The Sanford Underground Research Facility

Jaret Heise, Science Director
jaret@sanfordlab.org

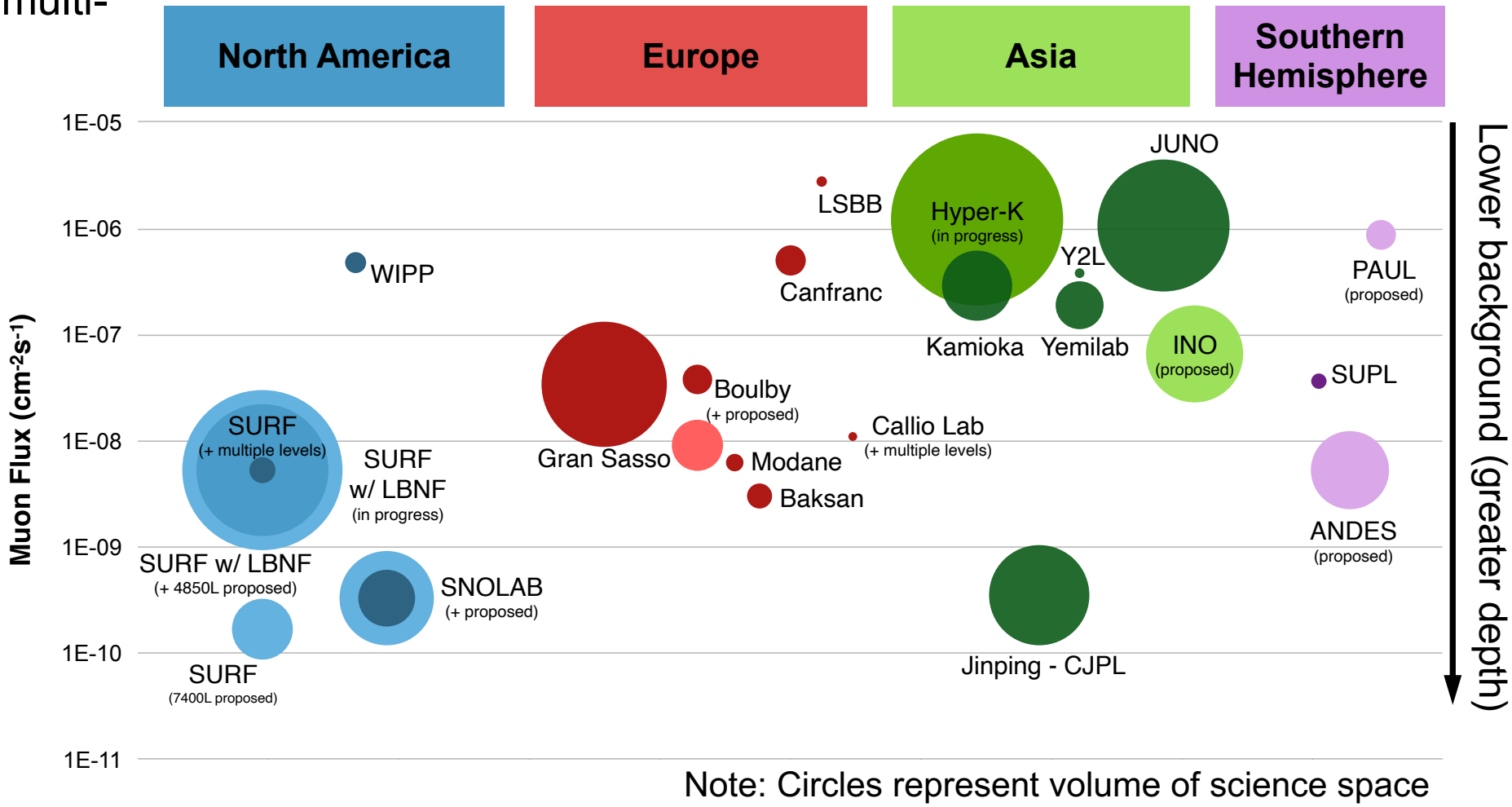
Sanford
Underground Research Facility
South Dakota Science and Technology Authority

RISQ Workshop May 31, 2024

SURF in the Global Context

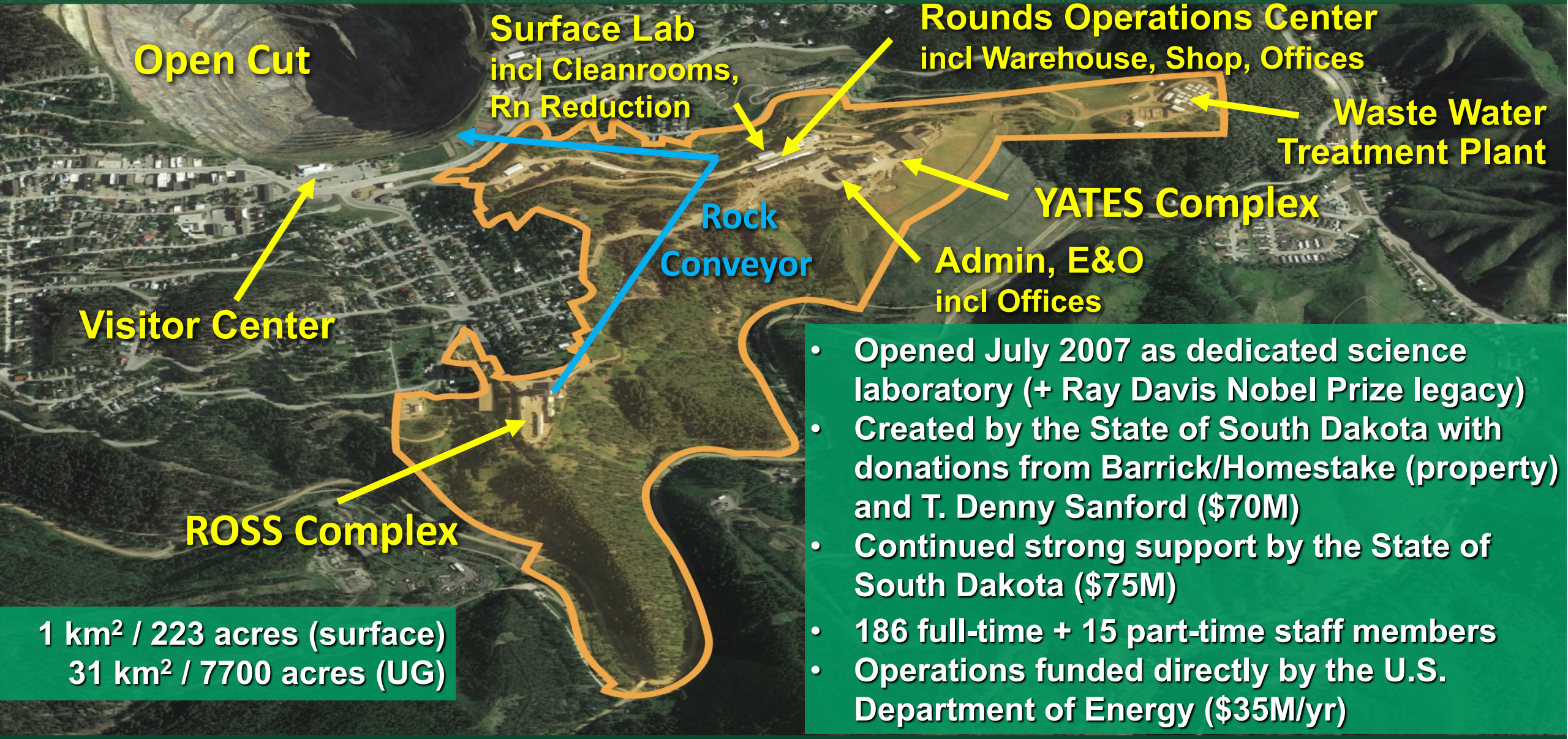
UG Facilities can provide:

- 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



Sanford Underground Research Facility

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

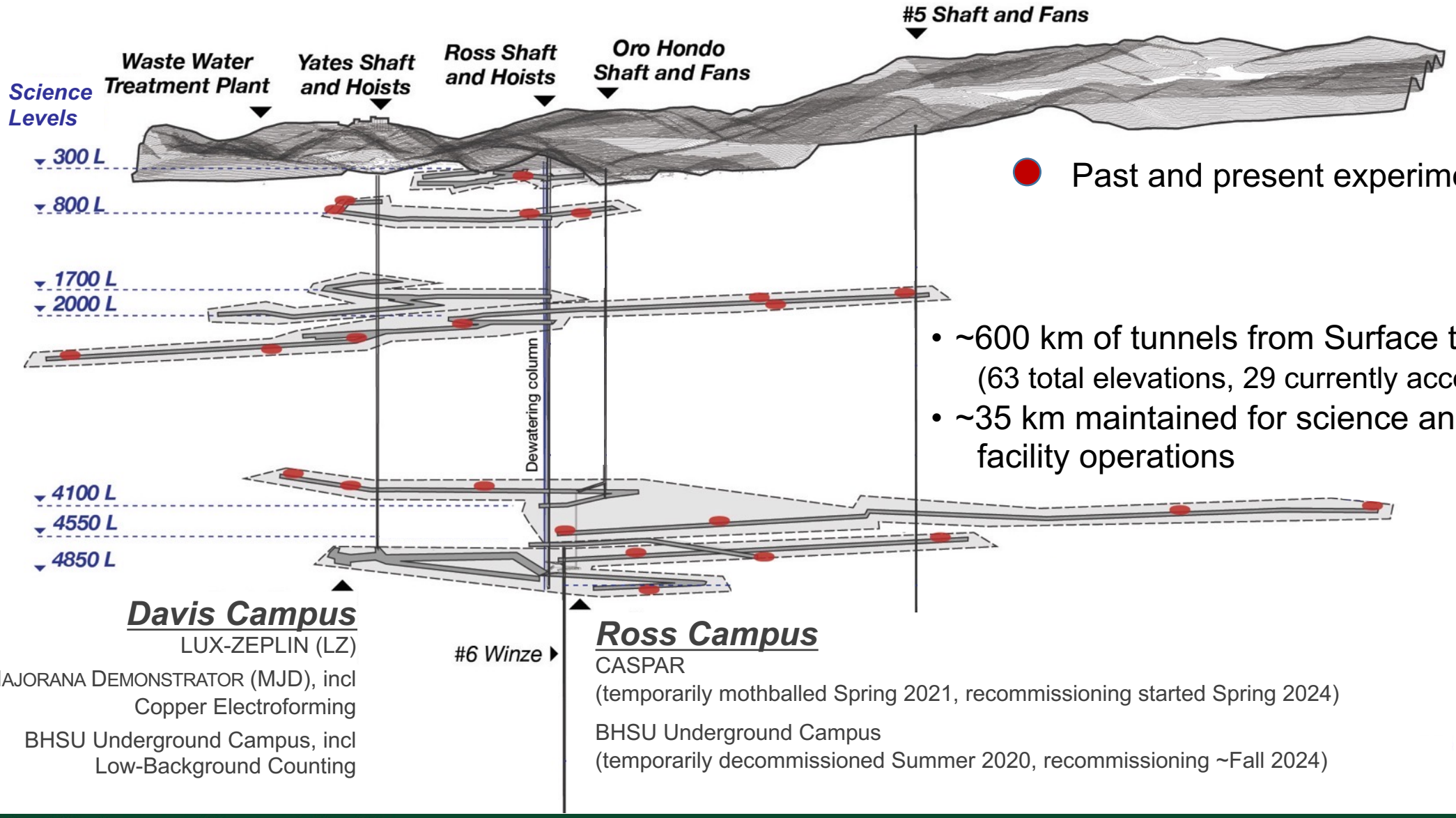


- Opened July 2007 as dedicated science laboratory (+ Ray Davis Nobel Prize legacy)
- Created by the State of South Dakota with donations from Barrick/Homestake (property) and T. Denny Sanford ($70M)
- Continued strong support by the State of South Dakota ($75M)
- 186 full-time + 15 part-time staff members
- Operations funded directly by the U.S. Department of Energy ($35M/yr)

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)
- ~35 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, recommissioning started Spring 2024)

BHSU Underground Campus
(temporarily decommissioned Summer 2020, recommissioning ~Fall 2024)

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

Dark Matter
LUX-ZEPLIN

Neutrinos
MAJORANA DEMONSTRATOR
LBNF /DUNE

Science Program

Biology
Extreme Life
Astrobiology

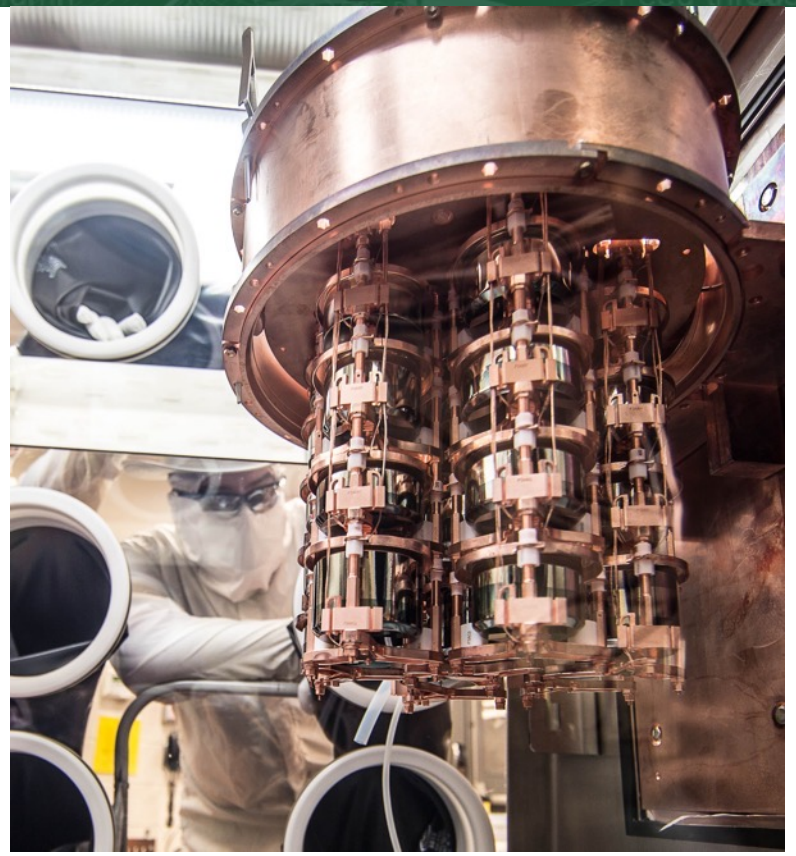
Geology
Geothermal Energy
Seismic Studies

SURF Science Program – Current Physics Highlights

Strong and diverse program with exciting future

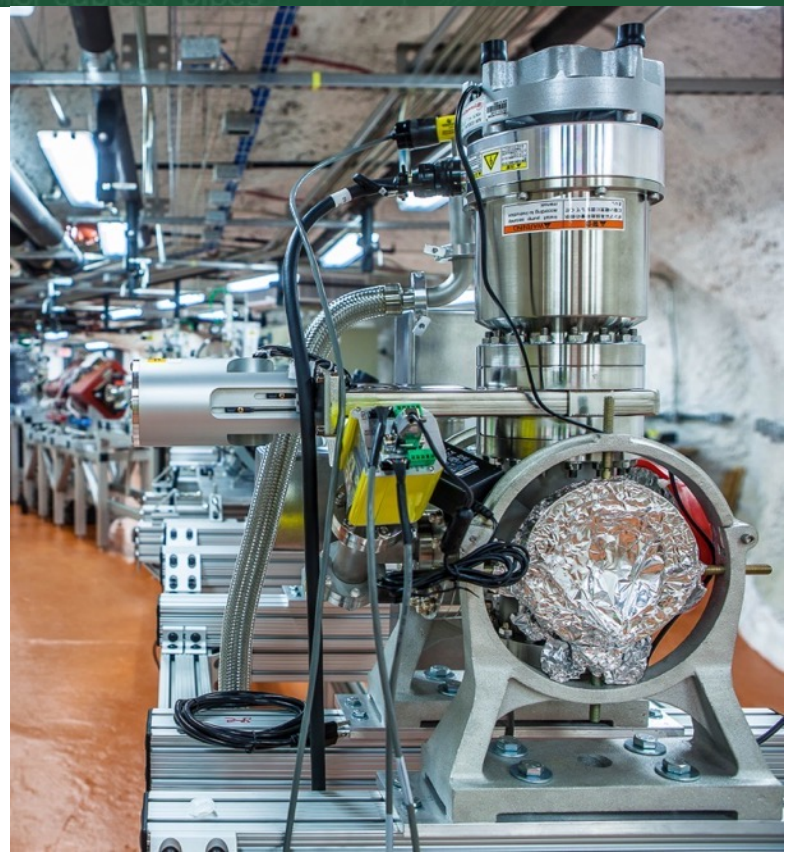
LUX-ZEPLIN (LZ)

