

# SURF Science Overview

Jaret Heise, Science Director

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SURF Higher Education  
Connections Workshop  
April 4, 2024



**Sanford**

Underground Research Facility

South Dakota Science and Technology Authority



# Jaret Heise – Science Director

- **15 years** SDSTA Science Director
- **20 years** science management experience
- **28 years** experience in underground science

Participation in Sudbury Neutrino Observatory (SNO) experiment (6800-ft level of active nickel mine, now SNOLAB), which resolved Solar Neutrino Problem first posed by Ray Davis Homestake Chlorine Experiment

- Univ BC PhD Student at SNO  
(detector construction, supernova neutrino search)
- LANL Postdoctoral Researcher at SNO  
(led neutron detector installation)
- Queen's Univ SNO Detector Operations Manager  
(member of onsite management team)





# SURF Science Program

## SURF serves a diverse community:

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





# SURF's Road to Multi-Disciplinary Science

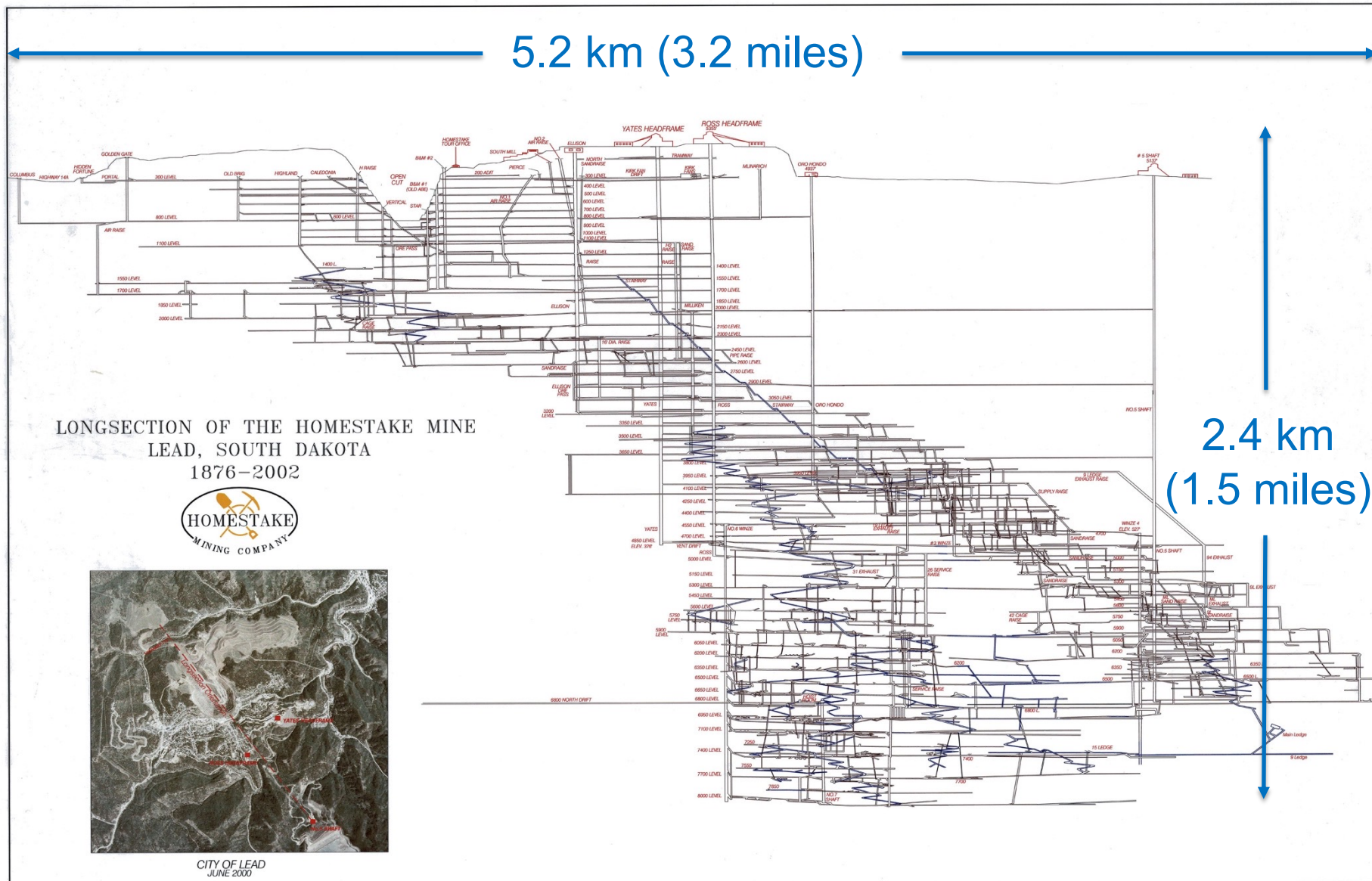
## Broad science program right from the start

- South Dakota and Black Hills Roots:
  - **Agriculture** is largest economic sector in state, many universities have strong biology departments & faculty
  - Locally, Black Hills region has strong ties to **mining/geology**; leveraged some industrial connections, also some early biology sampling during Homestake operations
  - Geographically near other interesting sites (e.g., Yellowstone National Park, well-known to researchers)
- DUSEL Roots:
  - Funding strategy for national UG lab was via National Science Foundation with **broad science mandate**
  - Strong leadership from U.S. national laboratory, LBNL, with **multi-disciplinary science portfolio**
- SURF Opportunities:
  - Significant footprint with access to **variety of environments** (range of temperature and humidity, rock formations/materials, water, depth, etc)
  - Drill core **repository**, access to underground **drill holes** (and **expertise** to modify), areas of **isolated water**
- SURF Multi-Disciplinary Science:
  - Biologists on SURF User Association (incl recent chair) and Science Program Advisory Committee
  - Planning at least one biology/geology Research Scientist hire in next 2 years
  - SURF Vision Workshop 2021: “No one has successfully created a true multi-disciplinary underground lab.”  
**SURF [and other laboratories] aspire to this goal!**



# SURF Underground Lab Geography

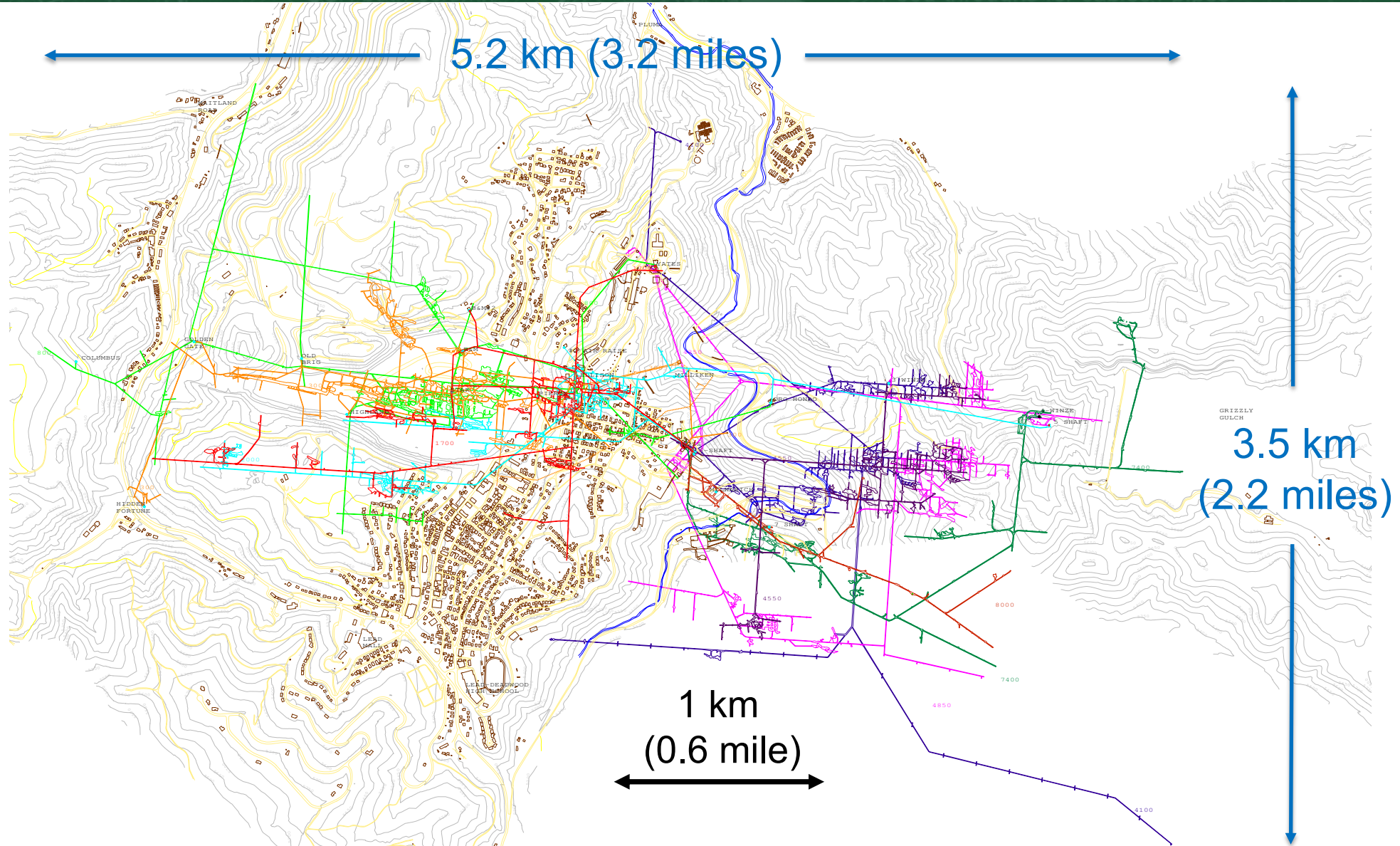
Significant underground footprint for science





# SURF Underground Lab Geography

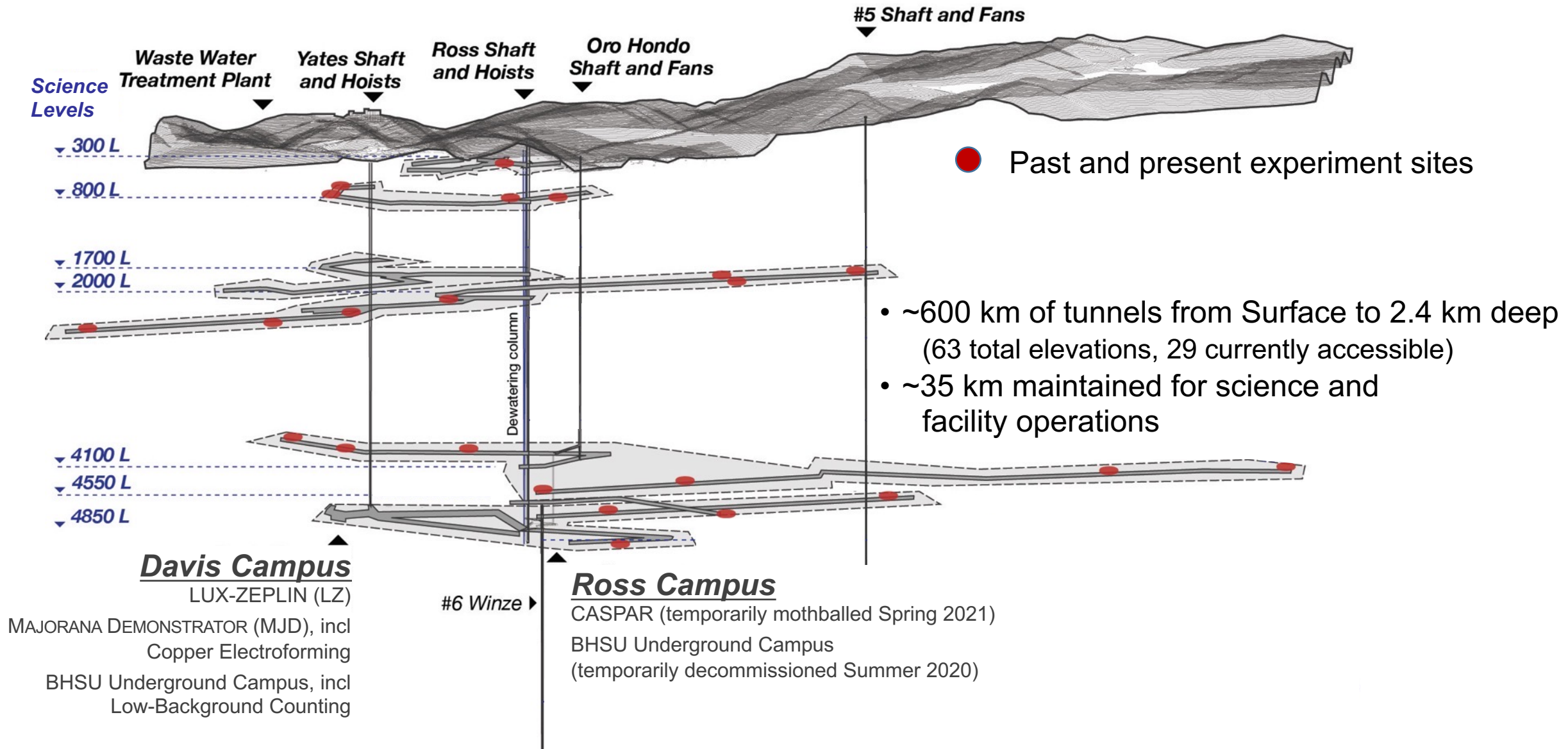
Significant underground footprint for science





