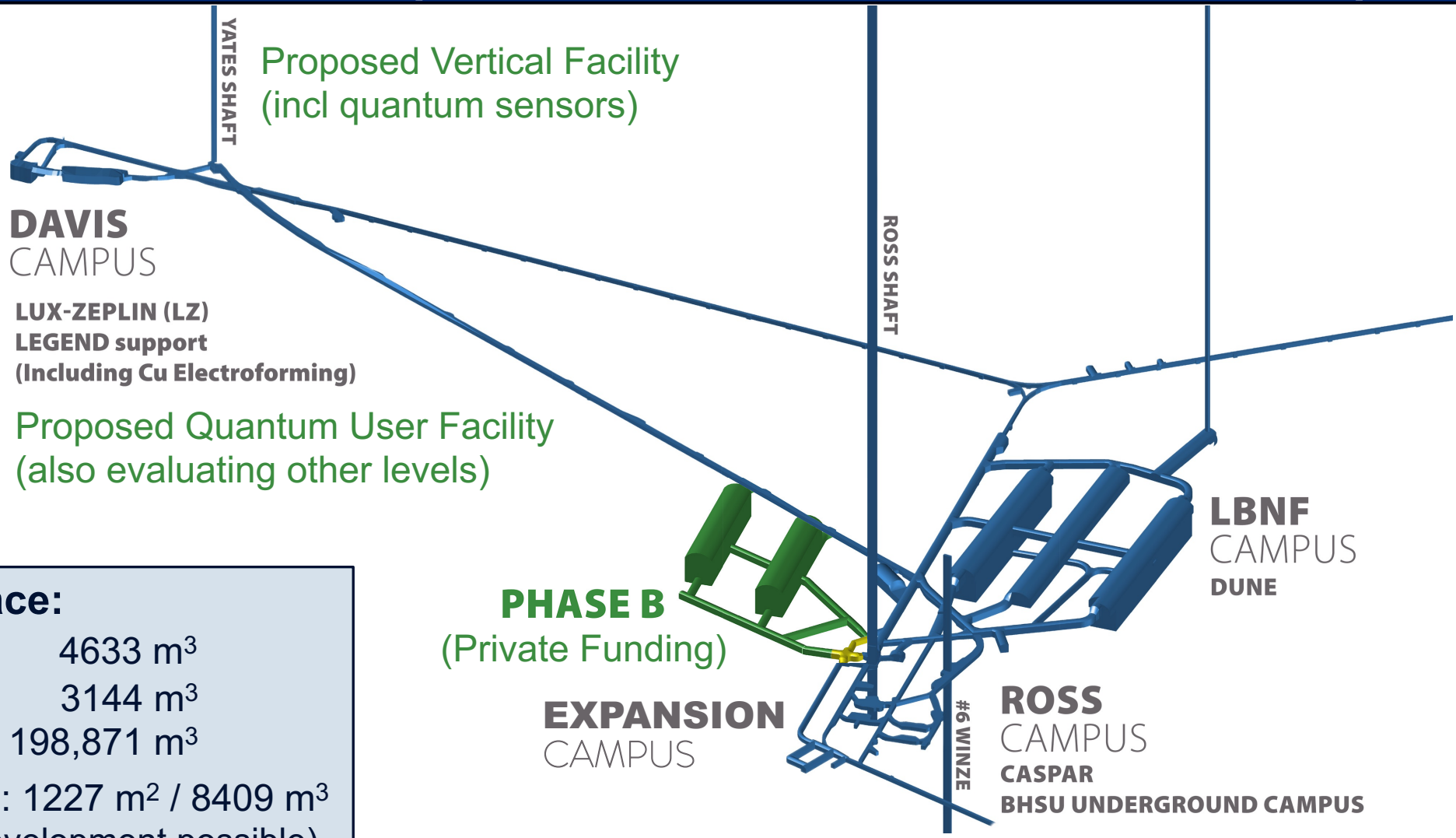
SURF hosts diverse research projects that leverage its stable rock, high in-situ stress, and extreme subterranean habitats.

- **Geology and Geomechanics:** Projects like the EGS Collab initiative aim to advance geothermal energy by studying hydraulic fractures in crystalline rock. Other projects, such as GEOX™ and portions of the EGS Collab project, focus on developing and deploying advanced sensing technologies to measure rock movement in real time, which is critical for underground construction and safety.
- **Biology and Microbial Ecosystems:** Research in this area explores life in extreme environments. For example, the Deep Mine Microbial Observatory (DeMMO) studies how microbes survive in harsh conditions through time. A separate, groundbreaking project discovered extremophiles at SURF that can convert CO_2 gas into a stable solid mineral in just ten days, which normally takes years. The discovery has a pending patent, highlighting its commercial potential.
- **Industrial and Academic Partnerships:** SURF serves as a valuable testbed for industries. Caterpillar (CAT) used the facility to develop its MineStar technology, a Wi-Fi-based system for tracking equipment and personnel in GPS-denied environments. SURF's in-house staff and expertise in deep underground work make it a strategic partner that can mitigate the risks and complexities of such projects. SURF continues to be an

Deep Space Needed for Future Experiments

U.S. strategic plan endorsed SURF expansion for neutrino and dark matter expts

4850L:
1400-1500 m depth
3900-4300 m.w.e.



Existing Laboratory Space:

- Davis Campus: 1018 m^2 / 4633 m^3
- Ross Campus: 920 m^2 / 3144 m^3
- LBNF Campus: 9958 m^2 / 198,871 m^3
- Expansion Campus (new): 1227 m^2 / 8409 m^3 (some amenities, further development possible)

See also: *Annu. Rev. Nucl. Part. Sci.* **76** 69-95 (2026)

The Institute for Underground Science at SURF

World-leading center for

- **Underground science collaboration and intellectual community**
- **Science education and engagement** (K-12 and public education & outreach programs)

THE INSTITUTE
FOR UNDERGROUND SCIENCE
AT SURF

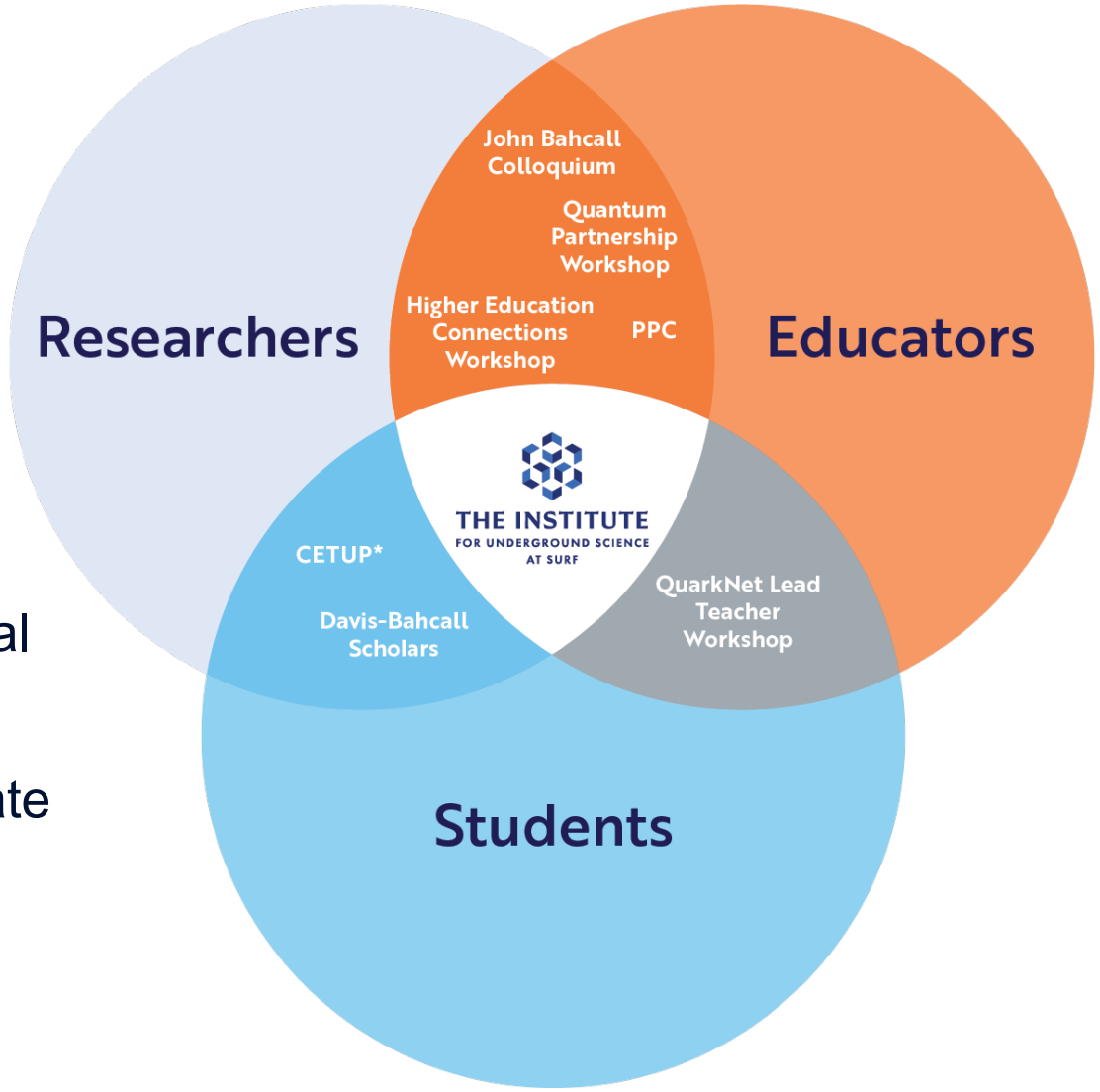


Institute for Underground Science at SURF

Advancing program vision using existing resources to build constituency

Vision

Create a dynamic intersection of KNOWLEDGE, PEOPLE, and PLACE, dedicated to building an unparalleled intellectual community and serving as a world-leading center for underground science and technology



Priorities

- Build Intellectual Community
- Expand Educational Opportunities
- Foster Interdisciplinary Collaboration
- Establish Passionate Partnerships
- Construct a Path for Future Generations

SURF Summary

- **SURF's Mission:** Advance world-class science and inspire learning across generations
  - For some of you, SURF is already a partner in research or education. For others, this may be your first time engaging with us. Either way, SURF exists to be a **connector** — a catalyst for science, engineering, and education across South Dakota, our nation and the world.

- SURF is *your* deep underground laboratory!
  - SURF has strong relationship with DOE that **benefits South Dakota science & education community** for **decades** to come
  - **Science:** Multi-disciplinary strategic planning completed. Planning for facilities to host quantum and other next-generation experiments underway
  - **Science Education & Engagement:** Eager to participate in grant proposals, with expertise and experience in effective implementation of outreach programming
  - **Institute** has had significant impact with initial programming that is building intellectual community. Strategic planning exercise completed, stay tuned for more opportunities to come!

Sanford Underground Research Facility

Thank You!

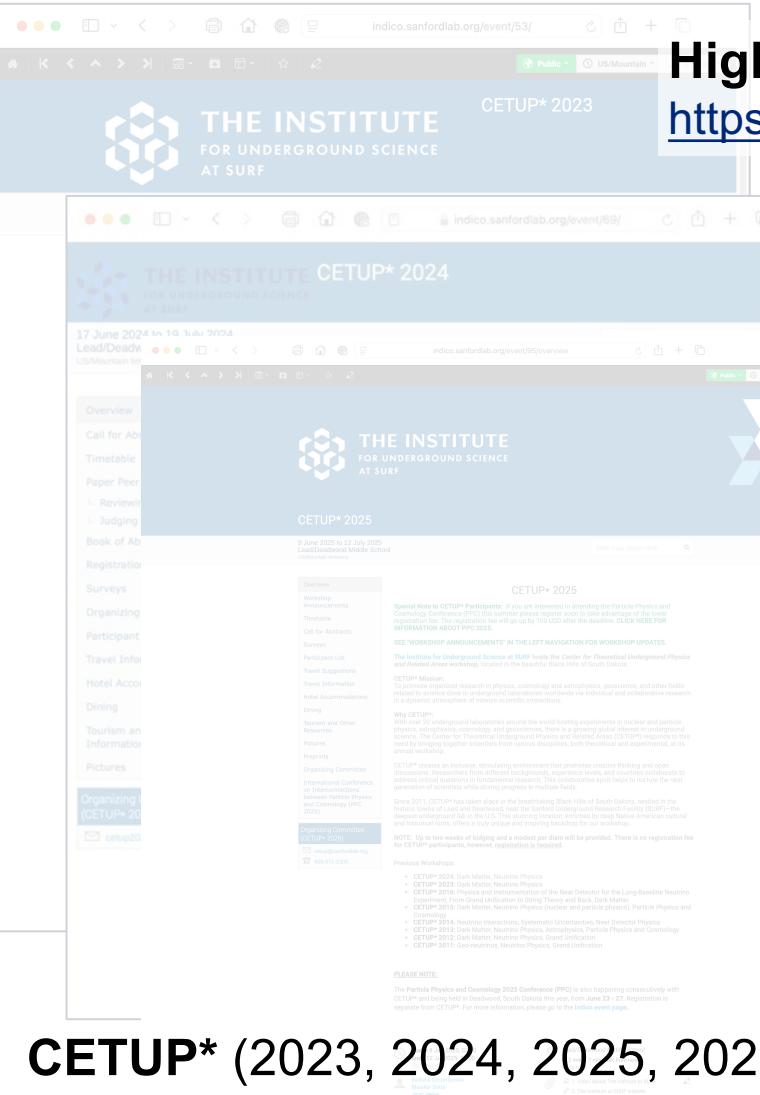




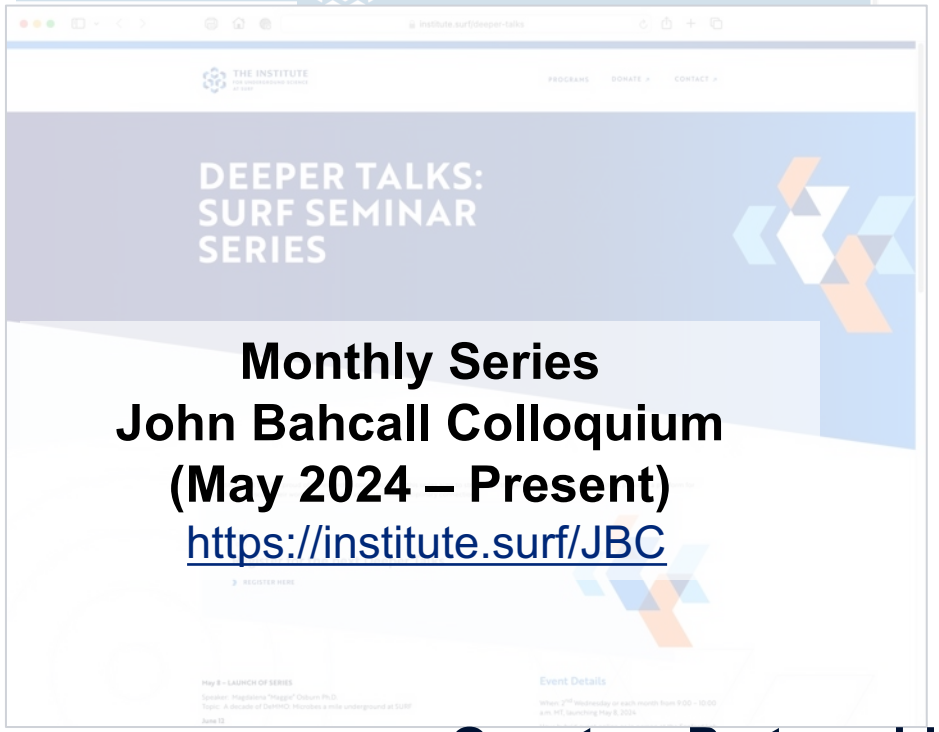
Agency Acknowledgement:
The Sanford Underground Research Facility (SURF) is a federally sponsored research facility under DOE-SC HEP Award Number DE-SC0020216 (cooperative agreement)

