

SURF Overview and Update

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Sanford

Underground Research Facility

South Dakota Science and Technology Authority

User Association General Meeting Oct 26, 2022

Sanford Underground Research Facility



SURF Mission:

We advance world class science and inspire learning across generations.

SURF Vision:

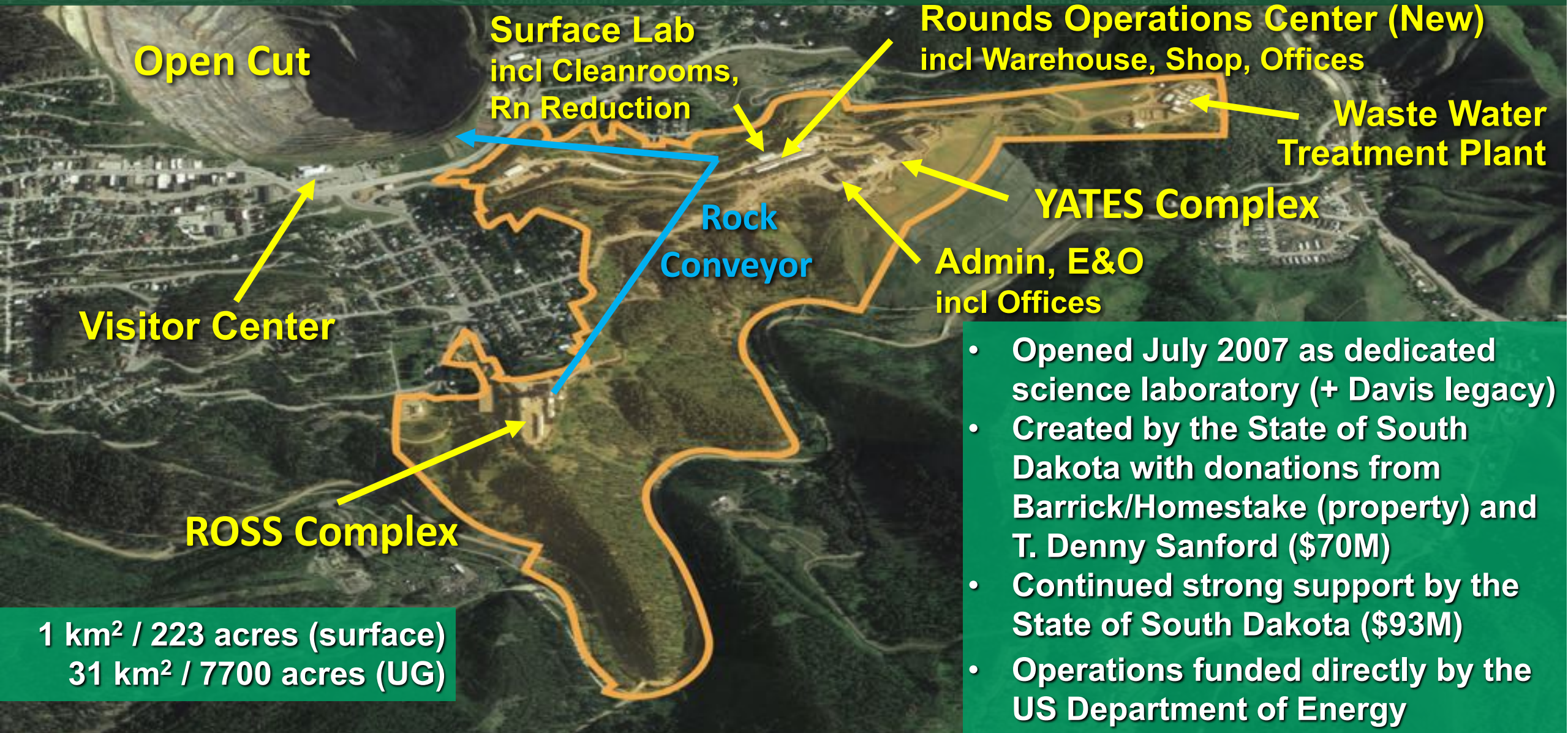
The world's preferred location for underground science and education.

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.

Sanford Underground Research Facility

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



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

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

Sanford Underground Research Facility

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



Ross Shaft

Yates Shaft



Administration Bldg



Rounds Operations Center

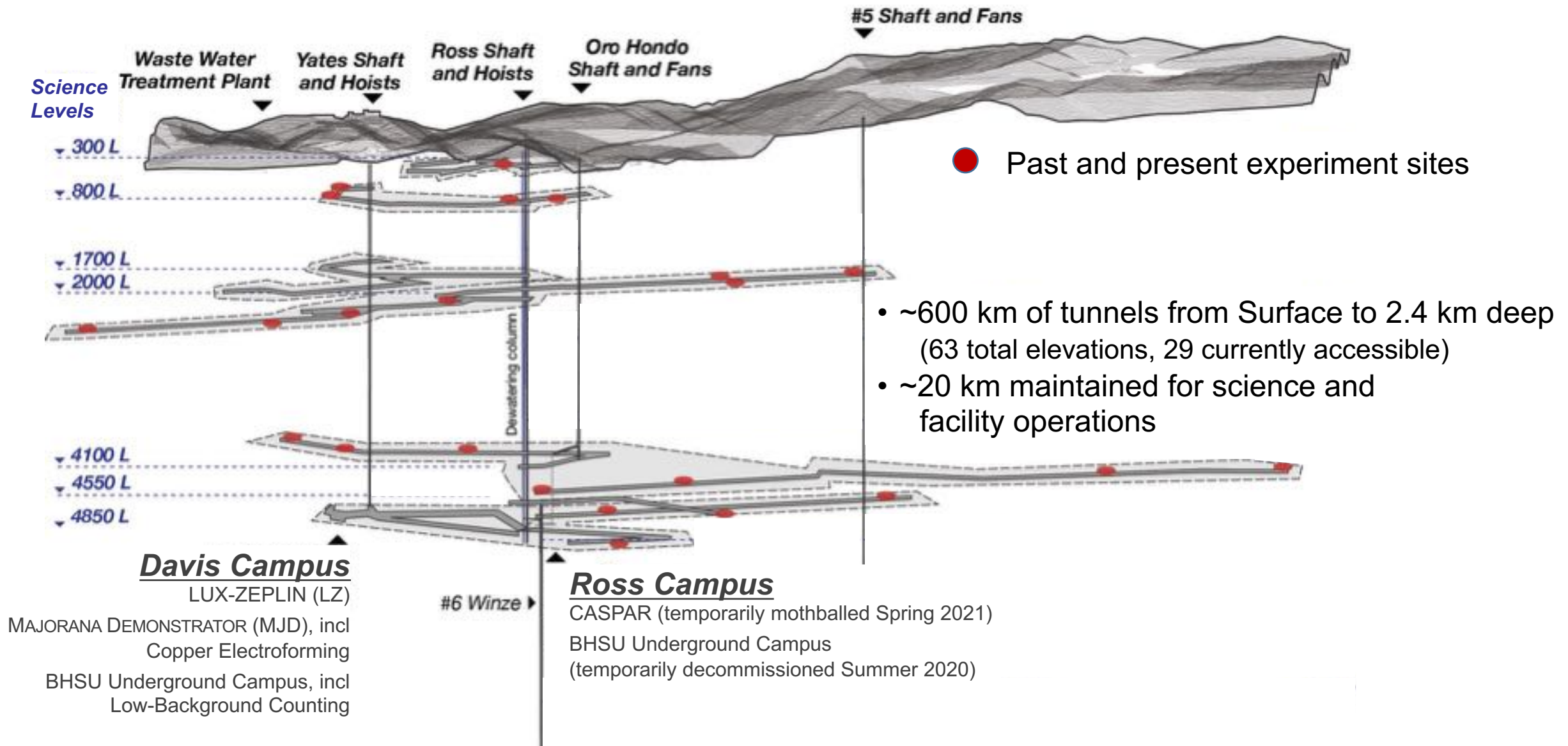
Surface Lab + RRS



Yates Hoistroom

SURF Underground Lab Geography

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



Underground Facilities



Underground Facilities

UG Facilities serve a diverse community:

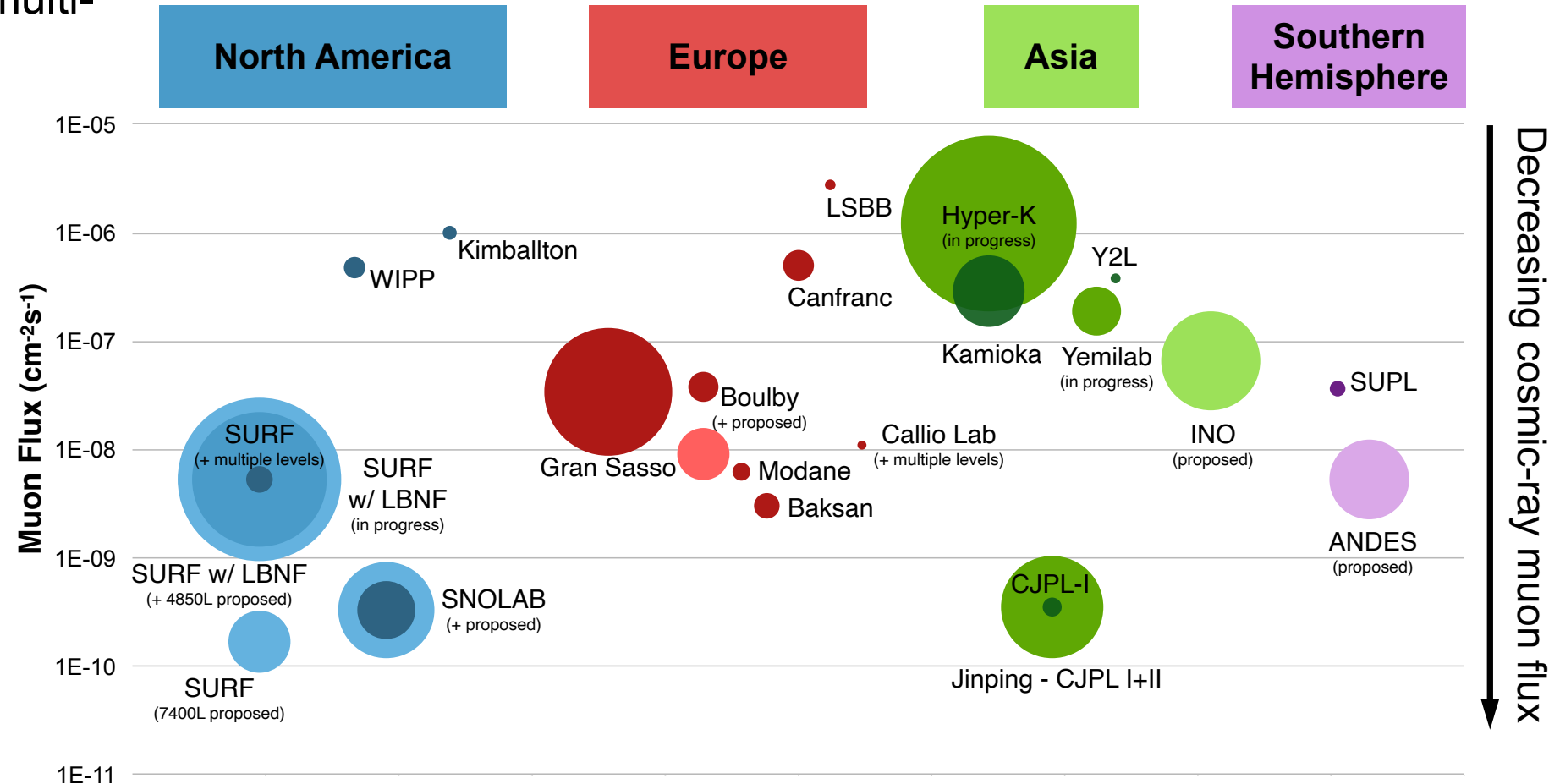
- Physics
 - Low-background environment to study rare processes
- Biology
 - Isolation from surface microorganisms
 - Variety of environmental conditions (temperature, humidity, etc)
 - Variety of niches (materials/rock geochemistry, water from different locations, trace gases, etc)
- Geology
 - Variety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