# SURF Underground Lab Geography

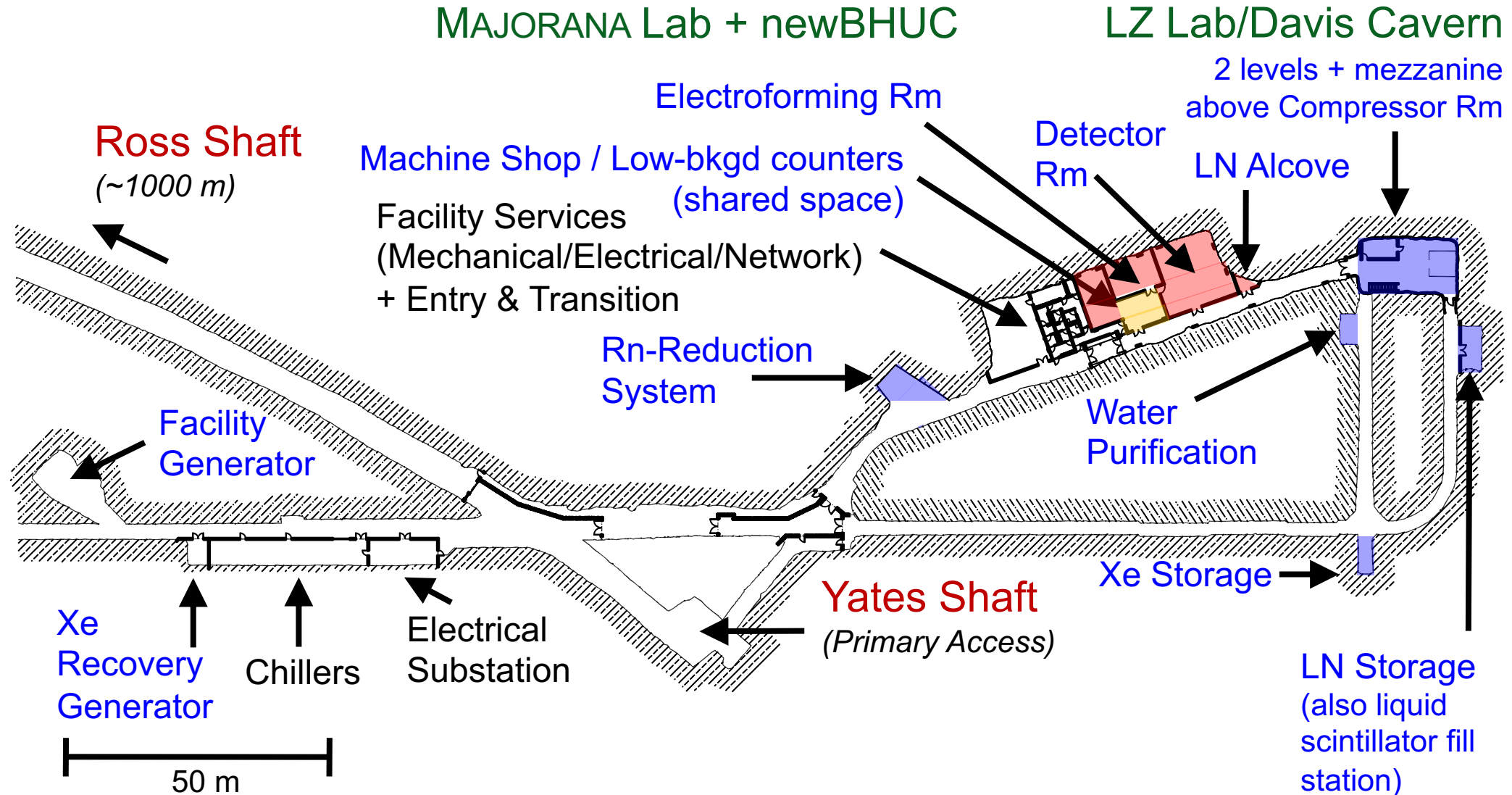
Yates & Ross Shafts + ventilation shafts, multiple levels for science





# 4850L Davis Campus

3,017 m<sup>2</sup> (Total) / 1,018 m<sup>2</sup> (Science)





# SURF 4850L Davis Campus

## Examples of laboratory space



### Detector Room (MJD):

Area = 140 m<sup>2</sup>, 11 m × 9.8-12.8 m × 2.7 m (H)  
(raised section: 5.9 m × 5.8 m × 3.2 m (H))

Sanford Underground Research Facility



### Davis Cavern, Lower (LZ):

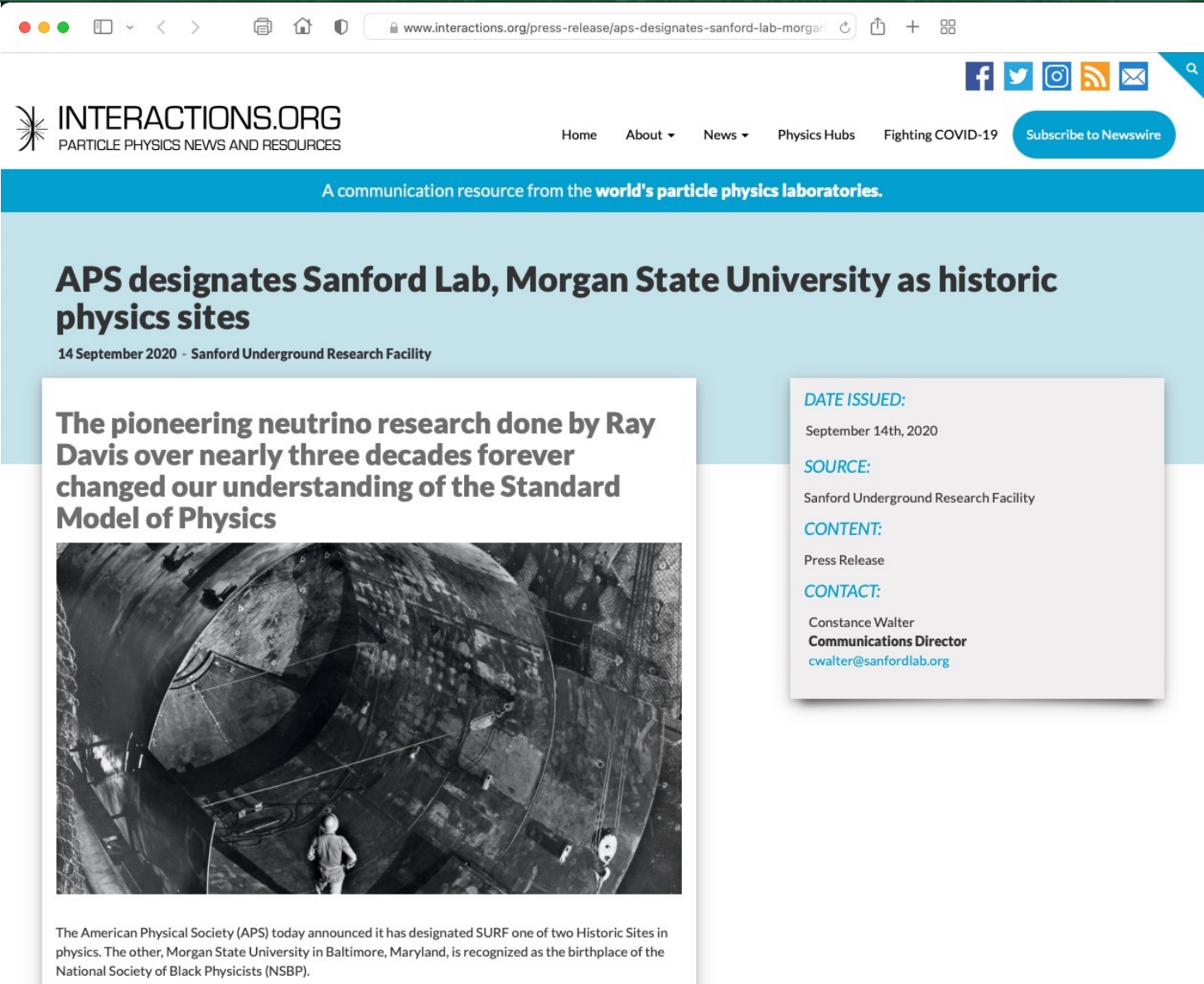
Area = 142 m<sup>2</sup>, 13.7 m × 9.1 m × 6.4 m (H)  
(incl tank: 7.6 m dia. × 6.4 m H). Total Cavern H = 10.8 m

SURF Science Overview | April 2024



# SURF Designated APS Historical Site

Announcement Sep 2020, Dedication May 2022



The screenshot shows the website interface for INTERACTIONS.ORG. The main headline reads "APS designates Sanford Lab, Morgan State University as historic physics sites" dated 14 September 2020. A sub-headline mentions "Sanford Underground Research Facility". The article features a large image of the underground facility and a text box with details: "The pioneering neutrino research done by Ray Davis over nearly three decades forever changed our understanding of the Standard Model of Physics". A metadata box on the right lists the date issued (September 14th, 2020), source (Sanford Underground Research Facility), content type (Press Release), and contact information for Constance Walter, Communications Director.

## 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

**DATE ISSUED:**  
September 14th, 2020

**SOURCE:**  
Sanford Underground Research Facility

**CONTENT:**  
Press Release

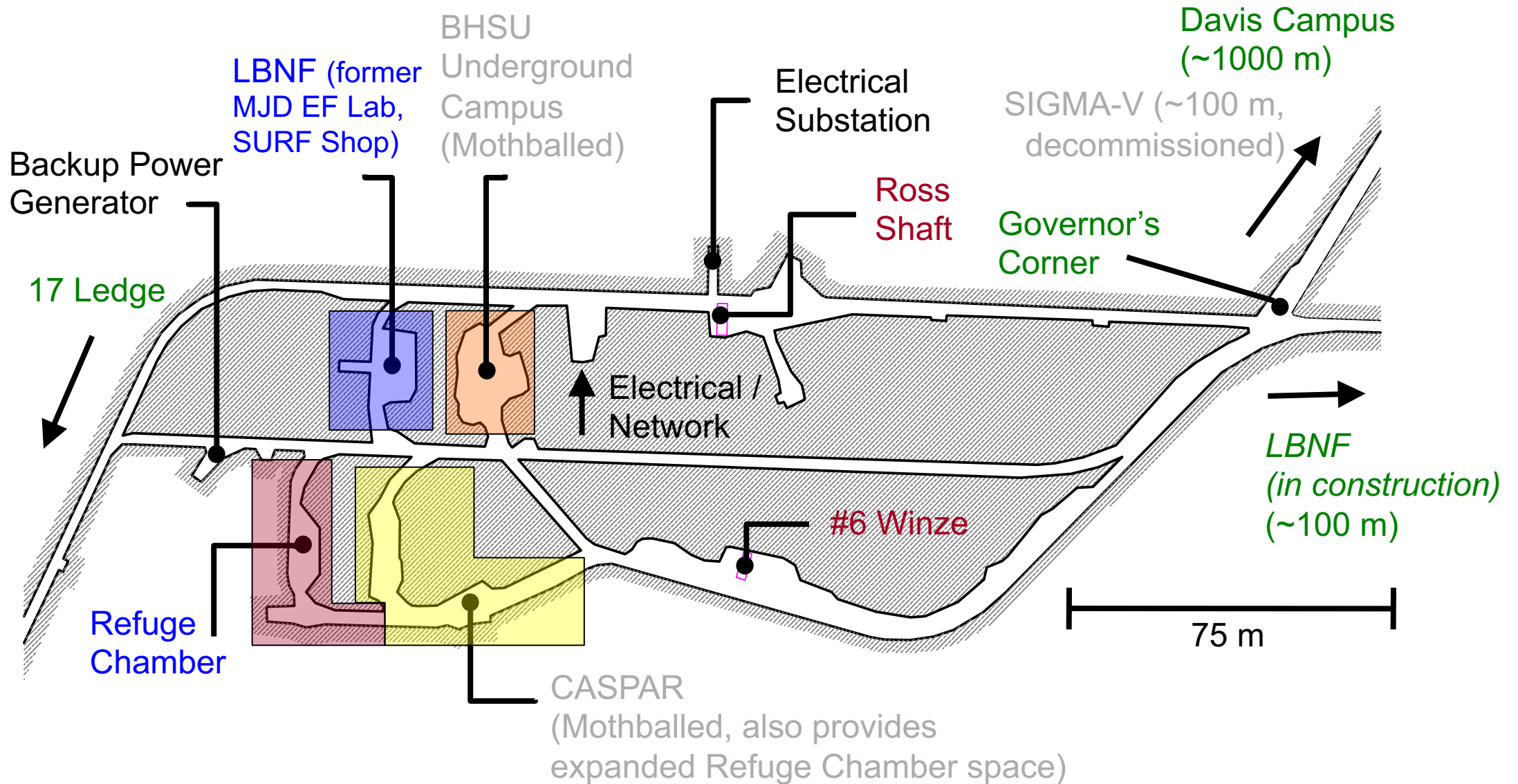
**CONTACT:**  
Constance Walter  
Communications Director  
[cwalter@sanfordlab.org](mailto:cwalter@sanfordlab.org)





# 4850L Ross Campus

2,653 m<sup>2</sup> (Total) / 920 m<sup>2</sup> (Science)