- Direct search for **dark matter** using 10 tonnes xenon
- World-leading WIMP-search results announced July 2022



MAJORANA DEMONSTRATOR (MJD)

- Investigate **neutrinoless double-beta decay** using 44 kg Ge
- Final Ge result July 2022, Ta-180 decay search first results June 2023

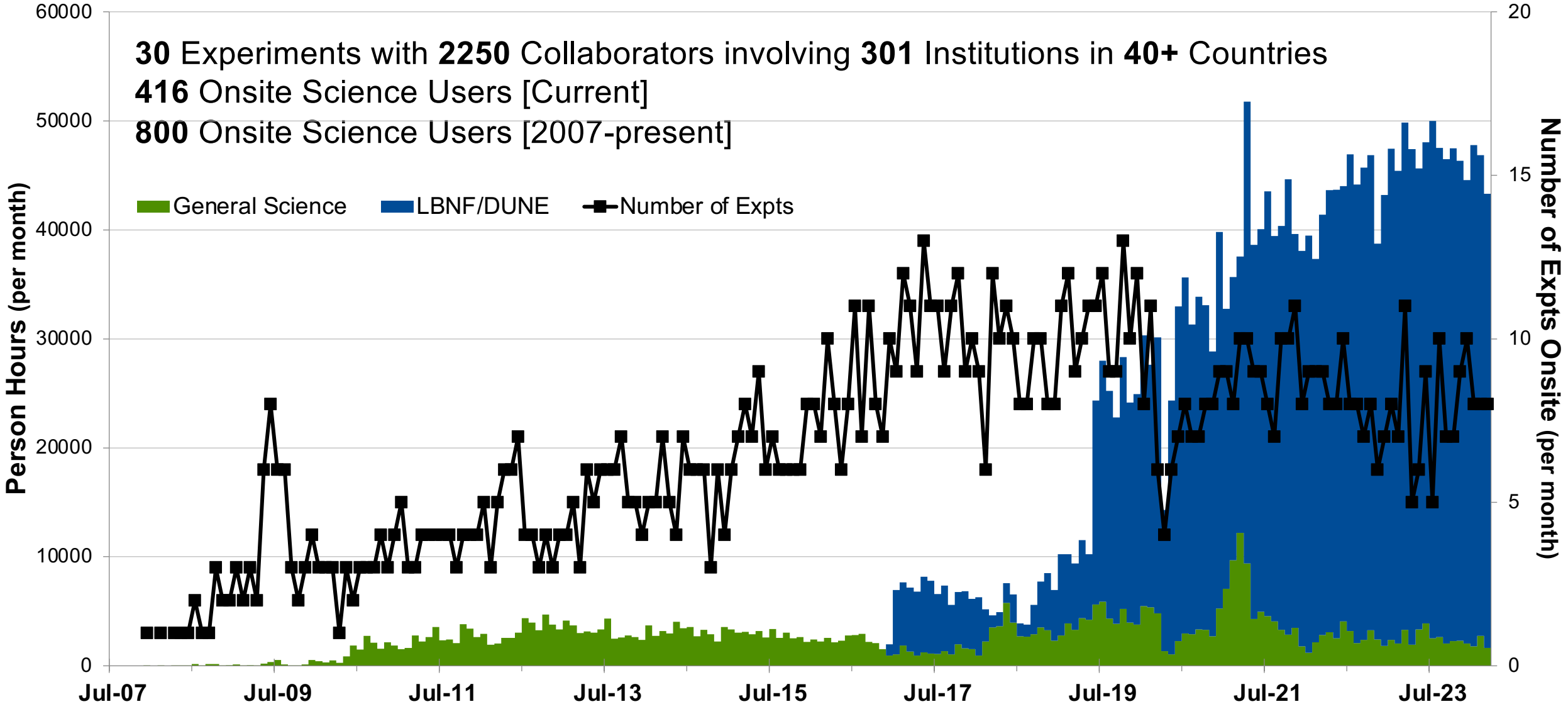


CASPAR

- Stellar fusion reactions to study **nucleosynthesis** using accelerator
- Initial phase ended in 2021, next phase starting in 2024

SURF Science Program

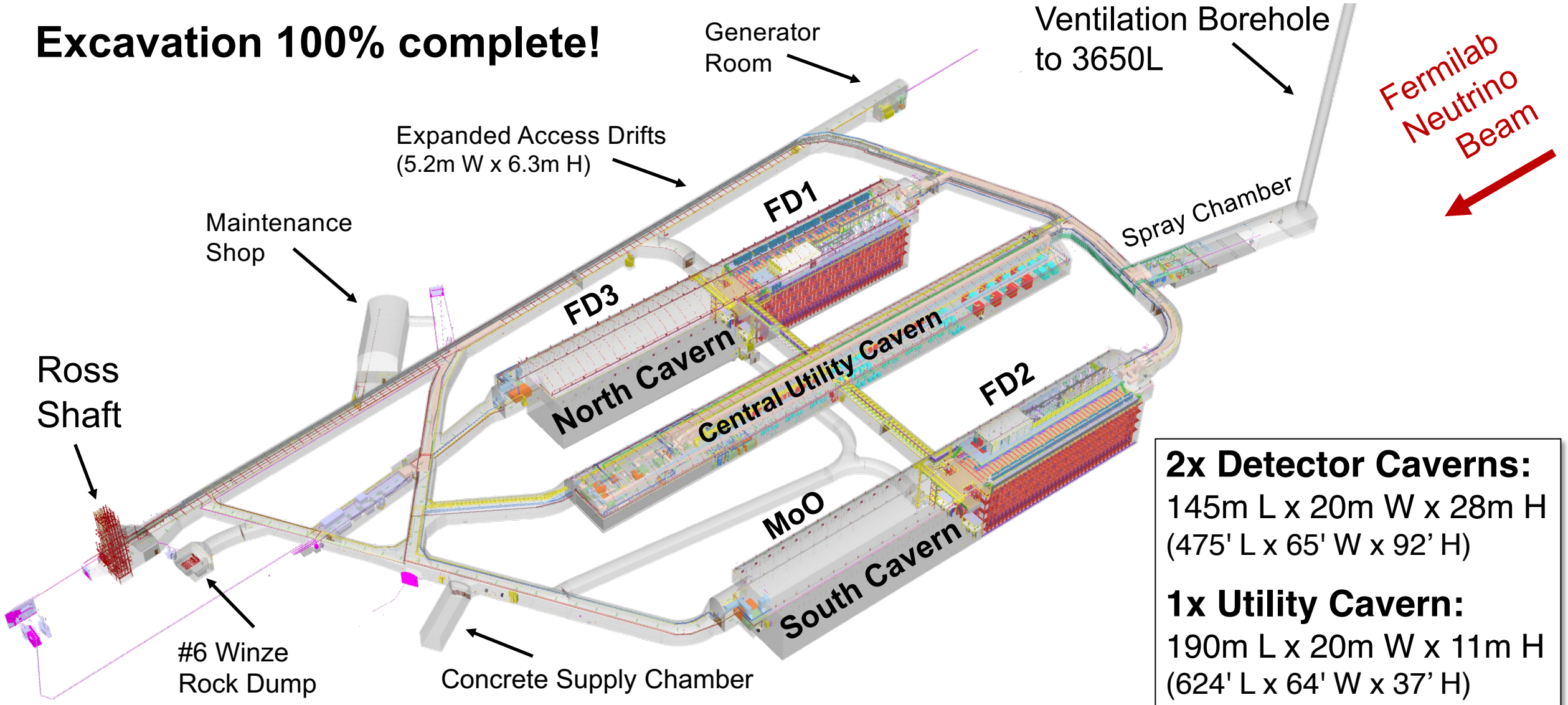
Hosting world-leading experiments and researchers from diverse scientific communities



Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

Excavation 100% complete!

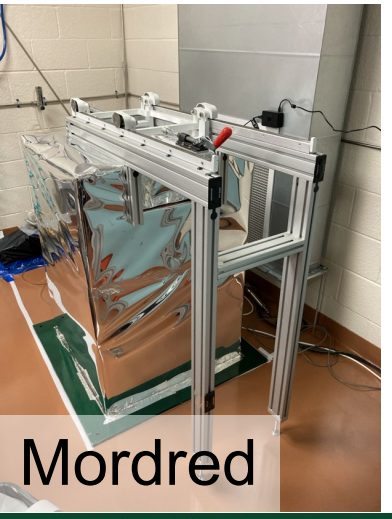


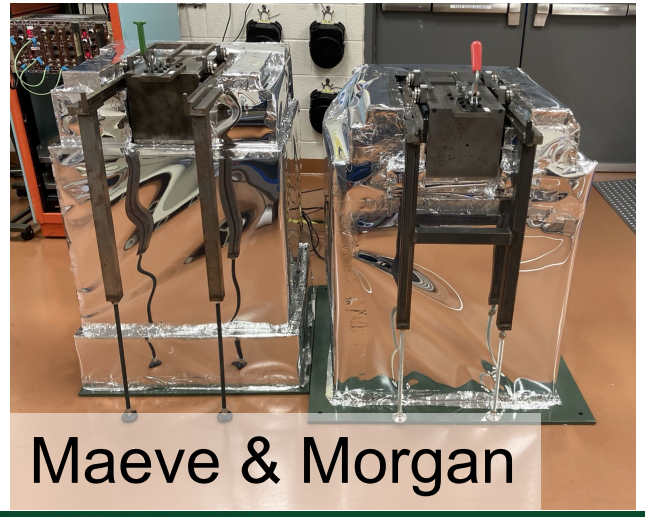
2x Detector Caverns:
145m L x 20m W x 28m H
(475' L x 65' W x 92' H)

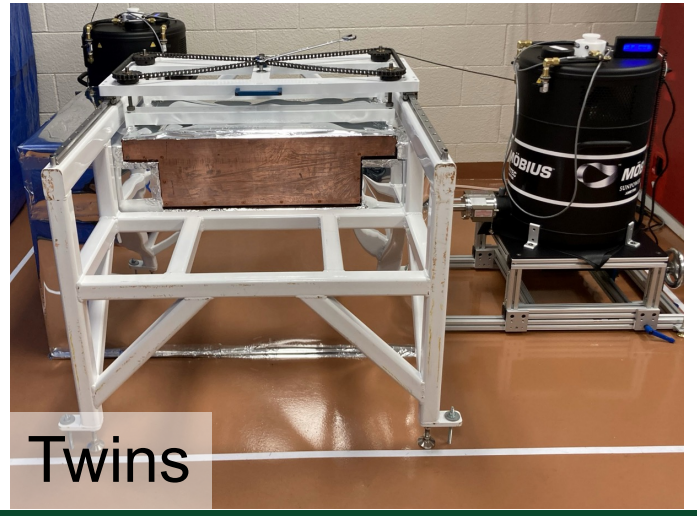
1x Utility Cavern:
190m L x 20m W x 11m H
(624' L x 64' W x 37' H)

SURF Material Assay at BHUC: Davis Campus

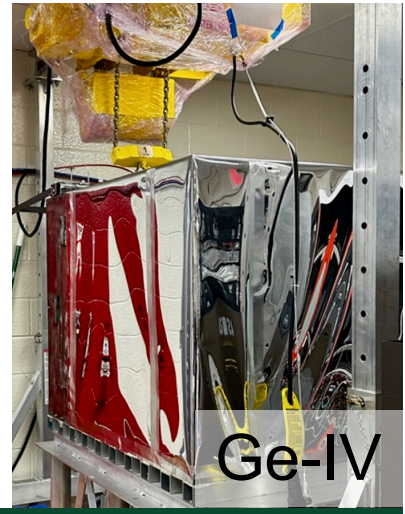
Low-background counting capabilities serving national & international community


Mordred


Maeve & Morgan


Twins


RHYM/RESN


Ge-IV

SURF Material Assay at BHUC

Low-background counting capabilities serving national & international community

Detector	Crystal		[U] mBq/kg	[Th] mBq/kg	Install Date	Status	Comments
	Type	Size					
Maeve (BLBF)	p-type (85%)	2.2 kg	**0.1** (10 ppt)	**0.1** (25 ppt)	Davis Campus: Nov 2020 (Ross Campus: Nov 2015; Davis Campus: May 2014)	Production assays	Relocated from Oroville. Old Pb (200-yr old) inner shielding. Cooling system upgrade 2020.
Morgan (BLBF)	p-type (85%)	2.1 kg	**0.2** (20 ppt)	**0.2** (50 ppt)	Davis Campus: Nov 2020 (Ross Campus: Nov 2015; Davis Campus: May 2015)	Production assays	Low-bkgd upgrade 2015. Cooling system upgrades 2020.
Mordred (USD/CUBED, BLBF)	n-type (60%)	1.3 kg	**0.7** (60 ppt)	**0.7** (175 ppt)	Davis Campus: Nov 2020 (Ross Campus: Jul 2016; Davis Campus: Apr 2013)	Production assays	Low-bkgd upgrade 2015-2016, shield access upgrade. Cooling system upgrades 2020.
Dual HPGe ("Twins") (BLBF, BHSU, UCSB)	p-type (2x120%)	2x 2.1 kg	**~0.01** (~1 ppt)	**~0.01** (~1 ppt)	Davis Campus: Sep 2020 (Ross Campus: Mar 2018, Jul 2017 (initial))	Operating	Low-bkgd upgrades 2016-2017; flexible shield. Cooling system upgrades 2020.
Ge-IV (Alabama, Kentucky)	p-type (111%)	2 kg	**0.04** (3 ppt)	**0.03** (8 ppt)	Davis Campus: May 2023, Nov 2020 (initial) (Ross Campus: Jul 2018, Oct 2017 (initial))	Operating until recently due to cryocooler issues	Vertical design, requires gantry + hoist. Cooling system upgrades 2020.
Dual HPGe ("RHYM+RESN") (LLNL)	p-type (2x65%)	2x 1.1 kg	**<0.1** (<10 ppt)	**<0.1** (<25 ppt)	Davis Campus: Feb 2022, Sep 2020 (initial)	Operating	Cryocooler, low-E ^{210}Pb (<2 mBq/kg).