Institute for Underground Science at SURF

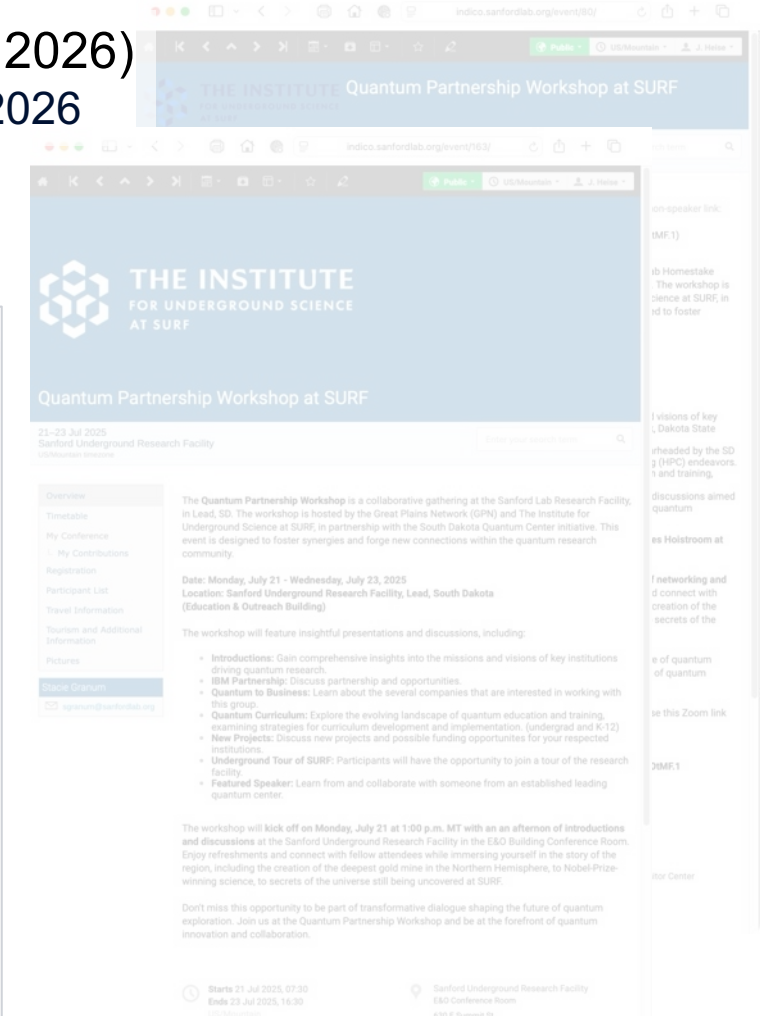
Activities since June 2023, formally launched December 2023



Higher Ed Connections Workshop (2024, 2025, 2026)
https://indico.sanfordlab.org/event/HECW2024 / 2025 / 2026



Monthly Series
John Bahcall Colloquium
(May 2024 – Present)
https://institute.surf/JBC



CETUP* (2023, 2024, 2025, 2026)
https://indico.sanfordlab.org/e/CETUP2023 / 2024 / 2025 / 2026

Quantum Partnership Workshop (2024, 2025, 2026)
https://indico.sanfordlab.org/e/QPW2024 / 2025 / 2026

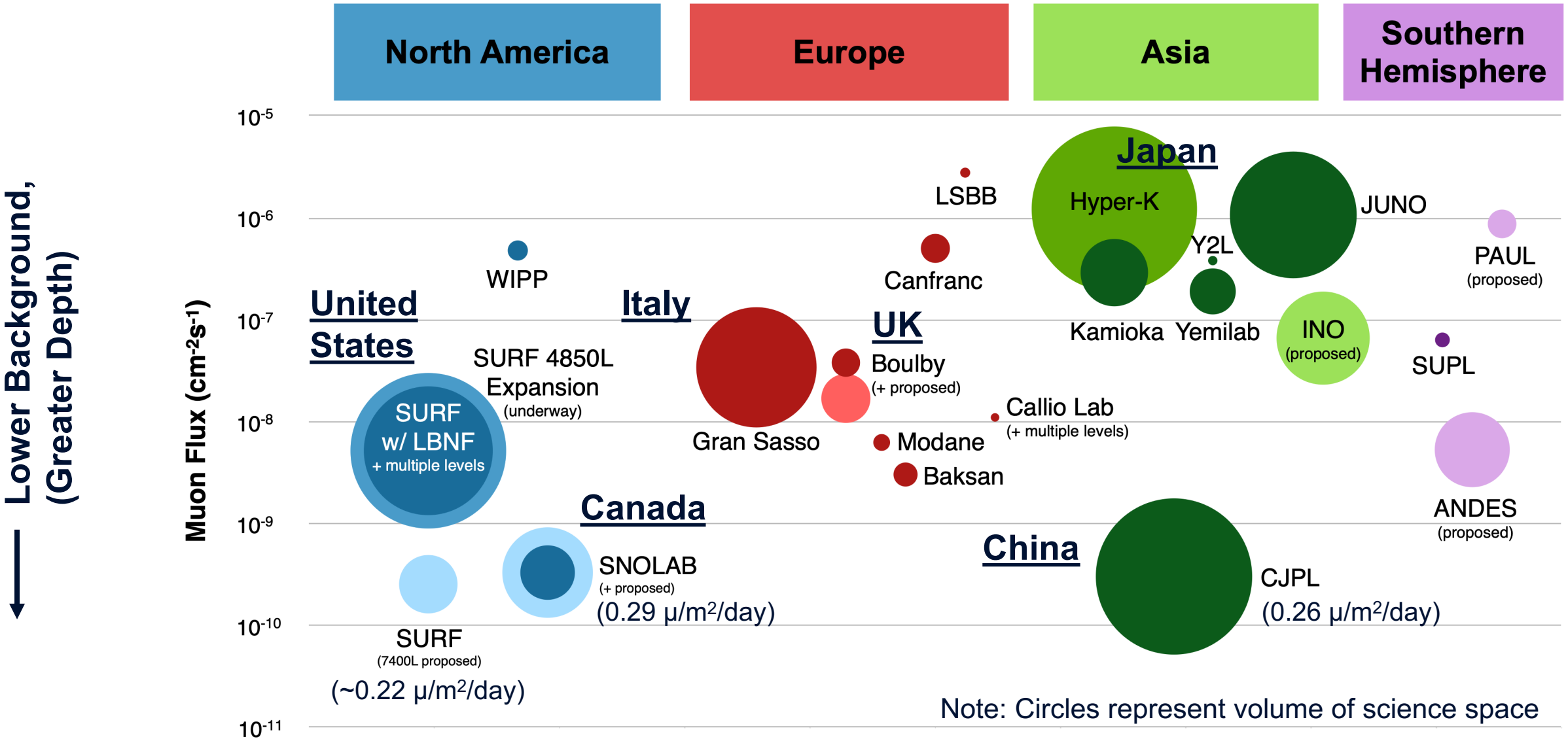
Where in the World is SURF?

Many underground laboratories currently operating (+ more proposed labs)



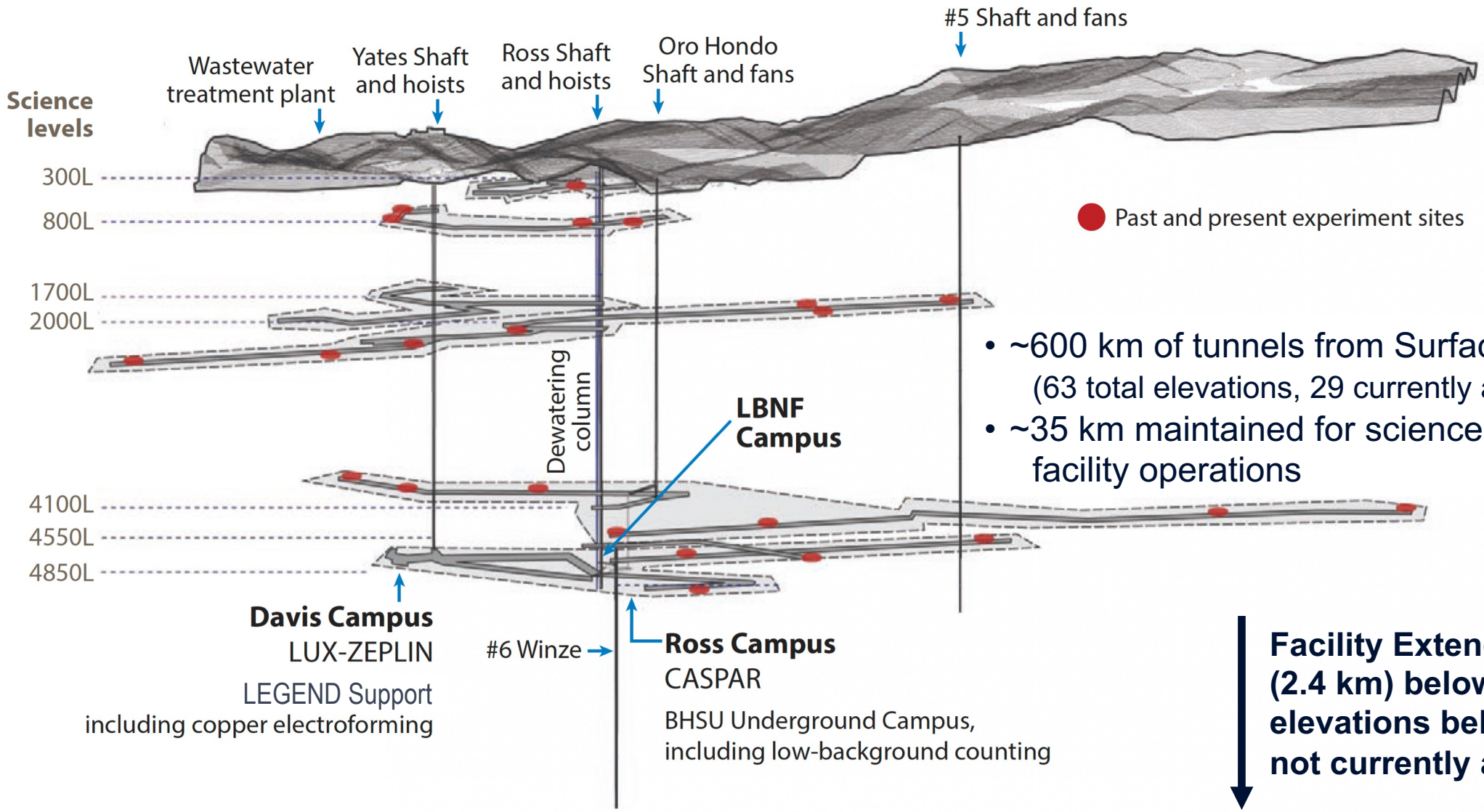
SURF in the Global Context

Deep site (4.5 μ/m²/day) with significant expansion potential, max depth 2450 m



SURF Underground Lab Geography

Largest footprint for science: access to rock mass of ~35 km^3, 35 km of tunnels

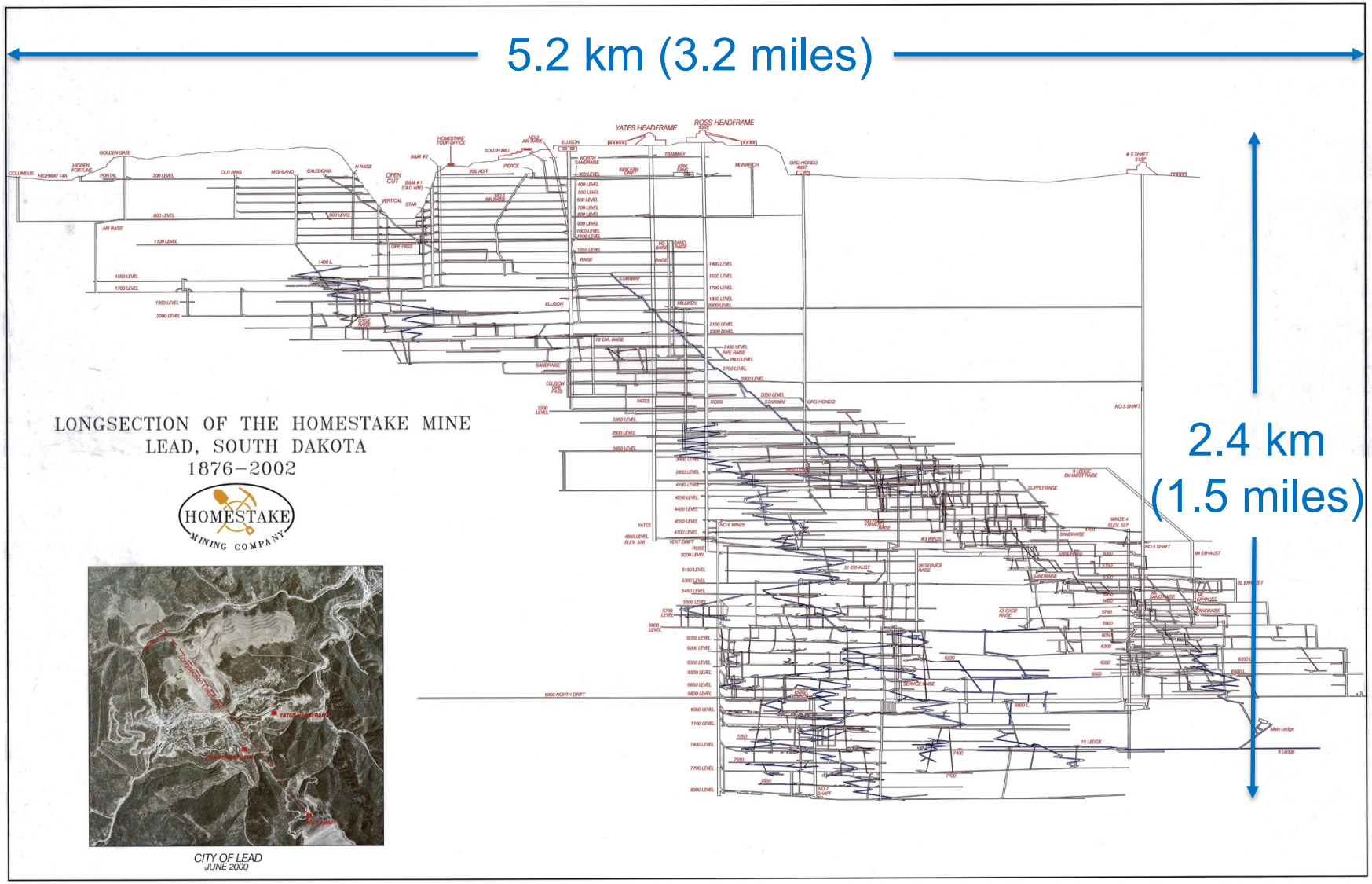


- ~600 km of tunnels from Surface to 2.4 km deep
  (63 total elevations, 29 currently accessible)
- ~35 km maintained for science and facility operations

Facility Extends to 8000L (2.4 km) below surface, elevations below 5000L not currently accessible