# SURF 4850L Ross Campus

## Examples of laboratory space



2010-2017

2015-2020, resume 2024

**Former MJD Electroforming:**  
Area = 228 m<sup>2</sup>  
(Cleanroom removed,  
current construction office)



**BHUC Cleanroom:**  
Cavern Area = 268 m<sup>2</sup>,  
Cleanroom = 12.1 m × 6.1 m ×  
2.4 m (H)

**CASPAR Hall:**  
Area = 236 m<sup>2</sup>,  
30 m × 3 m (min) × 2.8 m (H)

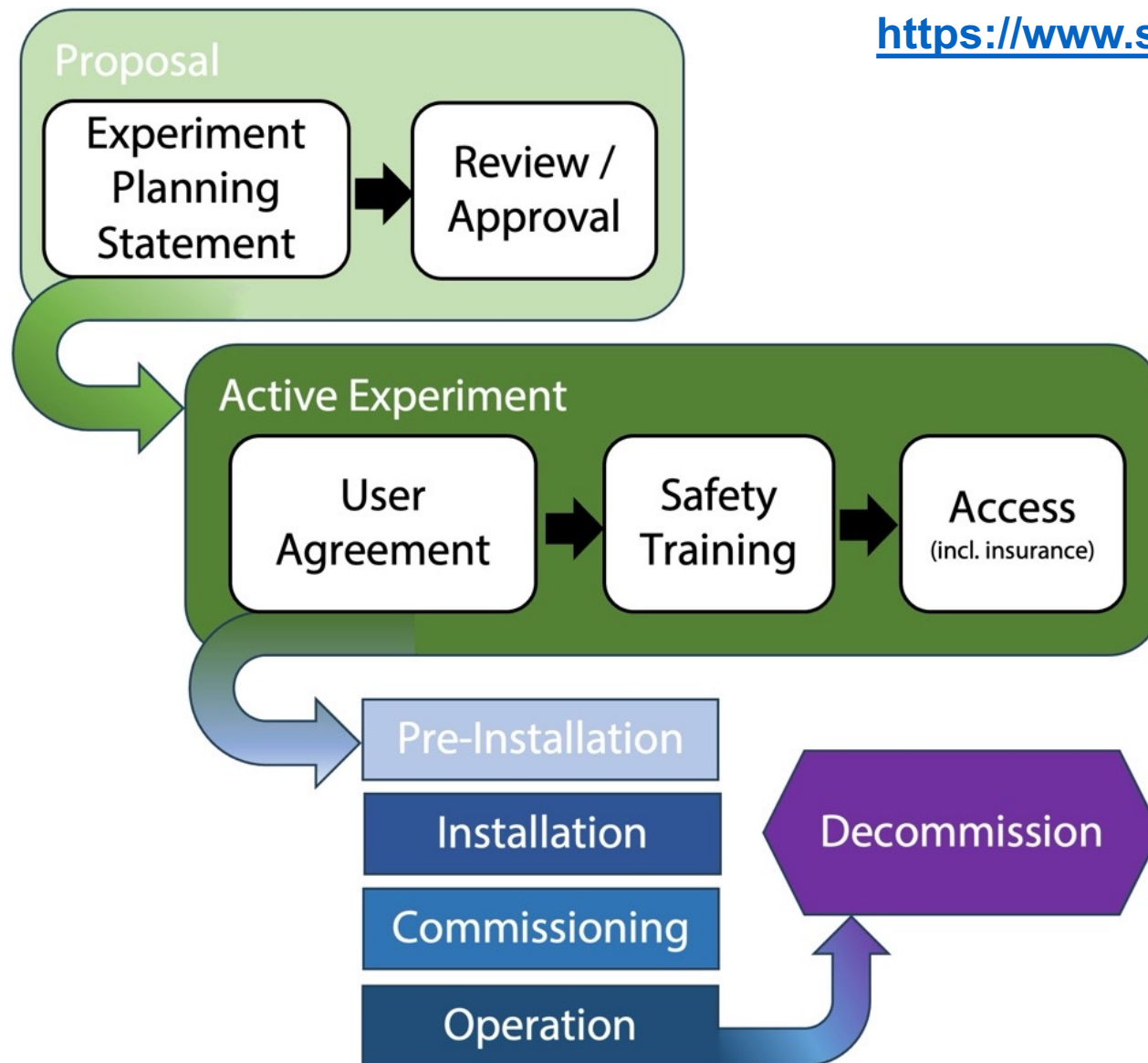
2015-2021, resume 2024



# SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework

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



The screenshot shows the 'Proposal Guidelines' page on the Sanford Underground Research Facility website. The page includes a navigation menu, a search bar, and a list of resources for researchers. The main content area features a 'Proposal Guidelines' section with a list of steps for researchers to follow. Below this is a 'Document and contact information' section with a table of documents available for download.

Document	Document	Document
<b>Experiment Implementation Program</b> 660.31 KB <a href="#">File Download</a>	<b>Experiment Integration and Support Standard</b> 337.86 KB <a href="#">File Download</a>	<b>Experiment Planning Statement</b> 274.98 KB <a href="#">File Download</a>
<b>MOU Template</b> 49.37 KB <a href="#">File Download</a>	<b>Publication Policy</b> 275.69 KB <a href="#">File Download</a>	<b>Acknowledgement of Risk and Waiver (required for all underground access)</b> 98.83 KB <a href="#">File Download</a>



# SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework

<https://www.sanfordlab.org/researchers/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  Geology

**Project Description**  
Provide a brief project description, including purpose, scientific merit and scope. Add rele

\_\_\_\_\_

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

\_\_\_\_\_

South Dakota Science and Technology Authority

Experiment Planning Statement (EPS)

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)		<input type="checkbox"/> Non-proprietary	<input type="checkbox"/> Proprietary
Experiment Implementation Program Requirements Additional documentation requirements.			
Required for all Experiments:		<input type="checkbox"/> User Agreement (UA)	<input type="checkbox"/> Insurance (General Liability, Workers' Compensation)
Services Agreements:		<input type="checkbox"/> General Services Agreement (GSA)	<input type="checkbox"/> 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:		<input type="checkbox"/> (JHA/SOP required for most activities)	
Minimum Training:		<input type="checkbox"/> Orientation (surface and/or underground)	<input type="checkbox"/> General Safety – Basic (and subsequent Annual Refresher Training (ART))
Other Training:		<input type="checkbox"/> SDSTA: _____	<input type="checkbox"/> Non-SDSTA: _____
Inventories:		<input type="checkbox"/> Chemicals <input type="checkbox"/> Electrical	<input type="checkbox"/> Hoisting & Rigging <input type="checkbox"/> Pressure Vessels <input type="checkbox"/> Radioactive Materials
Assessment Documents:		<input type="checkbox"/> Experiment Hazard Assessment Summary (EHAS), incl additional training	<input type="checkbox"/> Quantitative Analysis – Mechanical <input type="checkbox"/> Quantitative Analysis – ODH <input type="checkbox"/> Quantitative Analysis – Pressure
Reviews:		<input type="checkbox"/> Walk-through Inspection(s)	<input type="checkbox"/> Readiness Review(s) <input type="checkbox"/> 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

The screenshot shows the Sanford Underground Research Facility website. The main heading is "Proposal Guidelines". Below it, it states "All proposals must follow these guidelines". A list of five steps is provided: 1. Read the Experiment Implementation Program. 2. Read the Experiment Integration and Support document. 3. Complete a draft of the Experiment Planning Statement describing your project. 4. Contact the SURF Science Director. 5. Complete the Memorandum of Understanding (MOU). The MOU references the SURF waiver required for underground access, the SURF ESH Manual and the SURF Publication Policy.

Under "Document and contact information", there are three columns of document links:

Document <b>Experiment Implementation Program</b> 660.31 KB <a href="#">File Download</a>	Document <b>Experiment Integration and Support Standard</b> 337.86 KB <a href="#">File Download</a>	Document <b>Experiment Planning Statement</b> 274.98 KB <a href="#">File Download</a>
Document <b>MOU Template</b> 49.37 KB <a href="#">File Download</a>	Document <b>Publication Policy</b> 275.69 KB <a href="#">File Download</a>	Document <b>Acknowledgement of Risk and Waiver (required for all underground access)</b> 98.83 KB <a href="#">File Download</a>

At the bottom, there are sections for "Sanford Underground Research Facility" (listing job and internship opportunities, environment and safety manual, publications, legal attribution, and SURF foundation), "Updates" (listing social media links like Twitter, Facebook, LinkedIn, Vimeo, Photo Gallery, and YouTube), and "Resources for..." (listing researchers, educators, press, and contractors/vendors).



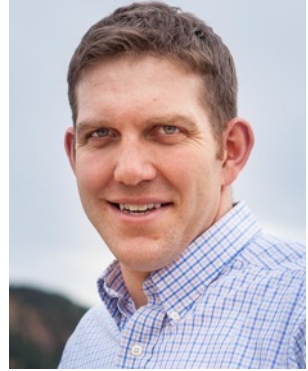
# SURF Organization – Science Staffing

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



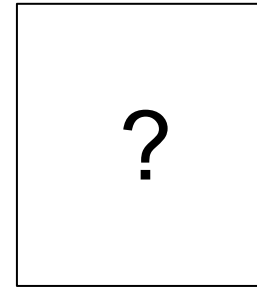
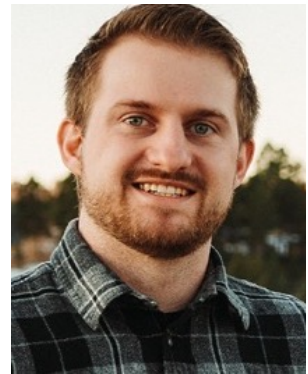
**Jaret Heise (PhD) – Director**  
- Manage dept and experiment implementation program



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



**Gavin Cox (MS)**  
**Expt Support Scientist**  
- LZ Operations



**Robyn Weis - Lab Custodians (Surface + UG) - TBD**



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

**Julia Delgaudio (BS)**  
**Expt Support Scientist**  
- LZ Operations





# 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** Xilinx, Inc\* – *Chip error testing*  
Thermal Breakout – *In-situ stress*  
Shotcrete – *Mining safety*  
Enviro Monitoring – *Ventilation airflow*  
Caterpillar\* – *Mining technology*

**Total = 29 groups**

**20 Active Projects**

67 Total Groups Since 2007

Significant interest from others  
**(26 groups in 2023)**

\* Denotes  
proprietary group

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](https://doi.org/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](https://doi.org/10.1016/j.biortech.2012.10.145).
- Insights into the phylogeny and coding potential of microbial dark matter, Rinke C, Schwiertek 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](https://doi.org/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](https://doi.org/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](https://doi.org/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](https://doi.org/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](https://doi.org/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](https://doi.org/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](https://doi.org/10.1103/PhysRevLett.118.261301).
- Search for Neutrinoless Double- $\beta$  Decay in  $^{76}\text{Ge}$  with the MAJORANA DEMONSTRATOR, C. E. Aalseth *et al.* (MAJORANA Collaboration) *Phys. Rev. Lett.* **120**, 132502 (2018) [doi: 10.1103/PhysRevLett.120.132502](https://doi.org/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](https://doi.org/10.1103/PhysRevLett.120.211804).
- Measurement of Low-Energy Resonance Strengths in the  $^{18}\text{O}(\alpha,\gamma)^{22}\text{Ne}$  Reaction, A.C. Dombos *et al.* (CASPAR Collaboration) *Phys. Rev. Lett.* **128**, 162701 (2022) [doi: 10.1103/PhysRevLett.128.162701](https://doi.org/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](https://doi.org/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](https://doi.org/10.1103/PhysRevLett.129.081803).
- Final Result of the MAJORANA DEMONSTRATOR's Search for Neutrinoless Double- $\beta$  Decay in  $^{76}\text{Ge}$ , I. J. Arnquist *et al.* (MAJORANA Collaboration) *Phys. Rev. Lett.* **130**, 062501 (2023) [doi: 10.1103/PhysRevLett.130.062501](https://doi.org/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](https://doi.org/10.1103/PhysRevLett.131.041002).
- Constraints on the Decay of  $^{180\text{m}}\text{Ta}$ , I. J. Arnquist *et al.* (MAJORANA Collaboration), *Phys. Rev. Lett.* **131**, 152501 (2023) [doi: 10.1103/PhysRevLett.131.152501](https://doi.org/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](https://doi.org/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), accepted by *Nature Physics*.



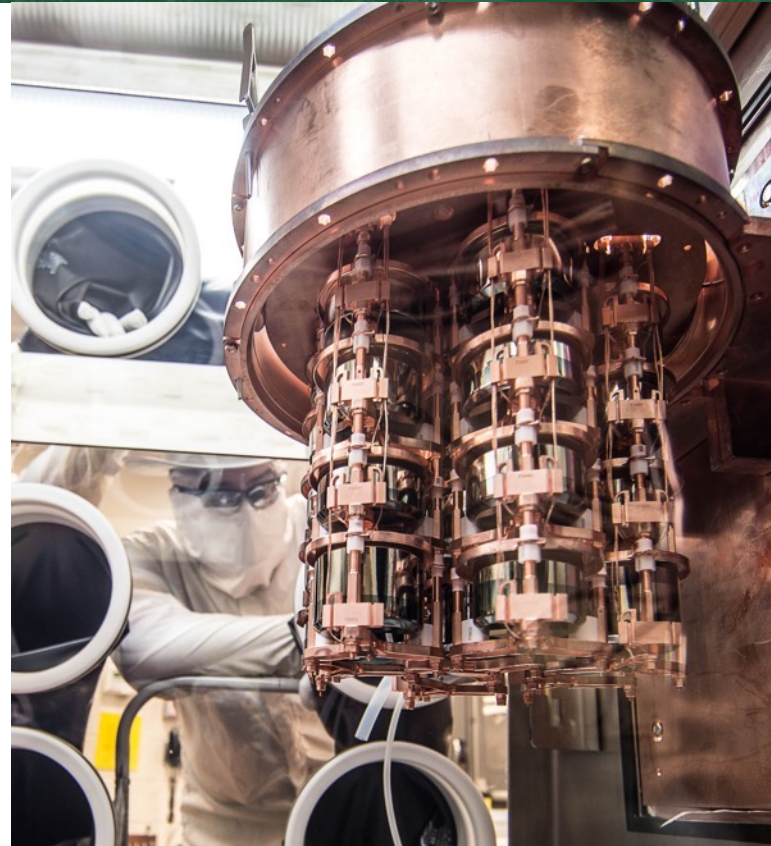
# SURF Science Program – Current Physics Highlights

Strong and diverse program with exciting future



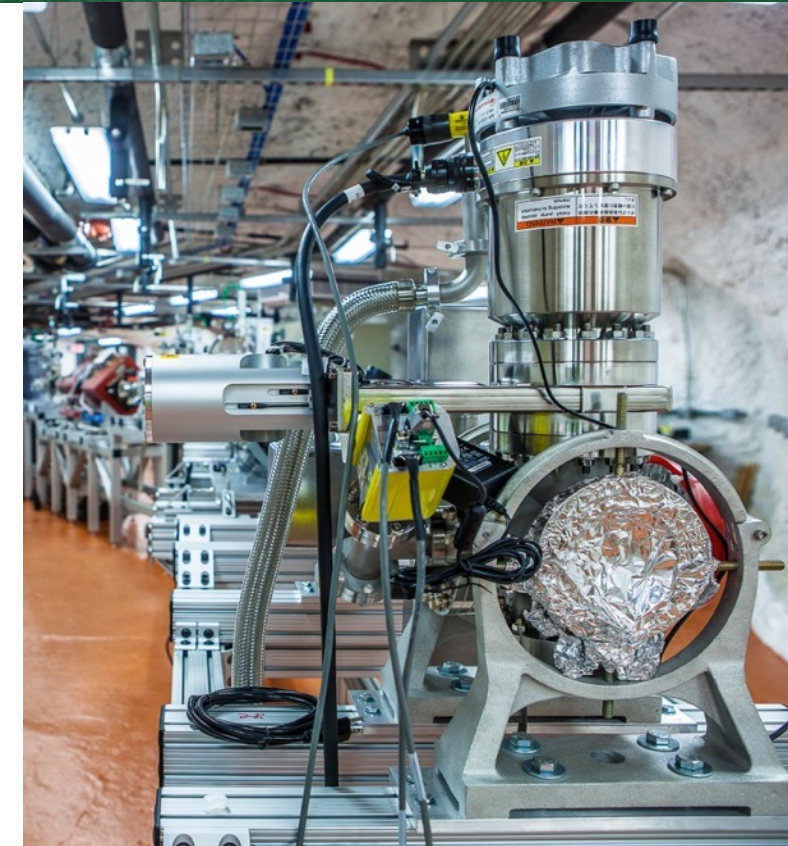
## LUX-ZEPLIN (LZ)