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

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

4850L Space Needed for Future Experiments

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

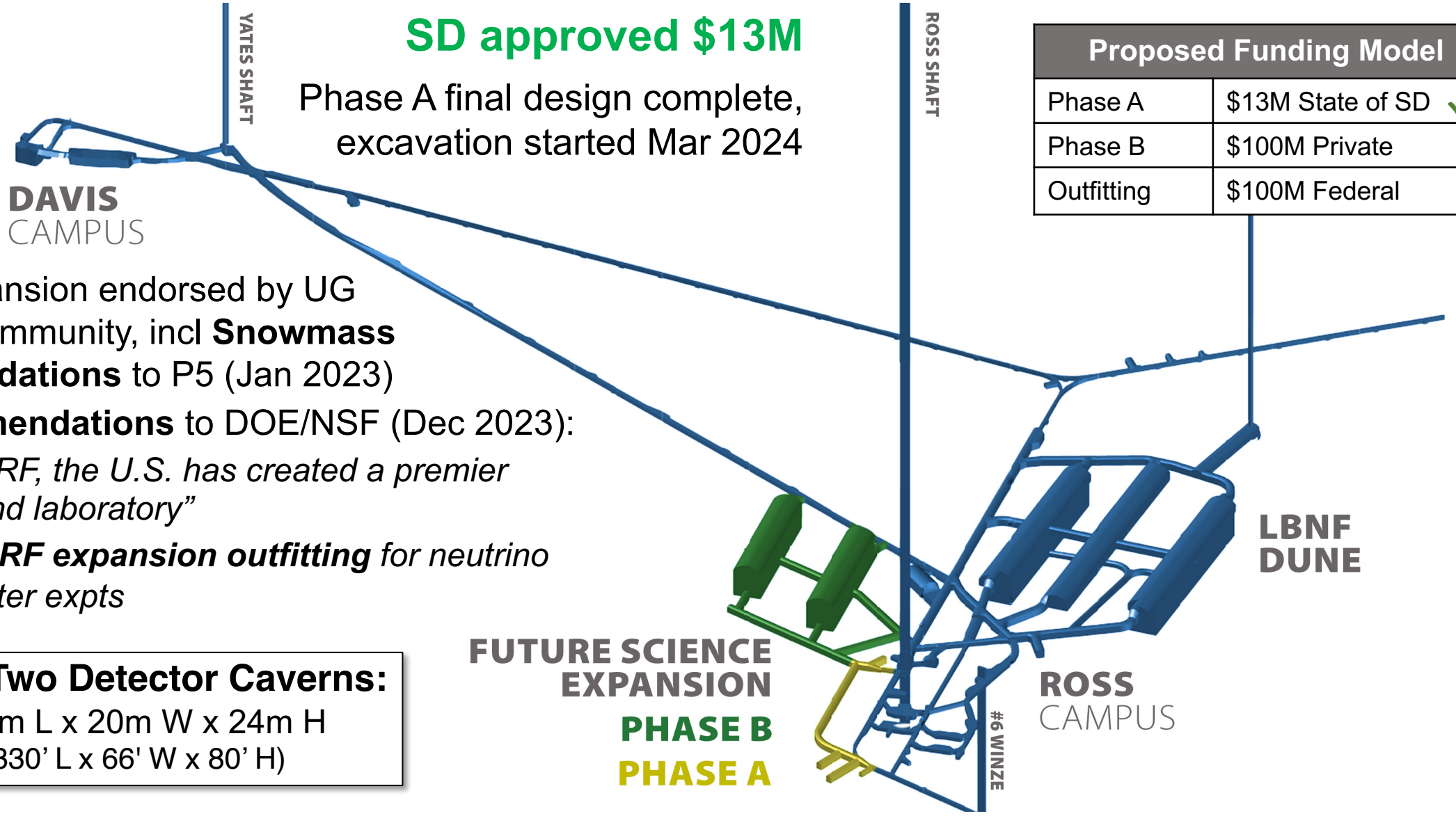
SD approved $13M

Phase A final design complete, excavation started Mar 2024

Proposed Funding Model	
Phase A	$13M State of SD ✓
Phase B	$100M Private
Outfitting	$100M Federal

- SURF Expansion endorsed by UG Science Community, incl **Snowmass recommendations** to P5 (Jan 2023)
- **P5 recommendations** to DOE/NSF (Dec 2023):
  - *"With SURF, the U.S. has created a premier underground laboratory"*
  - ***Fund SURF expansion outfitting*** *for neutrino & dark matter expts*

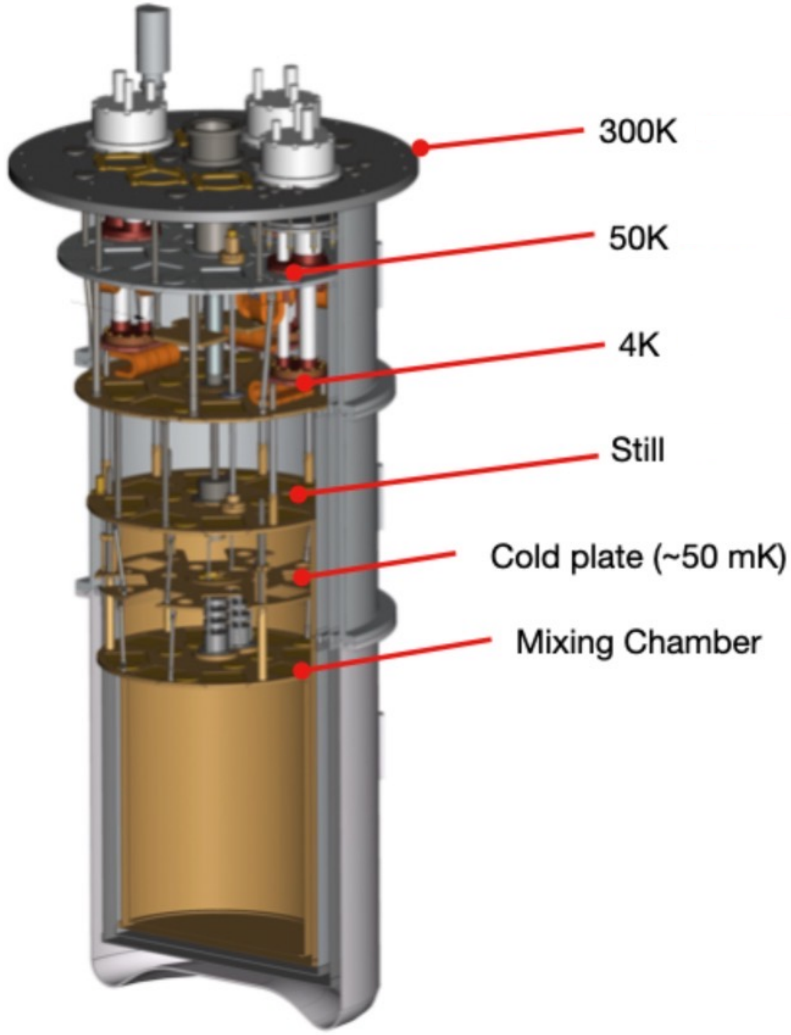
Up to Two Detector Caverns:
100m L x 20m W x 24m H
(330' L x 66' W x 80' H)



SURF Cryogenic User Facility

Proposal inline with becoming DOE scientific user facility

- **Multi-user, low-background, ultra-low temperature test facility for cryogenic detectors:**
  - Applications in **fundamental nuclear and particle physics research** (neutrinos and dark matter)
  - Detectors with extremely low energy thresholds and excellent energy resolution require **isolation from ionizing radiation** at deep facility like SURF to be effective
  - Detectors often rely on quantum thermal sensors with operating **temperatures in milli-Kelvin range** requiring dilution refrigerator
- **Cryogenic User Facility at SURF:**
  - **No <u>deep</u> underground cryogenic test facility in U.S.** (recent shallow sites addressing general shortage of underground cryogenic test infrastructure in U.S. – PNNL & FNAL!)
  - **Significant interest from U.S.-based groups**: low-mass dark matter (TESSERACT, SPLENDOR), neutrinoless double-beta decay (CUPID), quantum information systems (MIT, UIUC); collaborating with Virginia Tech
  - Underground cleanroom, cooling infrastructure available; clean shielding Pb and surface lab space possible.



Proposing Bluefors XLD1000SL dilution refrigerator to accommodate large payload (detectors/shielding)

South Dakota Support for Quantum Initiatives

Notable state investment attracting interest, also federal congressional support

24.585.12 99th Legislative Session 45

2024 South Dakota Legislature

Senate Bill 45

ENROLLED

AN ACT

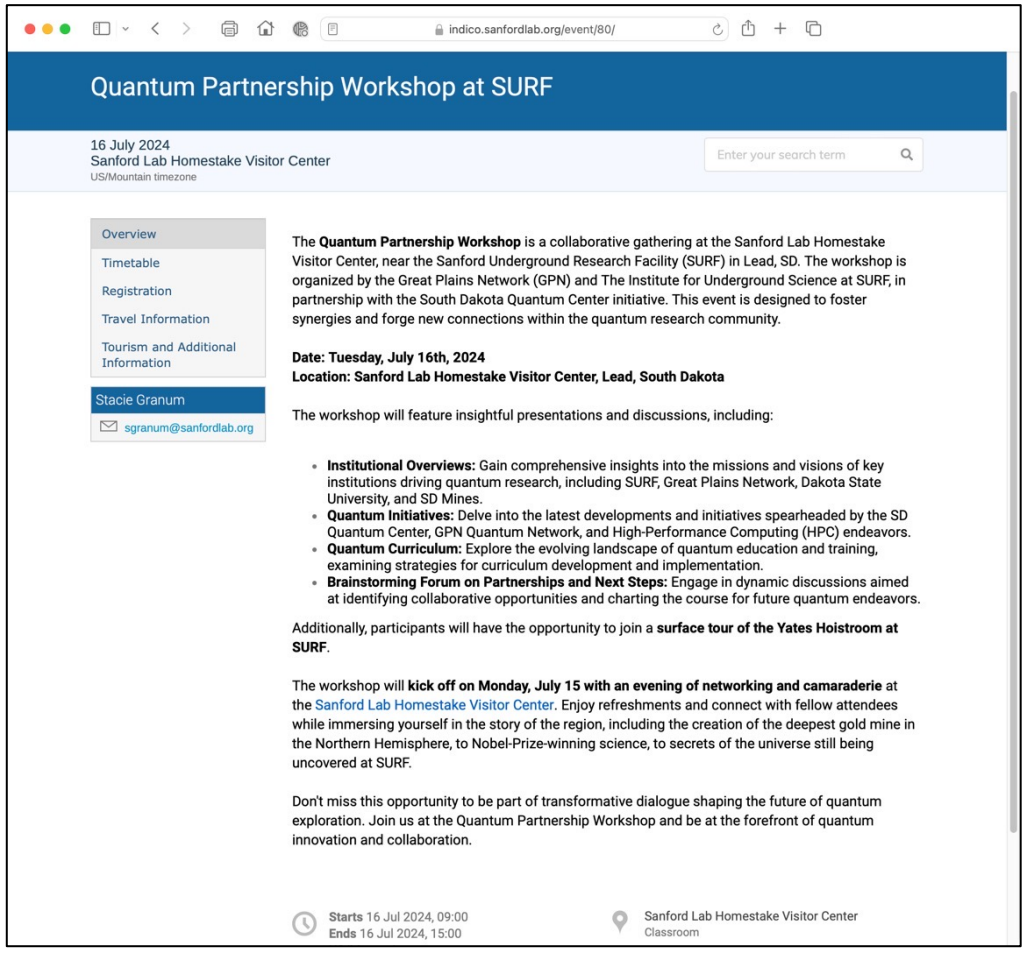
ENTITLED An Act to make an appropriation for the establishment of a Center for Quantum Information Science and Technology and to declare an emergency.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF SOUTH DAKOTA:

Section 1. There is hereby appropriated from the general fund the sum of $3,034,444 to the Board of Regents, for the purpose of establishing a Center for Quantum Information Science and Technology.

Information Science and Technology

Governor Kristi Noem signed SB 45, which funds the establishment of a Center for Quantum Information Science and Technology.



Jul 16, 2024:
Quantum Partnerships Workshop
https://indico.sanfordlab.org/event/80

SURF Call for Letters of Interest

Ensuring SURF used to its fullest scientific potential

Significance:

- SURF's first formal call to UG science community since 2005!
- Initial calls selected strong physics anchors for Davis Campus: MJD and LUX (which led to current LZ)
- 2024 call is opportunity for SURF to refine science strategic plan development (currently underway), ensure strong science program continues

Summary:

- Open to all disciplines: Physics, Geology, Biology, Engineering
- Identifies specific existing space on 4850L and 4100L, other undeveloped areas may be available now
- 4850L Expansion started Mar 17, 2024, space available ~2030 (nominally two detector caverns: 100 m L x 20 m W x 24 m H, LOIs and subsequent discussions will inform final design)
- Submissions will be reviewed by SURF Science Program Advisory Committee
- Nominal deadline May 17, 2024, **LOIs still being accepted**

Sanford Underground Research Facility

South Dakota Science and Technology Authority 630 E. Summit St. Lead, SD 57754

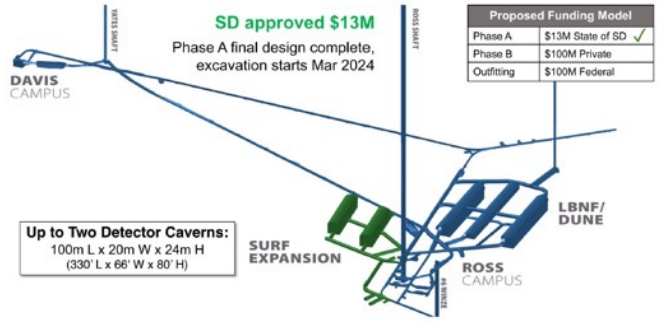
March 22, 2024

SURF Request for Letters of Interest 2024-01

Dear Researcher,

In support of our mission to advance world-class science, the Sanford Underground Research Facility (SURF) is seeking input from the global underground science community to ensure that scientific priorities are being accommodated and that SURF is being used to its fullest scientific potential.

SURF has a strong science program that currently comprises 29 experiment groups. Programs in some of our key 4850L laboratories are expected to complete in the next 1-4 years, which presents an opportunity to survey the community for new prospects. SURF is tremendously excited about new large laboratories that are being developed on the 4850L, with initial construction underway and space available on the timeframe of ~2030.



Leading into recent U.S. long-range planning, the SURF User Association held a Vision Workshop (https://indico.sanfordlab.org/e/Vision2021) and SURF participated in nuclear physics town halls and the particle physics Snowmass community input processes. As a result, SURF featured prominently in the strategic plans for both Nuclear (ref) and High Energy Physics (ref) communities. With the physics community long-range plans in-hand, SURF has set up a Steering Committee to distill opportunities and key elements relevant to the organization's science strategic plan (non-physics disciplines will also be addressed to inform the comprehensive strategic plan, but at a later date).

To help inform this process, we are inviting collaborations and scientists to submit short letters of interest (LOIs); maximum 3 pages. The information requested in the LOIs includes science goals, collaboration composition, facility requirements, access requirements, and timelines. Submitters are also invited to complete a SURF Experiment Planning Statement (EPS), supplemental to the LOI, that provides some additional experiment details as well as offering some SURF facility details: https://sanfordlab.org/researchers/proposal-guidelines.

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, incl leveraging strong partnerships with U.S. national laboratories.
- SURF wants to host other future world-leading experiments:
  - Construction is underway to **increase underground laboratory space**, plans advancing for new large caverns on 4850L (1500 m, 4100 mwe) on **timeframe of next-generation experiments (~2030)**.
  - **Call for Letters of Interest** underway to ensure existing and future space used to its fullest scientific potential.
  - Very interested in fostering **commercial partnerships**, especially in QIS.
- SURF is playing a strong role in the UG science community:
  - **User Association** serving as catalyst for community discussions: https://www.sanfordlab.org/surf-user-association.
  - **Strong community support** endorsing more space at SURF (Vision Workshop 2021, Snowmass 2021/2022).
  - **Strong recognition** and support for SURF in recent **P5 report for U.S. strategic planning**.

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)

Sanford Underground Research Facility
General summary

Site: Deepest underground lab in U.S., dedicated to science (former Homestake Gold Mine). Significant footprint with multiple tunnels, access from surface to ~1500 m (total depth = 2450 m).