Underground Facilities

UG Facilities can provide:

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



Note: Circles represent volume of science space

SURF Overview

Expanding community of researchers from multiple disciplines

Facility Highlights

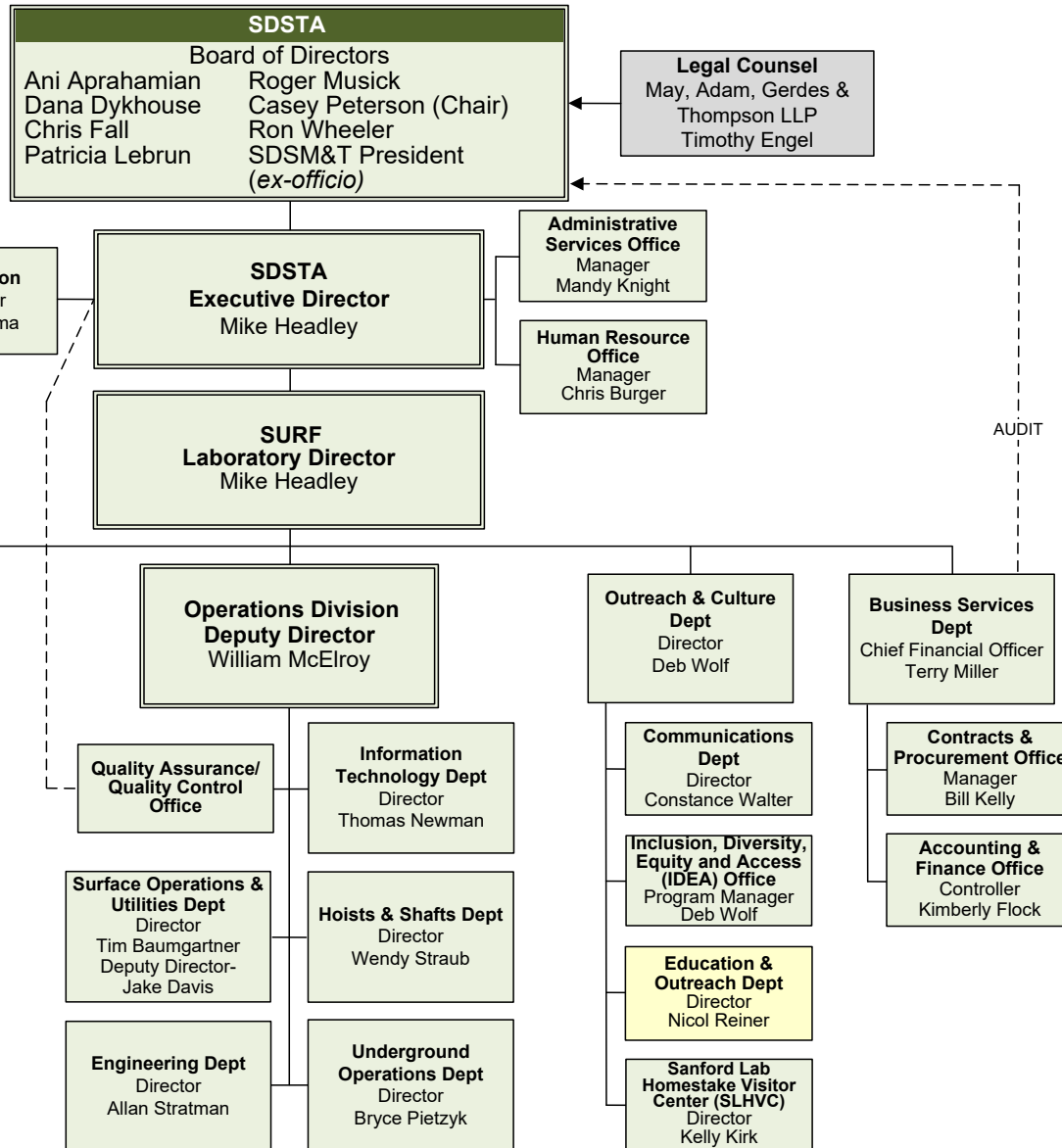
- **World-class services** and **unique attributes** attractive to physics, biology, geology and engineering
- **Deep** (1500 m, 4300 mwe) underground facility **dedicated** for science, with **capacity & expansion** possibilities (SURF strategic plan incl additional laboratories and deeper access to 2300 m, 6500 mwe)
- **Redundant** safe access with 2 principal shafts (incl redundant **power** and **network** utilities)
- **Robust Organization:** Resources to ensure safe and successful science: ~200 full/part-time staff, 11 departments such as Environment, Safety & Health (incl nurse, 24-hr emergency response), Engineering, Operations, Science + others
- **Mature Programs:** Experiment implementation, safety, operations; also monitoring
- **Community:** SURF **User Association** launched in 2020, SURF **Science Program Advisory Committee** established in 2021. Both groups support upcoming SURF application to become DOE Office of Science **User Facility**

SURF Organization

Resources to advance world class science and inspire learning across generations



Institutional Key:
 BHSU
 CONTRACT
 SDSTA



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

SURF Organization – Science Staffing

Resources to enable safe and successful implementation of experiments



Markus Horn (PhD)
Research Scientist
- Surface + UG Campuses

Charles Maupin (BSME, PE)
Expt Review Engineer
- Reviews, cryogen safety



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



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



Gavin Cox (MS)
Expt Support Scientist
- LZ Operations



Robyn Varland - Lab Custodians (Surface + UG) - Melissa Johnston



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

Julia Delgaudio (BS)
Expt Support Scientist
- LZ Operations



SURF Recent Highlights

- SURF DOE Operations Review successfully completed Jun 2022 (final report received Oct)
- Strategic planning:
 - **High Energy Physics:** Snowmass community planning underway (SURF whitepaper posted: <https://arxiv.org/abs/2203.08293>), report due ~Fall 2022. P5 report in 2023 (informs DOE + NSF)
 - **Nuclear Physics:** Long-Range Planning underway, initial report Oct 2023, final expected by mid-2024. NSAC report in 2024/2025 (informs DOE + NSF)
- Science program:
 - Science Program Advisory Committee (SPAC) first meeting Jan 2022 (next Nov 2022)
 - SURF Experiment Planning Statement updated to include IDEA section based on recommendation from SPAC
 - New SURF Experiment Integration & Support standard approved (basic support for all expts), update in process (incl machining services)
- Misc updates and plans:
 - May 2022: Davis Campus dedicated as historic physics site (announced Sep 2020)
 - May 2022: Davis Campus 10-year anniversary
 - Sep 2022: “Ask A Scientist” outreach initiative launched at Visitor Center
 - Oct 2022: SURF Safety & Support Perception survey (due Nov 18): <https://sanfordlab.org/sdstasafetysurvey>
 - Early 2023: New SURF public website design



SURF Recent Interruptions

(Not a complete list)

- Jul – Dec 2021: Yates Shaft maintenance (access via Ross Shaft, schedule restricted)
- Jul 19, 2022: (Unplanned) power outage
- Jul 30 – Aug 10, 2022: Ross electrical incident (no access)
- Oct 3, 2022: (Planned) power outage
- Oct 21 – Dec 2022?: Yates Shaft maintenance (access via Ross Shaft, schedule similar to regular)

SURF Goals for FY23 (Oct 2022 – Sep 2023)

- 3650L Pump Room rehabilitation underway
- Refuge Chamber on 4850L to support at least 250 ppl (phase 1)
- MineStar (real-time tracking) system operational at Yates and Ross Top
- Nationwide marketing and fundraising developed for Institute
- Launch Institute
- Ethnobotanical Garden is built
- Develop plan to re-open Ross Campus in FY24
- Complete strategic plan for science at SURF (15-year horizon)
- SURF named DOE Office of Science User Facility
- Develop and submit proposal for FY25-29 DOE Cooperative Agreement

SURF Infrastructure Improvement Projects

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

SURF Science Program

Research activities ranging from the surface to 1500+m underground

Physics LZ – *Dark matter, 2-phase Xe TPC*
MAJORANA DEMONSTRATOR / LEGEND –
Neutrinoless double-beta decay,
Ge-76, Ta-180m, also Cu e-forming
CASPAR – *Nuclear astrophysics with*
1 MV accelerator
LBNF/DUNE – *Neutrino properties, etc*
BHUC – *BHSU Underground Campus,*
mainly material screening
Berkeley LBF – *Low-bkgd counter (x3);*
also CUBED – Low-bkgd counter (x1)
(possibly future Crystal Growth)
nEXO – *Low-bkgd counter (x1)*
LLNL – *Low-bkgd counter (x1)*
SDSMT Bkgds – *Neutron bkgds*