- 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



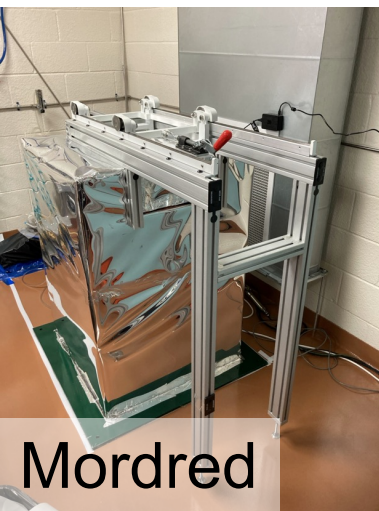
## CASPAR

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

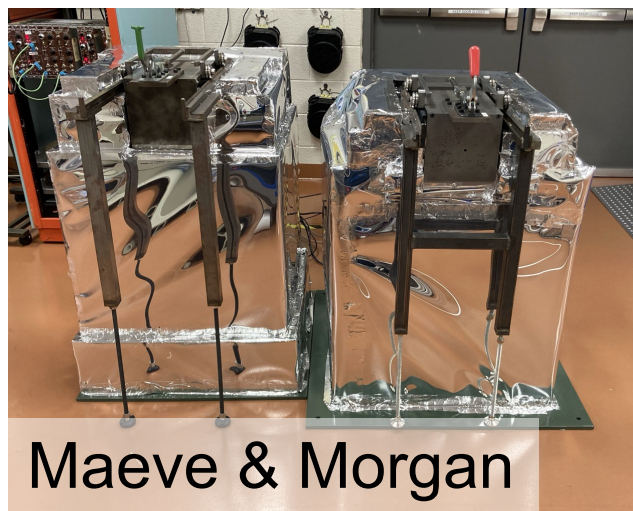


# SURF Material Assay at BHUC: Davis Campus

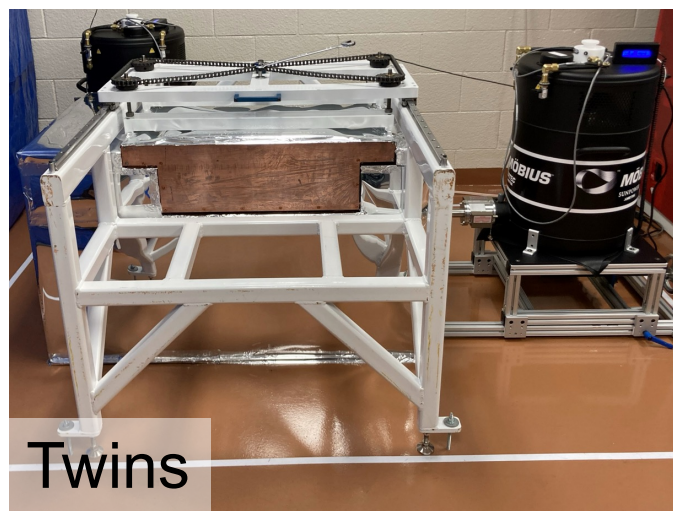
Low-background counting capabilities serving national & international community



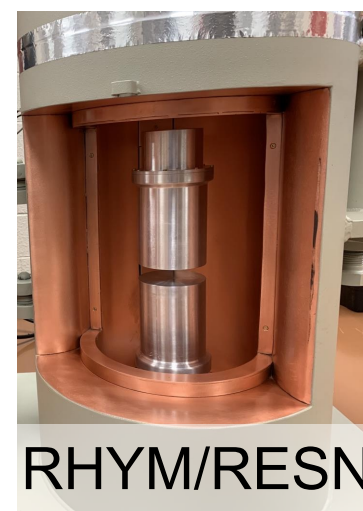
Mordred



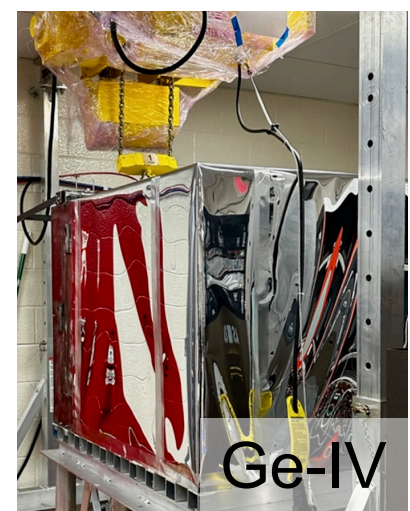
Maeve & Morgan



Twins



RHYM/RESN



Ge-IV



# Biologists in Action

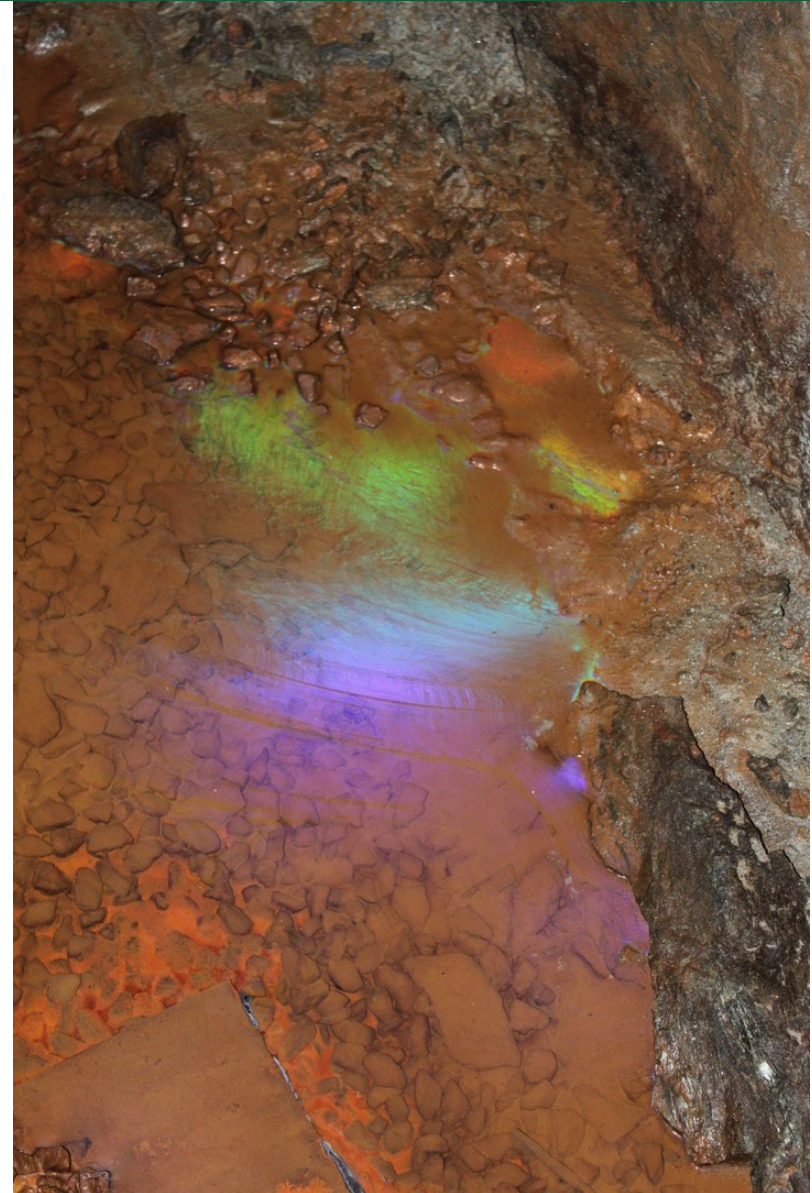
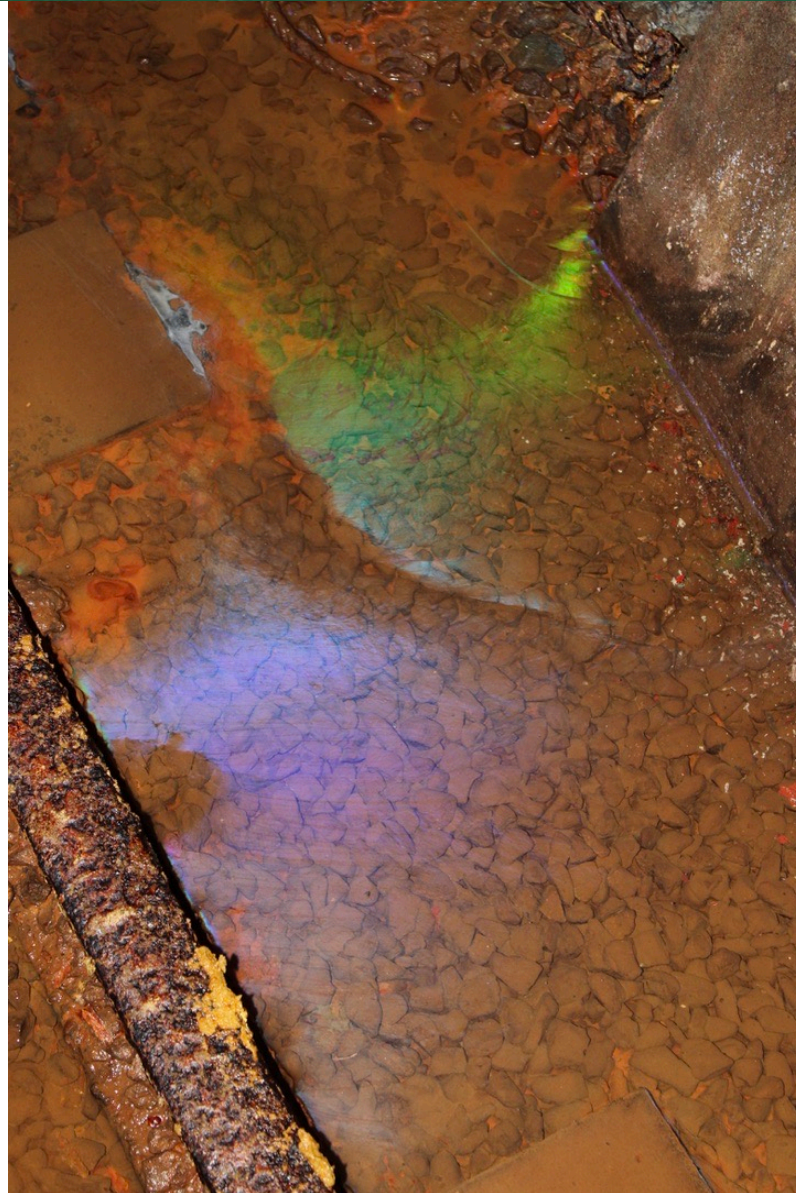
Biology / Geology / Engineering (Multiple Levels)





# SURF Biology in Action

Biology / Geology / Engineering (Multiple Levels)





# DEMO-FTES

## Demonstration of Fracture Thermal Energy Storage

- **Science Goal:** Study enhanced geothermal system (EGS) and fracture thermal energy storage (FTES) effects on 10-meter scale. Pressure systems used to isolate sections of holes and flow water between holes.
- **Collaboration:** DEMO-FTES (12 members, 4 institutions) [DOE Office of Energy Efficiency and Renewable Energy (EERE), Geothermal Technology Office (GTO)]; previous kISMET (35 members / 12 institutions), EGS Collab/SIGMA-V (128 members / 23 institutions).
- **Status:**
  - Onsite starting Dec 2023 (EGS Collab/SIGMA-V Oct 2017 – Dec 2022 and kISMET since Jun 2016).
  - Leveraging 4100L site: 11 drill holes (180-265 m long) and some existing instrumentation (no new drilling planned); future groups may use five 4850L kISMET holes (4x 50m, 1x 100m (72m useable)).
  - SURF upgrading electrical infrastructure for water heaters.
- **Future:**
  - SURF activities for ~1 year (until ~Dec 2024).
  - Interest from community, incl DOE-SC Basic Energy Sciences (e.g., CUSSP 2024 through 2027) and ARPA-E (e.g., Eden).