Science Program:

- **Past:** Davis Solar Neutrino Experiment, LUX, MAJORANA DEMONSTRATOR (0νββ)
- **Current:** LZ, MAJORANA DEMONSTRATOR (^{180m}Ta), CASPAR, Low-bkgd counting (BHUC), Geomicrobiology, Geoengineering (esp. geothermal), other industry/engineering
- **Future** (no funding/site decisions yet):
  - Dark Matter: Low-mass (SPLENDOR, HydroX), next-generation WIMP (XLZD, Argo), other (CrystaLiZe)
  - Neutrino: Water-based liquid scintillator (Theia), Beyond-ton-scale 0νββ, etc
  - QIS, gravitational waves/atom interferometry, etc

Facility:

- **4850L Existing:** Re-open Ross Campus in 2024 (CASPAR, BHUC labs temporarily closed due to LBNF)
- **4850L Construction:** LBNF/DUNE (excavation 100% complete, science starts mid-2029)
- **4850L Expansion:** Up to 2x caverns (100m L x 20m W x 24m H), develop in 2 phases (funding for first phase in-hand), excavation complete by ~2030
- **7400L Expansion:** One or more caverns (75m L x 15m W x 15m H), funding/schedule TBD

Sanford Underground Research Facility
Physical characteristics

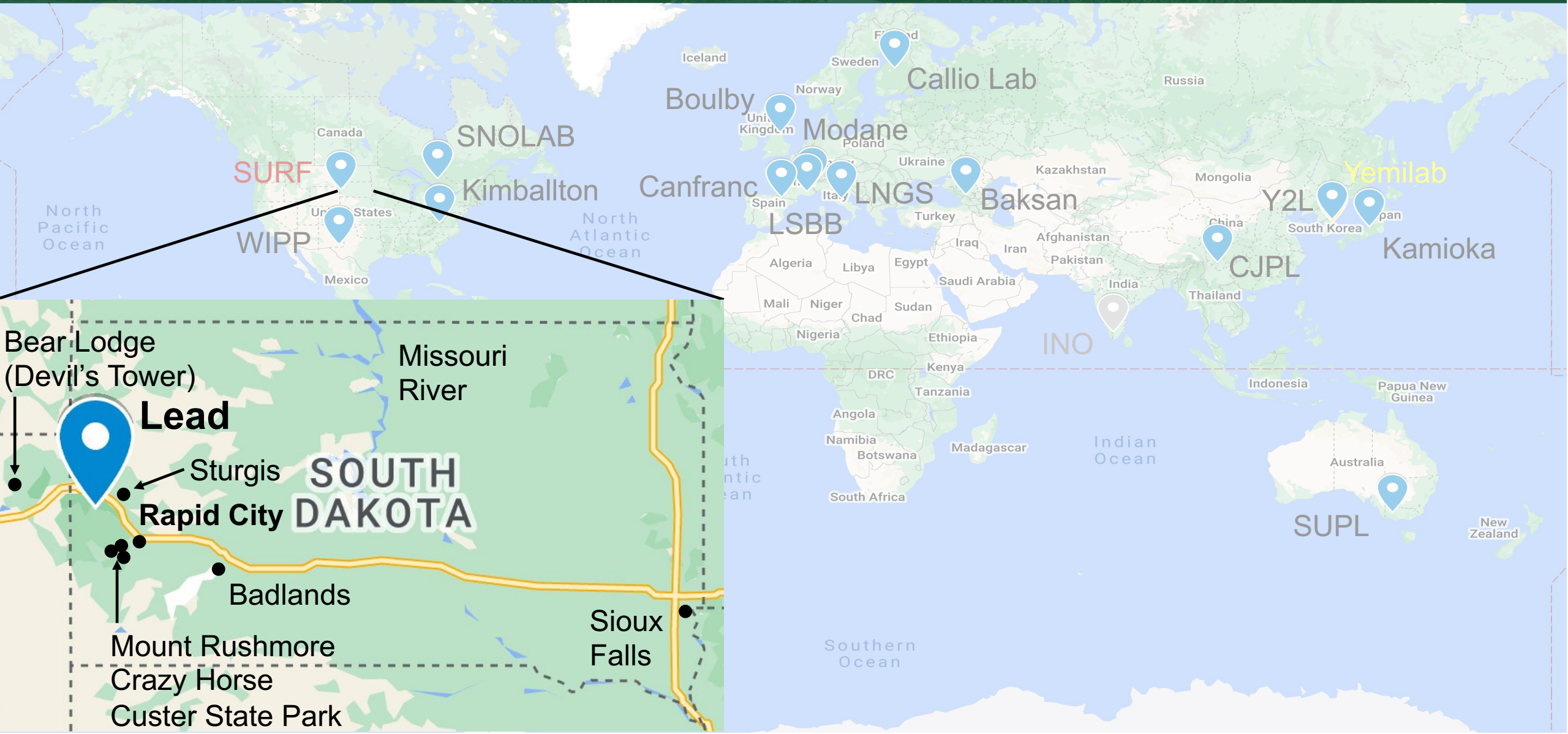
- **Property:** 1 km^2 (surface) with ~1600 m^2 storage (incl drill core) and 355 m^2 staging/assembly space. 31 km^2 (underground) with ~600 km of tunnels extending to over 2450 m below ground.
- **Access:** Vertical; personnel and materials via one of two main shafts (Yates Shaft currently undergoing extensive maintenance). 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)
- **Depth:** Deepest lab in U.S. Main UG level = 4850L (1490 m, 4300 mwe), muon flux = 5.31×10^{-5} $\mu/m^2/s$. 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 = 300 Bq/m^3, gamma = 1.9 $\gamma/cm^2/s$, neutron = 1.7×10^{-2} $n/m^2/s$.
- **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

Where in the world is SURF?

Sanford Underground Research Facility

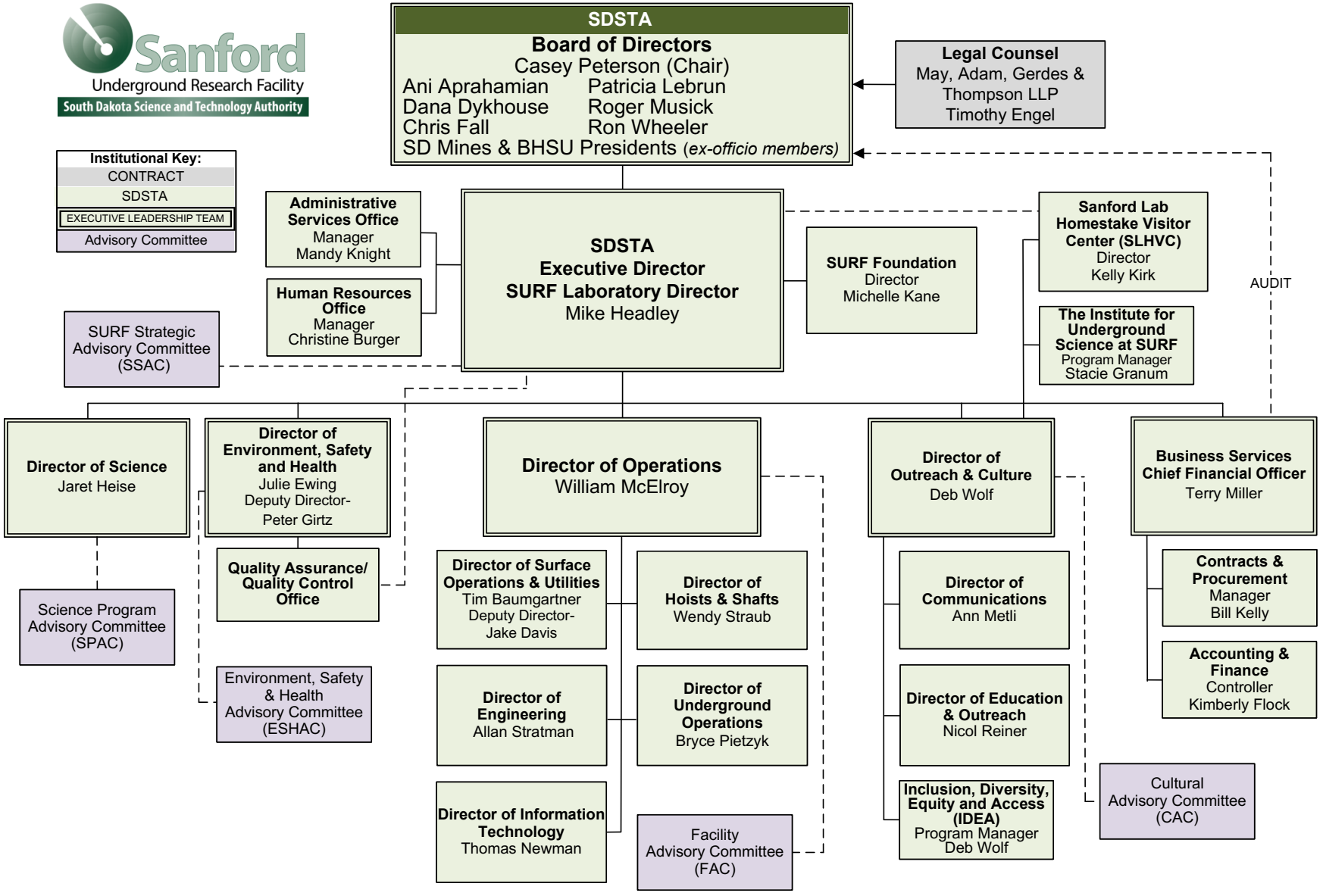
Where in the world is SURF?



Sanford Underground Research Facility

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

SDSTA Organization Structure



SURF Plans to Become DOE User Facility

Benefits:

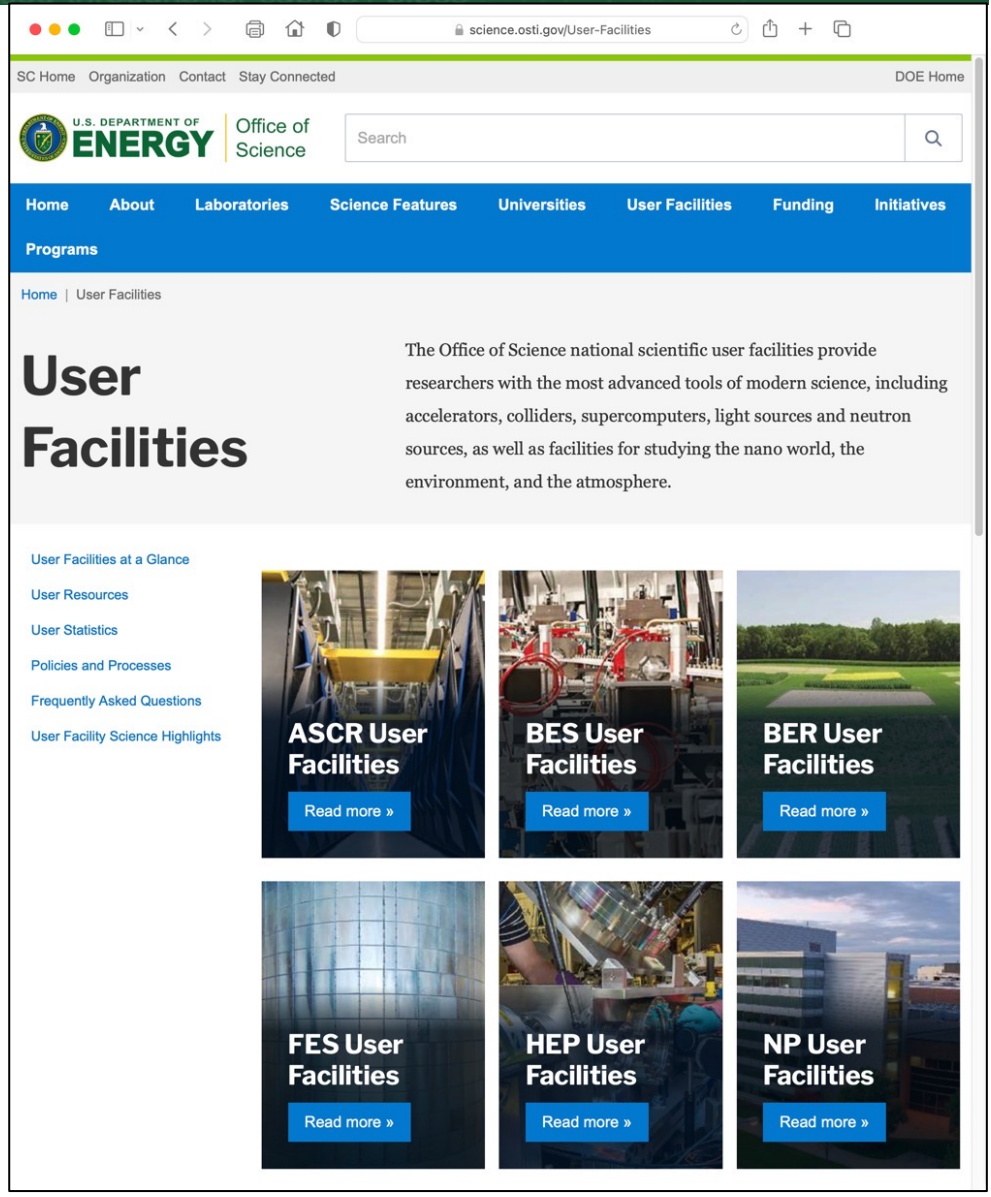
- Expands DOE User Facility portfolio to incl underground lab, raises SURF's stature within DOE community.
- Promotes underground science in U.S., increases funding opportunities.
- Enhances SURF's role in global science community.
- Communicates SURF is open to a broad range of science and users and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



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 – *Neutron bkgds*

Biology

- Astrobiology/DeMMO – *In-situ culture, isolate DNA*
- 2D Best – *Biofilms*
- Biodiversity – *Microbial communities*
- Biofuels – *Extremophile bioprospecting*
- m-sense – *Microbes and environment*
- Chemistry – *Env characterization*
- Liberty BioSecurity* – *Extremophiles*
- Plant Growth – *Low EM, cosmic ray muons*

Geology

- CUSSP – *Geothermal*
- 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

- AMD (was Xilinx, Inc)* – *Chip error testing*
- Thermal Breakout – *In-situ stress*
- Shotcrete – *Mining safety*
- Enviro Monitoring – *Ventilation airflow*
- Caterpillar* – *Mining technology*
- MAP – *Microbe-assisted phytoremediation*

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

* Denotes proprietary group

Significant interest from others
(26 groups in 2023)