Biology Astrobiology/DeMMO – *In-situ*
cultivation, DNA isolation
2D Best – *Biofilms*
Biodiversity – *Microbial communities*
Biofuels – *Extremophile bioprospecting*
BuG ReMeDEE – *Methane oxidation*
Carbon Sequestration – *Biology in core*
Chemistry – *Env characterization*
Liberty BioSecurity* – *Extremophiles*

Geology SIGMA-V – *Geothermal*
3D DAS – *Seismic monitoring using fiber*
Core Archive* – *Mainly gold deposits*
Hydro Gravity – *Gravity for water tables*
BH Seismic – *Global monitoring*
Transparent Earth – *Seismic arrays*

Engineering Xilinx, Inc* – *Chip error testing*
Thermal Breakout – *In situ stress*
Shotcrete – *Mining safety*
GEOX™ – *Env monitoring*
Caterpillar* – *Mining processes*
Blast Monitoring – *LBNF-related*

Total = 29 groups

21 Active Projects

60 Total Groups Since 2007

Significant interest from others
(17 groups in 2021)

* Denotes proprietary
group

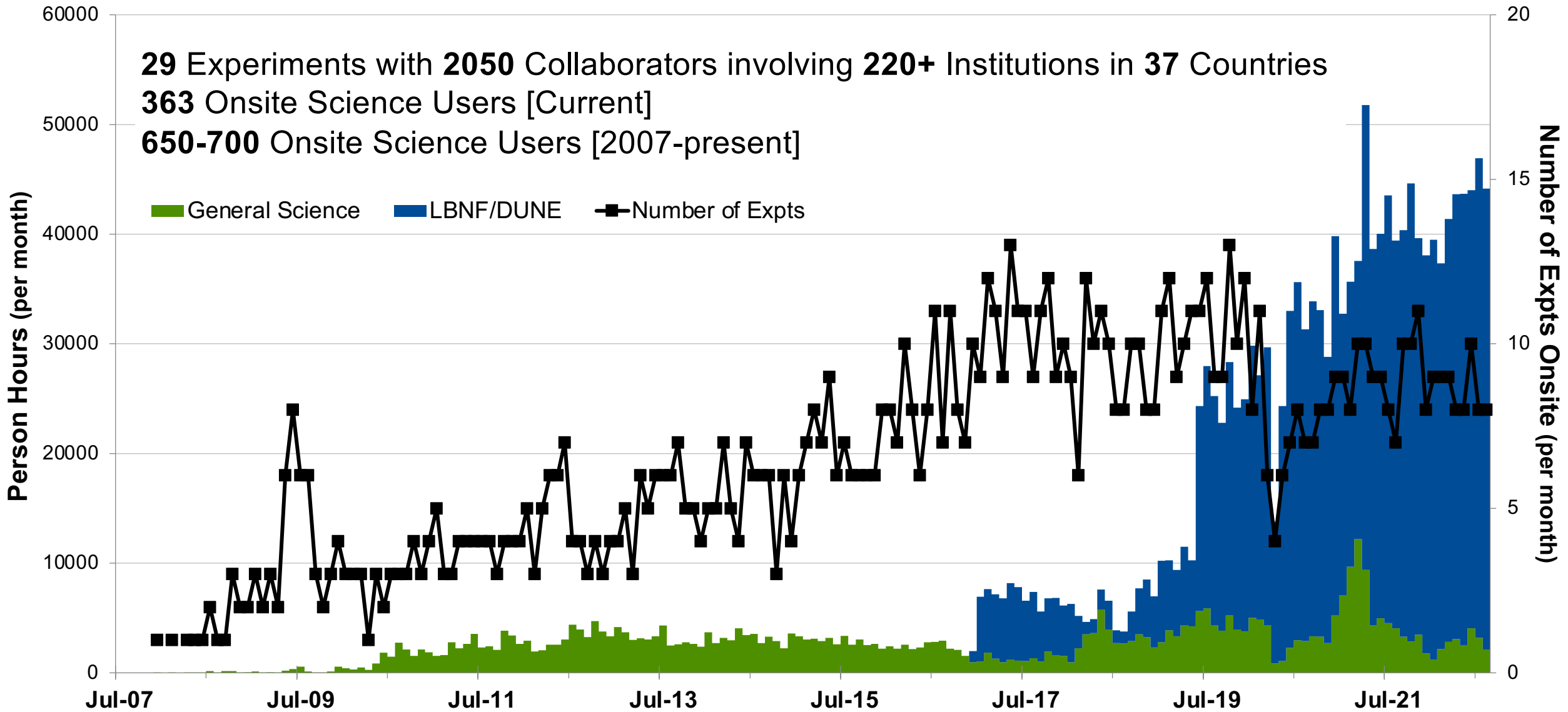
SURF High-Impact Science

<https://www.sanfordlab.org/publications-and-reports>

- 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](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).
- 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).
- 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).
- Search for Neutrinoless Double- β 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](https://doi.org/10.1103/PhysRevLett.120.132502).
- 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).
- First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment, J. Aalbers *et al.* (LZ Collaboration) submitted to *Phys. Rev. Lett.*
- Final Result of the MAJORANA DEMONSTRATOR's Search for Neutrinoless Double- β Decay in ^{76}Ge , I.J. Arnquist *et al.* (MAJORANA Collaboration) submitted to *Phys. Rev. Lett.*

SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities



SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities

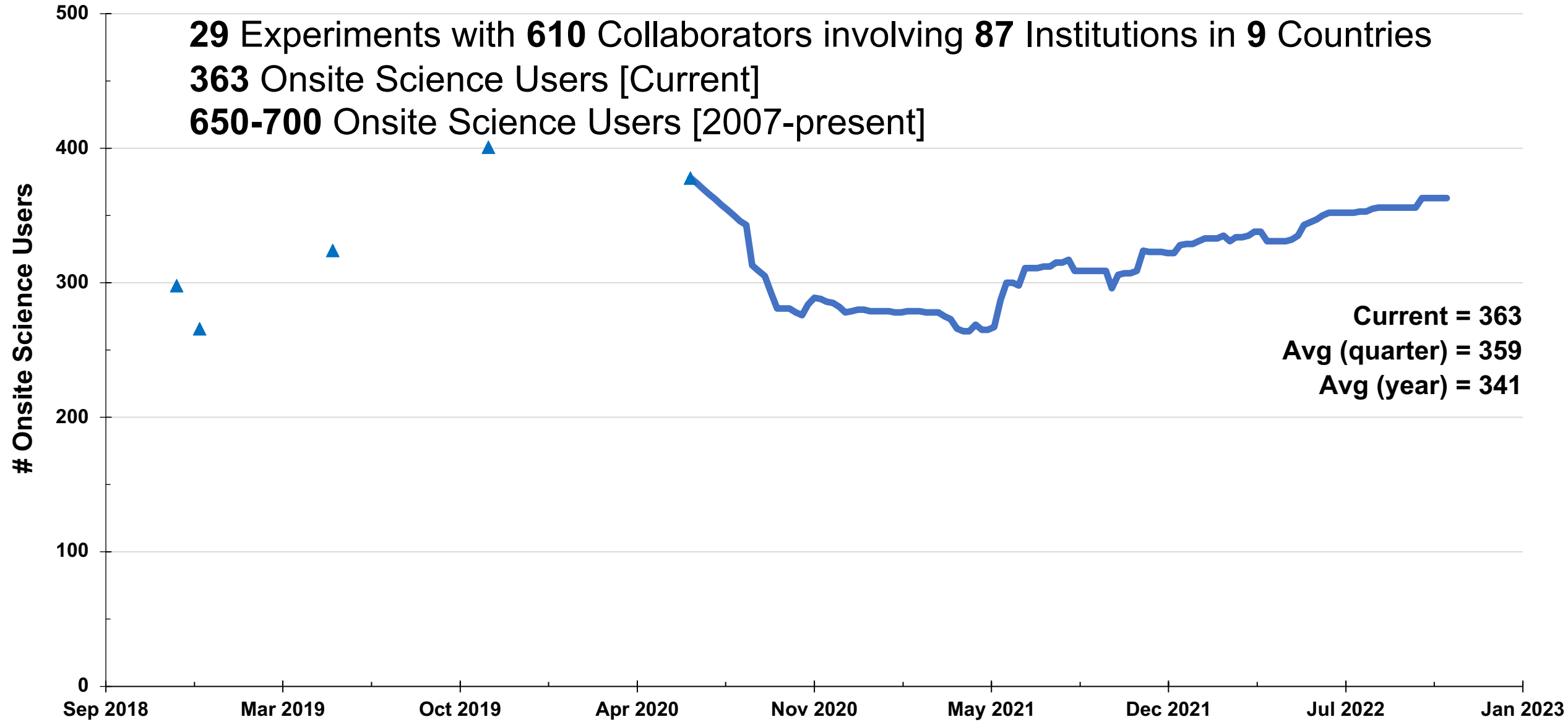


29 Experiments with **2050** Collaborators involving **220+** Institutions in **37** Countries
363 Onsite Science Users [Current]
650-700 Onsite Science Users [2007-present]

SURF Science Program

Hosting world-leading experiments and researchers from diverse scientific communities