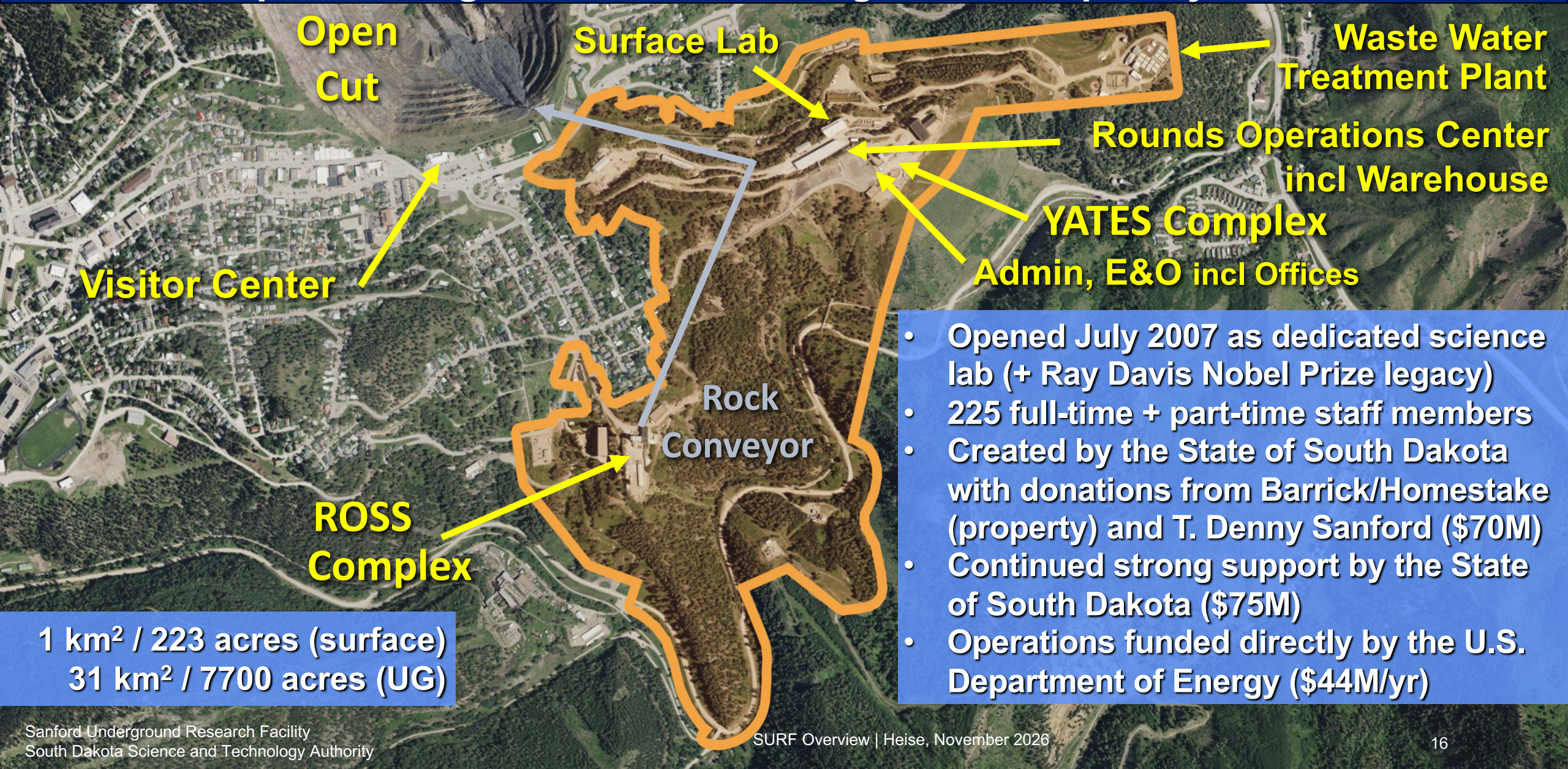
SURF Underground Lab Geography

Significant underground footprint for science



Sanford Underground Research Facility

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

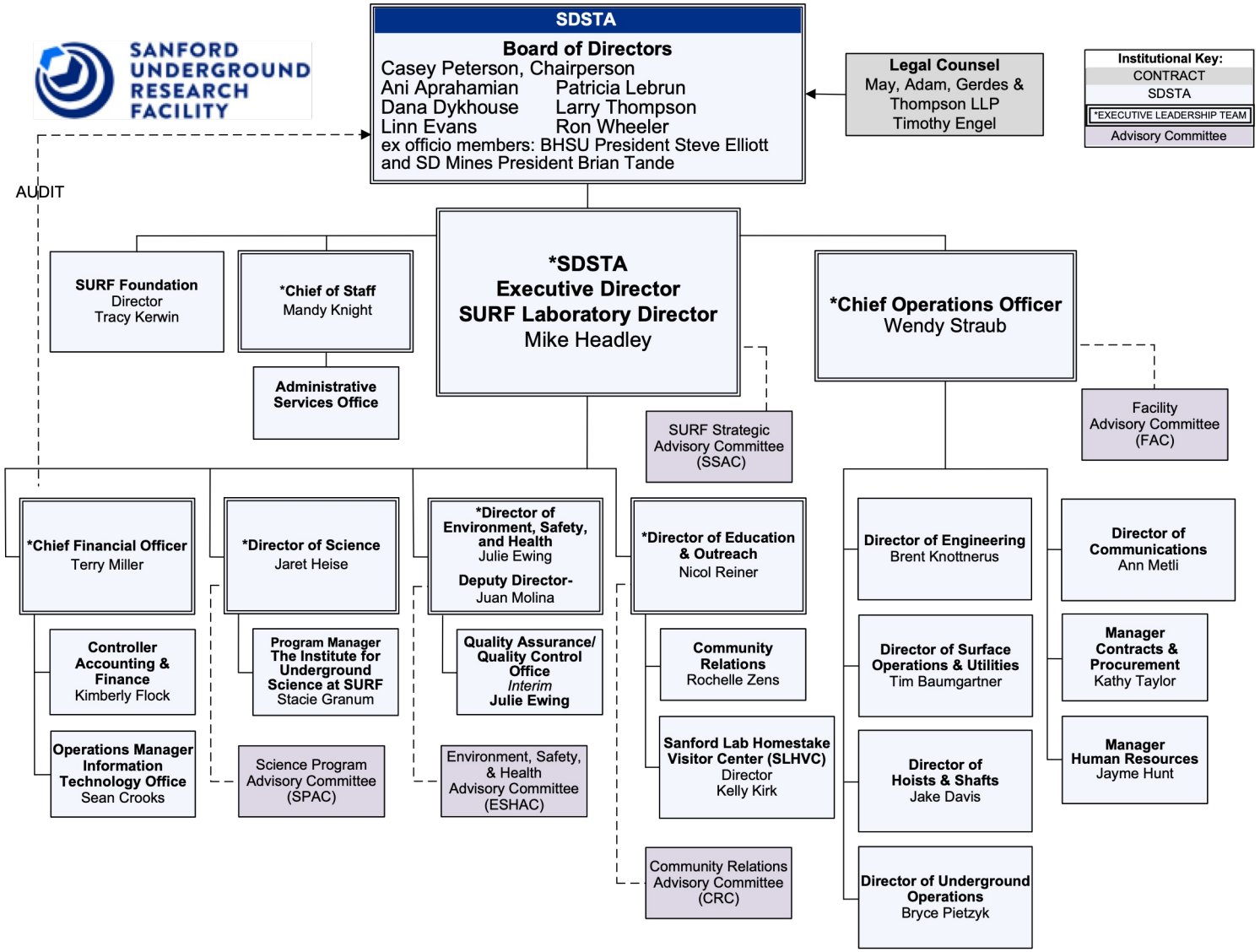


- Opened July 2007 as dedicated science lab (+ Ray Davis Nobel Prize legacy)
- 225 full-time + part-time staff members
- Created by the State of South Dakota with donations from Barrick/Homestake (property) and T. Denny Sanford ($70M)
- Continued strong support by the State of South Dakota ($75M)
- Operations funded directly by the U.S. Department of Energy ($44M/yr)

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

SDSTA Organization

Robust organization: 9 depts, 5 offices + Institute, Visitor Center and Foundation



Staffing Area	Current # ppl (%)	FY29 # ppl (%)
Admin / Mgmt	30 (13%)	30 (13%)
Engineering	13 (6%)	13 (6%)
ESH	21 (9%)	21 (9%)
Outreach	23 (10%)	23 (10%)
Scientific	5 (2%)	5 (2%)
Technical / Operations	133 (59%)	140 (60%)
TOTAL	**225**	**232 ***

* More LBNF/DUNE support possible

Current Science Direct Support = 19 ppl

SURF Science Program

Research activities ranging from surface to 1500+m underground

Physics

LZ – *Dark matter, 2-phase Xe TPC*

LEGEND Support – *Cu e-forming, machining for neutrinoless double-beta decay*

CASPAR – *Nuclear astrophysics with 1 MV accelerator*

Expt Bkgds – *Neutrons, gamma-rays*

LBNF/DUNE – *Neutrino properties, etc*

BHUC – *BHSU Underground Campus, mainly material screening*

Berkeley LBF – *Low-bkgd counter (x4);* also CUBED – *Low-bkgd counter (x1)*

AL/KY (was nEXO) – *Low-bkgd counter (x1)*

LLNL – *Low-bkgd counter (x1)*

NEMESIS – *Neutron detectors, dark matter*

Total = 30 groups

24 Active Projects

24 Groups with SD Involvement

79 Total Groups Since 2007

Significant interest from others

(34 groups in 2025)

* Denotes proprietary group

Biology

Astrobiology/DeMMO – *In-situ culture, DNA isolation*

Biodiversity – *Microbial communities*

Biofilms – *Deep biosphere methane cycling*

Carb EnZero – *Microbes for carbon capture, bio-leaching*

Chemistry – *Env characterization*

Delavie Sciences* – *Extremophiles*

DULIA-Bio/REPAIR – *Yeast in low-radiation (multi-lab)*

m-sense – *Microbes and environment*

SDSU Mesonet – *Climate station/modeling*

Geology

CUSSP – *Geothermal*

3D DAS – *Seismic monitoring using optical fiber*

Black Hills Seismic – *Global monitoring*

Core Archive* – *Mainly gold deposits*

Biosignatures – *Life signs for exobiology*

Transparent Earth – *Seismic arrays*

USGS Seismic – *Earthquake, nuclear monitoring*

Engineering

Environment Monitoring – *Ventilation airflow*

Safety Robotics – *Mining safety*

Shotcrete – *Mining safety*

Water – *Geothermal and resources*

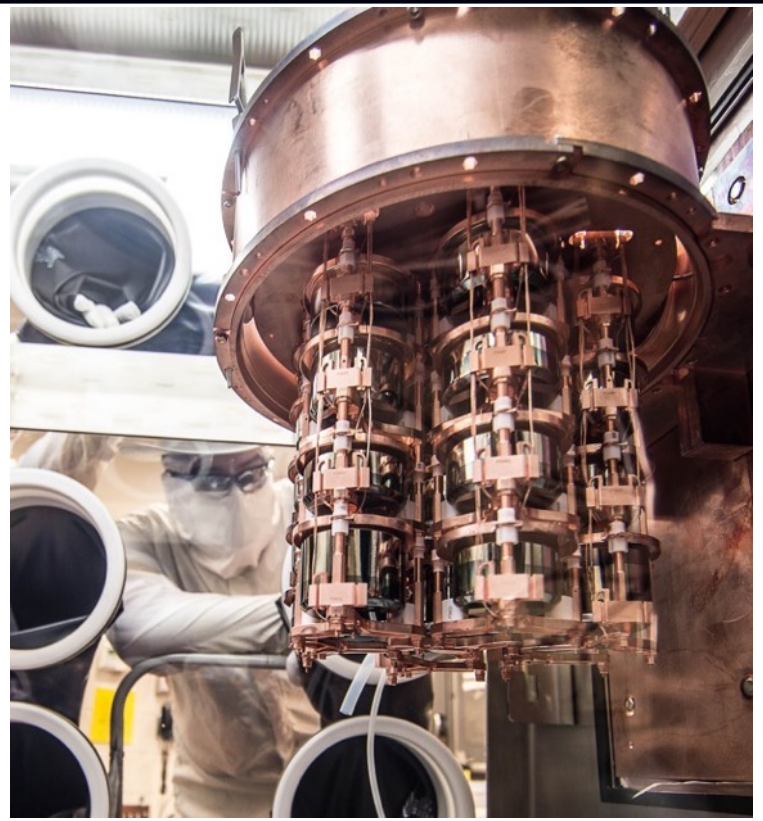
SURF Science Program – Current Physics Highlights

Strong and diverse program with exciting future



LUX-ZEPLIN (LZ)

- Direct **dark matter** search using 10 t Xe
- World-leading WIMP-search results since 2022, Sep 2026 HENR event (!)
- Proposal: LZ + HydroX into ~2034



MAJORANA DEMONSTRATOR (MJD)

- Searches complete: **neutrinoless double-beta decay** w/ Ge-76, Ta-180
- LEGEND-focused support continuing: UG Cu electroforming, clean materials



CASPAR

- Stellar fusion reactions to study **nucleosynthesis** using accelerator
- Initial phase 2015-2021, physics data resumed 2026 (^{19}F underway)

SURF Material Assay at BHUC

Low-background counting capabilities serving national & international community



SURF Material Assay at BHUC

Low-background counting capabilities serving national & international community

Detector	Crystal		[U] mBq/kg	[Th] mBq/kg	Status	Comments
	Type	Size				
Maeve (LBNL)	p-type (85%)	2.2 kg	**0.1** (10 ppt)	**0.1** (25 ppt)	Production assays	Relocated from Oroville. Old Pb (200-yr old) inner shielding.
Merlin (LBNL)	n-type (115%)	2.2 kg	**~0.2** (~20 ppt)	**~0.2** (~50 ppt)	Operating	Installed 2025.
Morgan (LBNL)	p-type (85%)	2.1 kg	**0.2** (20 ppt)	**0.2** (50 ppt)	Production assays	Low-bkgd upgrade 2015.
Mordred (USD/CUBED, LBNL)	n-type (60%)	1.3 kg	**0.7** (60 ppt)	**0.7** (175 ppt)	Production assays	Low-bkgd upgrade 2015-2016, shield access upgrade.
Twins (Dual HPGe) (LBNL, BHSU, UCSB)	p-type (2x120%)	2x 2.1 kg	**~0.01** (~1 ppt)	**~0.01** (~1 ppt)	Operating	Low-bkgd upgrades 2016-2017; flexible shield configuration.
RHYM+RESN (Dual HPGe) (LLNL)	p-type (2x65%)	2x 1.1 kg	**<0.1** (<10 ppt)	**<0.1** (<25 ppt)	Production assays	Cryocooler, low-E ^{210}Pb (<2 mBq/kg).
Ge-IV *(Alabama, Kentucky)*	*p-type (111%)*	*2 kg*	***0.04*** *(3 ppt)*	***0.03*** *(8 ppt)*	*Offline*	*Gantry + hoist for vertical design. Awaiting relocation to Ross Campus.*

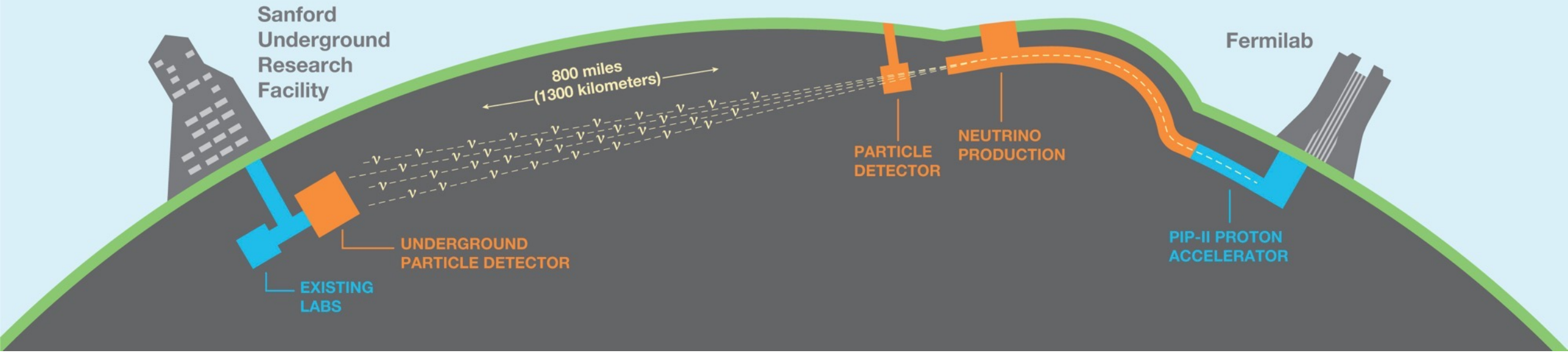
Also see: LZ Assay Paper https://arxiv.org/pdf/2006.02506

Local universities have some additional material screening capabilities: **HPGe** ([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)

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

U.S. DOE's Flagship Neutrino Experiment



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

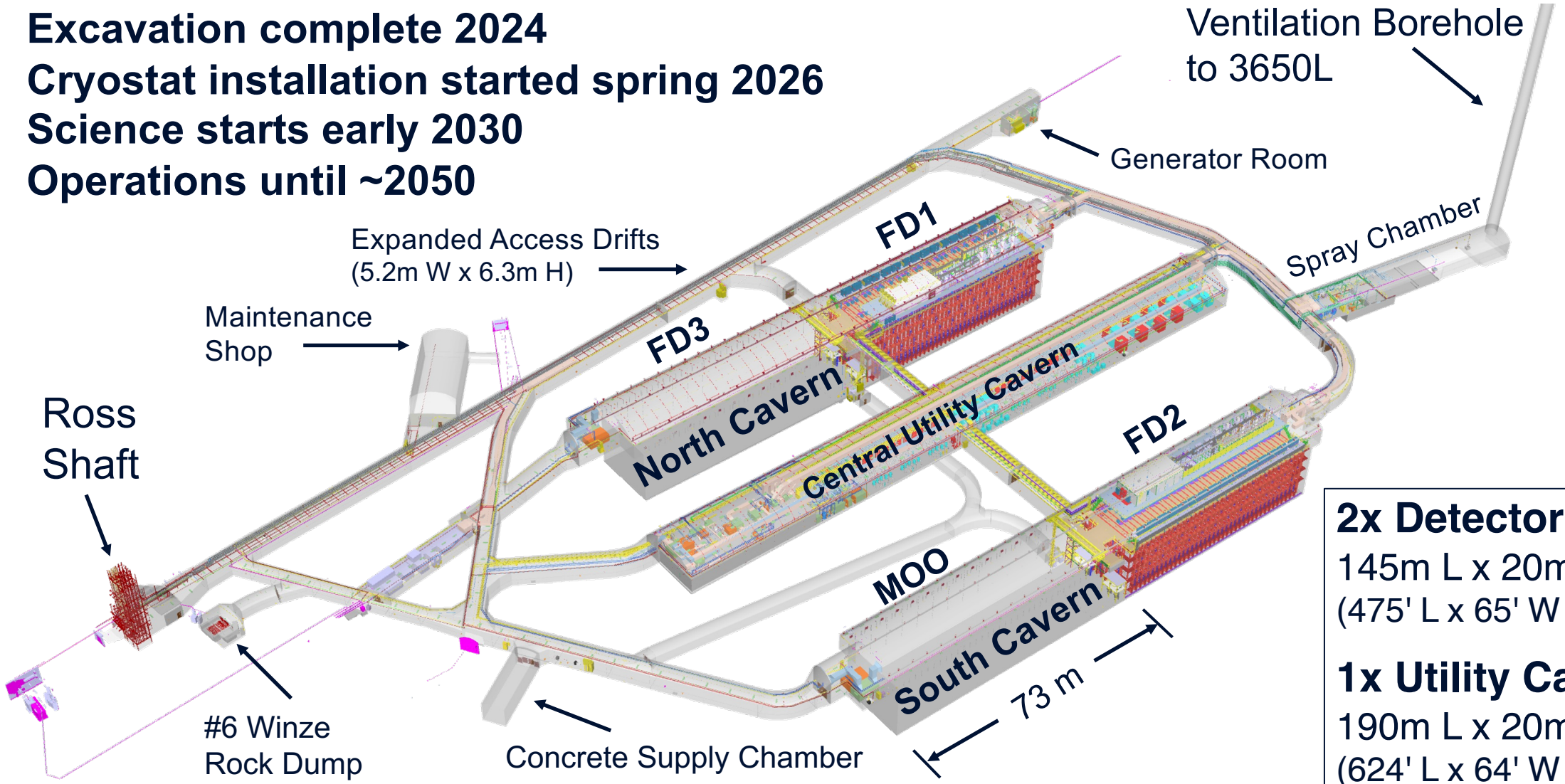
Supernova explosions and black hole formation: Ability to observe neutrinos from supernovae events and neutron star (or possibly black hole!) formation in real time.