SIMFIP tool installed for EGS/SIGMA-V



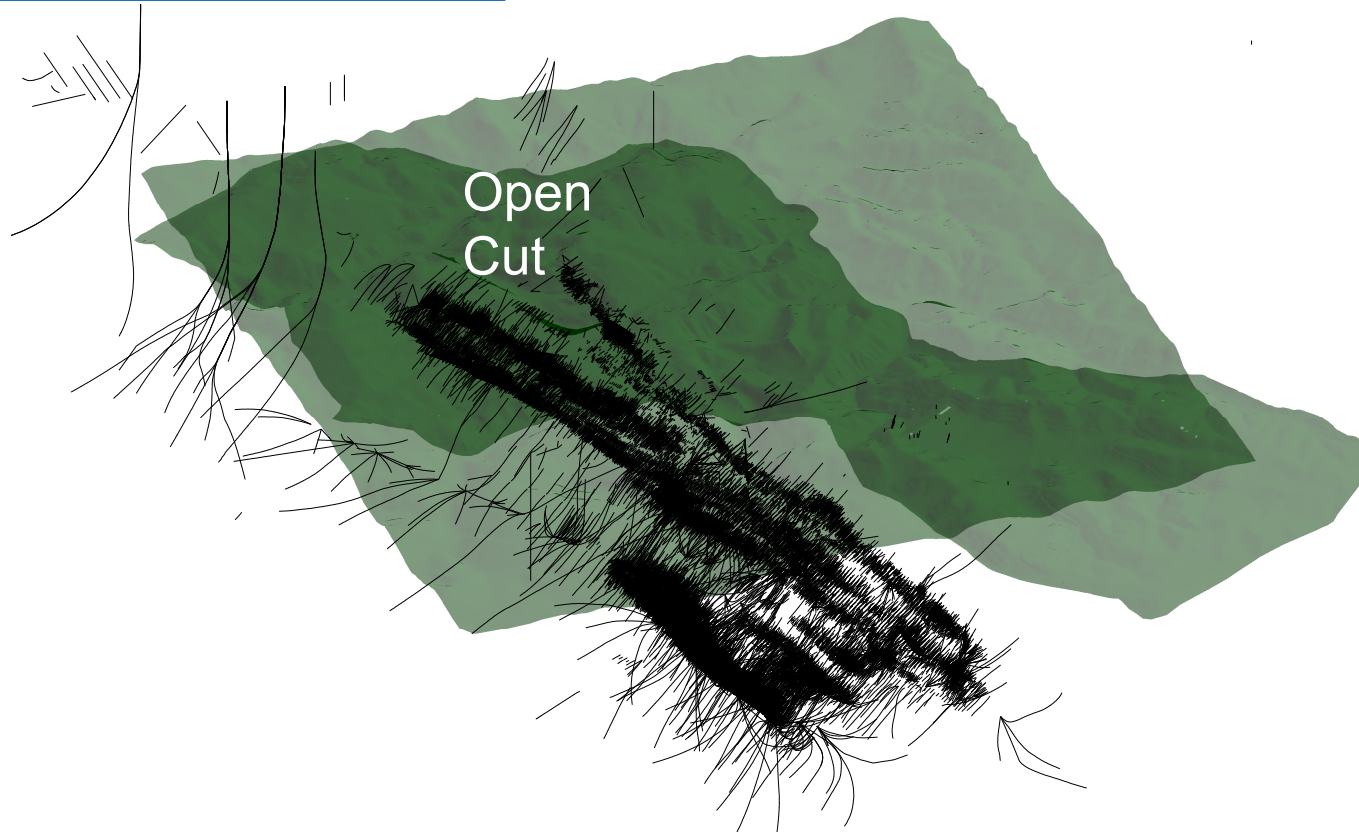
DOE-SC BES program manager visit



# SURF Science Opportunities – Drill Core

## Core repository

- Total of 27,870 drill holes (+ others) on Homestake property
- Portion of core retained and donated to SDSTA: 39,760 boxes of core for 2,688 drill holes (91 km!), SDGS initial help with stewardship
- SDGS database with 58,000+ entries, representing 1,740 drill holes:  
<http://cf.sddenr.net/homestake/>

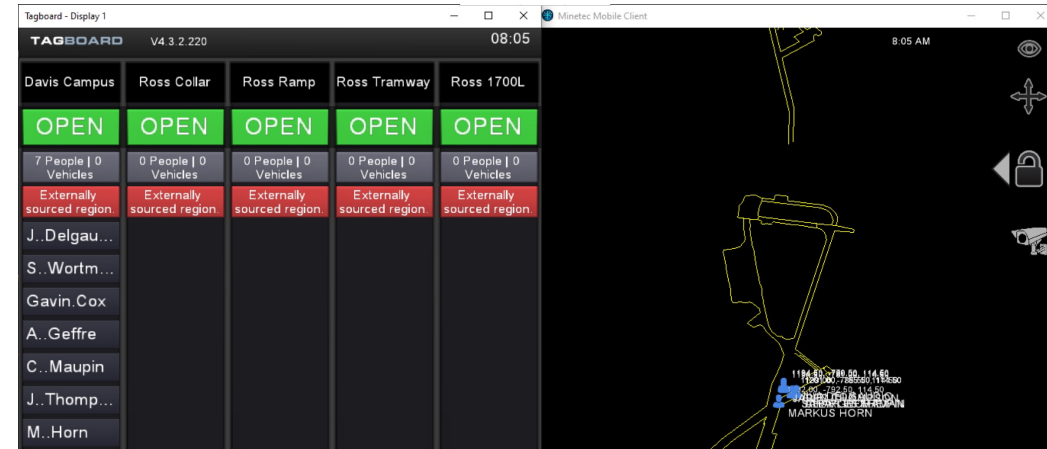




# CAT

## Caterpillar Underground Research Center

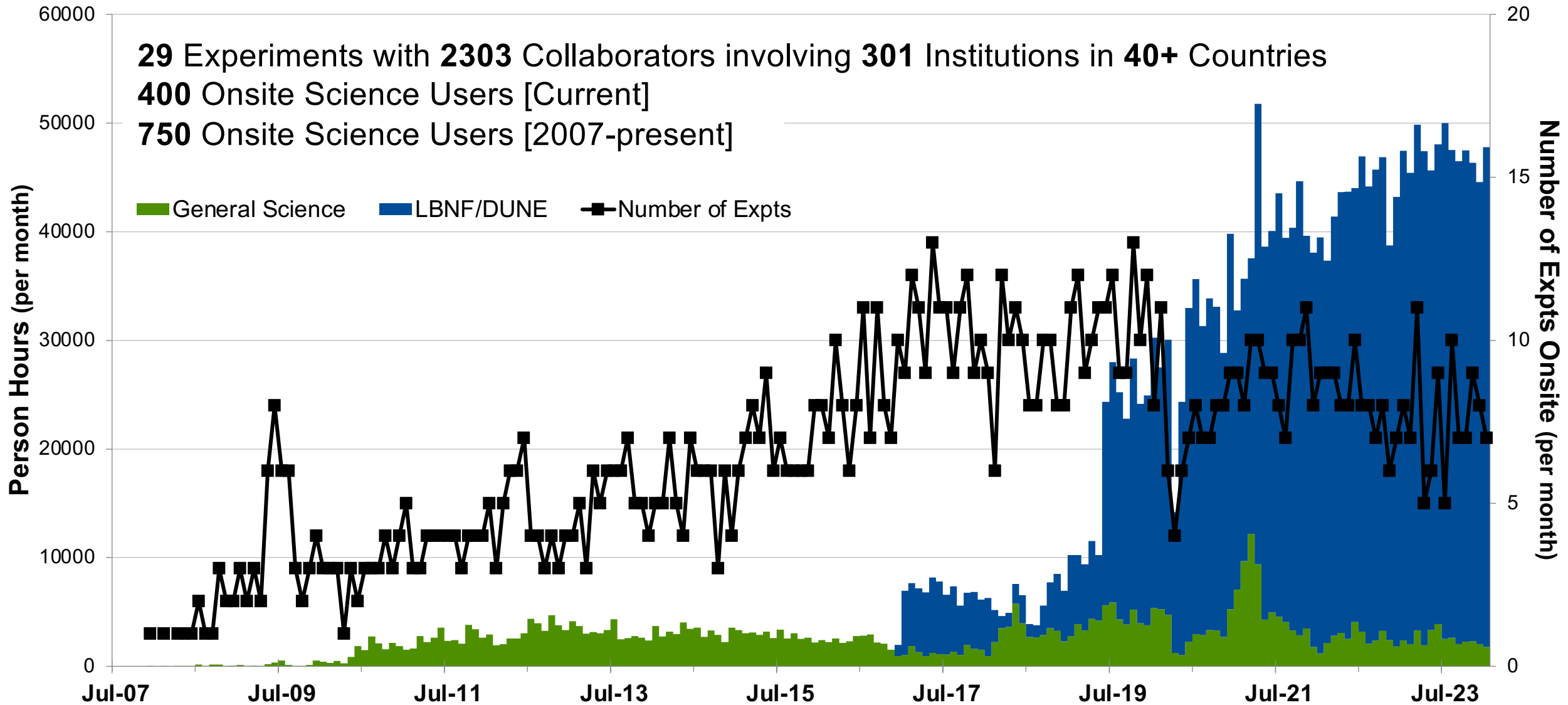
- **Industrial Partnership Goal:** Provide real-world, interactive environment for customer experiences, training and new product implementation.
- **Collaboration:** 12 core members (total of 271 ppl, incl customer groups), 46 institutions, lead = Caterpillar [institutional funding]; proprietary group requires full DOE cost recovery
- **Status:**
  - Onsite since Aug 2020 (initial inspections Feb 2019).
  - Former motor & loader barns (~925 m<sup>2</sup>), ~1000-m ramp. Total of 17,000+ rock bolts, 3000+ welded-wire mesh panels, new rail.
  - Over 1.5 km of MineStar tracking technology distributed throughout 1700L and 7 Ledge ramp to 1550L.
  - 6 utility vehicles currently UG at SURF using tracking technology.
  - Site-wide tracking system in development, currently in test mode (4850L, 1700L, surface) w/ Science, UMC, ERT, et al.
- **Future:**
  - Complete Ross Shaft fiber installation and deployment.
  - 10-yr agreement through Sep 2030.





# SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities





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

2022 SURF User Association Annual General Meeting

26–27 Oct 2022  
Zoom  
US/Mountain timezone

Overview  
Timetable  
Contribution List  
My Conference  
My Contributions  
Participant List

Timetable

Wed 26/10 Thu 27/10 All days

Print PDF Full screen Detailed view Filter

Session legend

- Active science updates
- Potential new research areas
- QA&Discussion
- SURF facility overview and updates

10:00	Greeting	Mike Headley
10:00 - 10:10	Zoom	
10:10	Facility Overview and Updates	Janet Heise
10:10 - 10:45	Zoom	
10:45	SURF Outreach and Culture	Dan West
10:45 - 11:05	Zoom	
11:05	SURF User Association Update	Billy Kruger
11:05 - 11:15	Zoom	
11:15	SURF Update	Chris Marshall
11:15 - 11:35	Zoom	
11:35	Rud Reinhold	Ralph Sev
11:35 - 11:45	Zoom	
11:45	LZ	Sally Shaw
11:45 - 11:55	Zoom	
11:55	CASPAR	Frank Stecker
11:55 - 12:05	Zoom	
12:05	DARMO	Magdalena Osburn
12:05 - 12:15	Zoom	
12:15	MJD	Ralph Messerlych
12:15 - 12:25	Zoom	
12:25	BHUC	Brianna Moore
12:25 - 12:35	Zoom	
12:35	Break	
12:35 - 12:45	Zoom	
12:45	Q3 Dark Matter	Akiva Kamaha
12:45 - 13:05	Zoom	
13:05	Atom Interferometry	Jason Hogan
13:05 - 13:25	Zoom	
13:25	Microbial Metabolomics	Jon Kolapp
13:25 - 13:45	Zoom	
13:45	QA&Discussion	
13:45 - 14:30	Zoom	

2022 SURF User Association Annual General Meeting

26–27 Oct 2022  
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US/Mountain timezone

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Contribution List  
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Timetable

Wed 26/10 Thu 27/10 All days

Print PDF Full screen Detailed view Filter

Session legend

- Initiating, expanding, funding science
- Physics community planning updates
- SURF Institute for Underground
- SURF Long Term Planning

10:00	Summary of the 2021 SURF User Association Vision Workshop	Kevin Lesko
10:00 - 10:20	Zoom	
10:20	Expanding SURF's Underground Footprint	Alan Strahan
10:20 - 10:40	Zoom	
10:40	Discussion/QA	
10:40 - 11:00	Zoom	
11:00	Physics community planning updates	
11:00 - 11:30	Zoom	
11:30	Break	
11:30 - 11:45	Zoom	
11:45	Getting Started with a Project at SURF	Janet Heise
11:45 - 12:40	Zoom	
12:40	Maintaining Work and Funding for Projects of Various Sizes	Billy Kruger
12:40 - 12:55	Zoom	
12:55	QA	
12:55 - 13:15	Zoom	
13:15	Institute: Overview and Future Plans	Mike Headley
13:15 - 13:45	Zoom	

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



# 2023 Particle Physics Strategic Plan

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

Exploring  
the  
Quantum  
Universe

Pathways to Innovation  
and Discovery  
in Particle Physics

DRAFT Report of the 2023 Particle Physics Project Prioritization Panel

## 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.

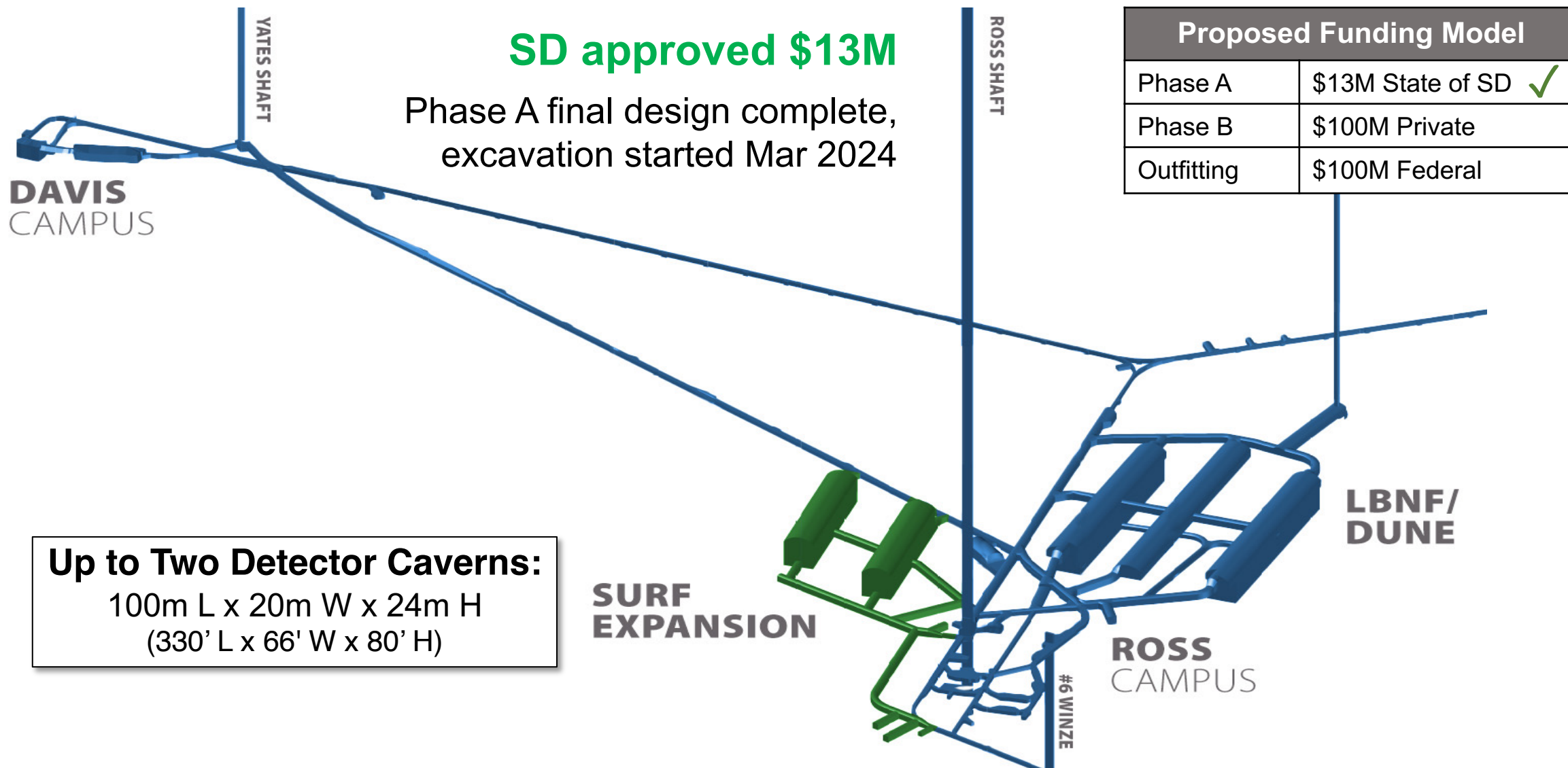
- Community input process “Snowmass” conducted through 2022
- Snowmass recommendations to P5 (Jan 2023):
  - **LBNF/DUNE Phase I & II and PIP-II**
  - **Leverage LBNF to increase underground space at SURF**
  - **Designate SURF as a formal U.S. DOE User Facility**
- P5 recommendations to DOE/NSF (Dec 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**