Also Science Programs for Students: 2x DOE RENEW, 1x NSF REU

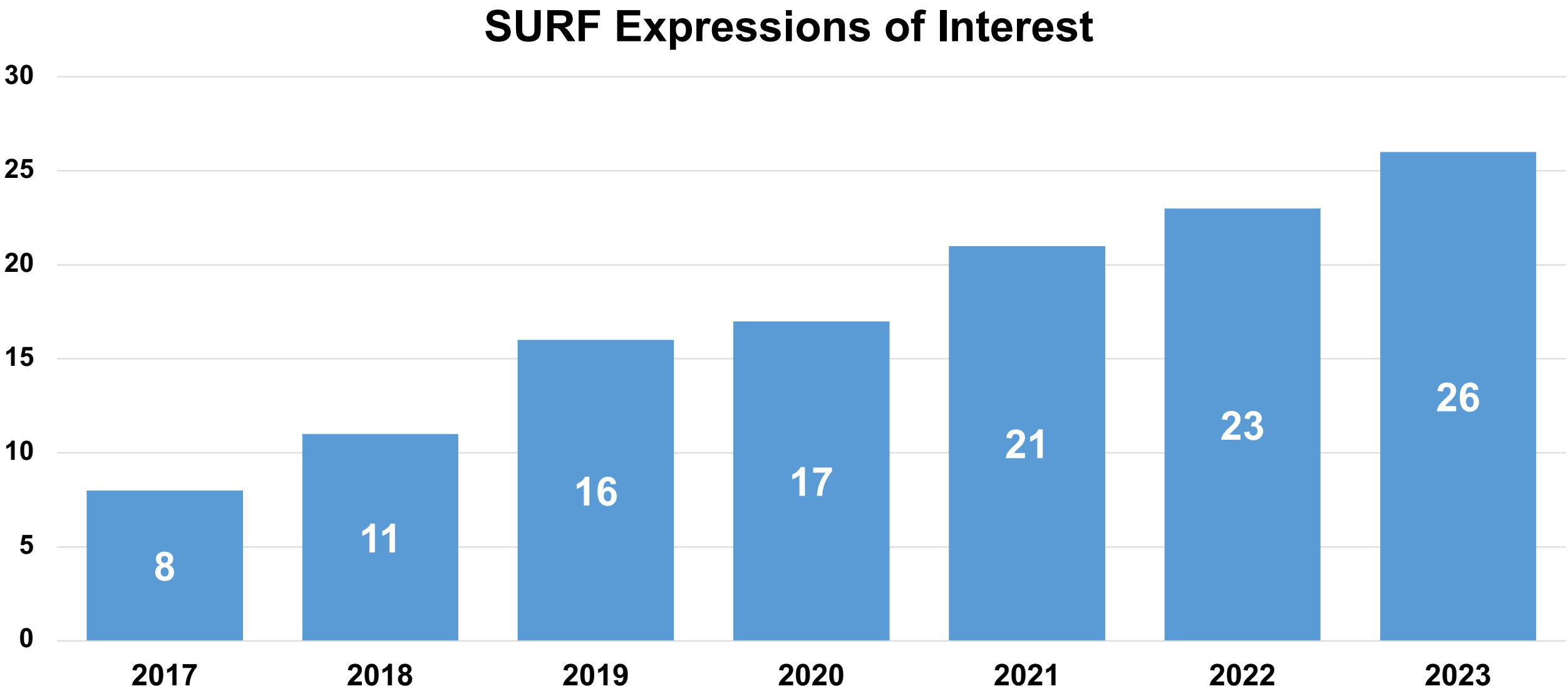
SURF High-Impact Science

Hundreds of papers have been published on science at SURF

- 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.
- Geological activity shapes the microbiome in deep-subsurface aquifers by advection, Y. Zhang, R.N. Horne, A.J. Hawkins, J.C. Primo, O. Gorbatenko, A.E. Dekas, *PNAS* **119**, 2113985119 (2022) doi: 10.1073/pnas.2113985119.
- 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) *Phys. Rev. Lett.* **131**, 041002 (2023) doi: 10.1103/PhysRevLett.131.041002.
- Constraints on the Decay of ^{180m}Ta, I. J. Arnquist *et al*. (MAJORANA Collaboration), *Phys. Rev. Lett.* **131**, 152501 (2023) doi: 10.1103/PhysRevLett.131.152501.
- Exotic Dark Matter Search with the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration) *Phys. Rev. Lett.* **132**, 041001 (2024) doi: 10.1103/PhysRevLett.132.041001.
- Search for Charge Nonconservation and Pauli Exclusion Principle Violation with the MAJORANA DEMONSTRATOR, I. J. Arnquist *et al*. (MAJORANA Collaboration), *Nat. Phys.* (2024) doi: 10.1038/s41567-024-02437-9.

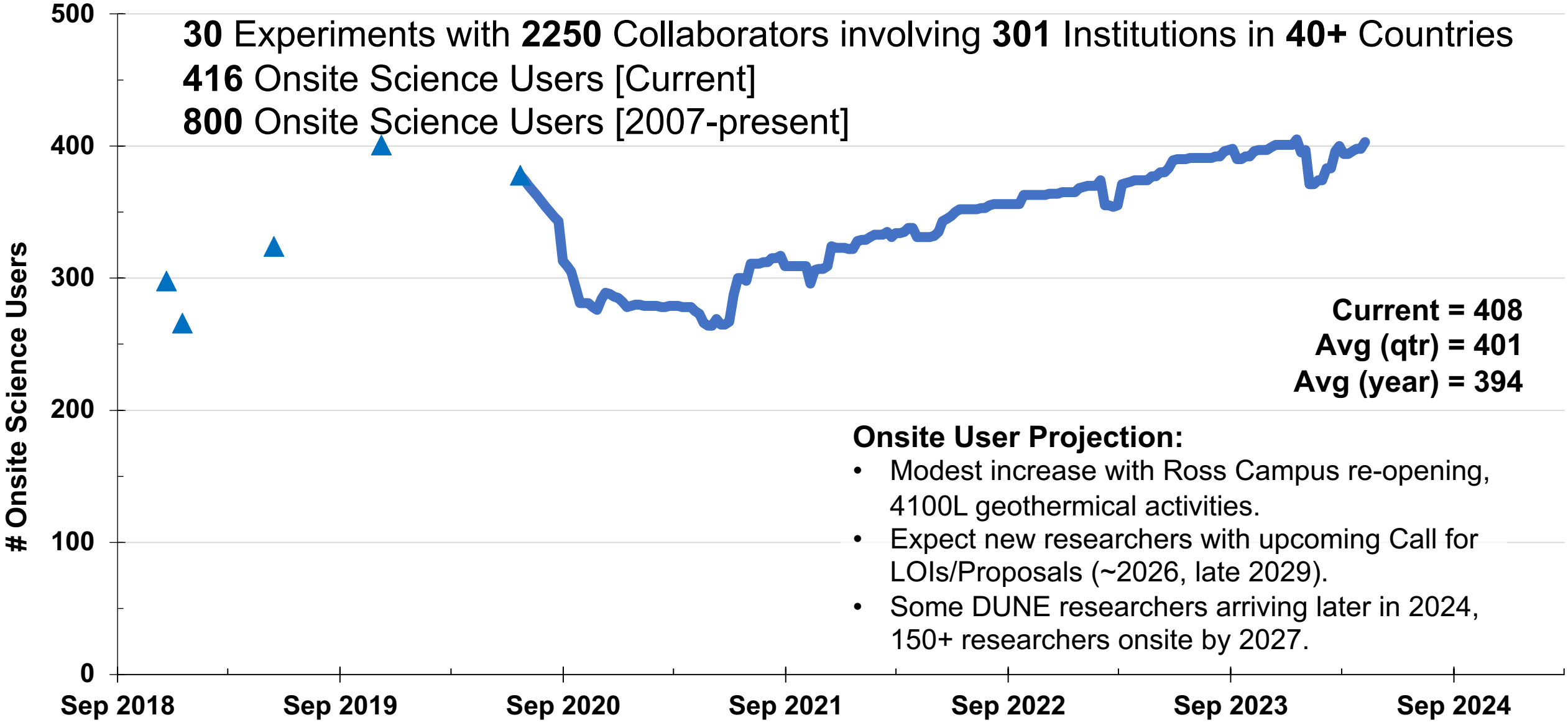
SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



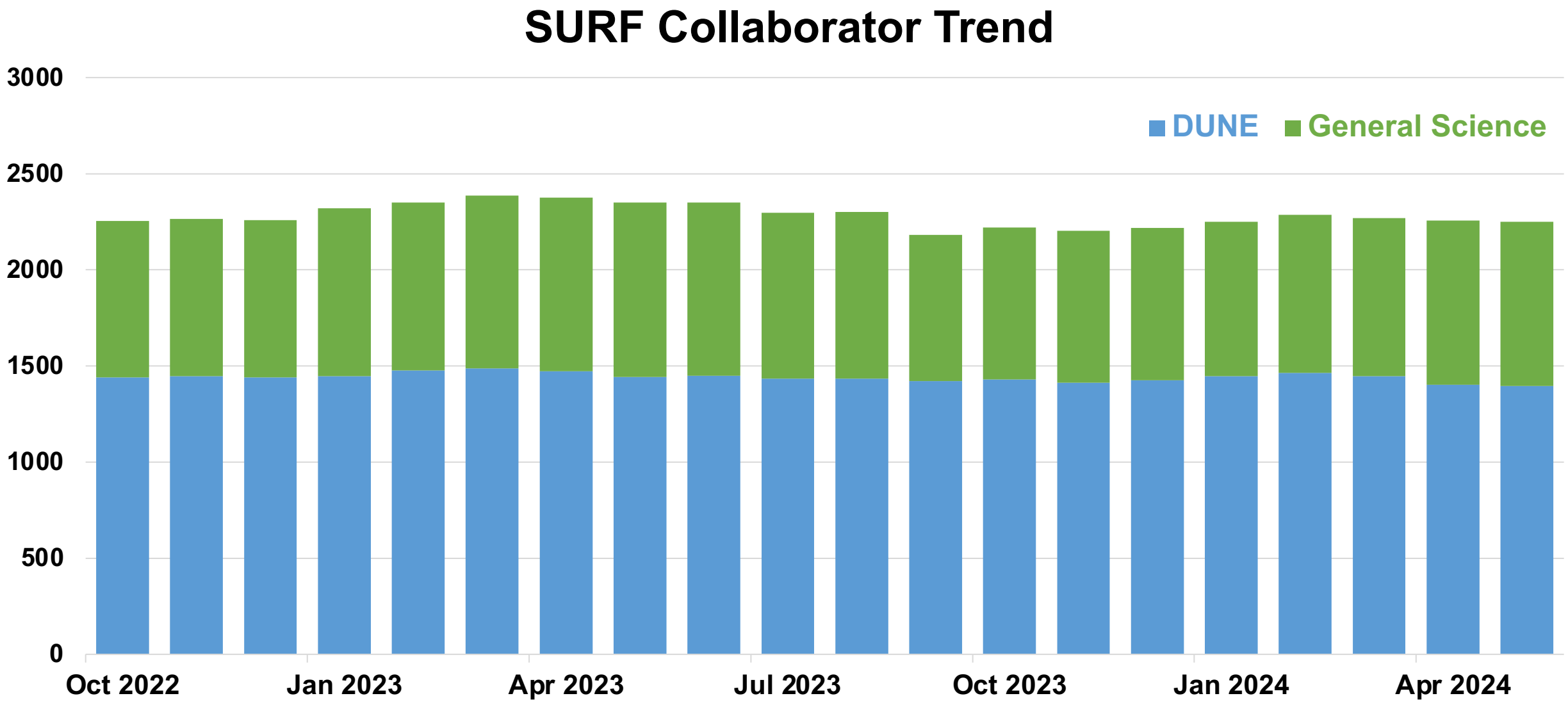
SURF Onsite Users

Opportunity for more engagement with UG science community



SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



SURF User Association

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

Purpose

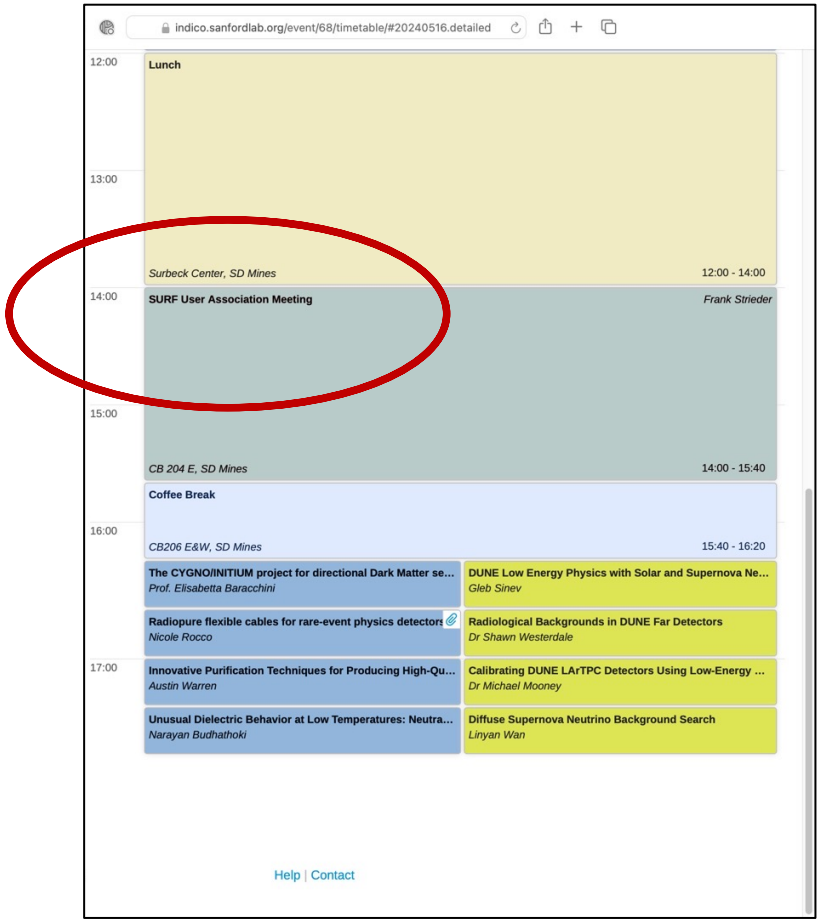
- **Two-way communication** on topics important to researchers.
- Promotes a **sense of community** amongst SURF experiments and researchers.
- Articulates and promotes **scientific case for UG science** and significance to society, provides channel for **advocacy**.

Organization

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

Meetings

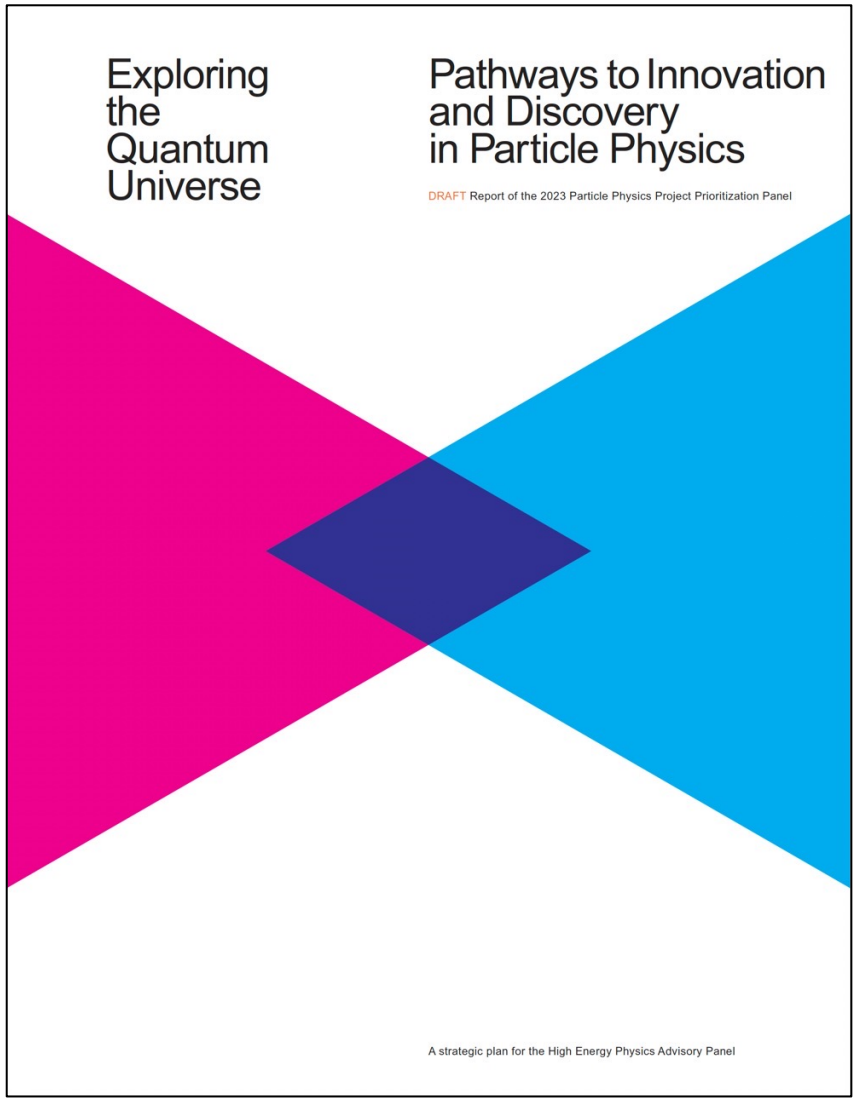
- **General meetings** typically held annually, session planned for CoSSURF (May 16, 2024).
- **Topical workshops**, incl community planning (e.g., Vision Workshop 2021). Next workshops 2024/2025.