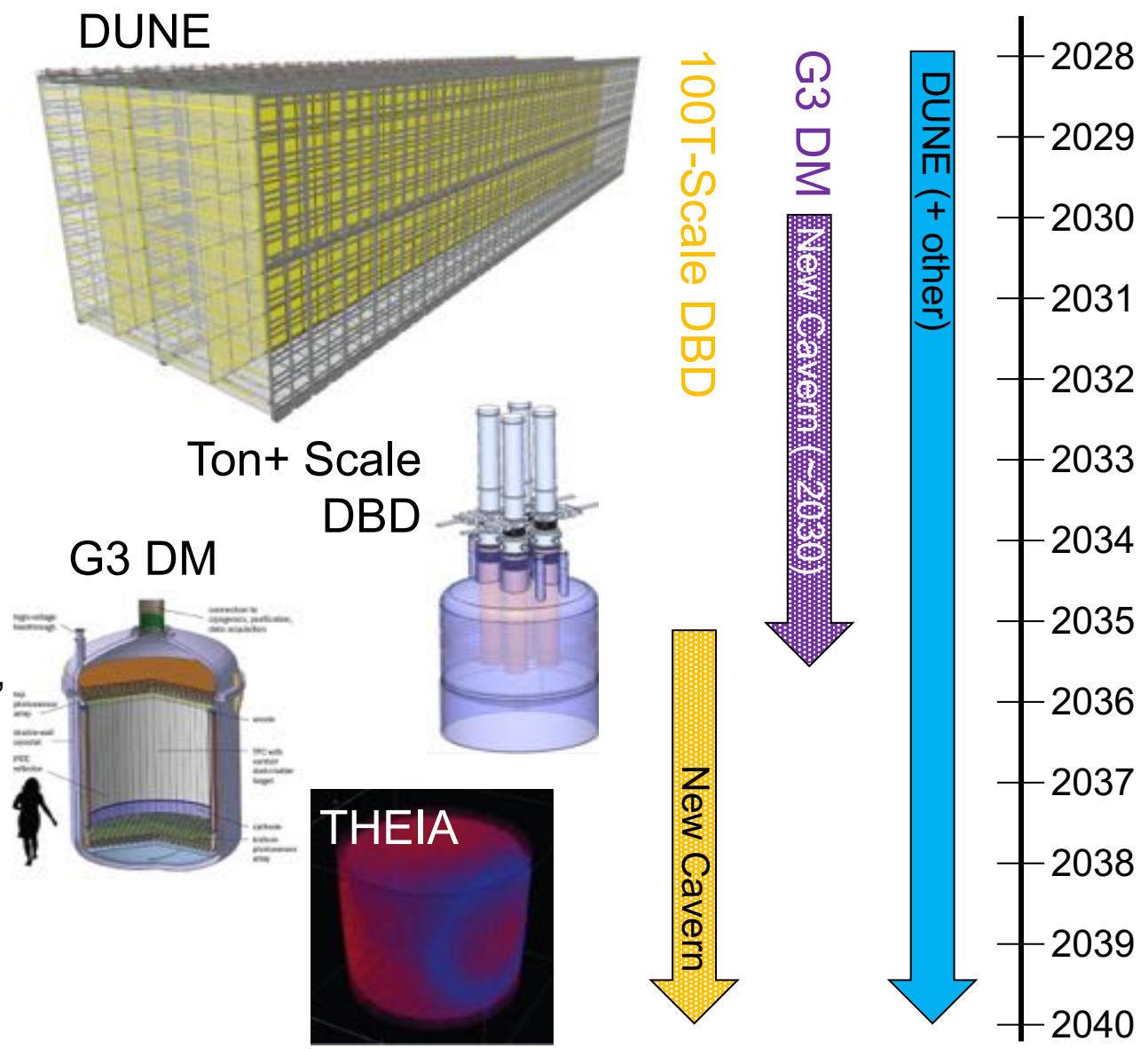
29 Experiments with **610** Collaborators involving **87** Institutions in **9** Countries
363 Onsite Science Users [Current]
650-700 Onsite Science Users [2007-present]



SURF Science Program – Planned / Future

Strong and diverse program with exciting future possibilities

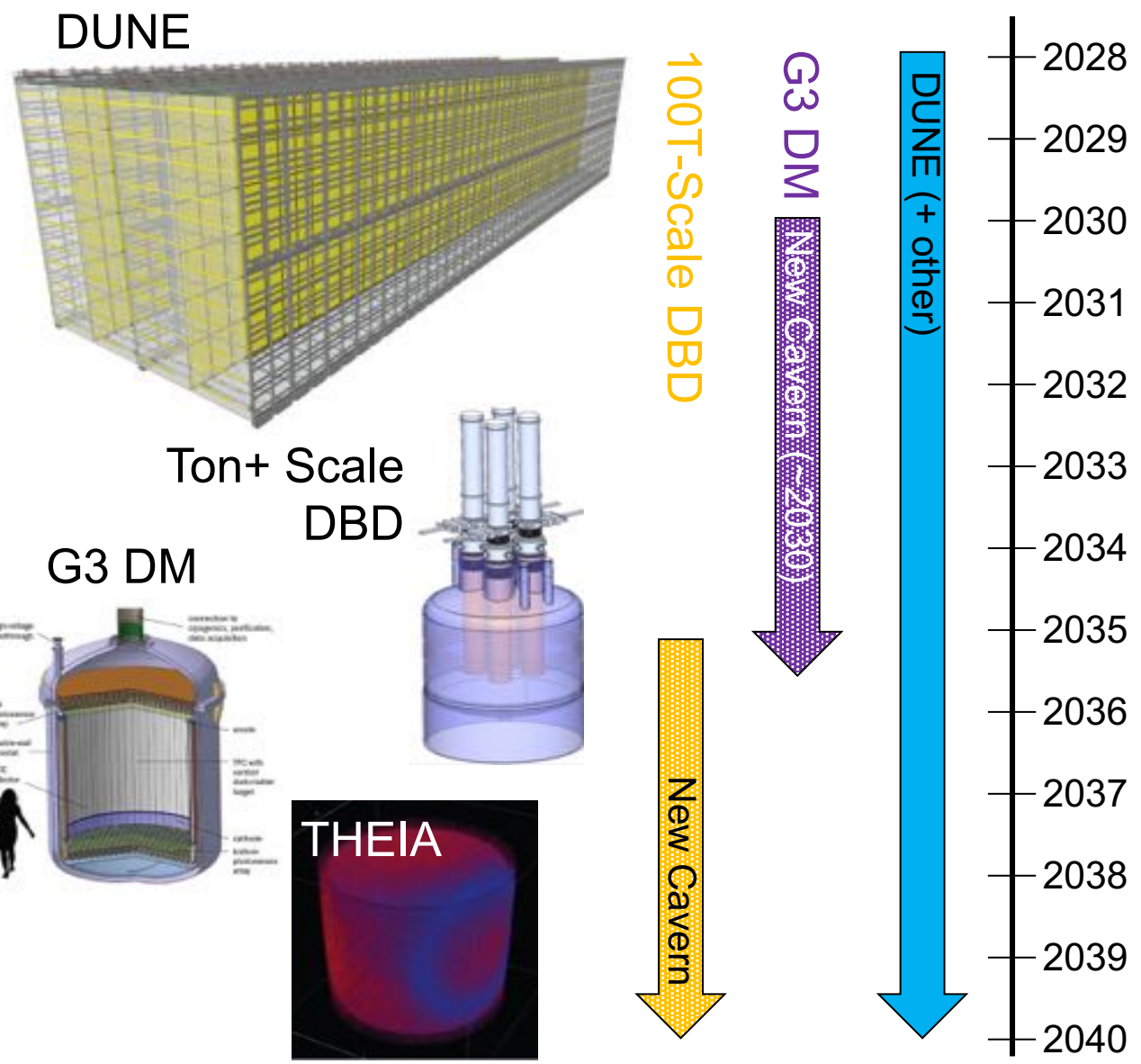
- **DUNE:** 4x 10 kT LAr detectors with horizontal/vertical drift for **neutrinos (CPV, MH, SN, proton decay, etc)**. Excavation complete in 2024, science starts **2028**. Renewed discussions for “**Module of Opportunity**”
- Neutrinoless Double-Beta Decay (Ton+ Scale): Investigate **neutrino properties** using ~1-100-tonne enriched isotope, inverted hierarchy coverage
- Dark Matter (Generation-3): Search for WIMP **dark matter** to neutrino background “floor/fog” using ~50-100 tonne Xe (e.g., XLZD) or other target
- THEIA: Water-based liquid scintillator (25-100 kT) using LBNF beam to investigate **neutrino properties (CPV, MH, CNO, DSNB, etc)**
- Low-Bkgd Module: **SoLAr (nu)**, **SLoMo (nu+DM)**, etc, targeting the “Module of Opportunity”
- Other:
 - Low-mass dark matter: **TESSERACT** (Al₂O₃, GaAs, LHe), **Scintillating Bubble Chamber** (Ar), Xe-based detectors (**Hydro-X** or **CrystaLiZe**)
 - Ge detector production, Quantum; *Vertical facility?*
 - Non-Physics, incl geothermal (DEMO-FTES, Eden)



SURF Science Program – Planned / Future

Strong and diverse program with exciting future possibilities

- **DUNE:** 4x 10 kT LAr detectors with horizontal/vertical drift for **neutrinos (CPV, MH, SN, proton decay, etc)**. Excavation complete in 2024, science starts **2028**. Renewed discussions for “**Module of Opportunity**”
- Neutrinoless Double-Beta Decay (Ton+ Scale): Investigate **neutrino properties** using ~1-100-tonne enriched isotope, inverted hierarchy coverage
- Dark Matter (Generation 2) **dark matter to target using**
- **Non-DUNE Projects Require New Cavern (and/or “Module of Opportunity”)**
- **100T-Scale DBD** liquid scintillator (25-100 kT) using **beam to investigate neutrino properties (CPV, MH, CNO, DSNB, etc)**
- Low-Bkgd Module: **SoLAr (nu), SLoMo (nu+DM), etc**, targeting the “Module of Opportunity”
- Other:
 - Low-mass **As, GaAs, Ge, Si, Cs, Bi, Te, Zn, Cu, Au, Pt, Pb, Bi, Po, At, Xe-based**
 - **Crystalize**
 - **detector production, Quantum; Vertical facility?**
 - Non-Physics, incl geothermal (DEMO-FTES, Eden)