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

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

Excavation complete 2024
Cryostat installation started spring 2026
Science starts early 2030
Operations until ~2050



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)

SURF Aspires to Become DOE User Facility

Important to have deep underground user facility in the U.S.

Benefits

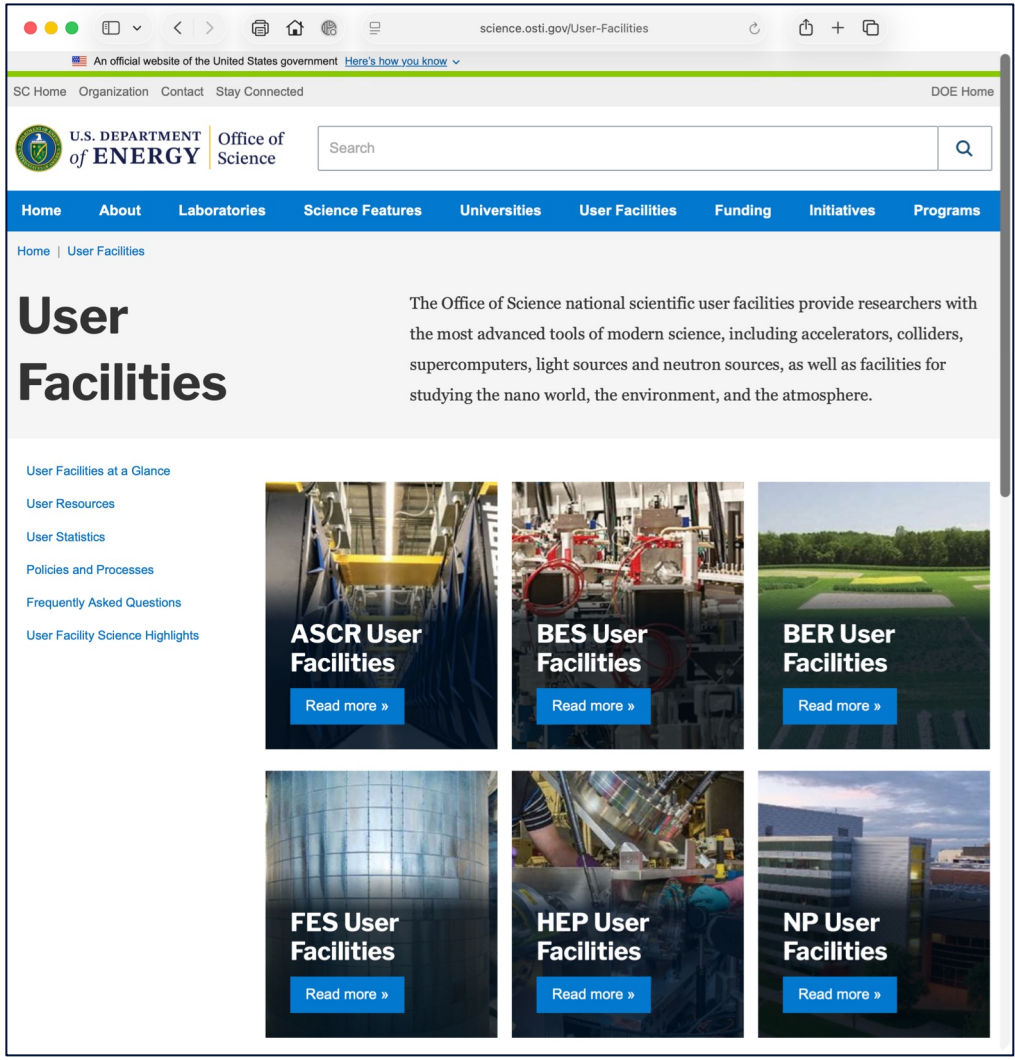
- Expands DOE User Facility portfolio to incl underground lab, raises SURF's stature within DOE community.
- Promotes underground science in U.S., increases SURF funding opportunities (FOAs encourage partnerships w/ User Facilities)
- Enhances SURF's role in global science community.
- Communicates SURF is open to a broad range of science and users, SURF processes for hosting science accepted by DOE.

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 + Science Program Advisory Committee established.
- Significant maintenance for Yates Shaft completed March 2025.
- Application drafted, revisit following DOE HENP re-organization.



SURF User Association

https://sanfordlab.org/surf-user-association (incl registration)

Purpose

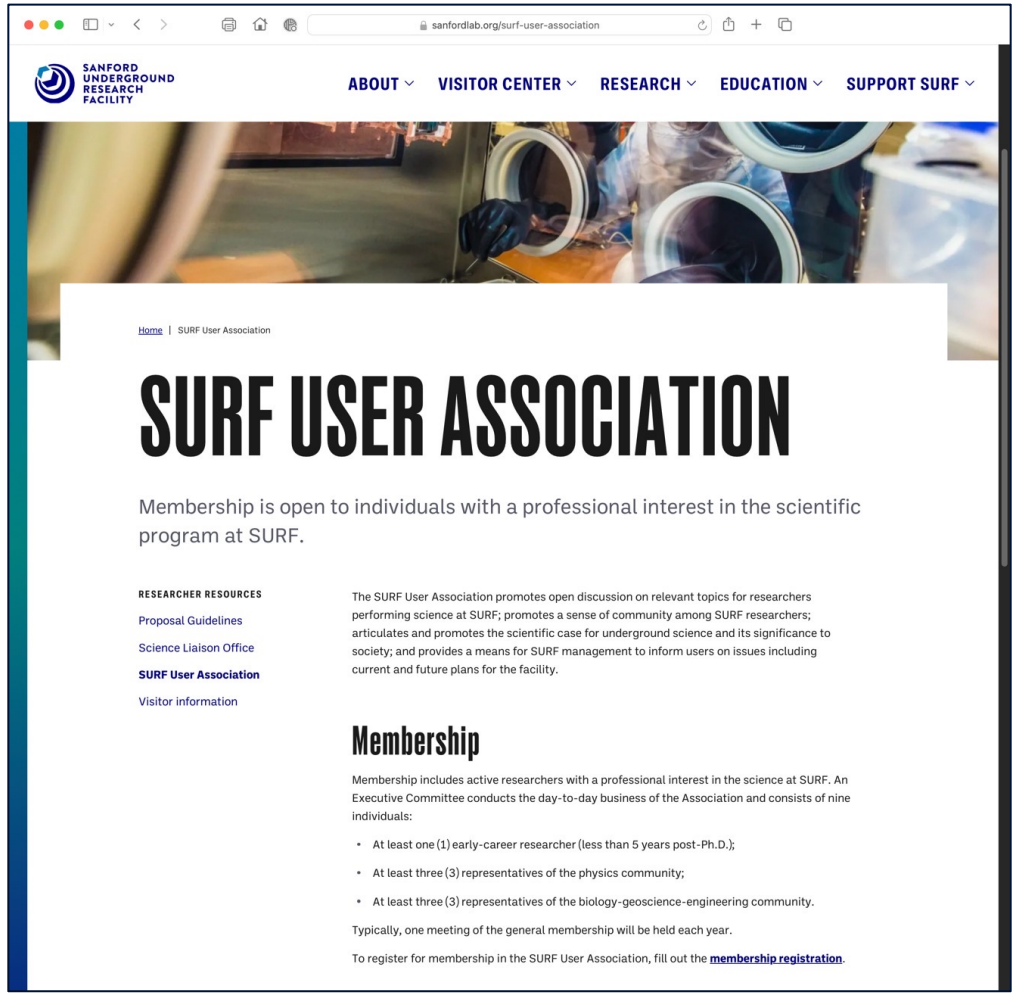
- **Two-way communication** on topics important to researchers
- Promotes a **sense of community** amongst SURF experiments and researchers
- Articulates and promotes **scientific case for UG science** and significance to society, provides channel for **advocacy**

Organization

- **Membership = 567** (open to all UG science community)
- **Executive Committee** consists of 9 individuals across scientific disciplines, incl early career. Quarterly meetings with SURF Management

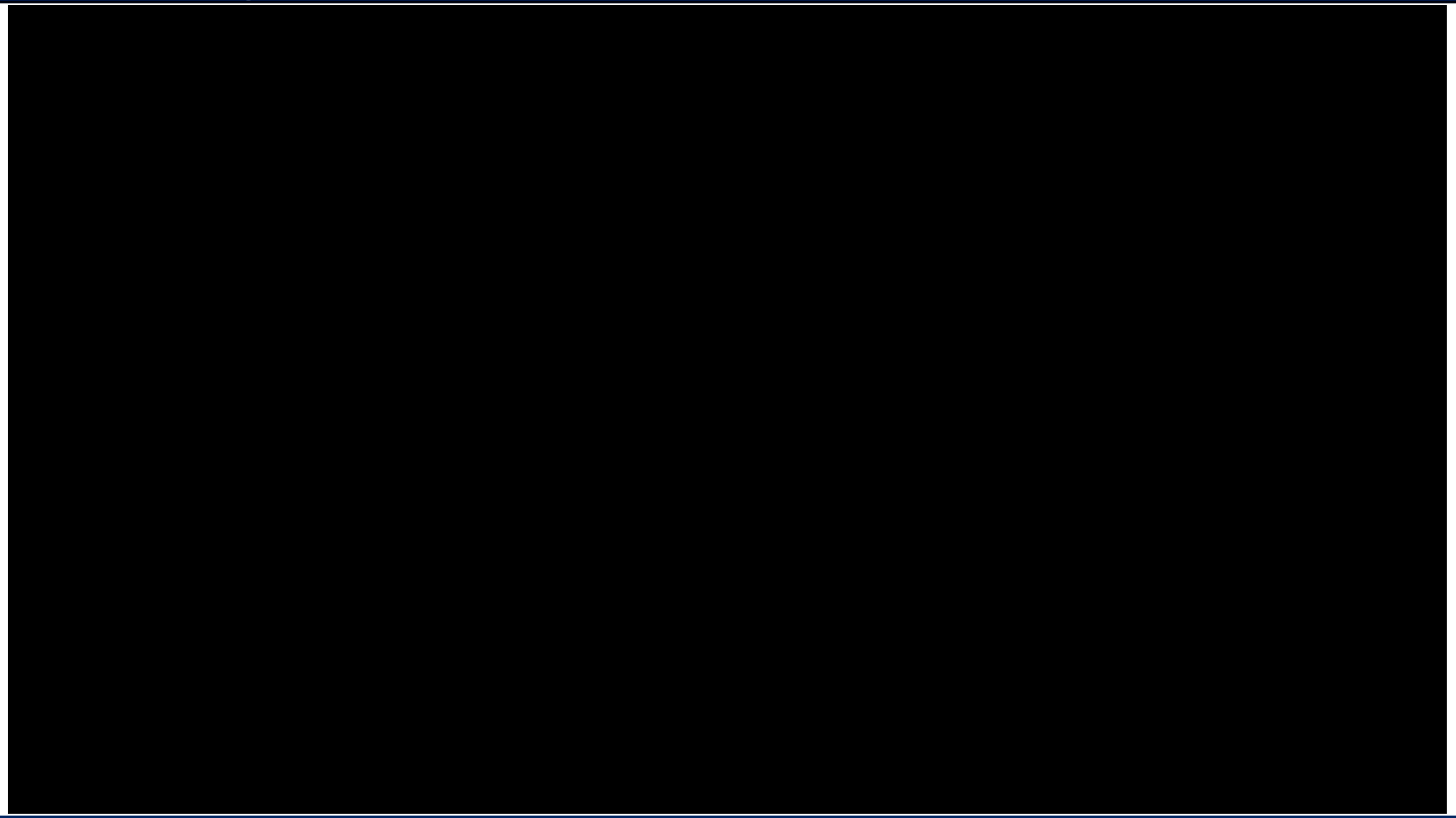
Events

- **Engagement** initiatives in progress, stay tuned in 2026
- **General meetings** typically annually, next @ CoSSURF 2027
- **Topical workshops**, incl community planning (e.g., Vision2021)
- **Advocacy**, with participation in 2026 HEP DC Visit (interactions with 27 congressional offices + OSTP)



4850L Laboratory Expansion – Phase A

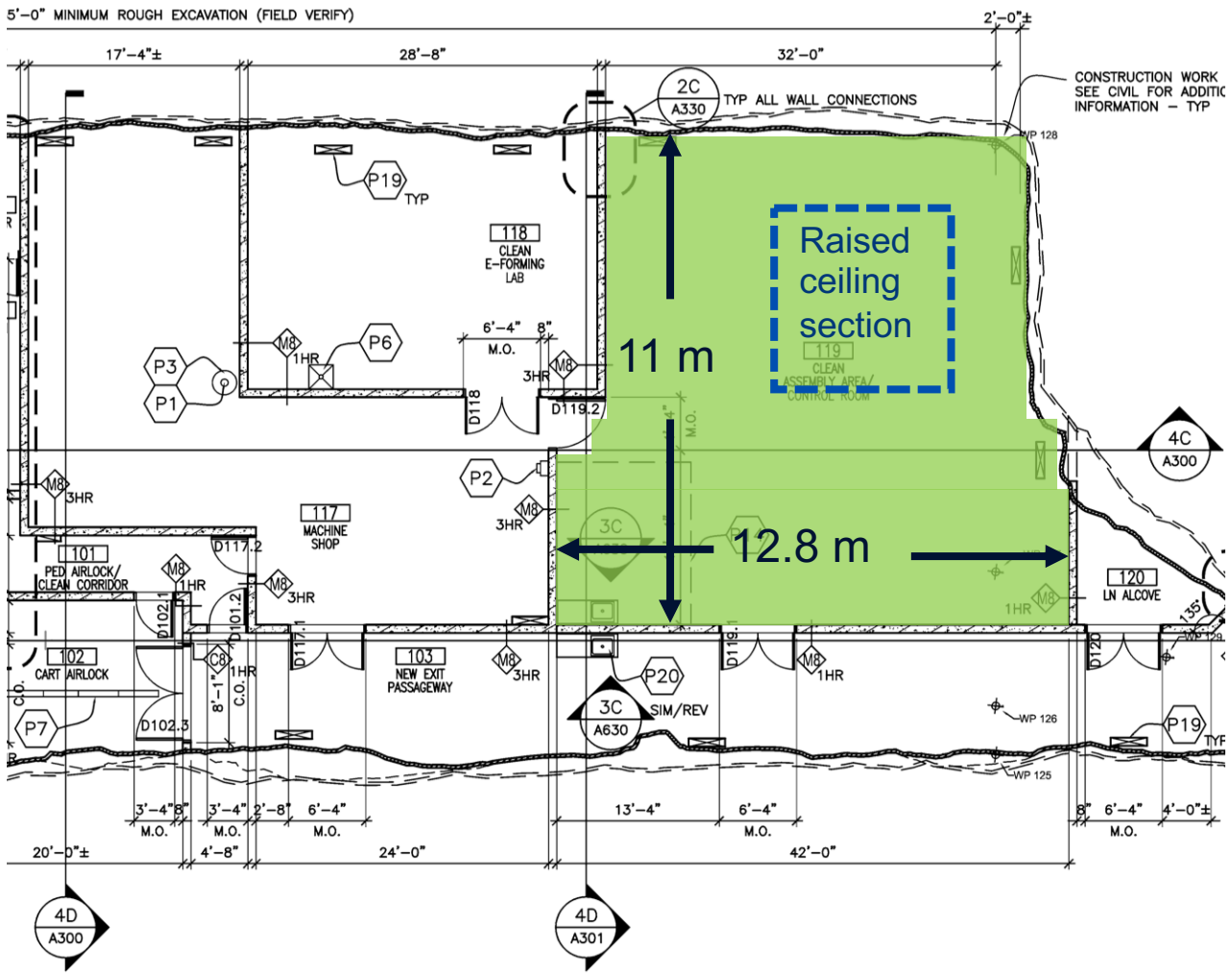
Expansion blasting video: https://vimeo.com/982238458