May 16, 2024:
SURF User Association Session During CoSSURF
https://indico.sanfordlab.org/event/68/timetable/ - 20240516.detailed

2023 Particle Physics Strategic Plan

New 10-year goals established within globally-aware 20-year vision



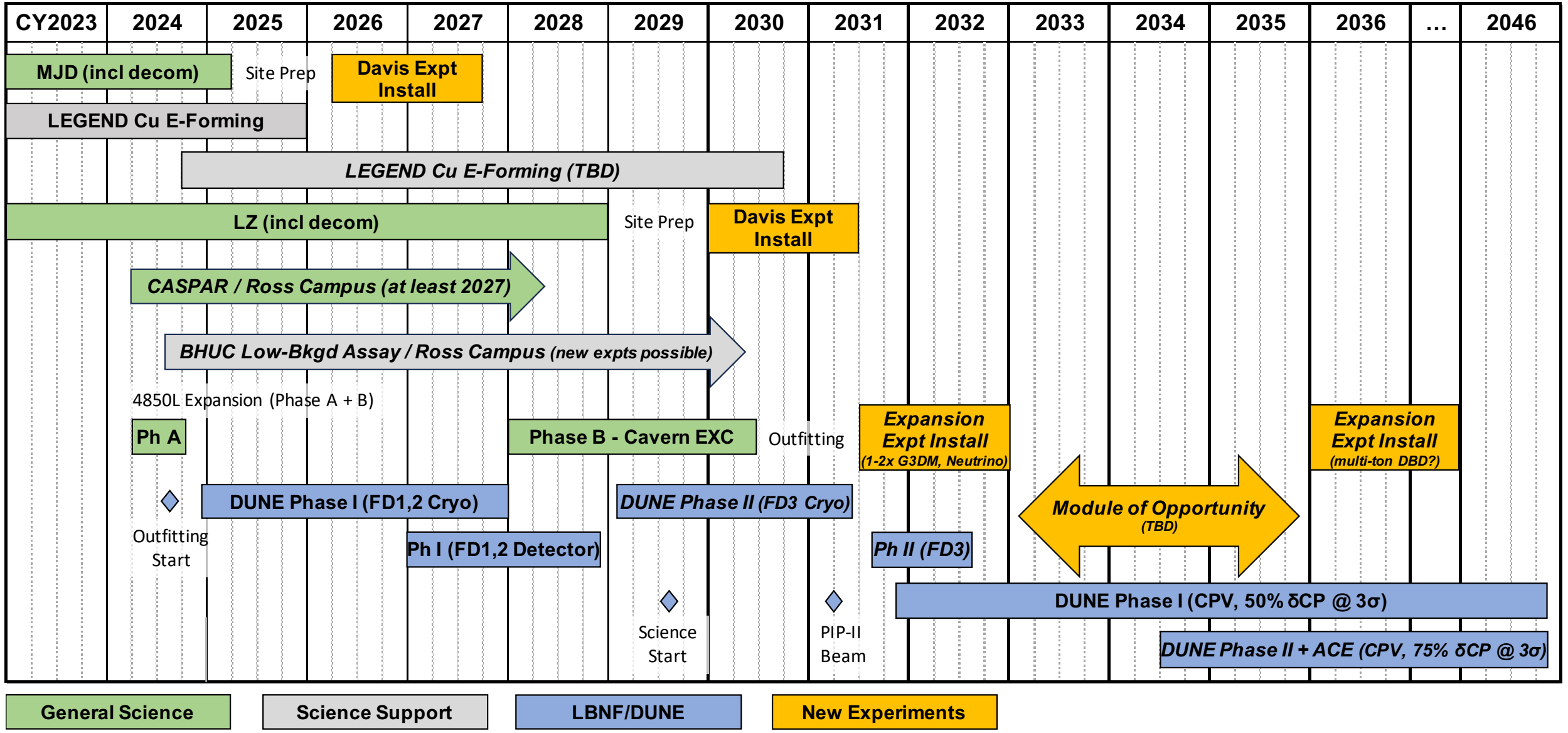
2023 P5

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" conducted through 2022
- Snowmass recommendations to P5 (Jan 2023):
  - ***LBNF/DUNE*** *Phase I & II and PIP-II*
  - *Leverage LBNF to* ***increase underground space at SURF***
  - *Designate SURF as a formal U.S.* ***DOE User Facility***
- P5 recommendations to DOE/NSF (Dec 2023):
  - *"With SURF, the U.S. has created a premier underground laboratory"*
  - ***LBNF/DUNE*** *Phase I & II and PIP-II (also "Module of Opportunity")*
  - ***G3 dark matter*** *experiment (at least one), preferably sited at SURF*
  - ***Fund SURF expansion outfitting*** *for neutrino & dark matter expts*

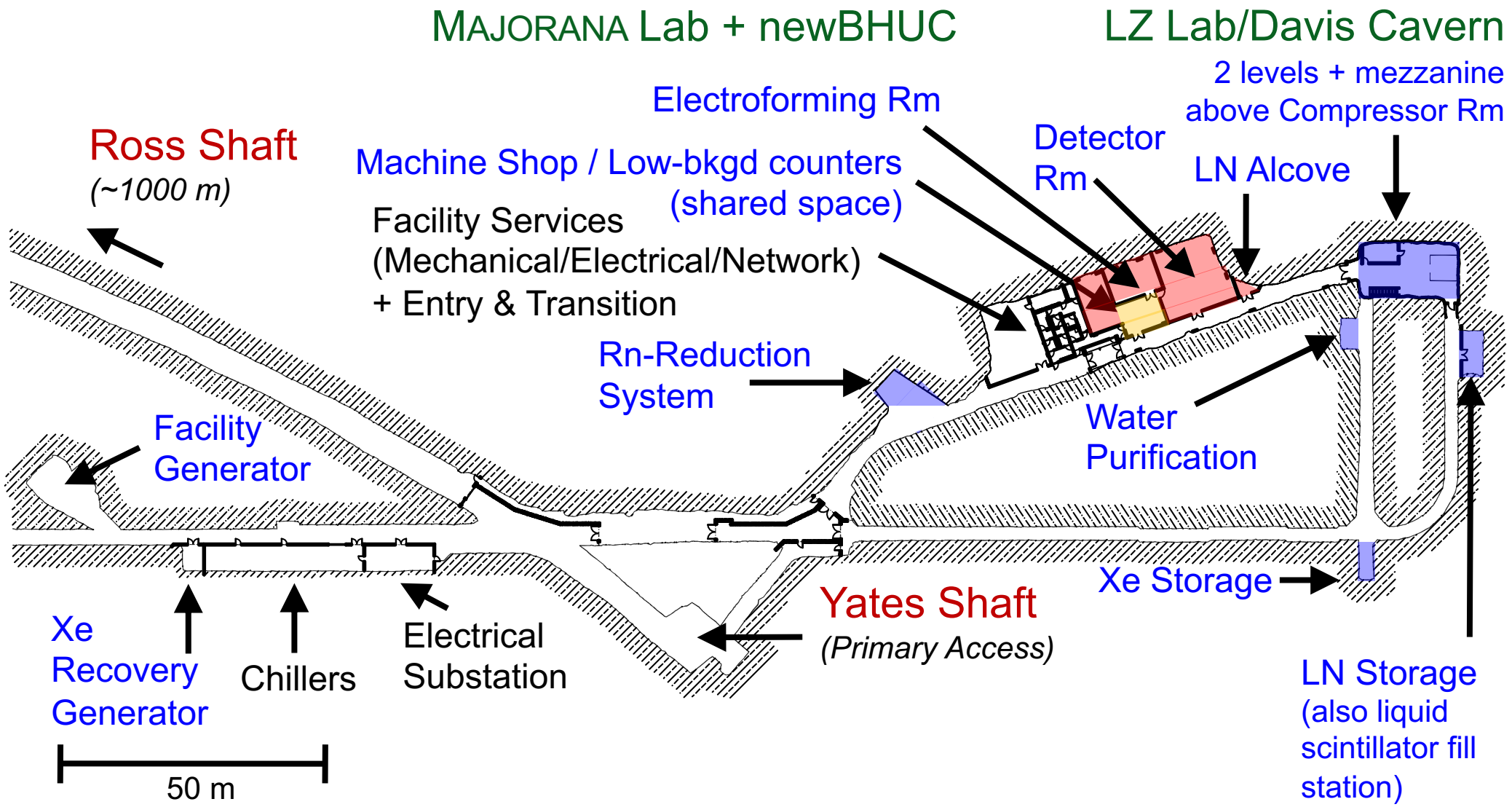
SURF Science Strategic Planning

Timeline



4850L Davis Campus

3,017 m² (Total) / 1,018 m² (Science)



SURF Designated APS Historical Site

Announcement Sep 2020, Dedication May 2022

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

INTERACTIONS.ORG
PARTICLE PHYSICS NEWS AND RESOURCES

Home | About | News | Physics Hubs | Fighting COVID-19 | Subscribe to Newswire

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

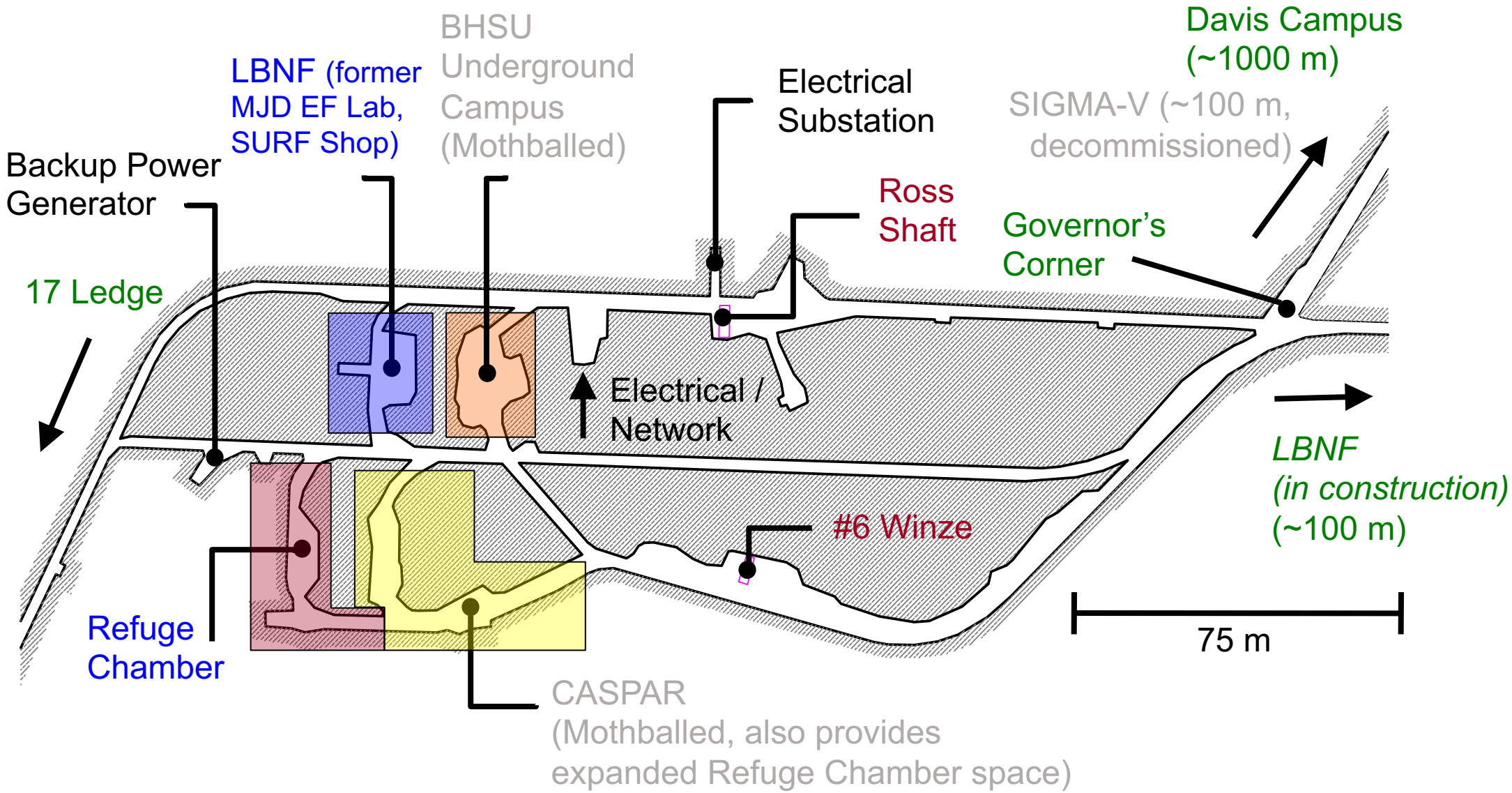
SOURCE:
Sanford Underground Research Facility

CONTENT:
Press Release

CONTACT:
Constance Walter
Communications Director
cwalter@sanfordlab.org

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 2024

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

2015-2021, resume 2024

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 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	~2028	LZ data complete early ~2028 + decommissioning
	MJD Lab – 2 Rooms + BHUC share	300	1,279	~2025+/2026+	Initial scope completed 2021, Ta-180m data 2022-24 + decommissioning; Cu e-forming through 2025+
	Cutout Rooms (4)	100	412	~2028	LZ timeframe for most spaces
Ross Campus (4850L)	Former E-forming	228	742	?	LBNF use currently, likely unavailable for several yrs
	BHUC (BHSU cleanroom)	266	773	N/A	Mothballed, equip and systems relocated to Davis Campus; re-occupy 2024 after LBNF excavation
	CASPAR	395	1,130	2027+	Mothballed, equip remains, re-occupy 2024 after LBNF excavation. (Also expanded Refuge Chamber)
	Refuge Chamber	258	866	?	Long-term use TBD
LBNF (4850L)	*LBNF*	*9,445*	*191,863*	*?*	*Excavation complete in Mar 2024*
4100L	Geoscience Lab	334	11 drill holes	2025	DEMO-FTES use 2023-2024, CUSSP 2024-2027
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 Experiment Implementation & Support

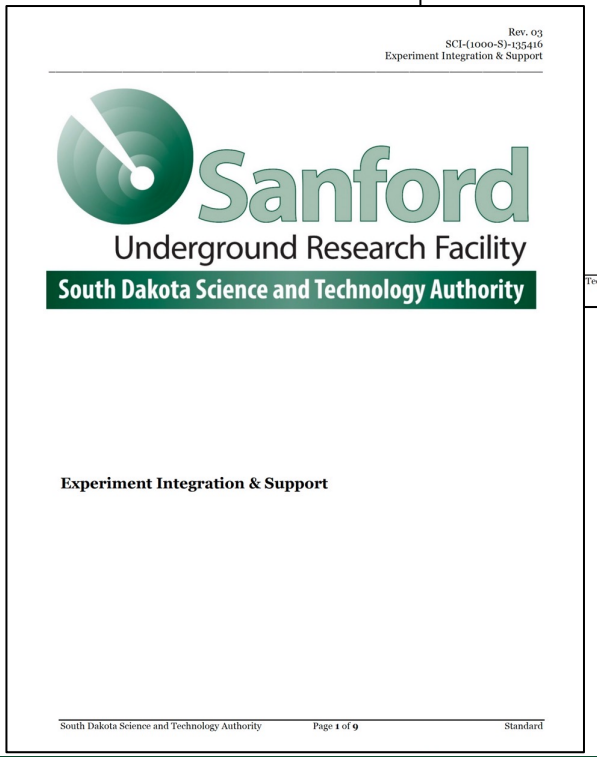
Main Science documents under IMS document control