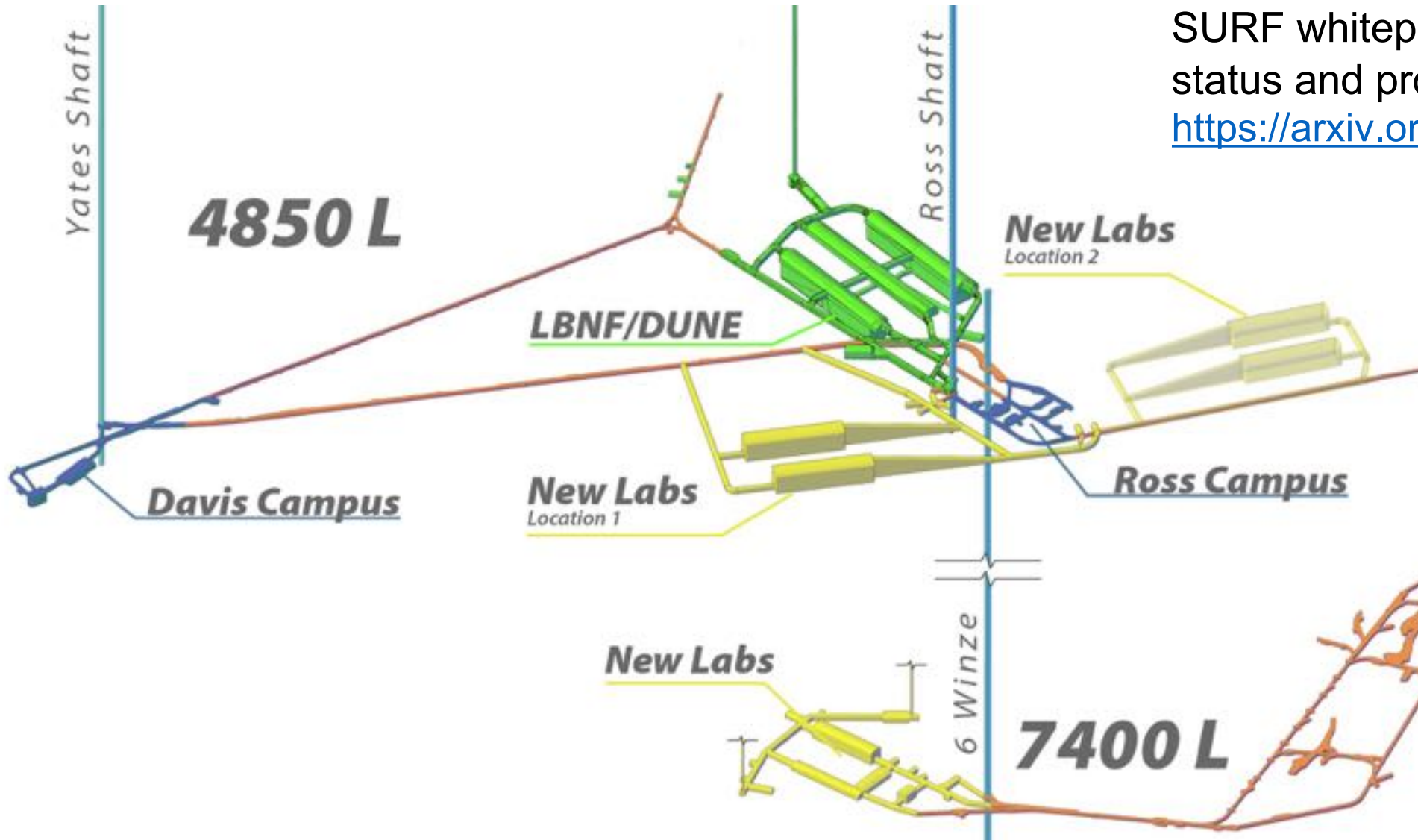
SURF Current & Future Facilities

Summary for various science campuses, including timelines

Location	Laboratory	Existing/ <i>Planned</i> Space		Available (CY)	Comments
		Area (m ²)	Vol (m ³)		
Surface	Surface Lab (+ RRS)	210	600	2021	LZ use ~complete, allowing use by others
Davis Campus (4850L)	LZ Lab – Davis Cavern (2 levels)	372	1,956	~2027	LZ data complete in ~2026 + decommissioning
	MJD Lab – 2 Rooms + BHUC share	300	1,279	~2024/2026	Initial scope completed 2021, Ta-180m data 2022-2023 + decommissioning; Cu e-forming through 2025+
	Cutout Rooms (4)	100	412	~2027	LZ timeframe for most spaces
Ross Campus (4850L)	Former E-forming	228	742	?	LBNF use now, SURF UG WWTP in next few years
	BHUC (BHSU cleanroom)	266	773	N/A	Mothballed, equip and systems relocated to Davis Campus; re-occupy FY24 after LBNF construction
	CASPAR	395	1,130	2029-2031	Mothballed, equip remains, re-occupy FY24 after LBNF construction. (Also expanded Refuge Chamber)
	Refuge Chamber	258	866	?	Long-term use TBD
<i>LBNF (4850L)</i>	<i>LBNF</i>	<i>9,445</i>	<i>191,863</i>	<i>~2024</i>	<i>Excavation complete in 2023, temporary use?</i>
4100L	Geoscience Lab	334	11 drill holes	Fall 2022	Leverage EGS/SIGMA-V infrastructure
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 Current & Future Underground Facilities

Strategic plan incl additional 4850L labs + deeper access



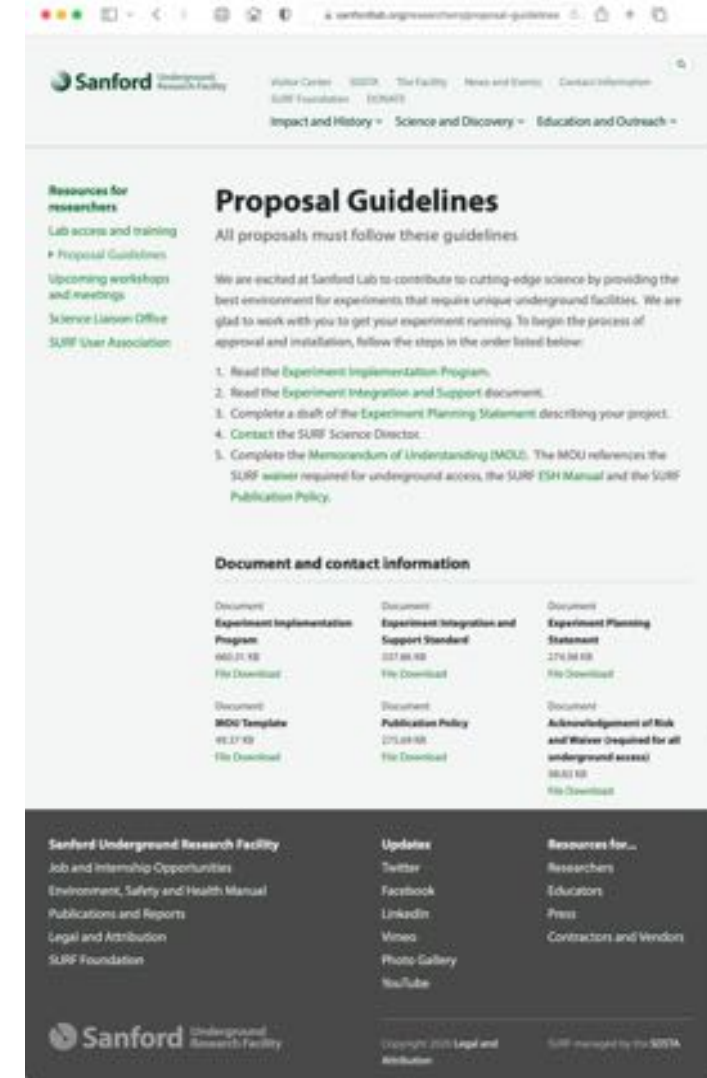
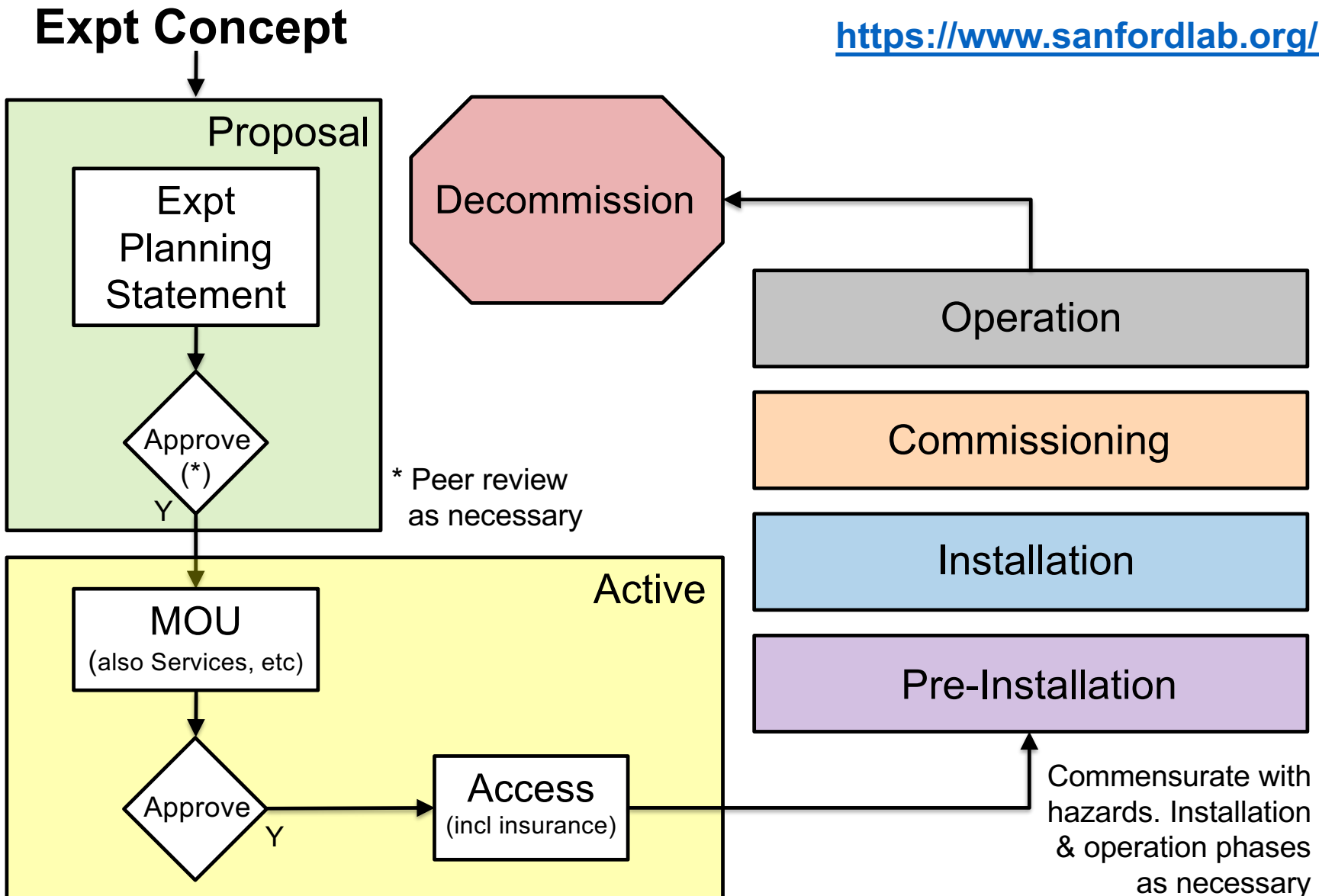
SURF whitepaper describing current status and proposed future facilities:

<https://arxiv.org/abs/2203.08293>

SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework

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



SURF Science Guidance

User Association

- 9-10 members spanning breadth of SURF science: physics, biology, geology, engineering.
- Scope: reinforce two-way communication, foster sense of community, promote scientific case for UG science.
- SURF Long-Term Vision Workshop held mid-Sep 2021. First General Meeting Sep 2021, next meeting Oct 2022.