SURF Quantum User Facility

Deep site at 4850L Davis Campus planned to support range of quantum science



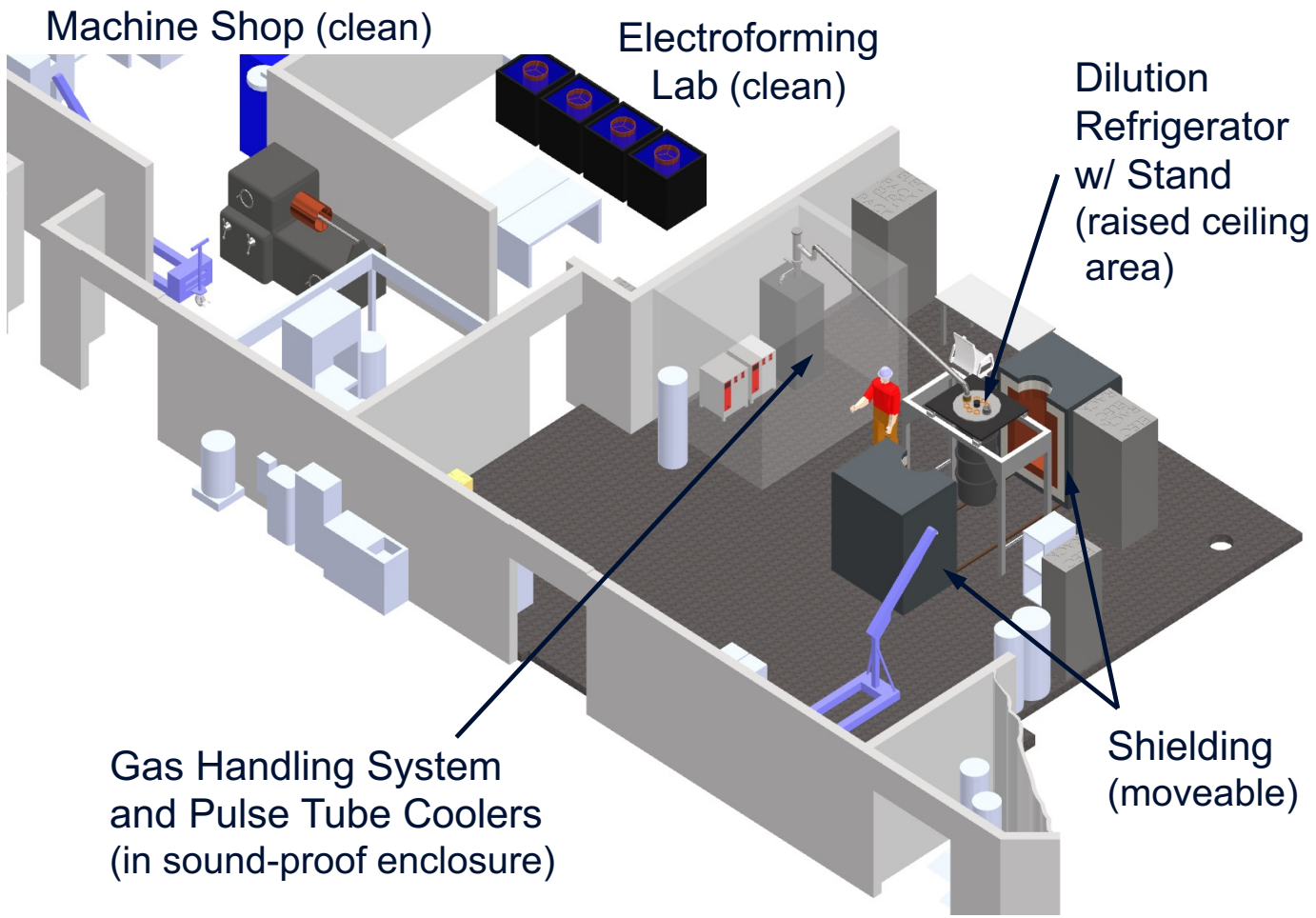


Area (total = **140 m²**): 11 m × 9.8-12.8 m × 2.7 m (H)
Area (raised section): 5.9 m × 5.8 m × 3.2 m (H)

SURF Quantum User Facility

Deep site at 4850L Davis Campus planned to support range of quantum science





Area (total = **140 m²**): 11 m × 9.8-12.8 m × 2.7 m (H)
Area (raised section): 5.9 m × 5.8 m × 3.2 m (H)

SURF Quantum User Facility

Multi-user, low-background, ultra-low temperature test facility

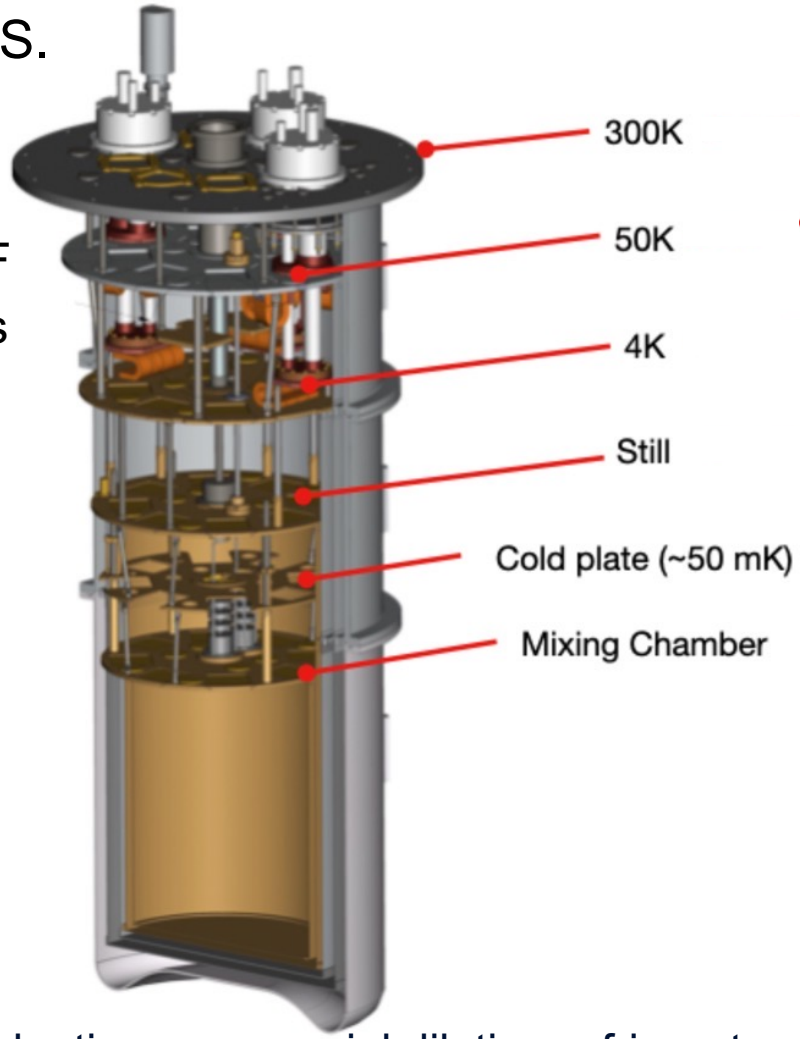
No deep underground quantum user facility currently exists in the U.S.

Establish internationally-competitive research resources

- Detectors with extremely low energy thresholds and excellent energy resolution require isolation from ionizing radiation at deep facility like SURF
- Serve experiments using cryogenic calorimeters, quantum phonon sensors for applications in particle astrophysics, incl dark matter, $0\nu\beta\beta$, CEνNS
- Attract industry leaders in quantum computing (Google, IBM, D-Wave)
- Bolster $3M investment in SD Center for Quantum Information Science & Technology

Planning underway

- Quantum Partnership Workshop (2026 event 3rd in series: https://indico.sanfordlab.org/e/Quantum2026) enhancing synergies with state QIS initiatives as well as broader interest in topics such as quantum communication networks
- Basic facility upgrades understood (mainly power, cooling)
- Cleanroom space available, also Pb shielding
- Exploring state-of-the-art electrical, vibrational requirements



Evaluating commercial dilution refrigerator options that would meet user needs

SURF Vertical Facility

Unique facility would serve broad range of science communities

Science

- Atom interferometry using quantum sensors (ultralight dark matter, gravitational waves)
- Quantum communication network; also atmospheric cloud chamber, microgravity studies, isotope separation, etc

Community Interest

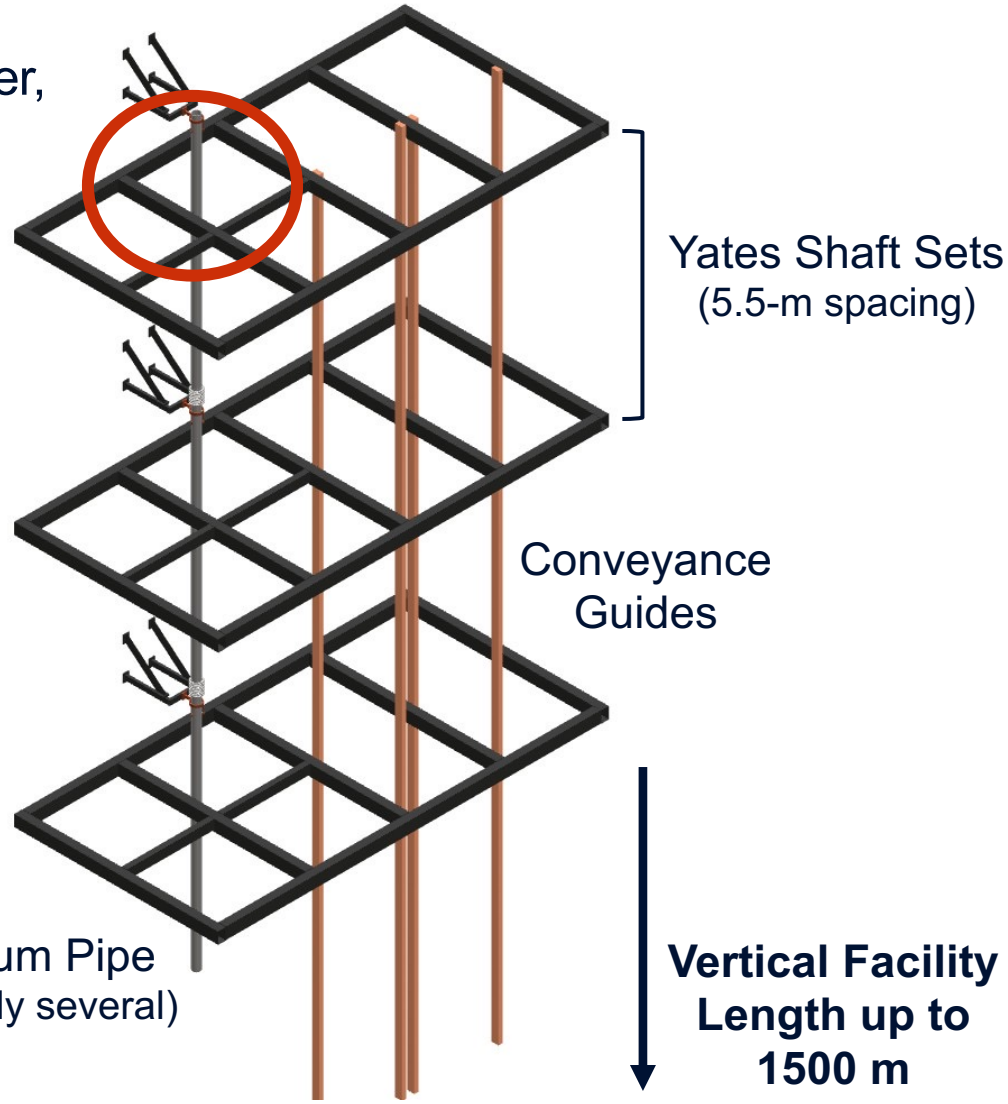
- Various workshops since 2008 to explore opportunities a SURF
- SURF joined TVLBAI collaboration in Oct 2025 (50+ institutions)

Expt Requirements (TVLBAI https://arxiv.org/pdf/2503.21366)

- **1.5-m diameter** shaft (minimum), **15-cm diameter** pipe for ultra-high vacuum
- Possibly separate pipes for separate applications

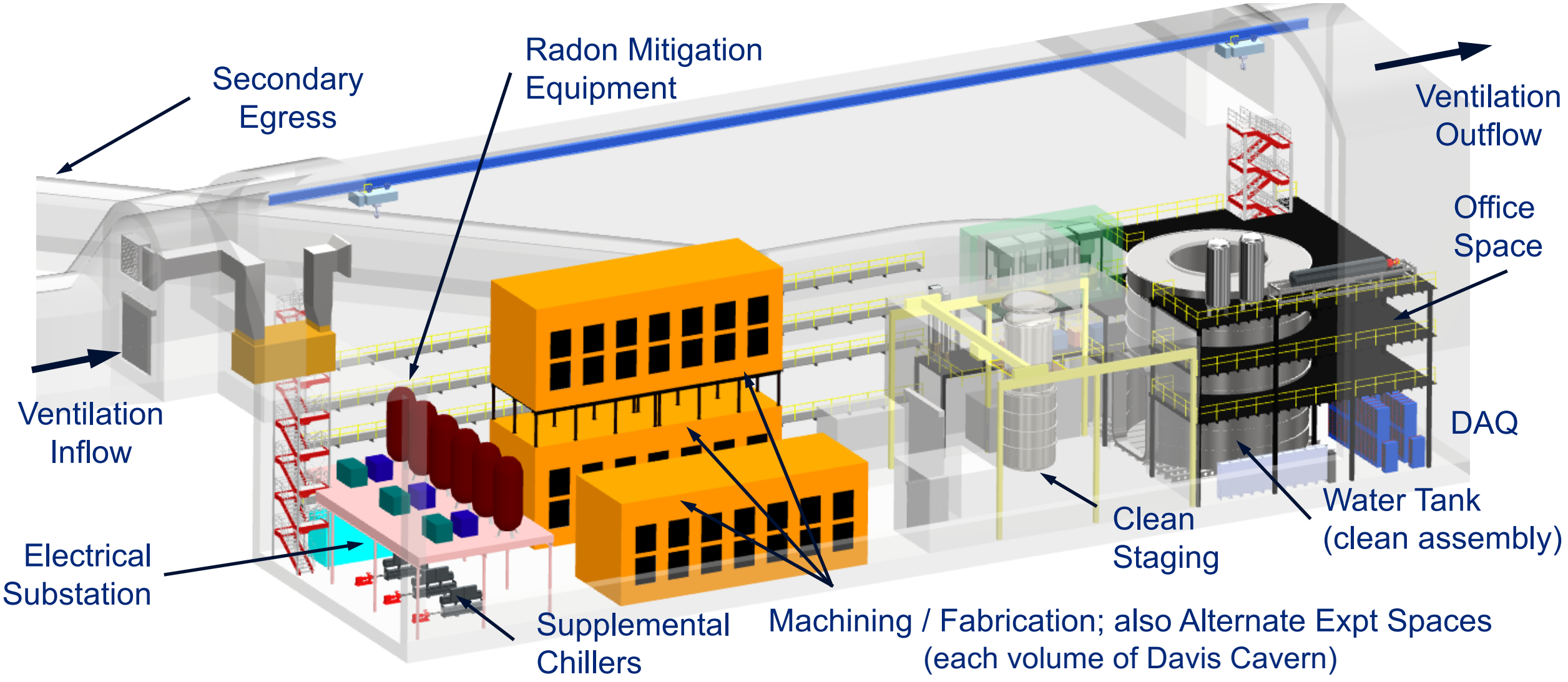
SURF Facility

- Initial shaft study completed March 2022
- **Yates Shaft refurbishment** in 2030s after related upgrades complete (electrical, incl hoists)
- Potential use of "Runabout" compartment **1.75m x 2.0m**