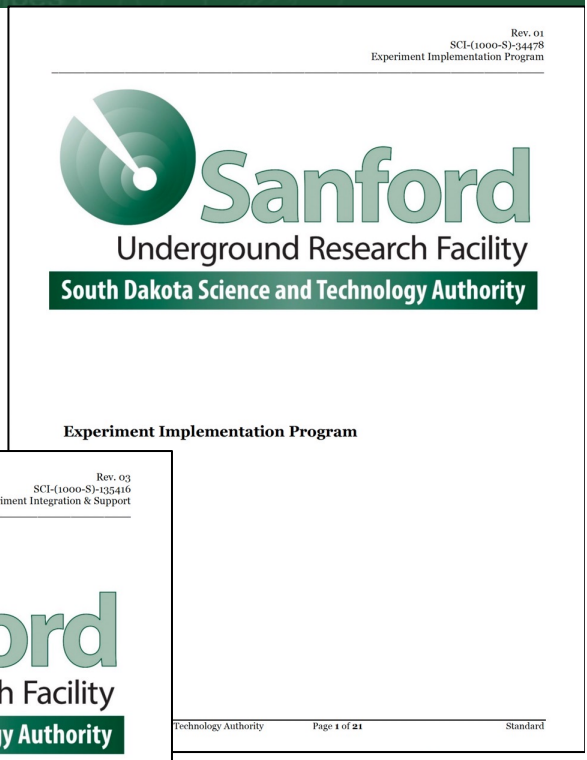
Experiment Implementation Program (EIP)

- Integral to the SDSTA institutional mission is advancement of compelling underground, multidisciplinary research
- EIP framework allows experiments to be implemented at SURF in effective and efficient manner
- References several key elements:
  - Experiment Planning Statement
  - User Agreement
  - Publication Policy
  - Experiment Decommissioning Statement

Experiment Integration & Support

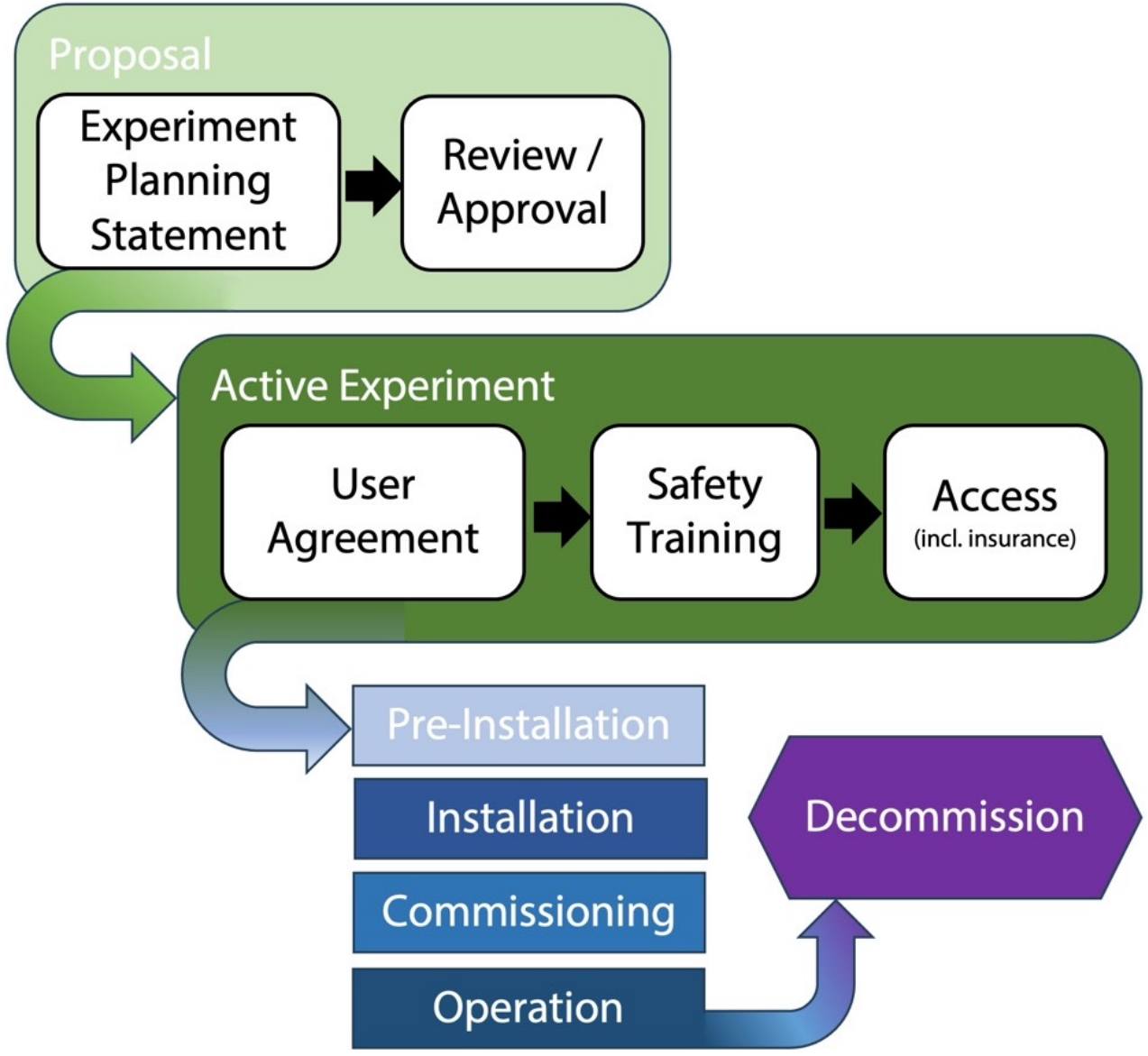
- In partnership with research groups, SDSTA aims to maintain a robust organization with resources to promote safe and successful experiment operations at SURF
- References several key elements:
  - Several specific ESH Standards (incl WPC)
  - SURF Applications/Databases (TAP, SARF, etc)
  - Table of responsibilities (SDSTA and Experiment)
  - Perception Survey, Information for Researchers Wiki, etc



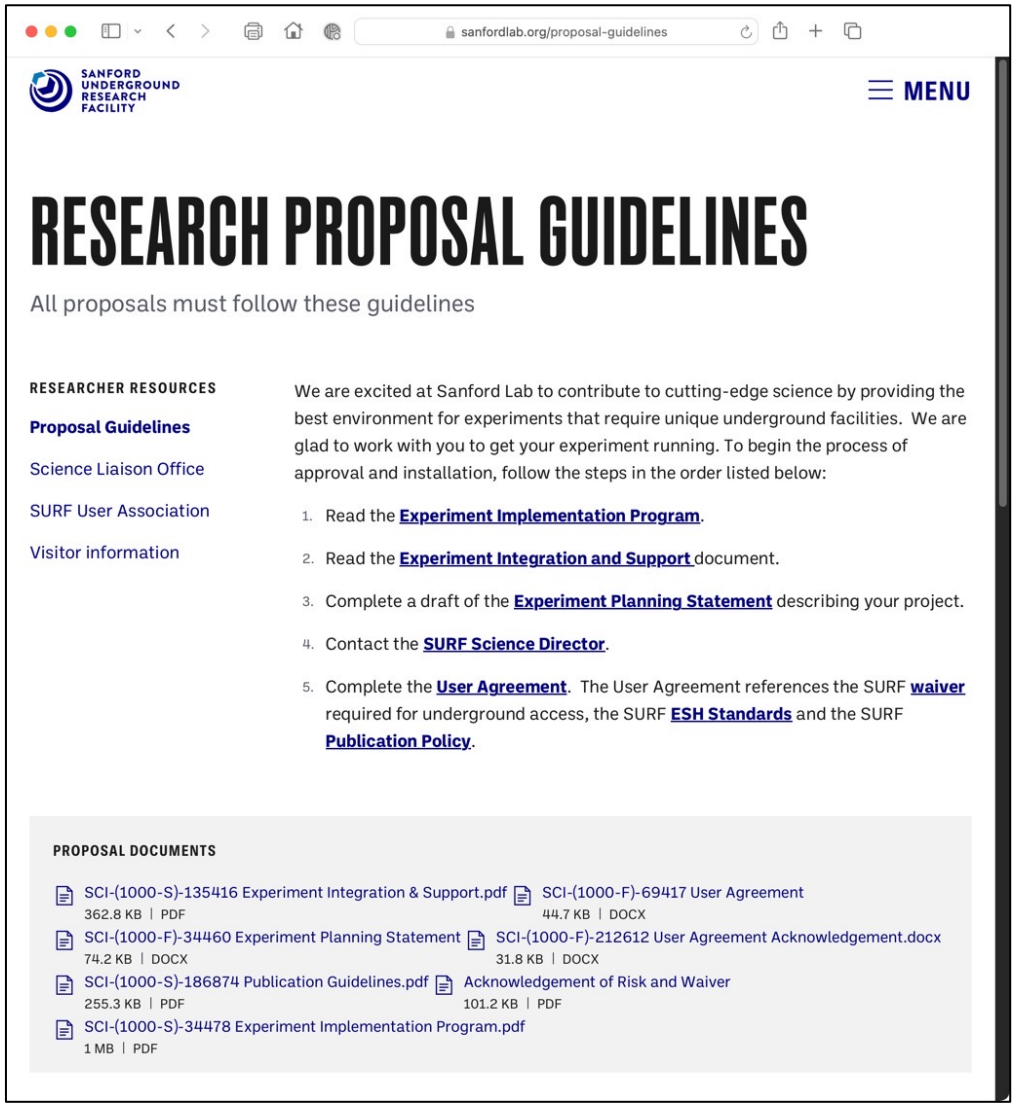


SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework



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



SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework

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

Rev. 02
SCI-(1000-F)-34460
SURF Experiment Planning Statement

Project Name

Date Submitted: **mm/dd/yyyy**

Status: ☐ Preliminary (Expression of interest, Support letter request) ☐ Formal implementation request ☐ Update

1. Project Summary

Discipline: ☐ Physics ☐ Biology

Project Description
Provide a brief project description, including purpose, scientific merit

IDEA – Inclusion, Diversity, Equity and Access
SDSTA is committed to creating a culture that centers on inclusion, d
and stakeholders embody SDSTA's commitment to IDEA as both a r
considerations in these areas.

South Dakota Science and Technology Authority

Rev. 02
SCI-(1000-F)-34460
SURF Experiment Planning Statement

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

Research Category (SDSTA determination based on user input)	☐ Non-proprietary	☐ Proprietary		
Experiment Implementation Program Requirements Additional documentation requirements.				
Required for all Experiments:	☐ User Agreement (UA)	☐ Insurance (General Liability, Workers' Compensation)		
Services Agreements:	☐ General Services Agreement (GSA)	☐ Contract		
Environment, Safety & Health Requirements Based on the information provided in the Experiment Planning Statement, the following training, documentation, and reviews are warranted.				
Hazard Analysis:	☐ (JHA/SOP required for most activities)			
Minimum Training:	☐ Orientation (surface and/or underground)	☐ General Safety – Basic (and subsequent Annual Refresher Training (ART))		
Other Training:	☐ SDSTA: _____	☐ Non-SDSTA: _____		
Inventories:	☐ Chemicals ☐ Electrical	☐ Hoisting & Rigging	☐ Pressure Vessels	☐ Radioactive Materials
Assessment Documents:	☐ Experiment Hazard Assessment Summary (EHAS), incl additional training	☐ Quantitative Analysis – Mechanical	☐ Quantitative Analysis – ODH	☐ Quantitative Analysis – Pressure
Reviews:	☐ Walk-through Inspection(s)	☐ Readiness Review(s)	☐ Merit Review	

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

Other Review (If applicable)	*Name*	*Date*	*Signature*
_____			
_____			

SDSTA Acceptance	*Name*	*Date*	*Signature*
SURF LABORATORY DIRECTOR			

South Dakota Science and Technology Authority Page **11** of **12** Form

Expt Planning Statement (EPS)

sanfordlab.org/proposal-guidelines

SANFORD UNDERGROUND RESEARCH FACILITY

MENU

RESEARCH PROPOSAL GUIDELINES

All proposals must follow these guidelines

RESEARCHER RESOURCES

Proposal Guidelines

Science Liaison Office

SURF User Association

Visitor information

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

1. Read the **Experiment Implementation Program**.
2. Read the **Experiment Integration and Support** document.
3. Complete a draft of the **Experiment Planning Statement** describing your project.
4. Contact the **SURF Science Director**.
5. Complete the **User Agreement**. The User Agreement references the SURF **waiver** required for underground access, the SURF **ESH Standards** and the SURF **Publication Policy**.

PROPOSAL DOCUMENTS

SCI-(1000-S)-135416 Experiment Integration & Support.pdf 362.8 KB | PDF
SCI-(1000-F)-69417 User Agreement 44.7 KB | DOCX
SCI-(1000-F)-34460 Experiment Planning Statement 74.2 KB | DOCX
SCI-(1000-F)-212612 User Agreement Acknowledgement.docx 31.8 KB | DOCX
SCI-(1000-S)-186874 Publication Guidelines.pdf 255.3 KB | PDF
Acknowledgement of Risk and Waiver 101.2 KB | PDF
SCI-(1000-S)-34478 Experiment Implementation Program.pdf 1 MB | PDF

The Institute for Underground Science at SURF

THE INSTITUTE
FOR UNDERGROUND SCIENCE
AT SURF

KNOWLEDGE.
PEOPLE. PLACE.

BENEATH THE BLACK HILLS of South Dakota, researchers advance the future of world-leading science. The Institute for Underground Science at SURF will unite today's research and tomorrow's discoveries.

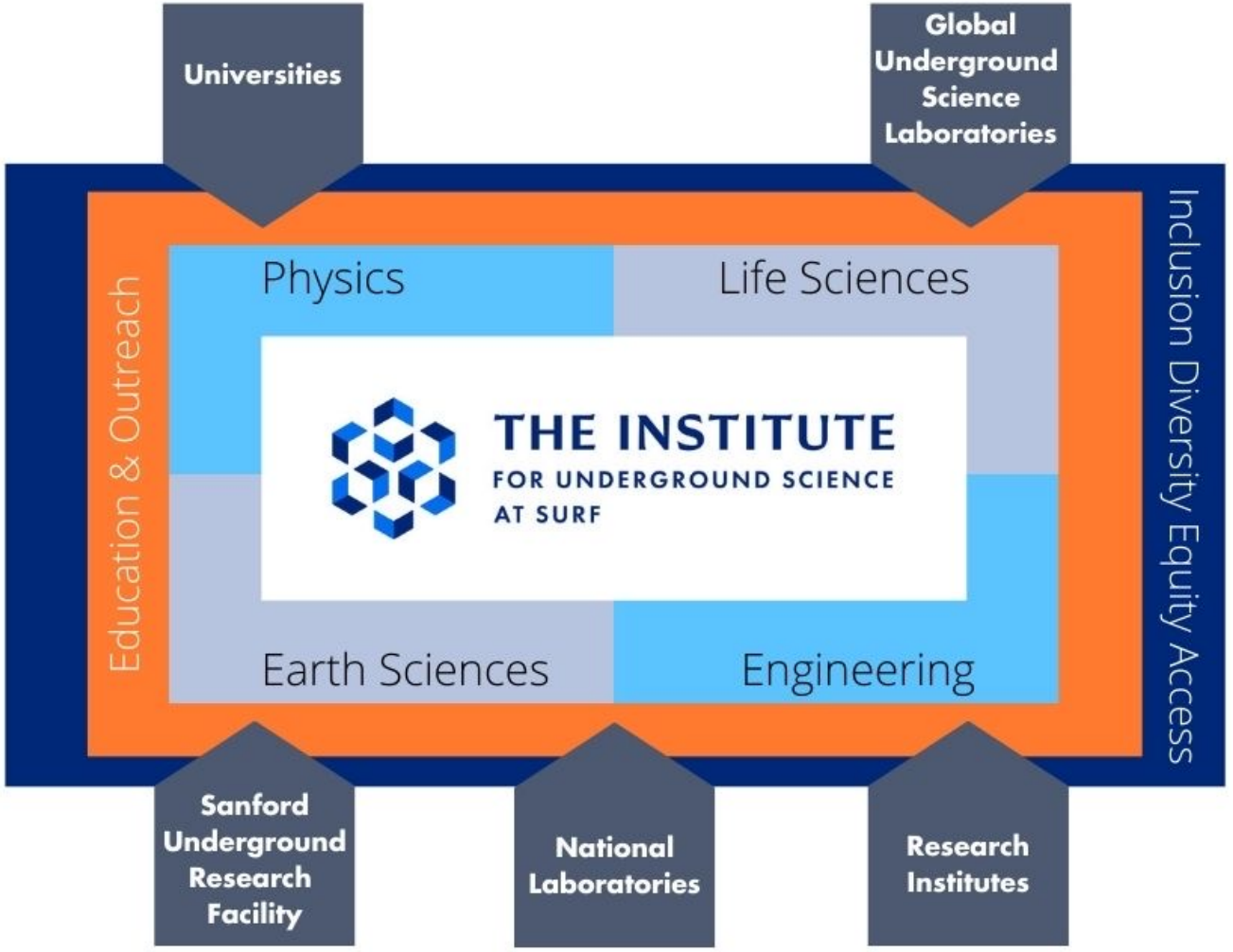
The Institute for Underground Science at SURF

Goal: The Institute for Underground Science at SURF constructed by Sep 2035

Institute for Underground Science at SURF

Kick-off held December 14, 2023

- Establish a 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 a “hub” for information on global underground science.
- Foster close collaboration and integration with the science and outreach programs.
- Establish world-leading programs in K-12 and public Education & Outreach.