1. Brittany Kruger (DRI/**Chair**)
2. Megan Smith (LLNL/**Secretary**)
3. Mark Hanhardt (SDSTA)
4. Kevin Lesko (LBNL)
5. Rachel Mannino (LLNL)
6. Ralph Massarczyk (LANL)
7. Sam Meijer (LANL)
8. Brianna Mount (BHSU)
9. Frank Streider (SD Mines)
10. Wenqin Xu (USD)

Also:

- SDSTA Board of Directors (SD Mines President *ex-officio*)
- SURF Strategic Advisory Committee
- SURF is looking to strengthen administrative and academic relationships with SD universities

Science Program Advisory Committee

- 14 members, national & international experts spanning breadth of SURF science with strategic and synergistic influences.
- Scope: Review science program, support and facilities. Peer review per DOE User Facility.
- First meeting held Jan 2022, next meeting Nov 2022.

1. David MacFarlane (SLAC/**Chair**)
2. Ed Blucher (Chicago)
3. Derek Elsworth (Penn State)
4. Joseph Formaggio (MIT)
5. Hunter Knox (PNNL)
6. Magdalena Osburn (Northwestern)
7. Federica Petricca (Max Planck)
8. Lance Roberts (SD Mines)
9. Hamish Robertson (Washington)
10. William Roggenthen (SD Mines)
11. Kate Scholberg (Duke)
12. Barbara Szczerbinska (TAMU-CC)
13. Mary Voytek (NASA)
14. TBD

Recent Conferences



May 11-13, 2022:
Conference on Science at SURF (SD Mines)
<https://indico.sanfordlab.org/e/CoSSURF2022>



Jun 14-17, 2022:
Low Radioactivity Techniques (SD Mines + SURF)
<https://indico.sanfordlab.org/e/LRT2022>

Summary

- SURF currently offers world-class service to the UG science community:
 - SURF has attracted world-leading experiments and scientists from diverse scientific communities
 - SURF has proven track record of enabling experiments to deliver high-impact science
- In addition to DUNE, SURF wants to host other future world-leading experiments
- SURF is actively exploring options to increase underground laboratory space:
 - Engineering studies have been completed to build large caverns on the 4850L to accommodate next-generation experiments
 - Previous engineering studies exist for the 7400L (2300 m, 6500 mwe)
 - Discussions have been renewed for the LBNF/DUNE “Module of Opportunity”
 - Recent briefings incl DOE-HEP and state officials, discussions with private investors planned in 2022
- SURF is playing a strong role in the UG science community:
 - SURF User Association is serving as catalyst for discussions and planning
 - SURF Science Program Advisory Committee has strength across multiple disciplines to help chart future science at SURF

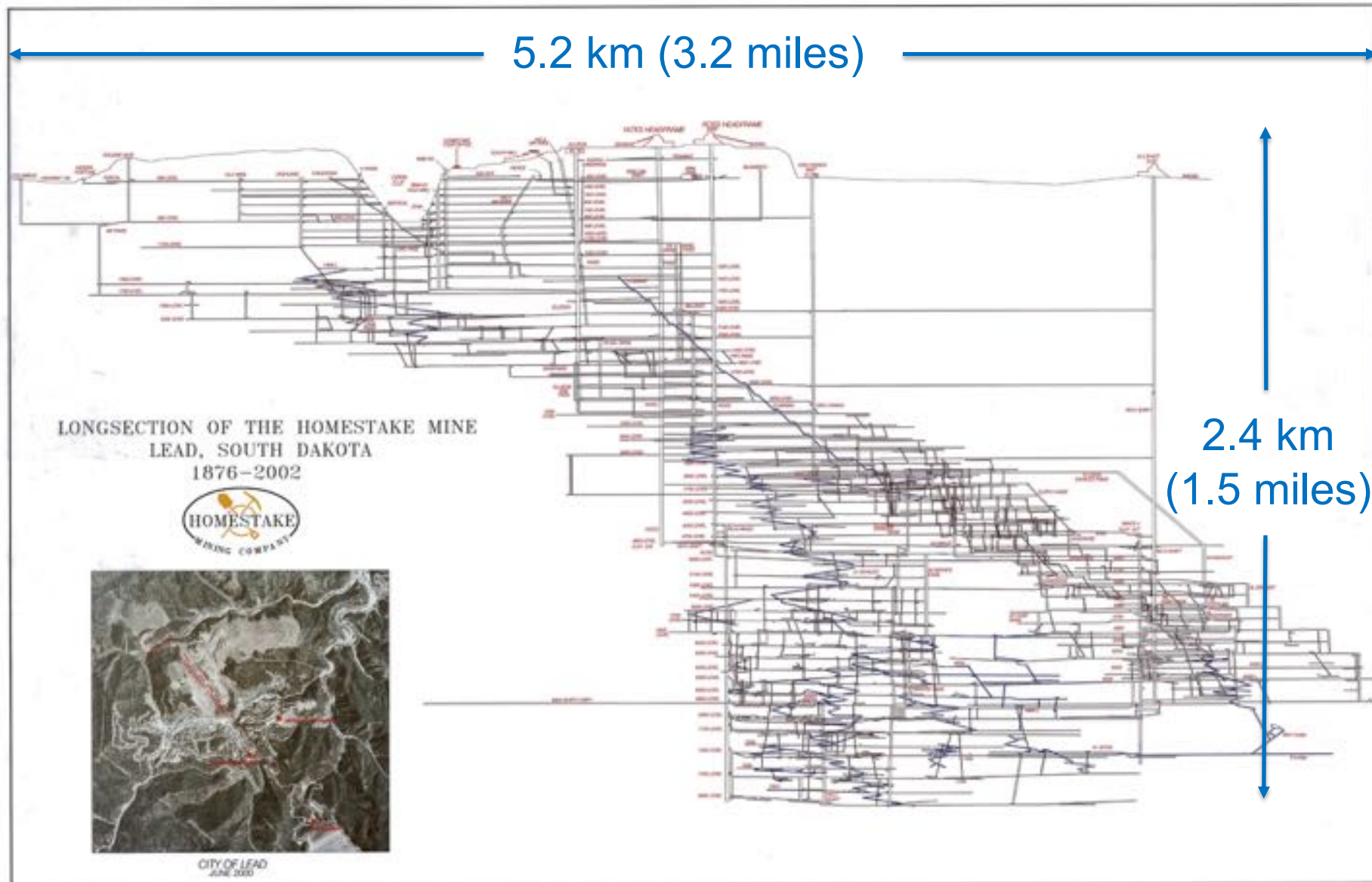
Sanford Underground Research Facility

Thank You!