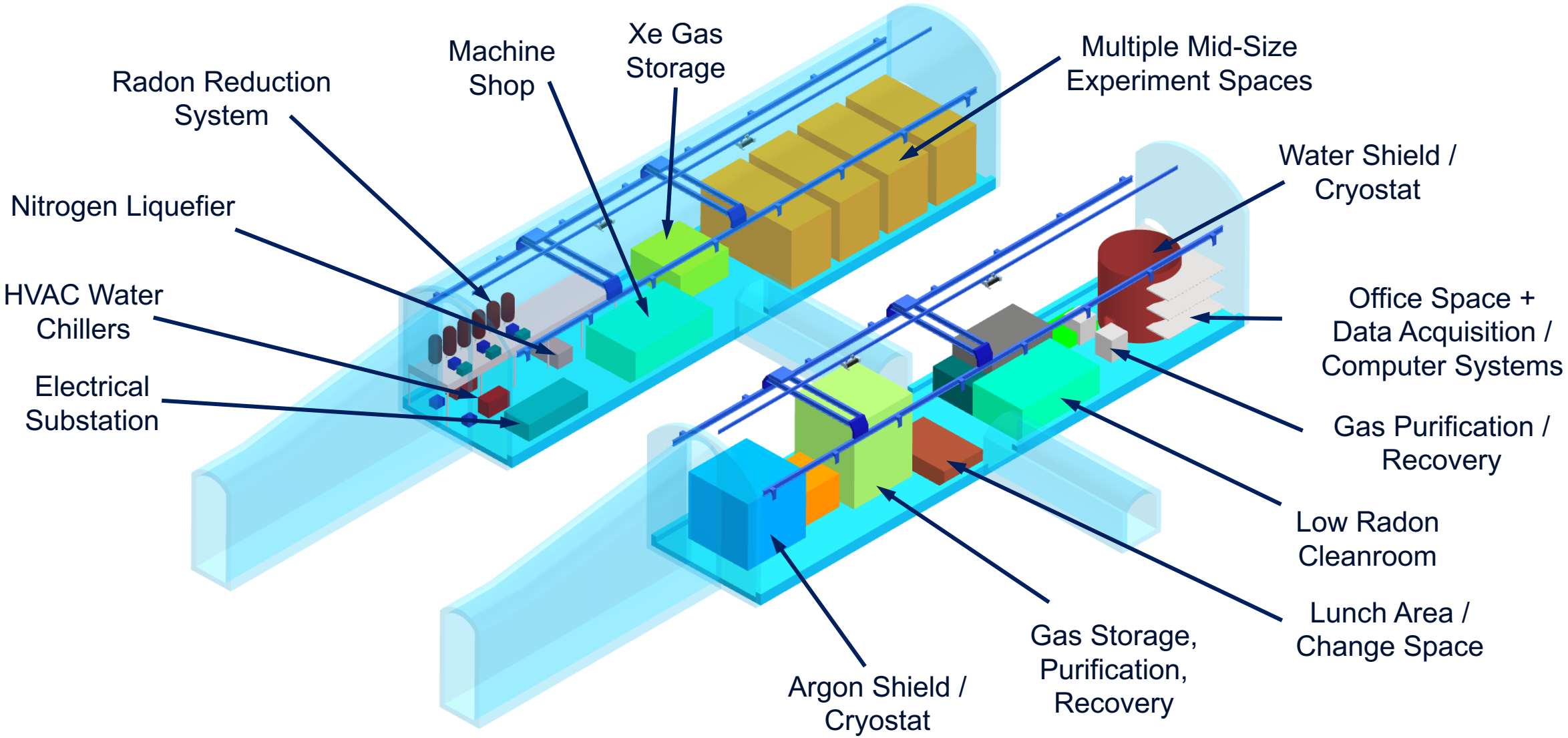
Next-Generation Science at SURF

Several deep options available



Next-Generation Science at SURF

Conceptual layout (2x 100m caverns), informed by DUSEL PDR, ARGO/XLZD, LZ

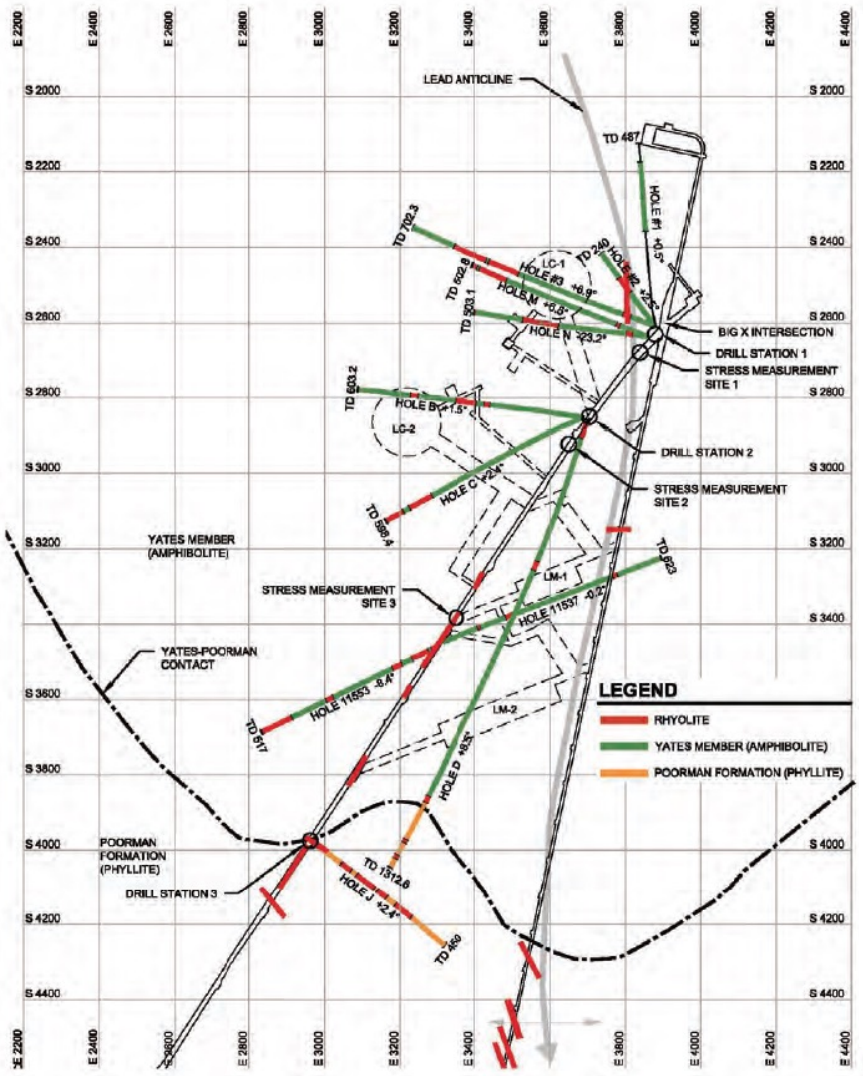


Next-Generation Science at SURF

Several deep options available, alternate geometries possible

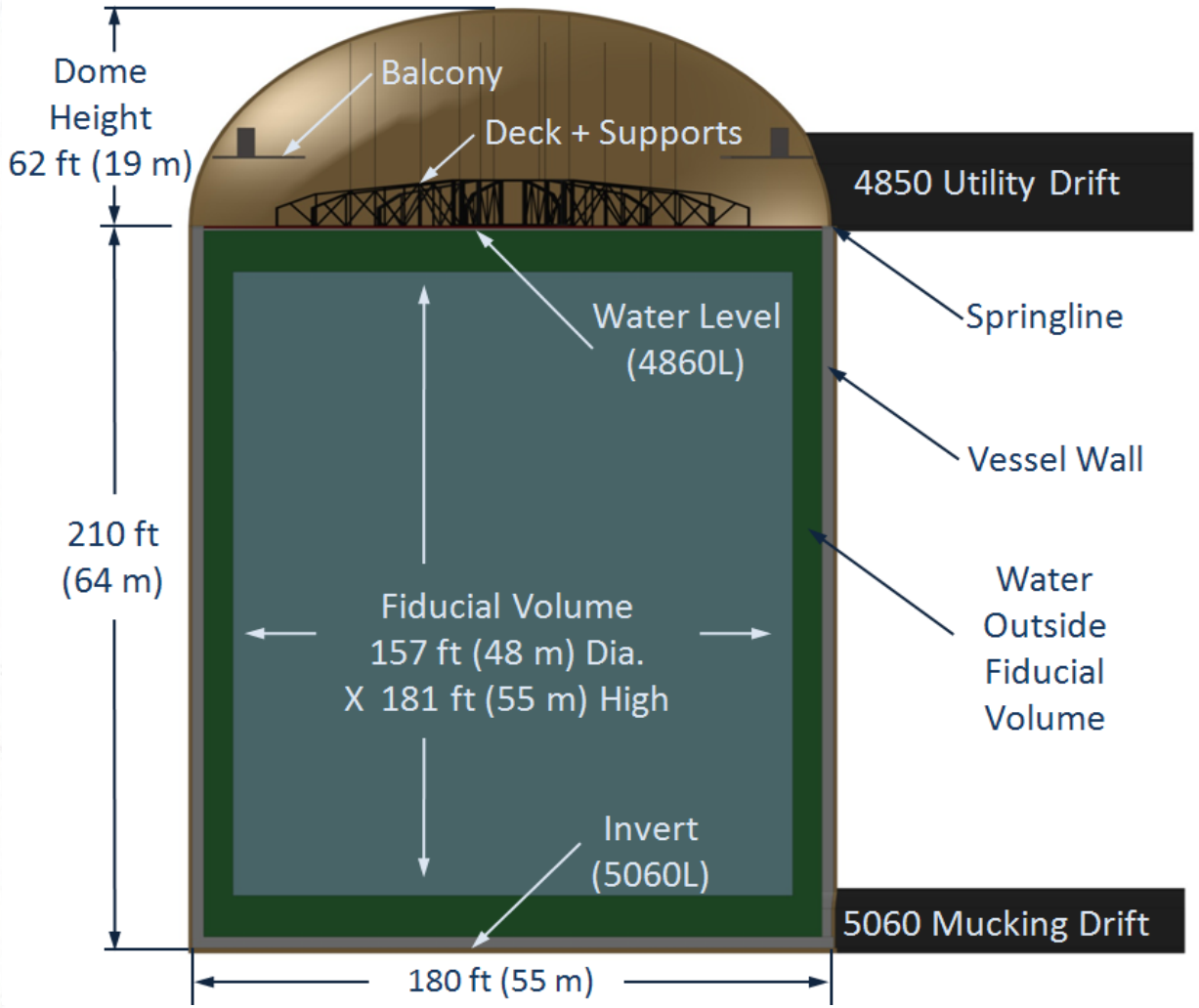
4850L Right Cylinder Studied

LBNE 100 kT Water Cherenkov (see DUSEL PDR: arxiv:1108.0959)



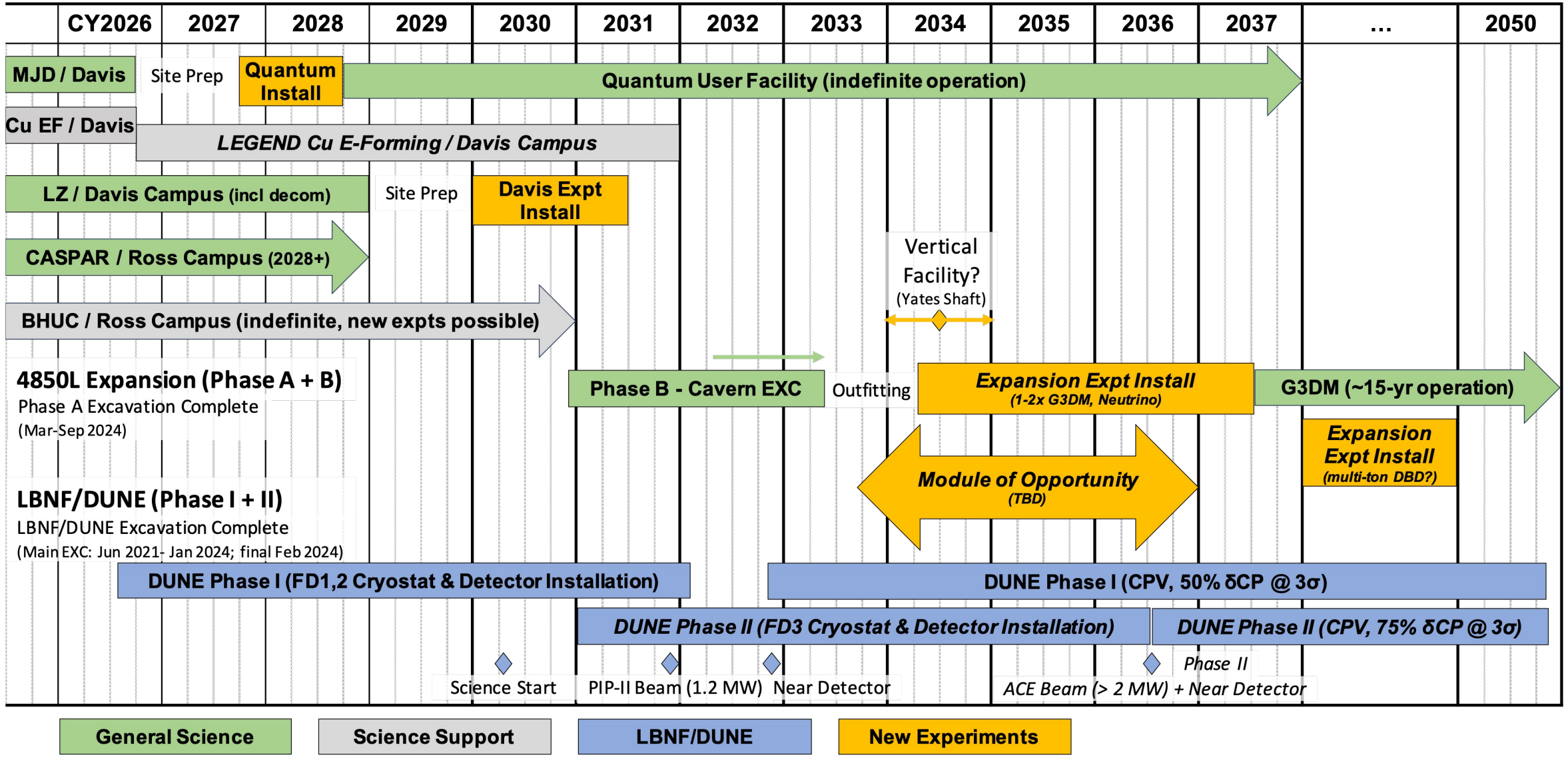
Ventilation

- **Exhaust:** 170,000 m^3/h (via raise to 4700L)
- **Fresh Air:** 30,600 m^3/h via Yates Shaft (1 exchange/hr)



SURF Science Strategic Planning

Timeline



SURF Science Program – SD Overview

Evolution of science programs at SD universities since inception of SURF

- SD Physics PhD Program established 2013, directly related to presence of SURF
- SURF links to university science & engineering programs:
  - Advisory Committees: Headley (SDSU, REACH), Heise (SD Mines, REACH Executive Committee)
  - Institute: Quantum Partnership Workshop (3 yrs), Higher Education Connection Workshop (3 yrs)
- Physics Highlights:
  - Ge-based activities since 2009 (CUBED Gov Reserarch Center) to present (Ge-STAR NSF E-RISE)
  - SD investment in QIS, growing interest in UG activities (incl Ge quantum sensors, quantum network)
  - DUNE collaborators:
    - SD Mines: 2+1 faculty (Reichenbacher, Martinez; Wang left summer 2026, backfill search soon) + 3 postdocs and 6 grad students; responsibilities in background characterization, calibrations and power systems
    - USD: 4 faculty (Mei, Liu, Kim, Vaidya) limited involvement (some outreach)
    - SDSU: 3 faculty (McTaggart + engineering) mainly involved in simulations, incl LAr fluid dynamics
    - Augustana: 1 faculty (Alton) student projects
    - BHSU?
- Other Highlights:
  - Biology: Microorganisms for various process since 2007: biofuels, carbon sequestration, biofilms
  - Geology: Seismic programs since 2008, geothermal involvement; also geotechnical and mining-related