A strategic plan for the High Energy Physics Advisory Panel



# 4850L Space Needed for Future Experiments

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

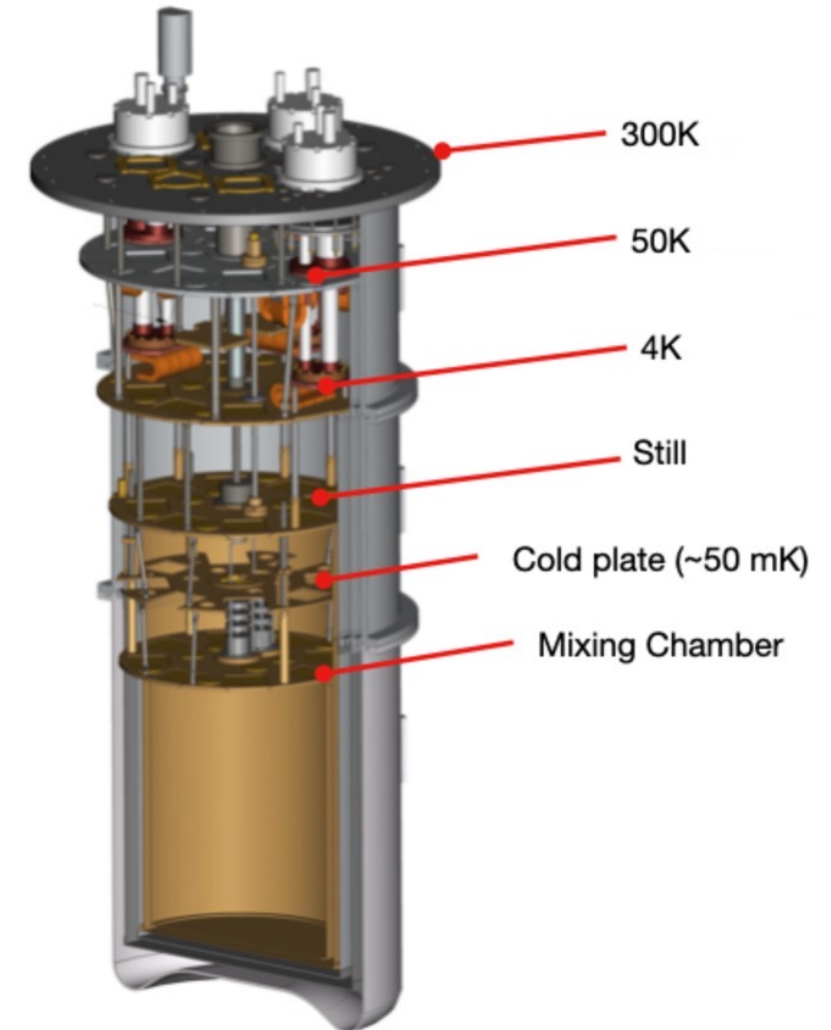




# SURF Cryogenic User Facility

## Preliminary step to becoming national 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
- **Need for Cryogenic User Facility at SURF:**
  - **No deep underground cryogenic test facility in U.S.** (generally, shortage of underground cryogenic test infrastructure in U.S.)
  - Due to strategic scientific value, many **other countries operate cryo facilities** (Europe, Canada) or are planning to build them (several countries in Asia)
  - **Significant interest from U.S.-based groups:** low-mass dark matter (TESSERACT, SPLENDOR), neutrinoless double-beta decay (CUPID), quantum information systems (MIT, UIUC)





# SURF Call for Letters of Interest

## Ensuring SURF used to its fullest scientific potential

### Significance:

- First formal call to UG science community since March 2008! (Note: 2008 call strongly leveraged earlier 2005 call for LOIs)
- 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

### 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: 100m 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
- Deadline for LOIs (+ EPS): **Fri May 17, 2024 at 11:59 PM MT**



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

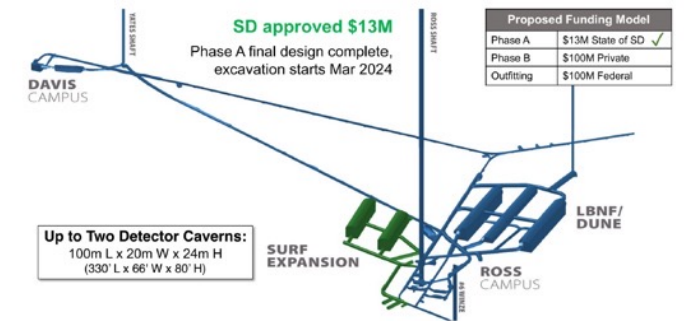
March 22, 2024

#### 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.



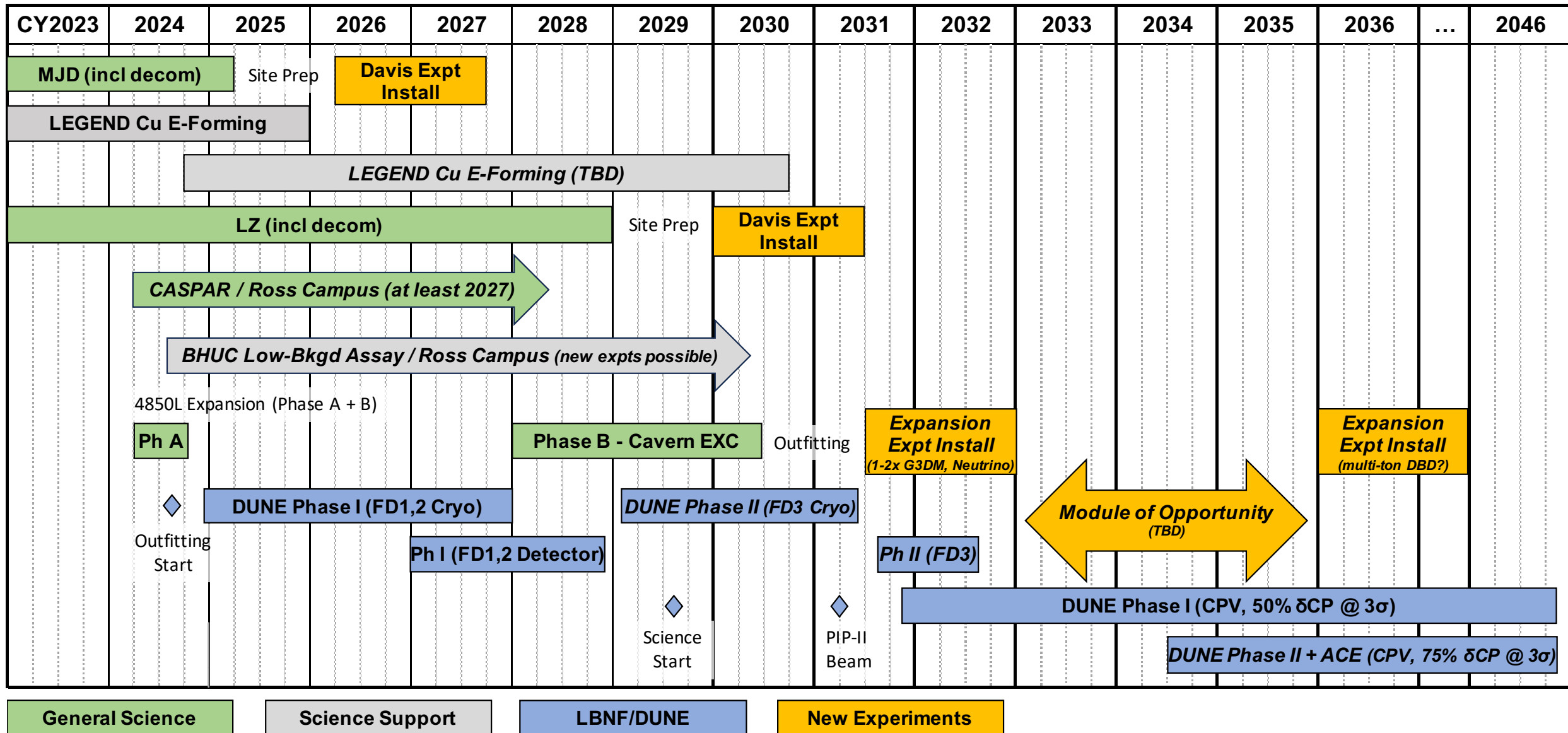
Leading into recent U.S. long-range planning, the SURF User Association held a Vision Workshop (<https://indico.sanfordlab.org/e/Vision2021>) and SURF participated in nuclear physics town halls and the particle physics Snowmass community input processes. As a result, SURF featured prominently in the 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 Science Strategic Planning

## Timeline





# Sanford Underground Research Facility

Thank You!





# 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.
  - **LBNF/DUNE is SURF's top priority**.
- SURF wants to host other future world-leading experiments:
  - All existing and near-term lab space at SURF is **fully subscribed**.
  - Leveraging LBNF/DUNE excavation contractor offers **significant development advantages**.
  - SURF is preparing to **increase underground laboratory space**, plans advancing for new large caverns on 4850L (1500 m, 4100 mwe) on **timeframe of next-generation experiments (~2030)**.
- SURF is playing a strong role in the UG science community:
  - **User Association** serving as catalyst for community discussions and will leverage for future planning.
  - **Strong community support** endorsing more space at SURF (Vision Workshop 2021, Snowmass 2021/2022).
  - **Strong recognition** and support for SURF in recent **P5 report for U.S. strategic planning**.



# 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 ( $0\nu\beta\beta$ )
- **Current:** LZ, MAJORANA DEMONSTRATOR ( $^{180\text{m}}\text{Ta}$ ), CASPAR, Low-bkgd counting (BHUC), Geomicrobiology, Geoengineering (esp. geothermal), other industry/engineering
- **Future** (no funding/site decisions yet):
  - Dark Matter: Low-mass (TESSERACT, HydroX), next-generation WIMP (XLZD, Argo), other (CrystaLiZe)
  - Neutrino: Water-based liquid scintillator (Theia), Beyond-ton-scale  $0\nu\beta\beta$ , 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<sup>2</sup> (surface) with ~1600 m<sup>2</sup> storage (incl drill core) and 355 m<sup>2</sup> staging/assembly space. 31 km<sup>2</sup> (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 =  $5.31 \times 10^{-5}$   $\mu$ /m<sup>2</sup>/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<sup>2</sup> (cleanrooms = 92 m<sup>2</sup> / 914 m<sup>3</sup>)
  - 4850L (science space, as low as class 100): Davis Campus (1018 m<sup>2</sup> / 4633 m<sup>3</sup>), Ross Campus (920 m<sup>2</sup> / 3144 m<sup>3</sup>)
  - Radon-reduction: Surface = 2200x reduction @ 300 m<sup>3</sup>/h (Ateko), Davis = 700x reduction @ 150 m<sup>3</sup>/h (SD Mines)
- **Bkgds (4850L):** Radon = 300 Bq/m<sup>3</sup>, gamma = 1.9  $\gamma$ /cm<sup>2</sup>/s, neutron =  $1.7 \times 10^{-2}$  n/m<sup>2</sup>/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.