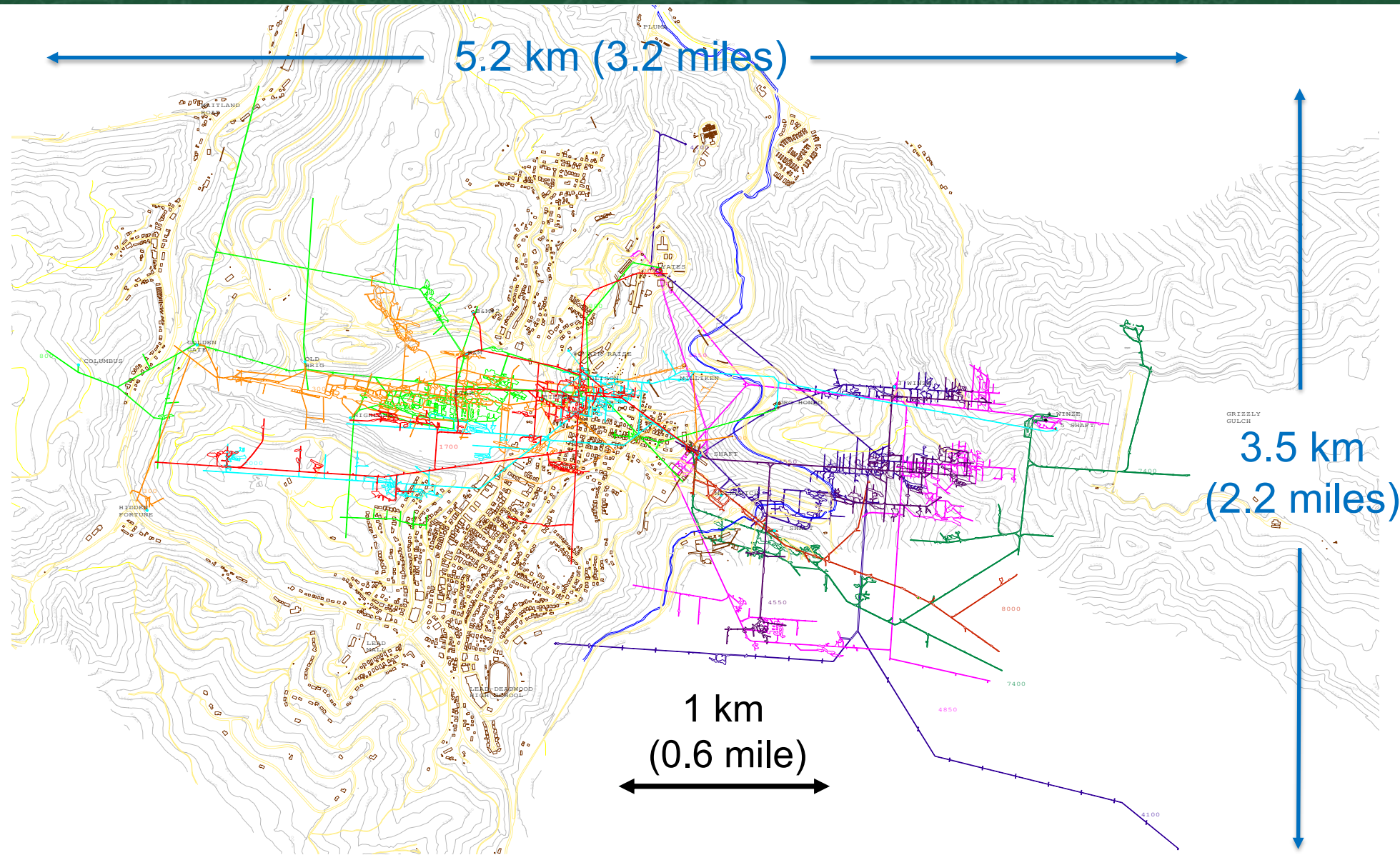
SURF Underground Lab Geography

Significant underground footprint for science



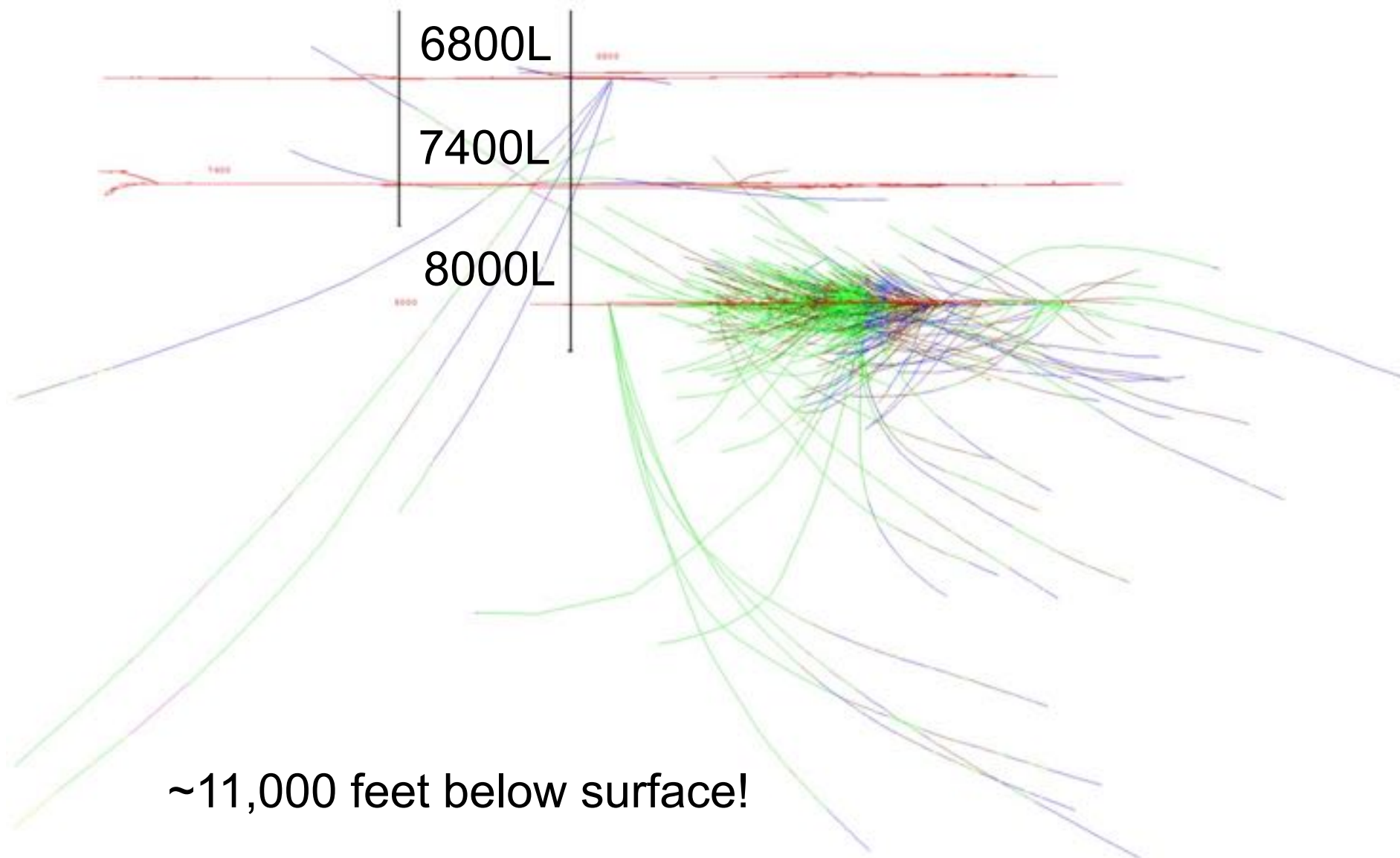
SURF Underground Lab Geography

Significant underground science footprint



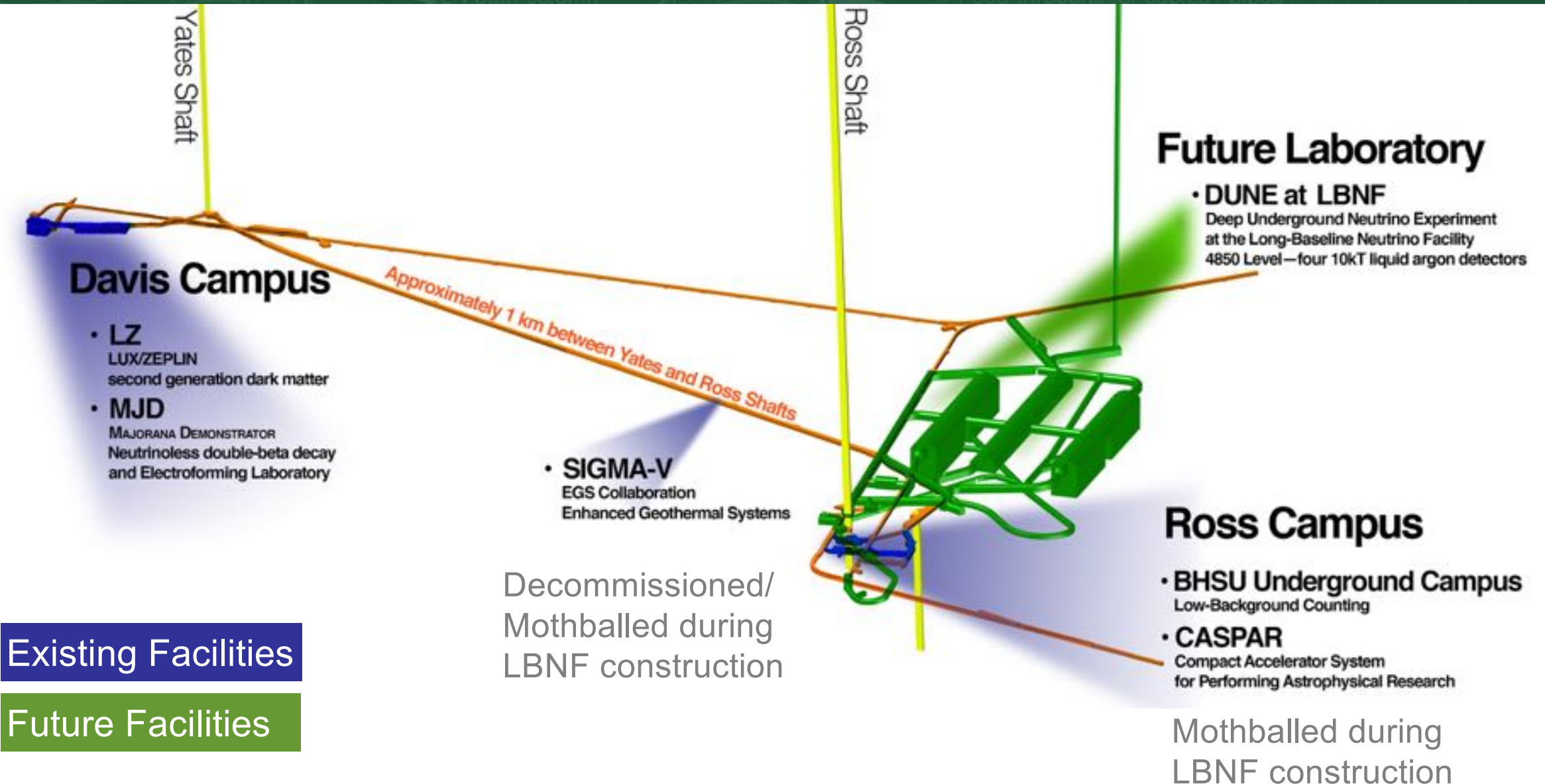
SURF Underground Lab Geography

Future Possibilities to Access Existing Deep Holes?



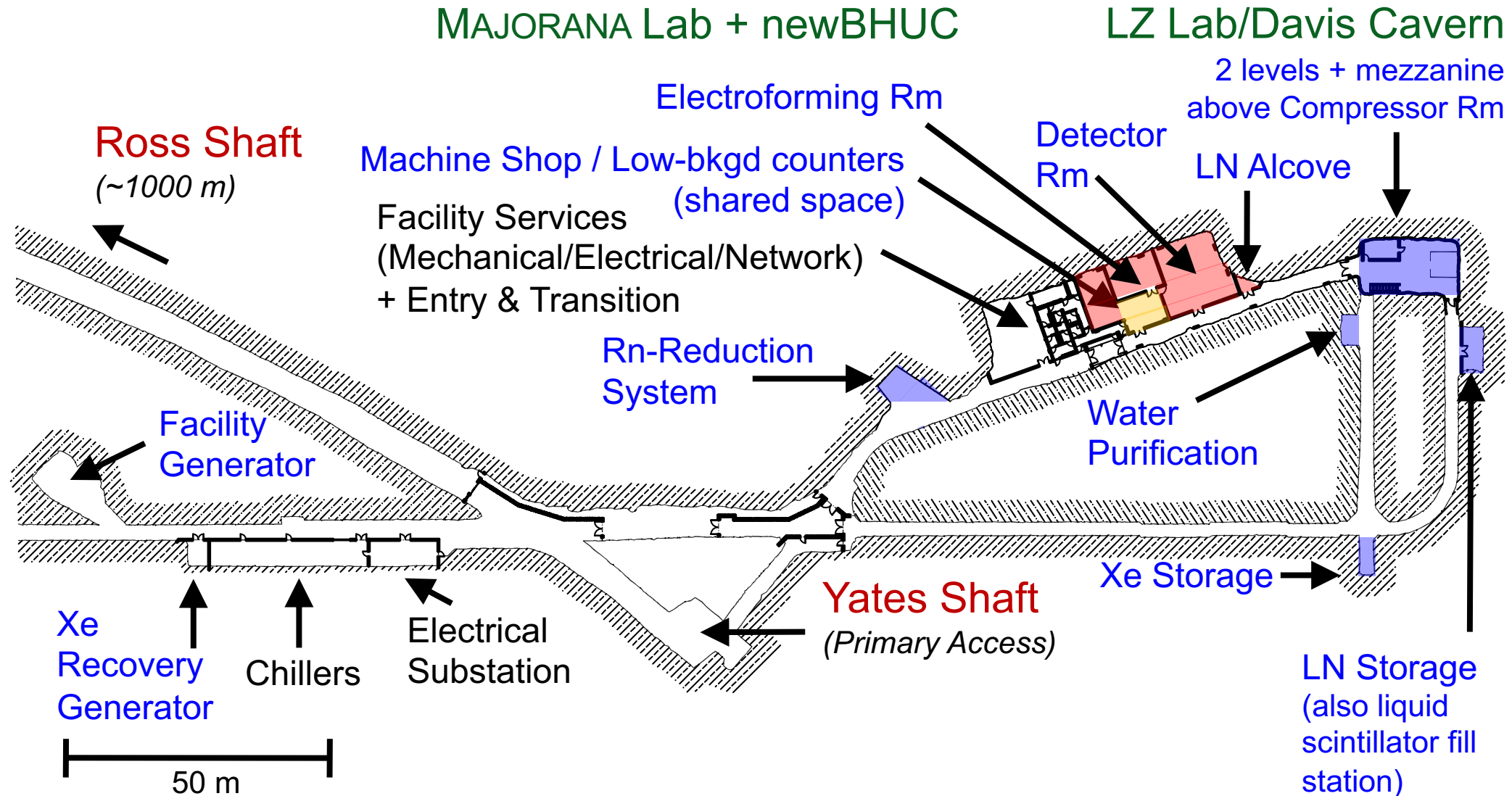
Current & Future Underground Facilities

SURF research through 2050 and beyond



4850L Davis Campus

3,017 m² (Total) / 1,018 m² (Science), New Excavation + Davis Cavern



4850L Davis Campus

Examples of laboratory space



Detector Room (MJD):