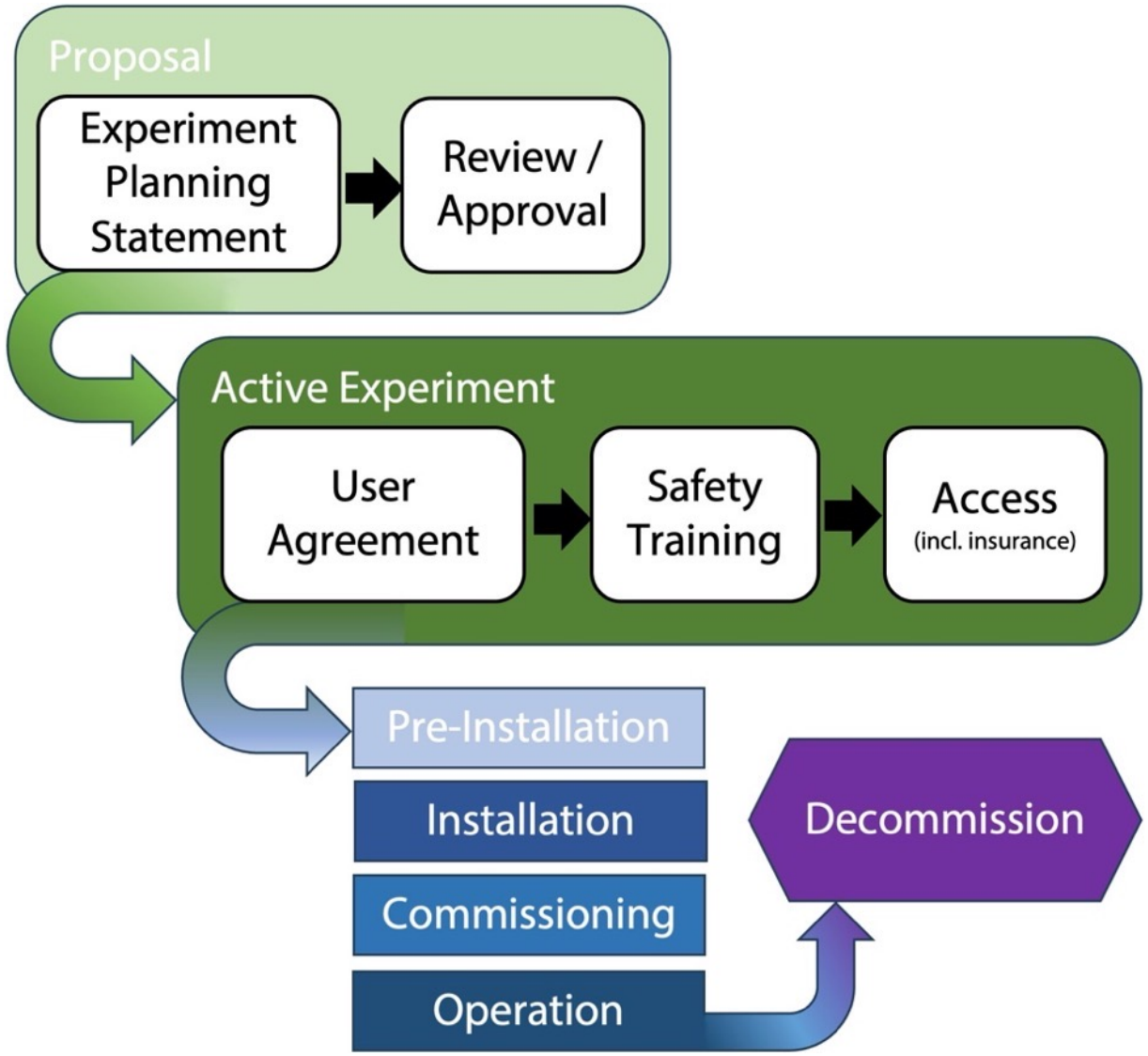
SD University Involvement and Partnership Highlights

	Augustana	• Augustana faculty - DUNE collaborator • SDSTA staff serve on Augustana Board of Trustees • SDSTA staff supporting Augustana Jr. Science Symposium • SDSTA E&O staff support pre-service education undergrads • Faculty attend SURF Higher Ed Connections Workshop • Co-collaborators on state E-CORE grant
	BHSU	• Joint development and operation of the BHSU Underground Campus (BHUC) on 4850L • BHSU faculty – LZ, biology collaborators (future DUNE?) • NSF REU program (internships) – SURF experience • BHSU faculty serve on SURF User Association Exec Cttee • BHSU faculty - Quantum initiatives partner • BHSU president SDSTA Board of Directors (ex-officio) • SDSTA E&O staff support pre-service education undergrads • BHSU and E&O collaborate on multiple federal grants including EPSCoR, E-CORE, and CIRLCES Alliance • BHSU faculty support Davis-Bahcall Scholars program • SDSTA supports the BHSU Women in Science program • Faculty attend SURF Higher Ed Connections Workshop
	DSU	• Supports SURF information technology security program • DSU Faculty - Quantum initiatives partner • Co-collaborators on state E-CORE grant • Faculty attend SURF Higher Ed Connections Workshop
	Northern	• Co-collaborators on state E-CORE grant • SDSTA E&O staff support pre-service education undergrads

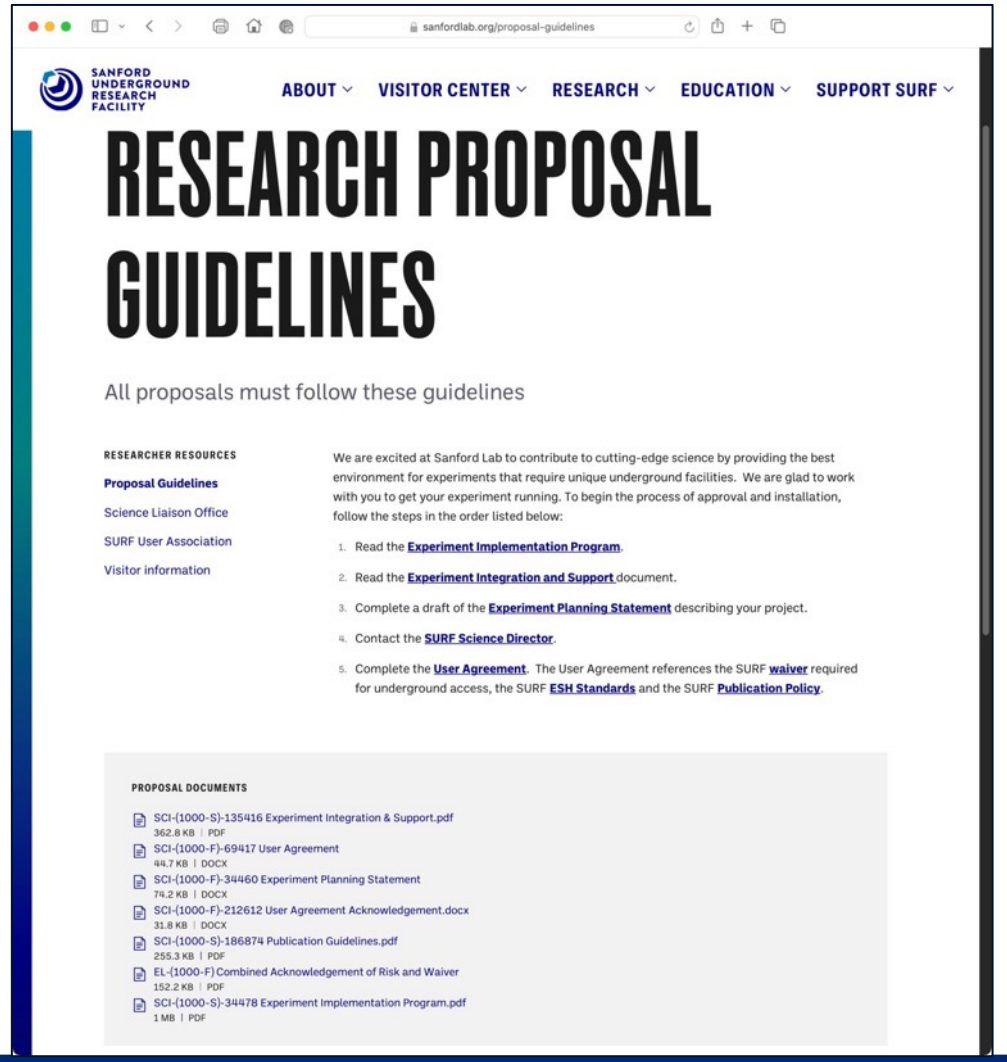
	OLC	• Co-collaborators on state E-CORE grant • SDSTA staff supported OLC educator professional dev • OLC staff served as 2024 SURF Artist-in-Residence • Faculty attend SURF Higher Ed Connections Workshop (!)
	SD Mines	• SDMines faculty – CASPAR PI, collaborators on DUNE, MJD/ LEGEND, LZ, geology, biology, engineering expts • SDMines hosts *Conference on Science at SURF* (CoSURF) since 2015 • SDMines faculty serve on SURF Science Program Advisory Committee and SURF User Association Exec Committee • SDMines faculty - Quantum initiatives partner • Co-collaborators on state E-CORE grant • SDMines president SDSTA Board of Directors (ex-officio) • Faculty attend SURF Higher Ed Connections Workshop • SDSTA supports the SDMines Women in Science program
	SDSU	• SDSU faculty – DUNE, bioengineering collaborators • SDSU engineering student projects involving SURF • SDSU interest in quantum initiatives • SDSU and SDSTA E&O staff co-designed and facilitated K-8 STEM education professional development • SDSTA E&O staff support pre-service education undergrads • Co-collaborators on state E-CORE grant • Faculty attend SURF Higher Ed Connections Workshop
	USD	• CUBED SD Gov Research Center PI for Ge applications • Interest in UG germanium detector lab at SURF • Interest in quantum initiatives • SDSTA E&O staff support pre-service education undergrads • Faculty attend SURF Higher Ed Connections Workshop • PI on Ge-STAR Ge-based E-RISE grant • Co-collaborators on state E-CORE grant

SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework



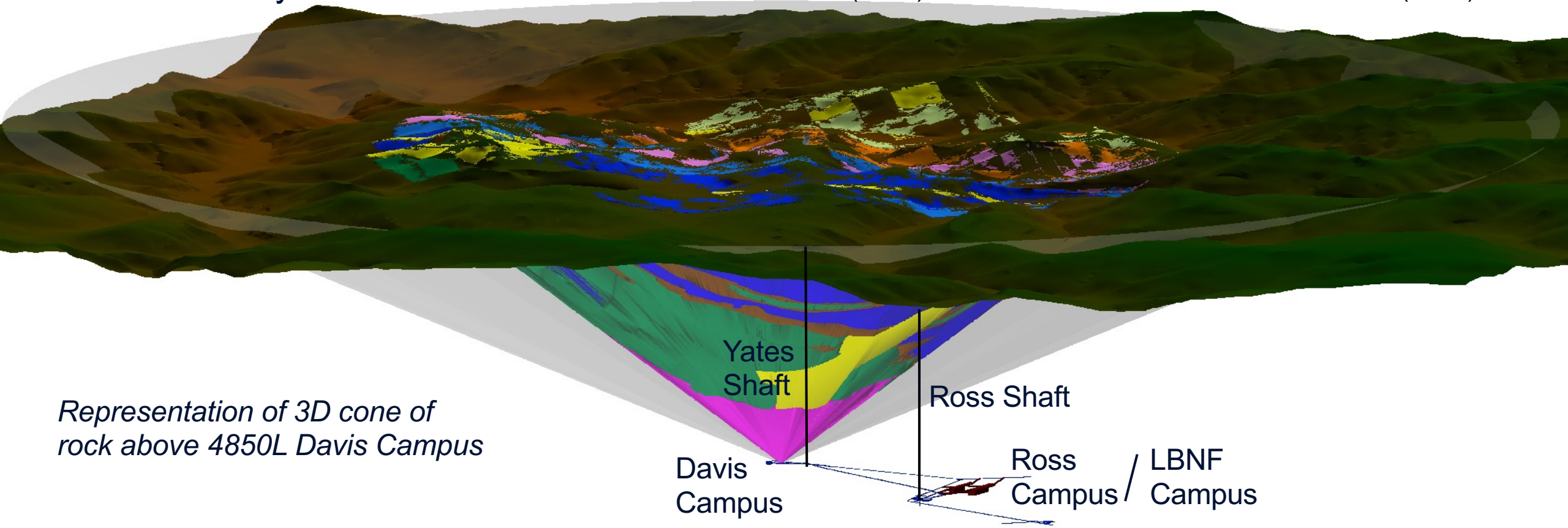
https://sanfordlab.org/proposal-guidelines



SURF Science Support – Geology Model

Site well understood, including drill core & logs

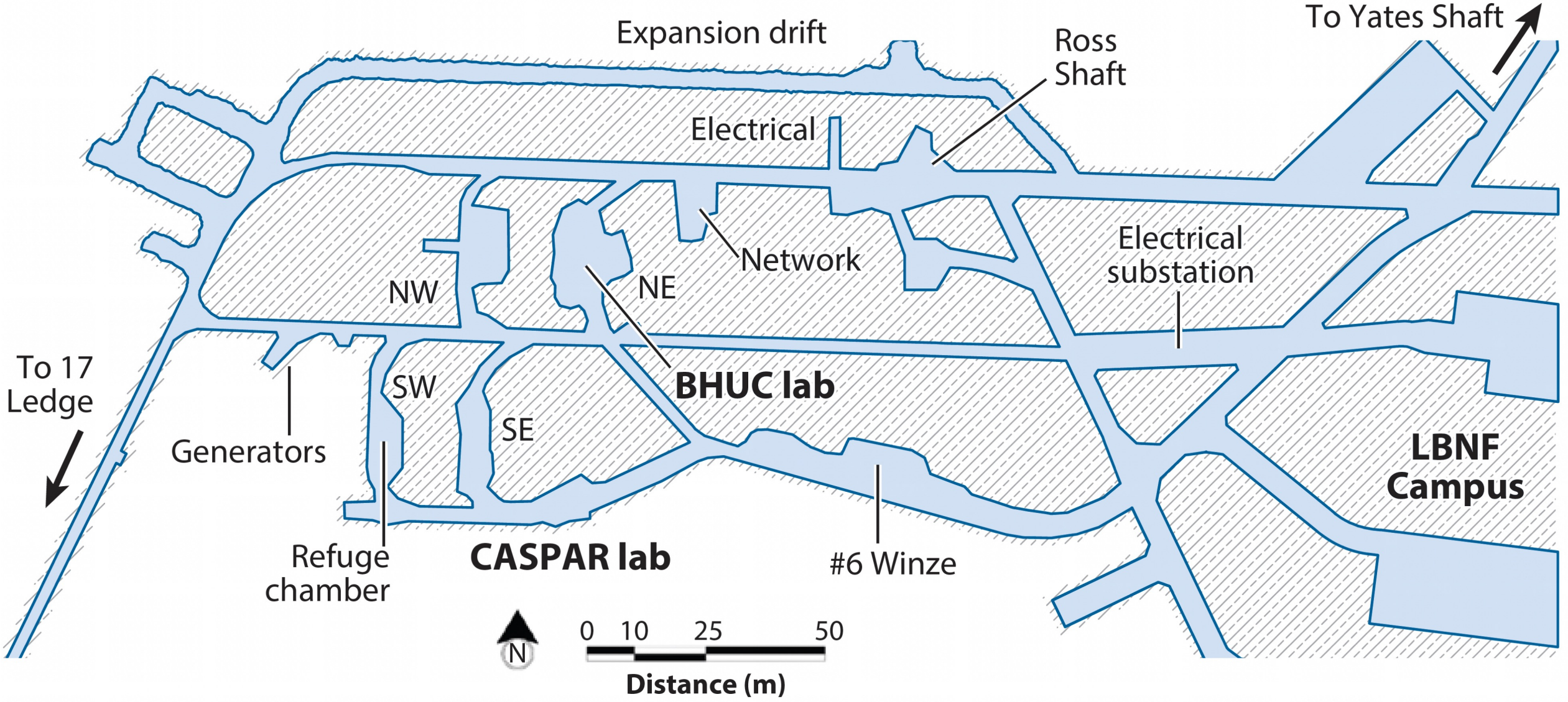
- 3D model of 12 rock formations (including rhyolite/phonolite intrusives)
- Detailed surface topology: Aerial survey for site performed 2011 (1' contours)
- Global coordinates: Survey performed summer 2016 (incl world's longest plumb bob)
- Rock density data: KH, TCT, WR, JH, *SD Acad. Sci.* **93**, 33 (2014); JH *Annu. Rev. Nucl. Part. Sci.* **76** 69-95 (2026)