# SURF Plans to Become DOE User Facility

## Benefits:

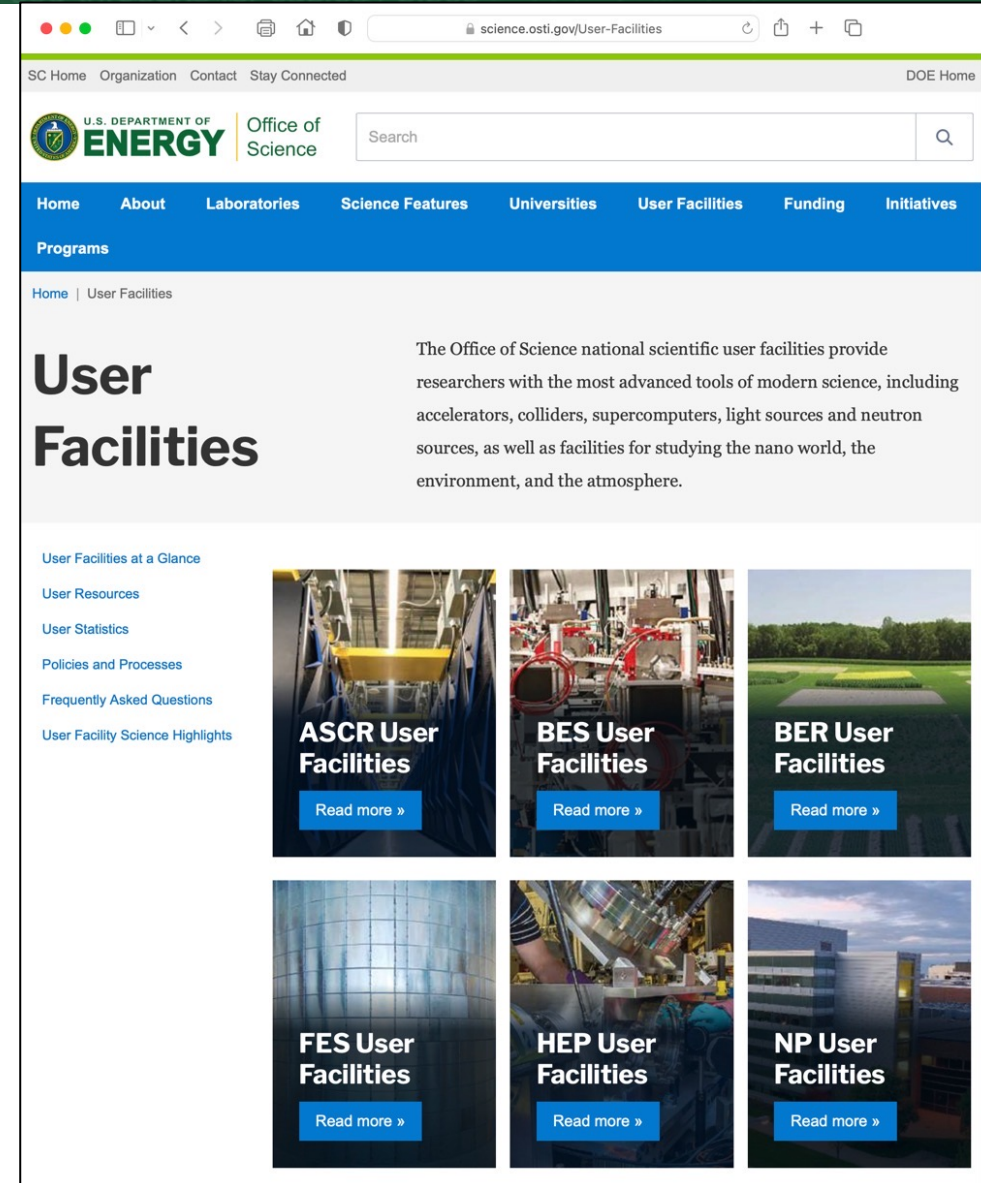
- Expands DOE User Facility portfolio to incl underground lab, raises SURF's stature within DOE community.
- Promotes underground science in U.S., increases funding opportunities.
- Enhances SURF's role in global science community.
- Communicates SURF is open to a broad range of science and users and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





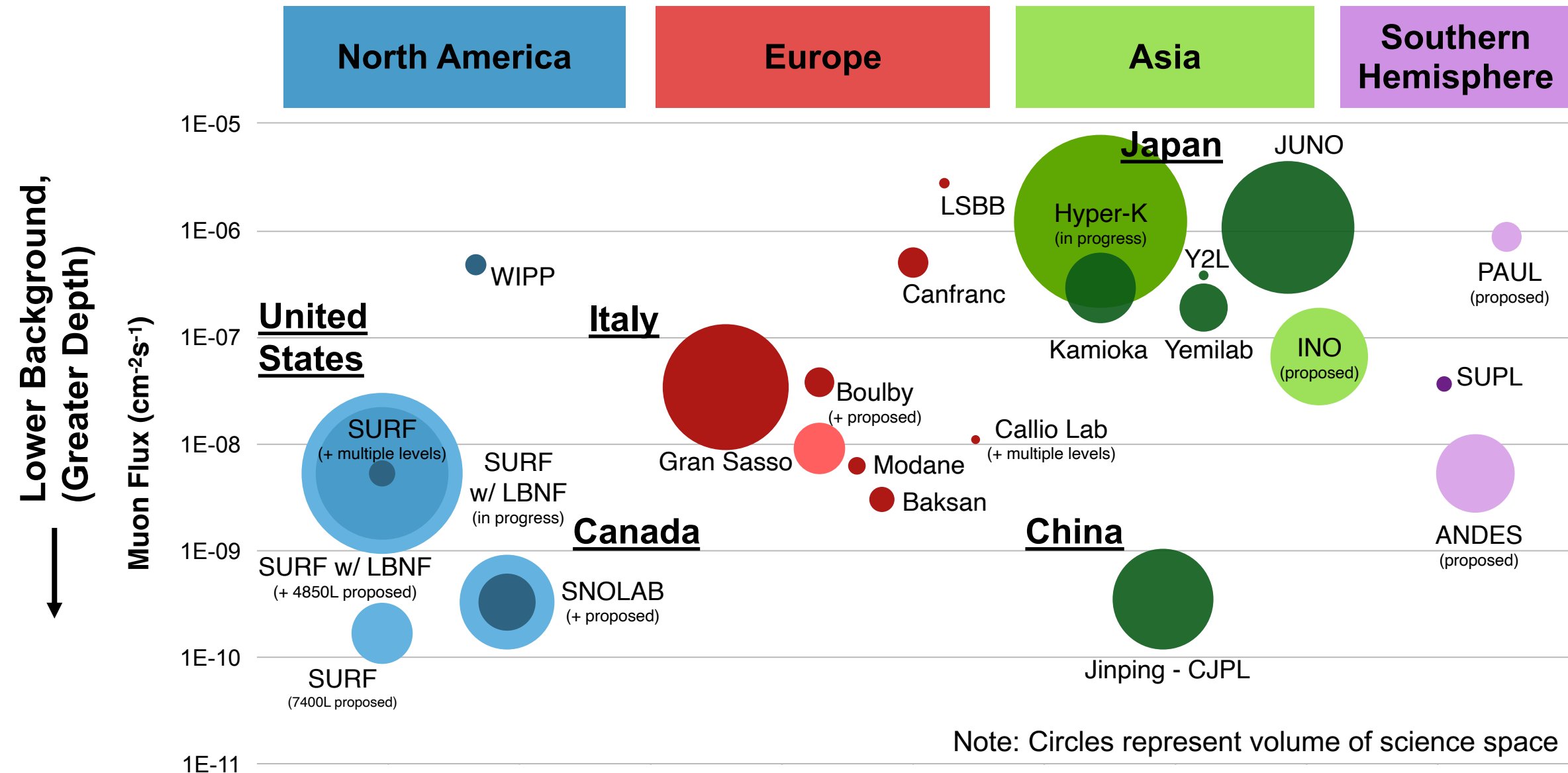
# Sanford Underground Research Facility

## Where in the world is SURF?





# SURF in the Global Context





# SURF Current & Future Facilities

Summary for various science campuses, including timelines

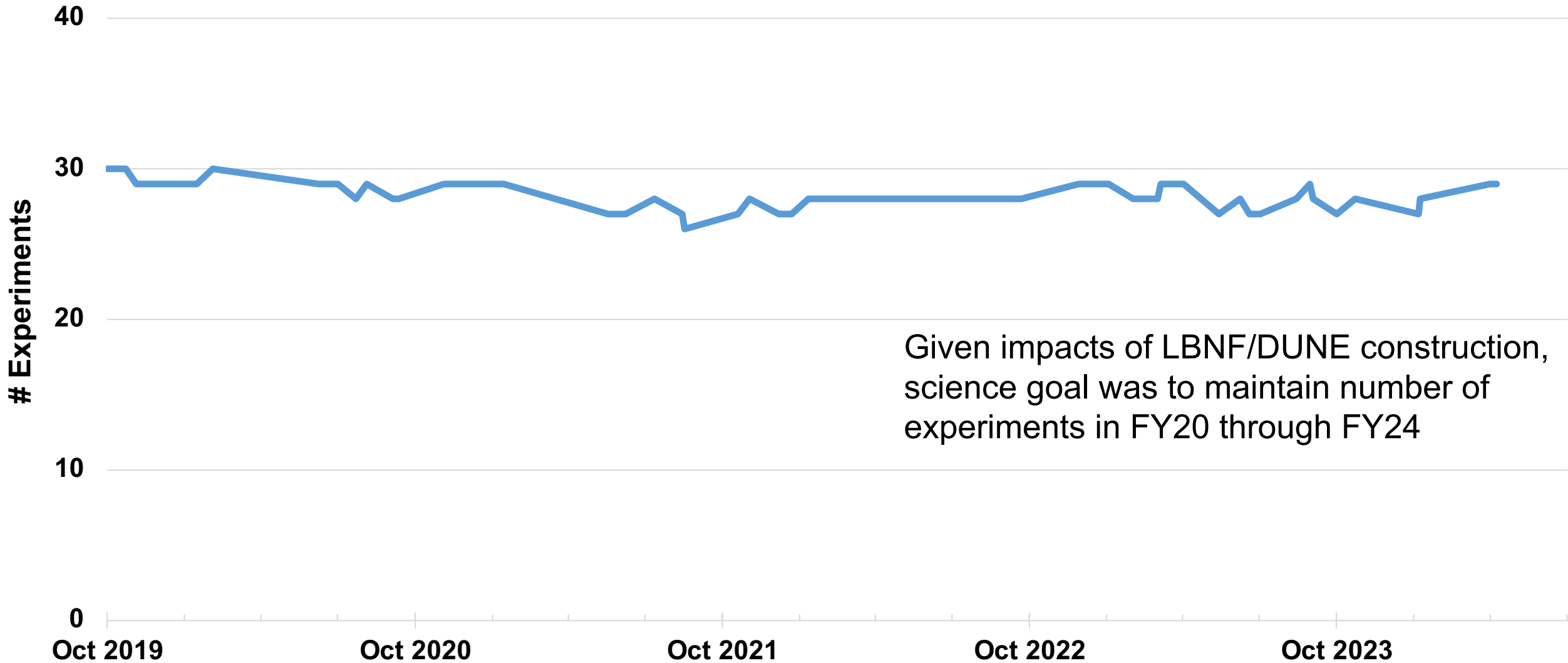
Location	Laboratory	Existing/ <i>Planned</i> Space		Available (CY)	Comments
		Area (m <sup>2</sup> )	Vol (m <sup>3</sup> )		
Surface	Surface Lab (+ RRS)	210	600	2021	LZ use ~complete, allowing use by others
Davis Campus (4850L)	LZ Lab – Davis Cavern (2 levels)	372	1,956	~2028	LZ data complete early ~2028 + 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
<i>LBNF (4850L)</i>	<i>LBNF</i>	<i>9,445</i>	<i>191,863</i>	<i>?</i>	<i>Excavation complete in Mar 2024</i>
4100L	Geoscience Lab	334	11 drill holes	2025	DEMO-FTES use 2023-2024, CUSSP 2024-2027
4850L	<i>New Labs (2 proposed)</i>	<i>4,022</i>	<i>94,608</i>	<i>Earliest new: excavation 2027, complete ~2030</i>	<i>Each 20m (W) x 24m (H) x 100m (L)</i>
7400L	<i>New Labs (2 proposed)</i>	<i>4,178</i>	<i>42,440</i>		<i>Each 15m (W) x 15m (H) x 75m (L) + other supporting</i>



# SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities

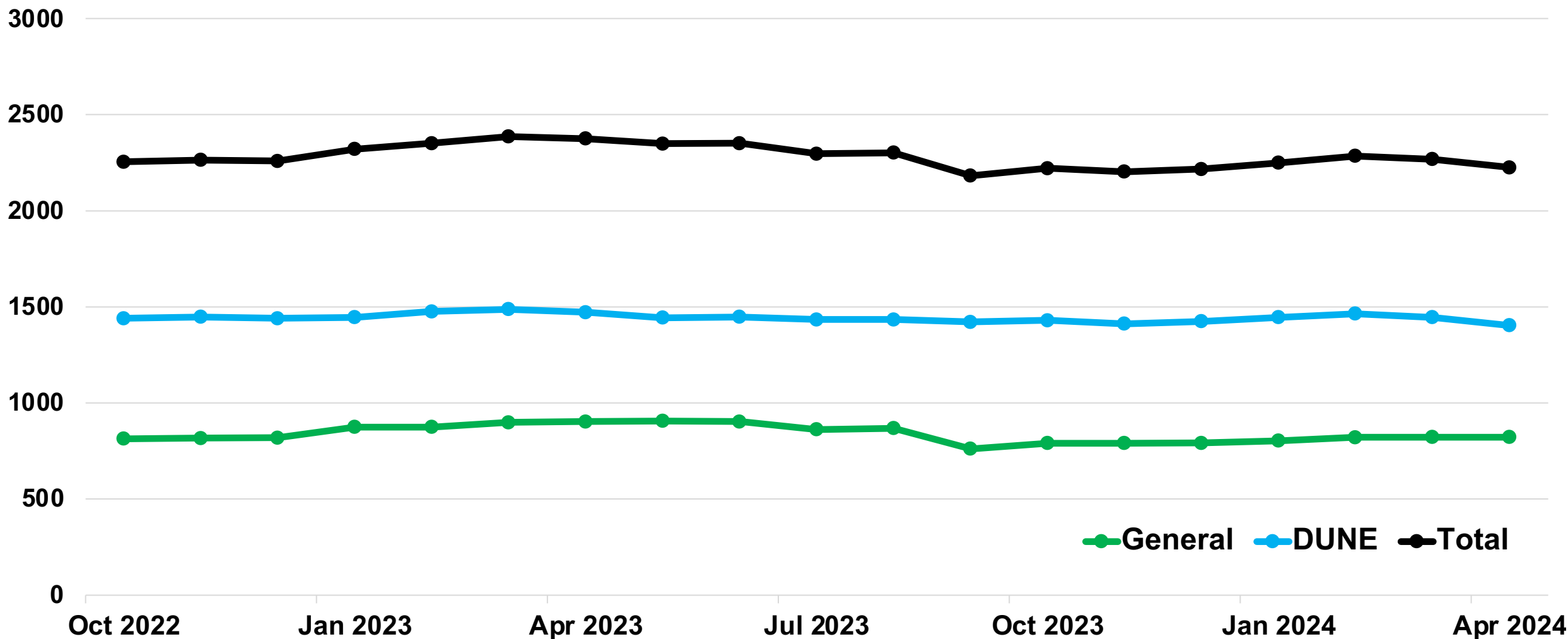
## SURF Experiment Trend



# SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities

## SURF Collaborator Trend

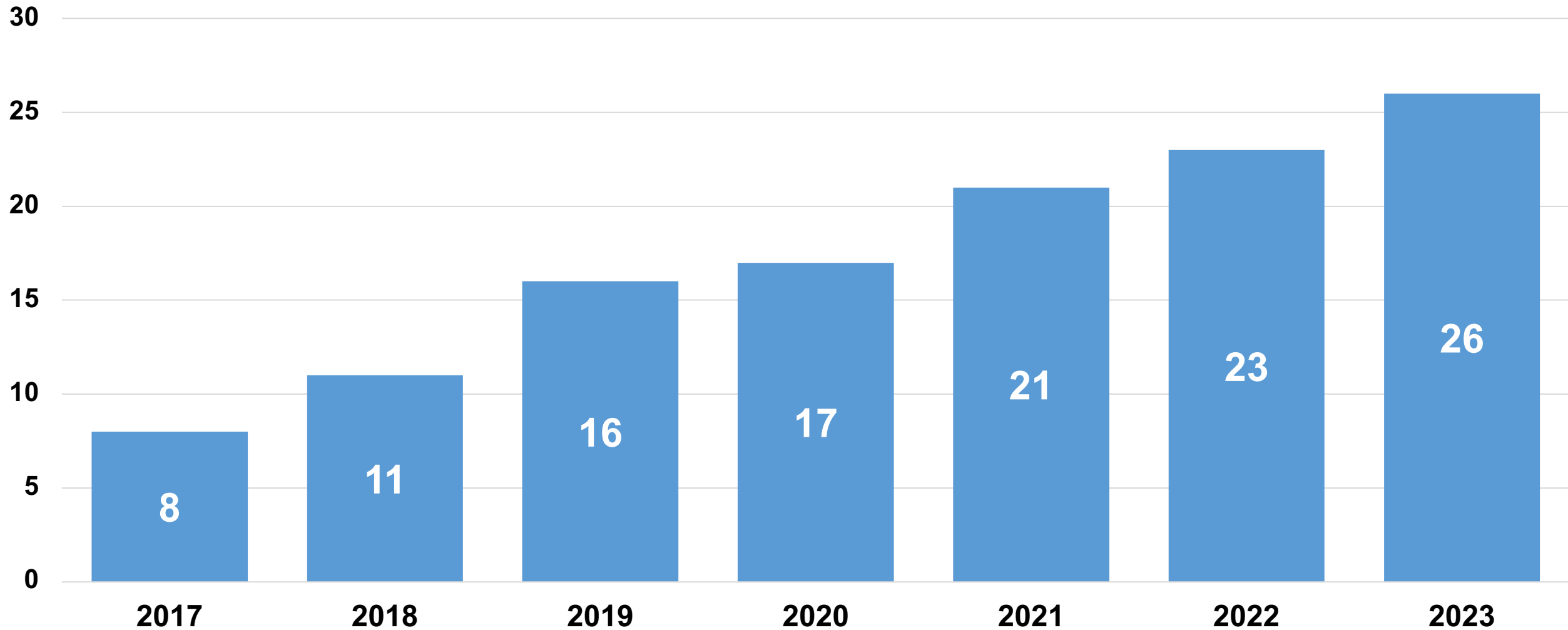




# SURF Science Program

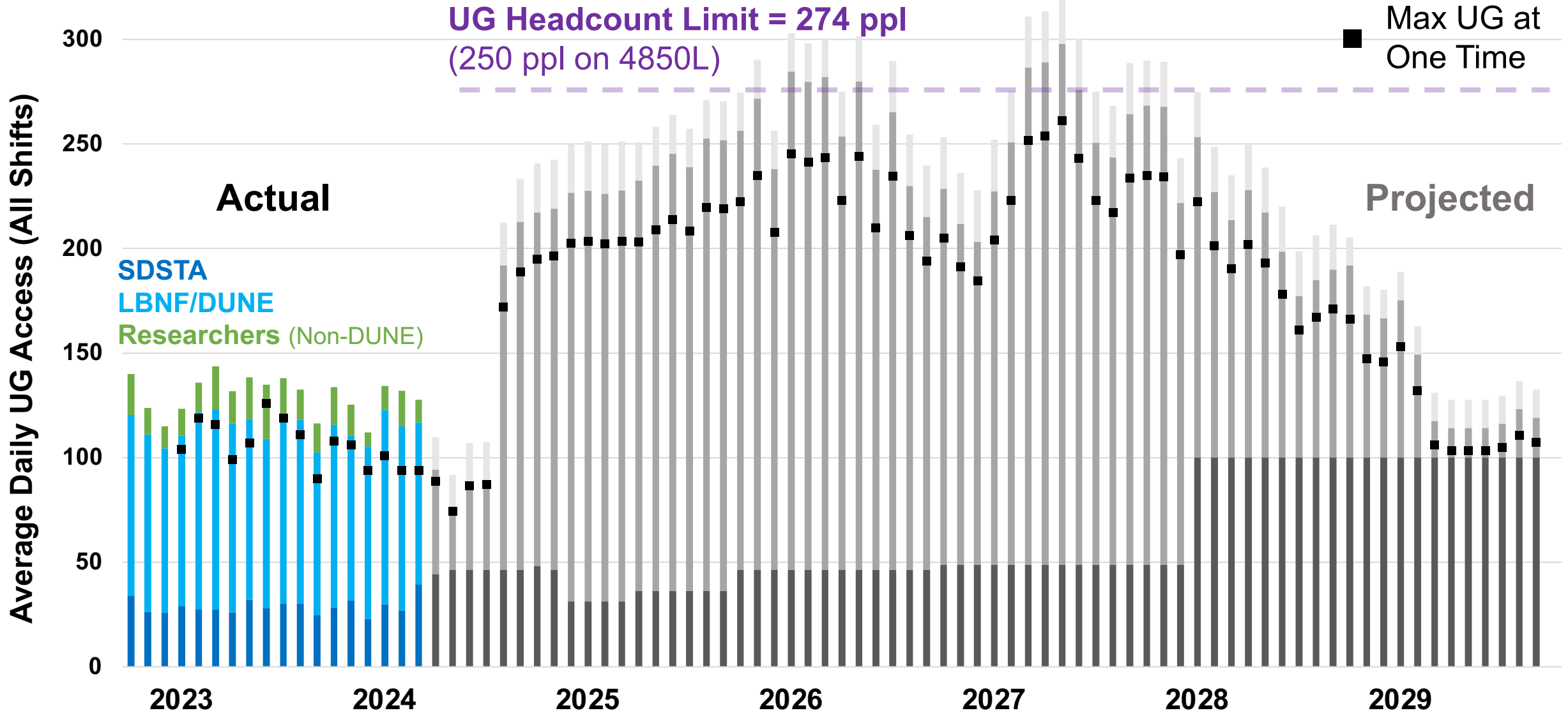
Hosting world-leading experiments and researchers from diverse scientific communities

## SURF Expressions of Interest



# SURF Average Daily Underground Access

Includes SDSTA + Contractors, Researchers, LBNF/DUNE (BSI, FDC, Consortia)





# 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

Rev. 01  
SCI-(1000-S)-34478  
Experiment Implementation Program



Experiment Implementation Program

Rev. 03  
SCI-(1000-S)-135416  
Experiment Integration & Support



Experiment Integration & Support

South Dakota Science and Technology Authority Page 1 of 9 Standard

Technology Authority Page 1 of 21 Standard

# Biology: DeMMO

## Deep Mine Microbial Observatory

- **Science Goal:** Explore and understand rock-hosted microbial ecosystems by performing long-term water sampling from drill core holes (new and legacy), testing for life in drill core (new); also test various substrates, incl electrode-assisted cultivation (bioreactor).
- **Collaboration:** DeMMO (7 members, 2 institutions) [Institutional]; previous Life Underground: NASA Astrobiology Institute (15 members, 6 institutions; lead = USC)
- **Status:**
  - Onsite since 2014 (NASA funding 2014-2018).
  - Synergistic collaboration between biology, geology & physics.
  - Outfitted 6 holes for long-term monitoring: 2x 800L, 1x 2000L, 1x 4100L, 2x 4850L.
  - Collected and analyzed LBNF drill core, incl JPL's *in situ* laser spectrometer SHERLOC, technology concept used on Perseverance rover (part of Mars 2020 mission).
- **Future:**
  - Continue sampling indefinitely (and somewhat infrequently).
  - One 4850L site may be impacted by upcoming 4850L lab expansion.



NAI collected LBNF core



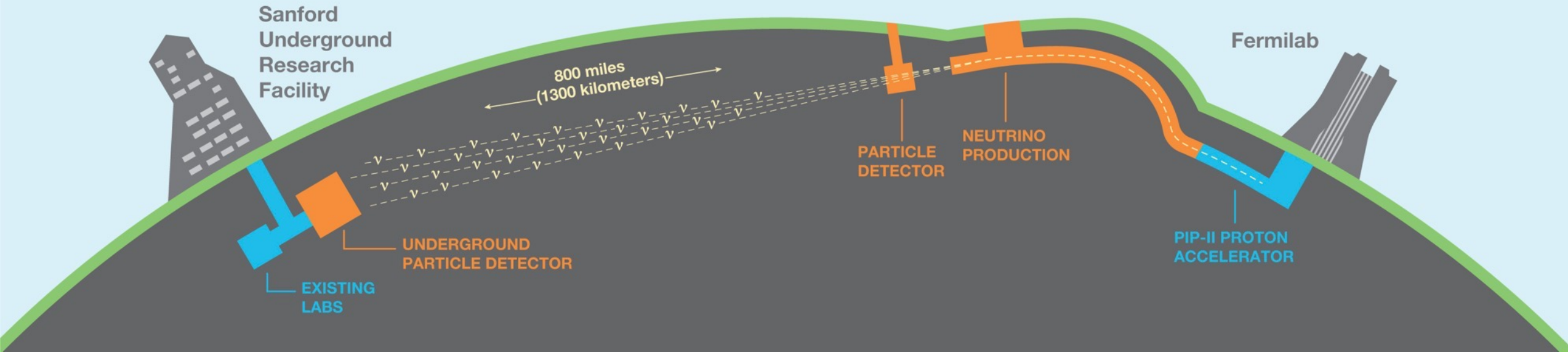
Sampling water from legacy drill hole



# Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

## U.S. DOE's Flagship Neutrino Study 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.

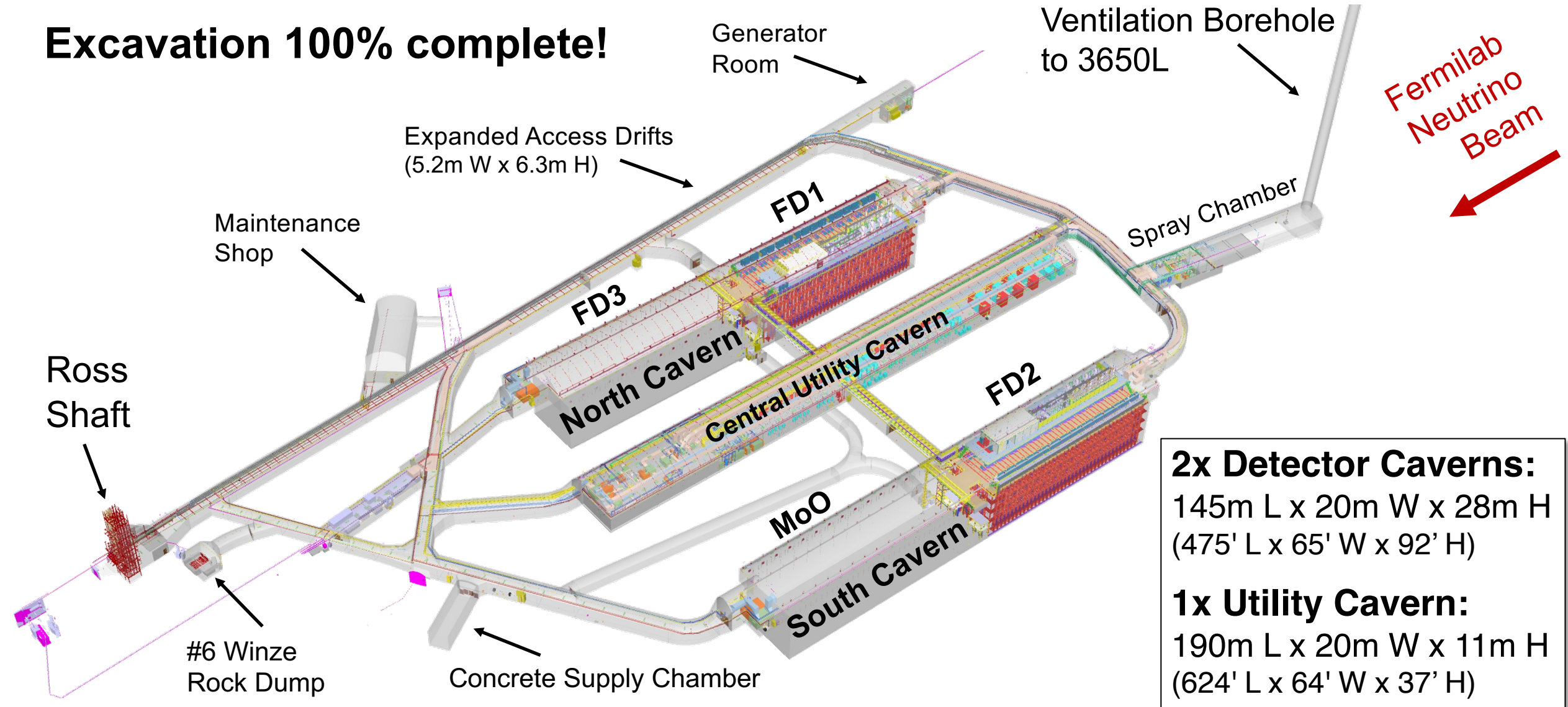


**Unification of forces:** Investigate nucleon decay, advance unified theory of energy and matter.

# Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

**Excavation 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)