Institute for Underground Science at SURF

CETUP* Topical Workshop held summer 2023! Registration underway for 2024

indico.sanfordlab.org/event/53/

Public | US/Mountain | J. Heise

THE INSTITUTE FOR UNDERGROUND SCIENCE AT SURF

CETUP* 2023

19 June 2023 to 14 July 2023
Lead/Deadwood Middle School
US/Mountain timezone

Enter your search term

- Overview
- Call for Abstracts
- Timetable
- Contribution List
- Book of Abstracts
- Registration
- Organizing Committee
- Participant List
- General Information
- Travel Information
- Accommodations
- Dining

Organizing Committee (CETUP* 2023)
cetup2023@sanfordlab....

CETUP* 2023, Hosted by The Institute for Underground Science at SURF

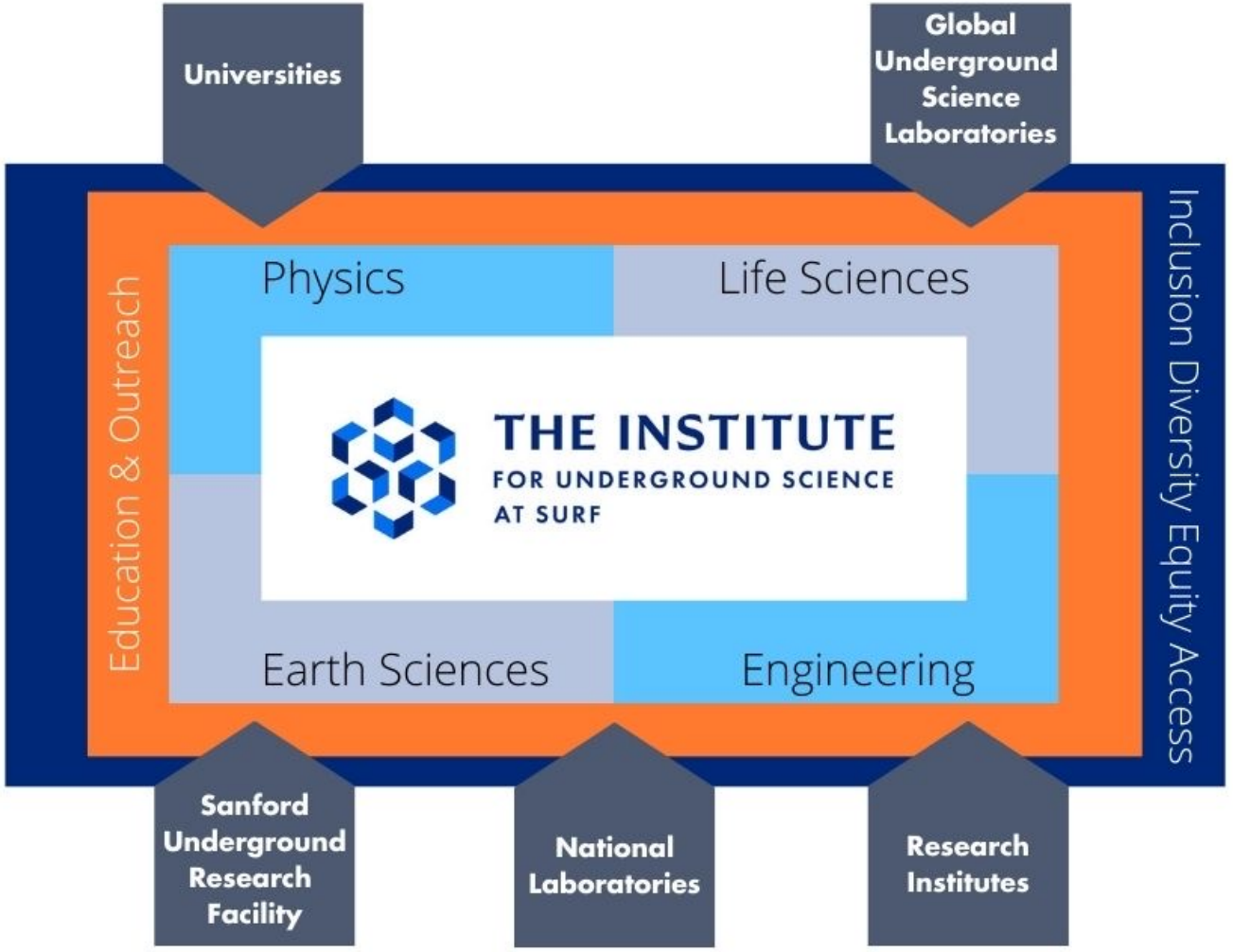
Around the globe more than 20 underground laboratories provide space for experiments in nuclear and particle physics, astrophysics and cosmology as well as geosciences, drawing scientists from all over the world. In response to the growing interests in underground science, the Center for Theoretical Underground Physics and Related Areas (CETUP*) brings together scientists working in theoretical and experimental aspects of a variety of disciplines during its annual workshop.

CETUP* provides a stimulating environment for creative thinking and open discussion. Researchers with varying experience, and from different countries and scientific backgrounds collaborate to attract rising young scientists to participate. The combined expertise allows this intellectual community to address the most pressing questions in fundamental research:

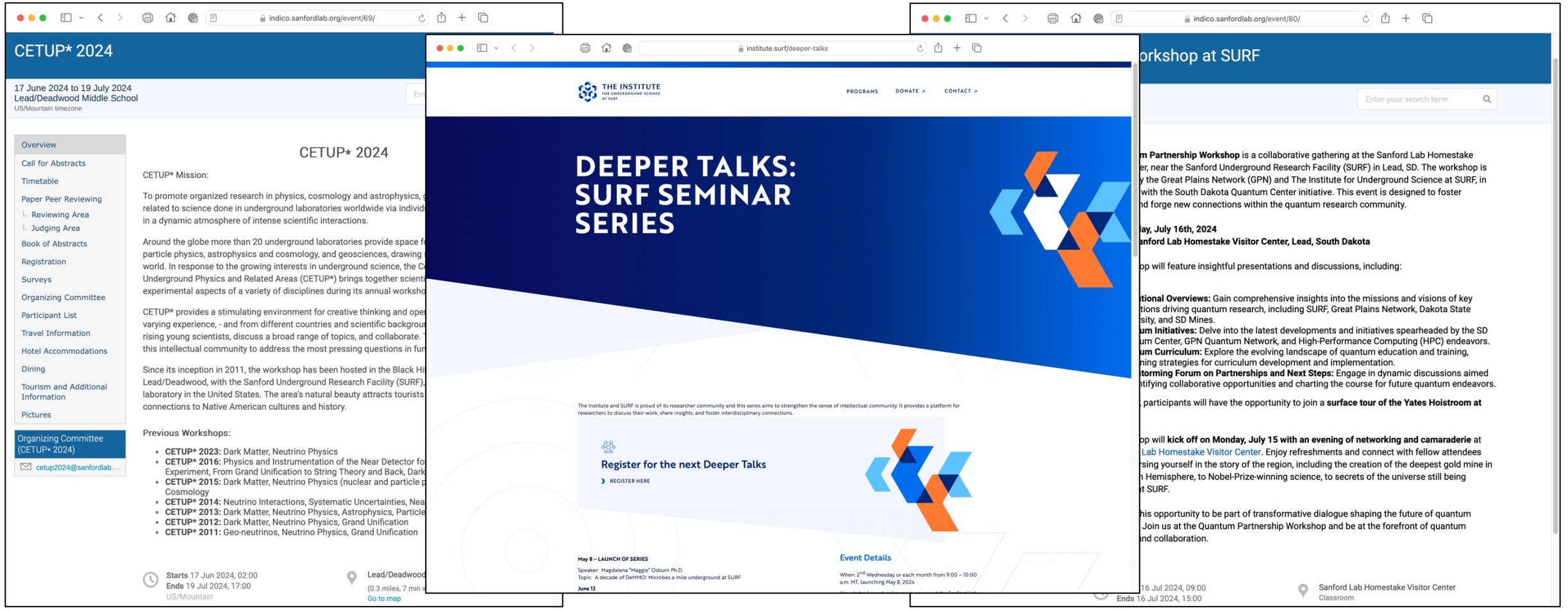
- What is the nature of dark matter?
- What is the origin of neutrino masses?
- How have neutrinos shaped the evolution of the universe?
- How do supernovae explode?
- What is the origin of the matter-antimatter asymmetry in the Universe?

Since its inception in 2011, the workshop has been hosted in the Black Hills of South Dakota in Lead/Deadwood, near the Sanford Underground Research Facility (SURF), which is the deepest underground laboratory in the United States. The area's natural beauty attracts tourists year-round, and has strong connections to Native American culture and history.

This year CETUP* returns under the auspices of the Institute for Underground Science at SURF. The Institute will be a global center for collaboration and intellectual community focused on underground science for the international underground research community. CETUP* is one of the Institute's first science-focused endeavors.



Upcoming Events – Workshops



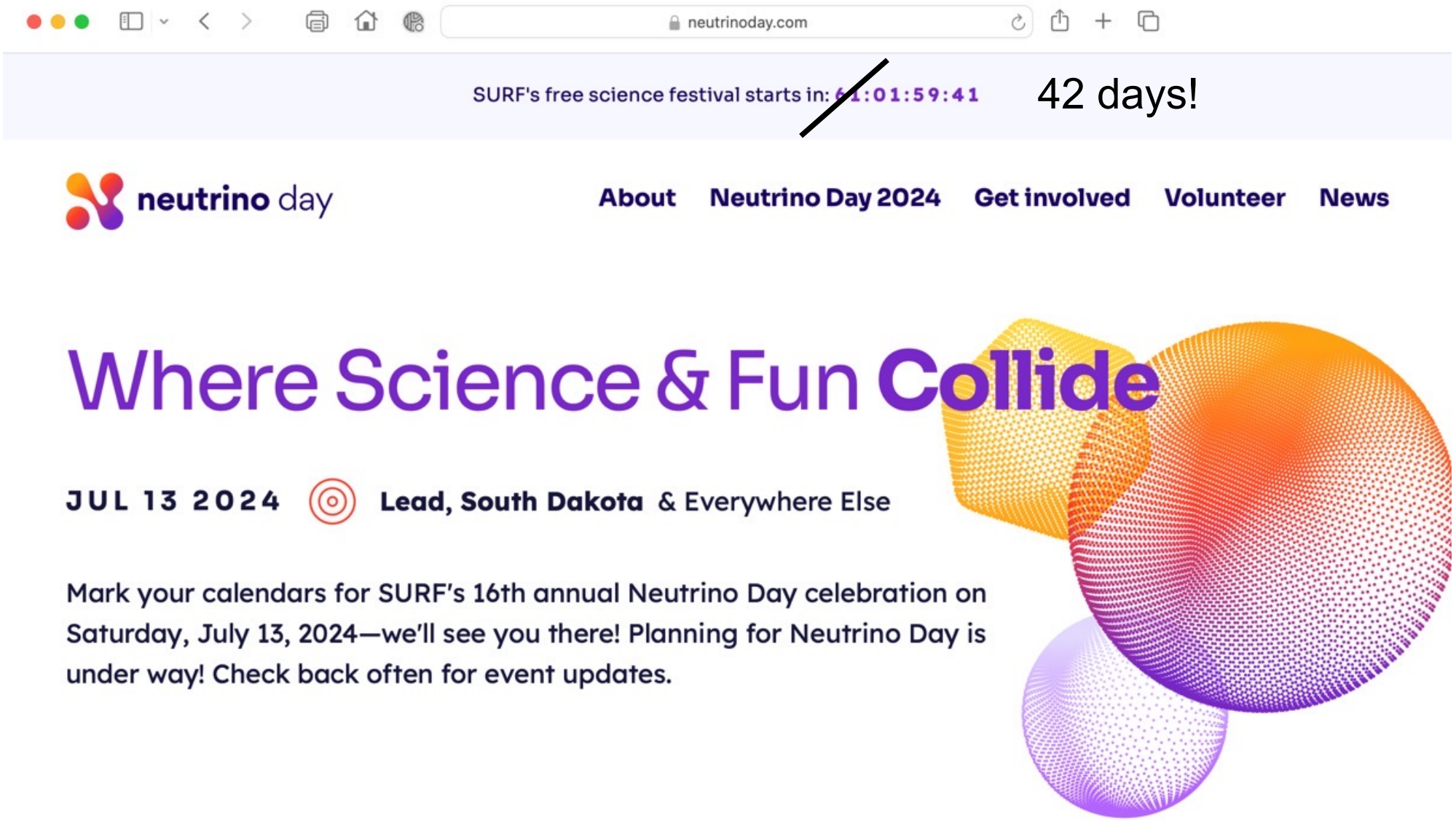
Jun 17-Jul 19, 2024:
CETUP* 2024
https://indico.sanfordlab.org/e/CETUP2024

Monthly Seminar Series
https://institute.surf/deeper-talks

Jul 16, 2024:
Quantum Partnerships Workshop
https://indico.sanfordlab.org/event/80

Upcoming Events – Neutrino Day

July 13, 2024 (http://www.neutrinoday.com)



SURF Long-Term Goals

By 9/30/2035, SURF will have world-leading multi-disciplinary experiments in operations with proposed experiments actively competing for newly developed underground laboratory space including:

1. The Long-Baseline Neutrino Facility (LBNF) and Deep Underground Neutrino Experiment (DUNE) have been constructed and are fully operational.
2. Yates Shaft and Hoists have been fully reconstructed and modernized.
3. Two additional large lab modules on the 4850L have been constructed and are fully operational.
4. The Institute for Underground Science at SURF has been constructed and is fully operational with compelling, vibrant science and education programs.
5. Foster commercial partnerships to advance technology development in the region, increase facility operations efficiency and safety, and expand workforce development opportunities.

Sanford Underground Research Facility

SURF Mission:

We advance world class science and inspire learning across generations.

SURF Vision:

The world's preferred location for underground science and education.

SURF serves the entire underground science community.

SURF welcomes and encourages research from all disciplines that are able to take advantage of the unique attributes of our laboratory.