Representation of 3D cone of rock above 4850L Davis Campus

SURF 4850L Ross Campus

2,653 m² (Total) / 920 m² (Science)



SURF 4850L Ross Campus

Examples of laboratory space



2010-2017



Copper Electroforming



2015-2020, resumed 2025

Former MJD Electroforming:
Area = 228 m^2
(Cleanroom removed,
current construction office)



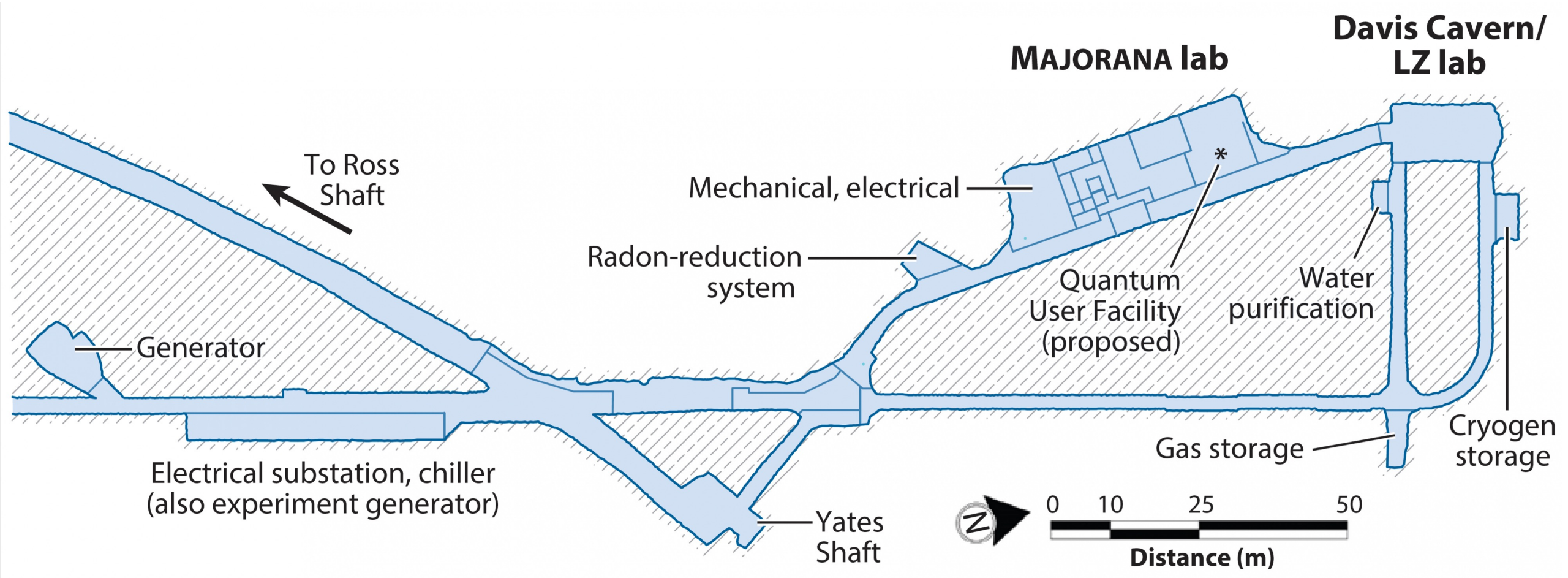
2015-2021, resumed 2025

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)

SURF 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-morgan

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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).

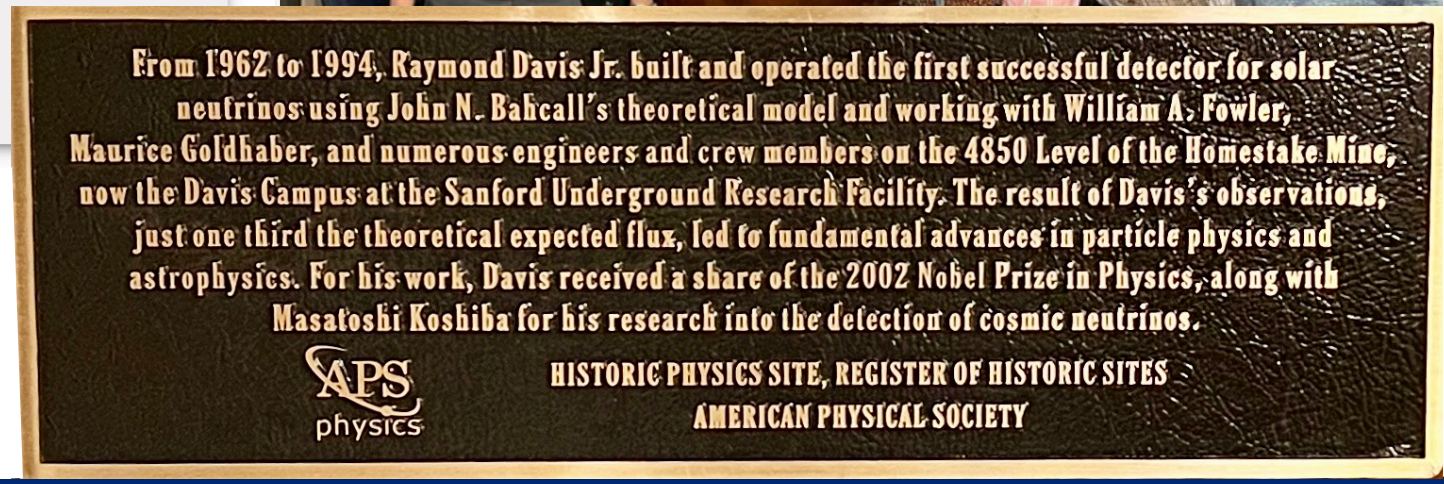
DATE ISSUED:
September 14th, 2020

SOURCE:
Sanford Underground Research Facility

CONTENT:
Press Release

CONTACT:
Constance Walter
Communications Director
cwalter@sanfordlab.org





SURF Science & Education Opportunities

SURF Programs

- **Summer Internships** (Bozied/Bauer/Headley)
  - Science, engineering, operations, environmental science and communications, incl underrepresented groups https://sanfordlab.org/internships
- **Davis-Bahcall Scholars Program**
  - Multidisciplinary studies at U.S. & European labs/industries https://sanfordlab.org/dbs

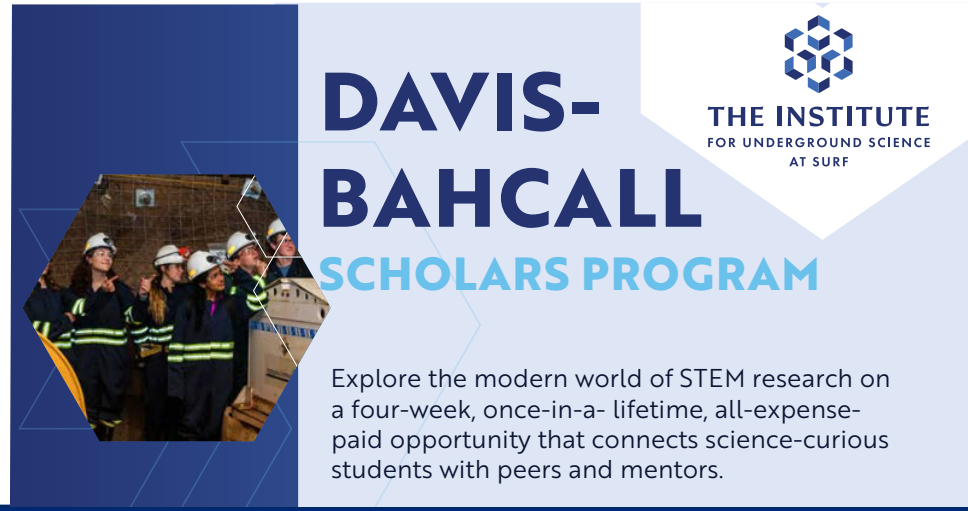
National Programs

- NSF Research Experiences for Undergraduates (REU):
  - **BHSU** multidisciplinary program since 2016 (physics, chemistry, biology) https://bhsu.edu/academics/programs/physics.html
  - **SD Mines Li-SMART** (Lithium, Mining, Recycling and Technology) started 2025 https://www.sdsmt.edu/news/releases/Li-SMART.html
- DOE Reaching a New Energy Sciences Workforce (RENEW):
  - **RENEW-Midwest:** From the Underground to the Cosmos, student diversity in STEM (BHSU, UMich, Benedictine) https://www.pathwaystoscience.org
  - **NuPUMAS**: Neutrino Physics for Undergraduate Minority Advancement in Science, student diversity in STEM (UHouston / Texas Physics Consortium) https://nupumas.physics.uh.edu

Other Opportunities

- **BHSU Underground Campus:** Promoting undergraduate research
- **Local Researchers:** BHSU, SD Mines, RESPEC; also USD, SDSU, DSU





STEM Education at SURF



- SURF Education & Outreach team reaches **22,000+** K-12 students per year
  - Presentations and field trips
  - Curriculum units
- Professional development for more than **400** educators per year
- **Davis-Bahcall Scholars** program and **summer internship** opportunities (Apply this fall!)

K-12 Education & Outreach

Presentations and Field Trips	Curriculum Units and Resources	Career Exploration and Development	Supporting Teachers
• K12 presentations • Face-to-face • Virtual options • Field trips	• 17 unique curriculum units available for checkout • 5-15 hours of fully designed and resourced science curriculum	• Davis-Bahcall Scholars Program • Summer internship opportunities • Pre-service educator program support	• Professional development offerings • Curriculum resources • Science content support • Just-in-time support









Education & Outreach – By the Numbers

School Year	2019-2020 (covid begins)	2020-2021 (during covid)	2021-2022	2022-2023	2023-2024	2024-2025
Field Trips	254	58	485	972	966	1,501
Classroom Presentations	3,704	2,005	14,038	12,799	10,281	14,712
Curriculum Units	3,236	3,384	3,718	2,554	3,965	4,171
Other	918	298	1,468	1,596	1,368	1,729
Total Student Contacts	8,112	5,745	19,709	17,921	16,580	22,113

August 2024 – July 2025: Developed and facilitated more than 6000 people hours of professional development for more than 400 educators

Connecting Science, Art and Learners



Rachel Berg







Chris Combs



Gina Gibson







Marty Two Bulls Jr.

Sanford Lab Homestake Visitor Center

Acquired January 2022. Greatly expands public outreach opportunities.



Sanford Lab Homestake Visitor Center (SLHVC)

Building meaningful relationships with range of audiences

Audiences

- Intergenerational year-round programming
- Venue space for SURF and its affiliates
- Local community
- Tourists



Engaging Content

- Docent tours
- Ask-a-Scientist events
- *Deep Talks* lecture series
- *Deep Roots* cultural events
- Tours to hoist room and Čhaŋgléška Wakȟáŋ



Accessible Opportunities

- Accessibility strategic plan in process
- Serves as SURF's public "front door"
- Multi-use space
- Community partner:
  - Voter polling site
  - Visitor center for tourists
  - Exploring public EV charging station



By the Numbers

	2023	2024	2025
Visitors	57,317	58,136	55,484
States	*50*	*50*	*50*
Countries	*33*	*42*	*41*
Buses	139	137	158
Events	121	124	140

Čhaŋgléška Wakȟáŋ, the Ethnobotanical Garden at SURF

Public tours started summer 2024



Sanford Underground Research Facility
General summary

Site: Deepest underground lab in U.S., largest footprint for scientific pursuits (former Homestake Gold Mine). Operations funded directly by U.S. Department of Energy ($44M/yr). Robust org, total staff = 228 ppl.

Science Program:

- **Past:** Davis Solar Neutrino Experiment, LUX, MAJORANA DEMONSTRATOR ($0\nu\beta\beta$, ^{180m}Ta), others (incl Deep Underground Gravity Lab, affiliated w/ LIGO collaboration; Industry/engineering w/ Caterpillar)
- **Current:** LZ, CASPAR, Low-bkgd counting (BHUC), Geoengineering (esp. geothermal, seismic), Geomicrobiology, Engineering
- **Future** (no funding/site decisions yet):
  - Dark Matter: Low-mass (SPLENDOR, HydroX), next-generation WIMP (XLZD, Argo), other (CrystaLiZe)
  - Neutrino: Liquid scintillator (Theia), multi-ton-scale $0\nu\beta\beta$ (LEGEND 6000), XLZD, etc
  - QIS, atom interferometry – gravitational waves, ultra-light dark matter: km-scale vertical or horizontal

Facility:

- **4850L Existing:** Davis Campus and Ross Campus operating well
- **4850L Quantum User Facility:** Fridge(s) for QIS at Davis Campus/Expansion (exploring funding)
- **4850L LBNF/DUNE:** Excavation complete, “Module of Opportunity” for expanded science program (DOE)
- **4850L Expansion:** Up to 2x caverns (100m L × 20m W × 24m H), complete in early 2030s (private/DOE?)
- **Vertical Facility:** Accommodate during Yates Shaft refurbishment, schedule TBD / ~2030s (DOE/other?)

Sanford Underground Research Facility
Physical characteristics

- **Property:** 1 km^2 (surface) with ~1600 m^2 storage (incl drill core) and 355 m^2 staging/assembly space; 31 km^2 (total underground) with ~600 km of tunnels extending to over 2450 m below ground.
- **Access:** Vertical; personnel and materials via one of two main shafts (Yates Shaft extensive maintenance campaign completed, DOE funding discussions for full refurbishment). Facility dedicated to science.
  - Yates Shaft: 1.39 × 3.77 × 2.58 m, 4.8 tonnes (lengths up to 7.3 m possible at reduced payload mass)
  - Ross Shaft: 1.40 × 3.70 × 3.62 m, 6.1 tonnes (lengths up to 8.2 m possible at reduced payload mass; new cage soon)
- **Depth:** Main UG level = 4850L (1480 m, 4300 mwe), muon flux = $(5.18 \pm 0.27)\times10^{-5}$ $\mu/m^2/s$ (4.5 $\mu/m^2/d$). Several other UG elevations for science: 300L, 800L, 1700L, 2000L, 4100L, 4550L.
- **Space:**
  - Surface (science space, as low as class 10-100): 210 m^2 (cleanrooms = 92 m^2 / 914 m^3)
  - 4850L (science space, as low as class 100): Davis Campus (1018 m^2 / 4633 m^3), Ross Campus (920 m^2 /3144 m^3)
  - Radon-reduction: Surface = 2200x reduction @ 300 m^3/h (Ateko), Davis = 700x reduction @ 150 m^3/h (SD Mines)
- **Bkgds** (4850L): Radon* = 210-330 Bq/m^3, gamma = 1.9 $\gamma/cm^2/s$, neutron (thermal) = 1.7×10^{-2} $n/m^2/s$.

* Studies conducted Summer 2024, expect to reduce Rn concentration

- **Utilities:**
  - Power = 24,000 kW capacity (20,000 kW available now, 15,000 kW in FY27); Standby = 3 diesel generators (390 kW)
  - Chilled water (2x 246 kW), purified water (37.8 lpm), compressed air (up to 1100 scfm, 140 scfm at Davis Campus)
  - Network = 20 Gbps internally, 10 Gbps externally (100 Gbps planned), WiFi available surface + underground

Sanford Underground Research Facility
Capabilities

- **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 laboratories in the world (1500 m, 4300 mwe). SURF is expanding to meet the needs of next-generation experiments
- **Local radiation shielding:** Water tank and corresponding water purification system, steel shielding; also selection of low-activity facility construction materials/finishes (e.g., concrete, shotcrete)
- **Assay capabilities:** Low-bkgd counting serving national & international community (~10 μBq/kg U/Th)
- **Material production/purification:** One of only a few labs where UG Cu electroforming is performed (average U, Th decay chain ≤ 0.1 μBq/kg)
- **Environmental control:** Experience w/ HEPA filtration cleanrooms, dehumidifier, 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**