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

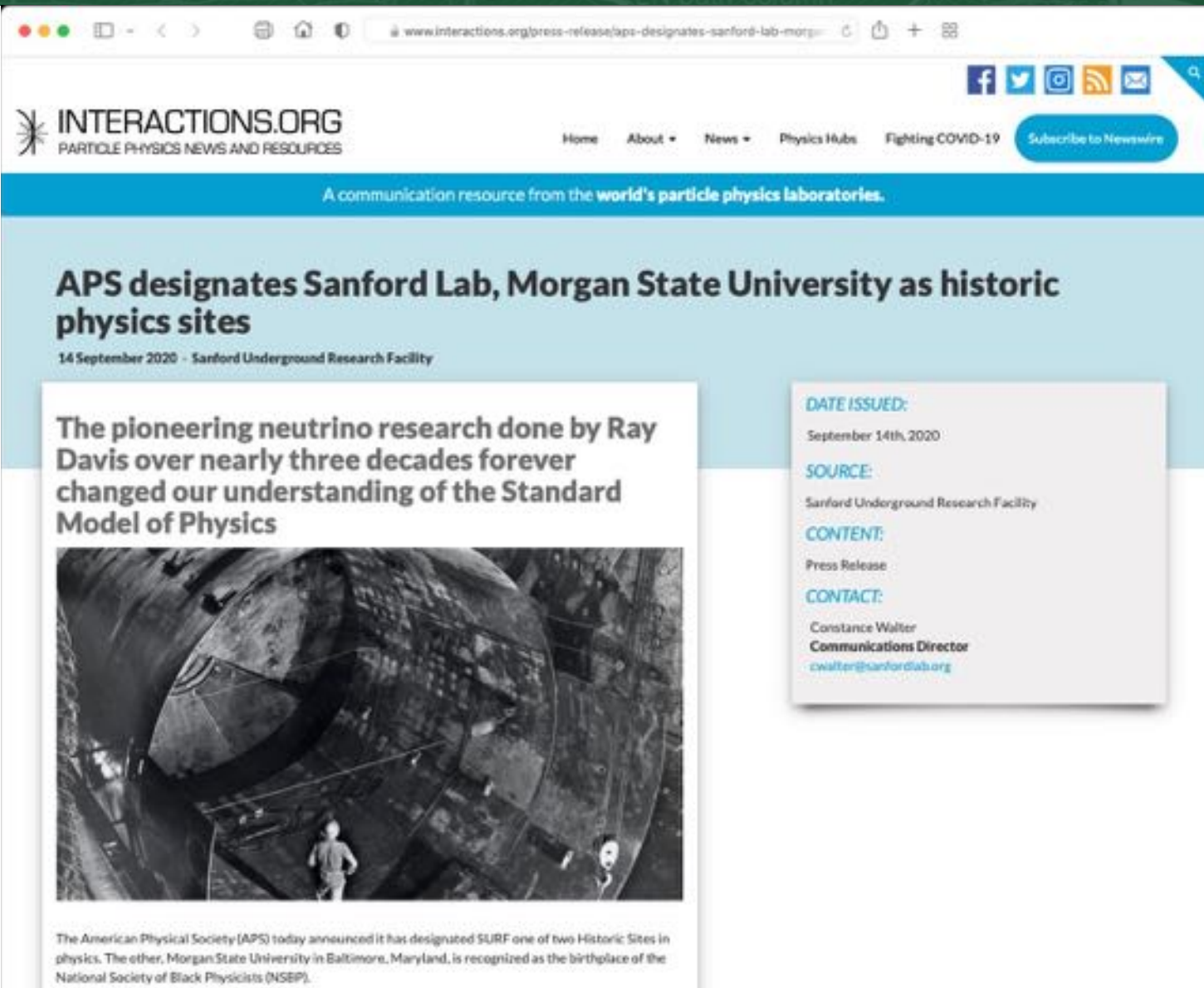


Lower Davis Cavern (LZ):

Area = 142 m², 13.7 m × 9.1 m × 6.4 m (H)
(incl tank: 7.6 m diameter × 6.4 m H)

SURF Designated APS Historical Site

Announcement Sep 2020, Dedication May 2022



www.interactions.org/press-release/aps-designates-sanford-lab-morgan-state-university-as-historic-physics-sites

INTERACTIONS.ORG
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A communication resource from the world's particle physics laboratories.

APS designates Sanford Lab, Morgan State University as historic physics sites

14 September 2020 - Sanford Underground Research Facility

The pioneering neutrino research done by Ray Davis over nearly three decades forever changed our understanding of the Standard Model of Physics



The American Physical Society (APS) today announced it has designated SURF one of two Historic Sites in physics. The other, Morgan State University in Baltimore, Maryland, is recognized as the birthplace of the National Society of Black Physicists (NSBP).

DATE ISSUED:
September 14th, 2020

SOURCE:
Sanford Underground Research Facility

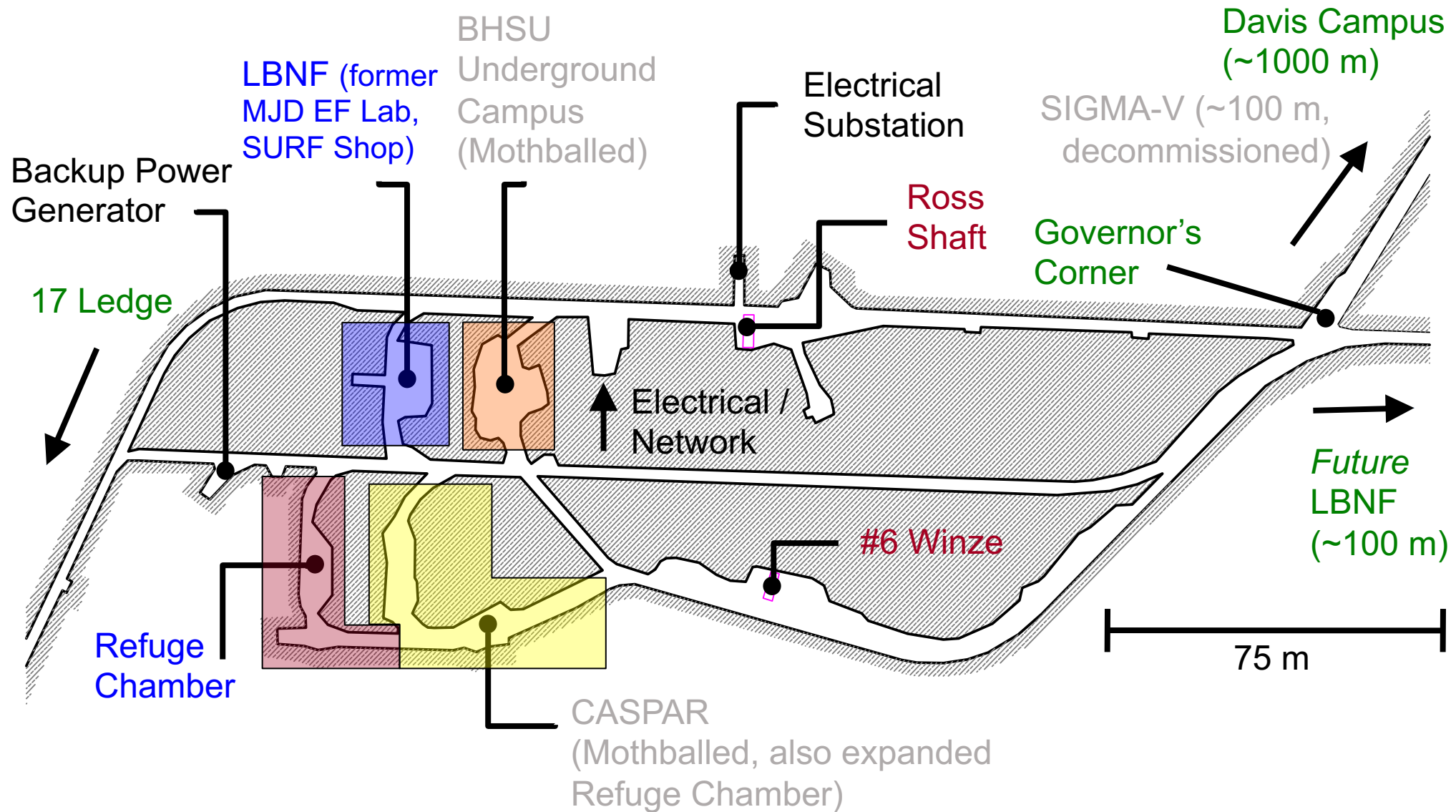
CONTENT:
Press Release

CONTACT:
Constance Walter
Communications Director
cwaller@sanfordlab.org



4850L Ross Campus

2,653 m² (Total) / 920 m² (Science), Existing Excavations Improved



4850L Ross Campus

Examples of laboratory space



2010-2017

Former MJD Electroforming:

Area = 228 m²
(Cleanroom removed, future UG WWTP)

CASPAR Hall:

Area = 236 m²,
30 m × 3 m (min) × 2.8 m (H)



Copper Electroforming



2015-2020, resume FY24

BHUC Cleanroom:

Cavern Area = 268 m²,
Cleanroom = 12.1 m × 6.1 m ×
2.4 m (H)

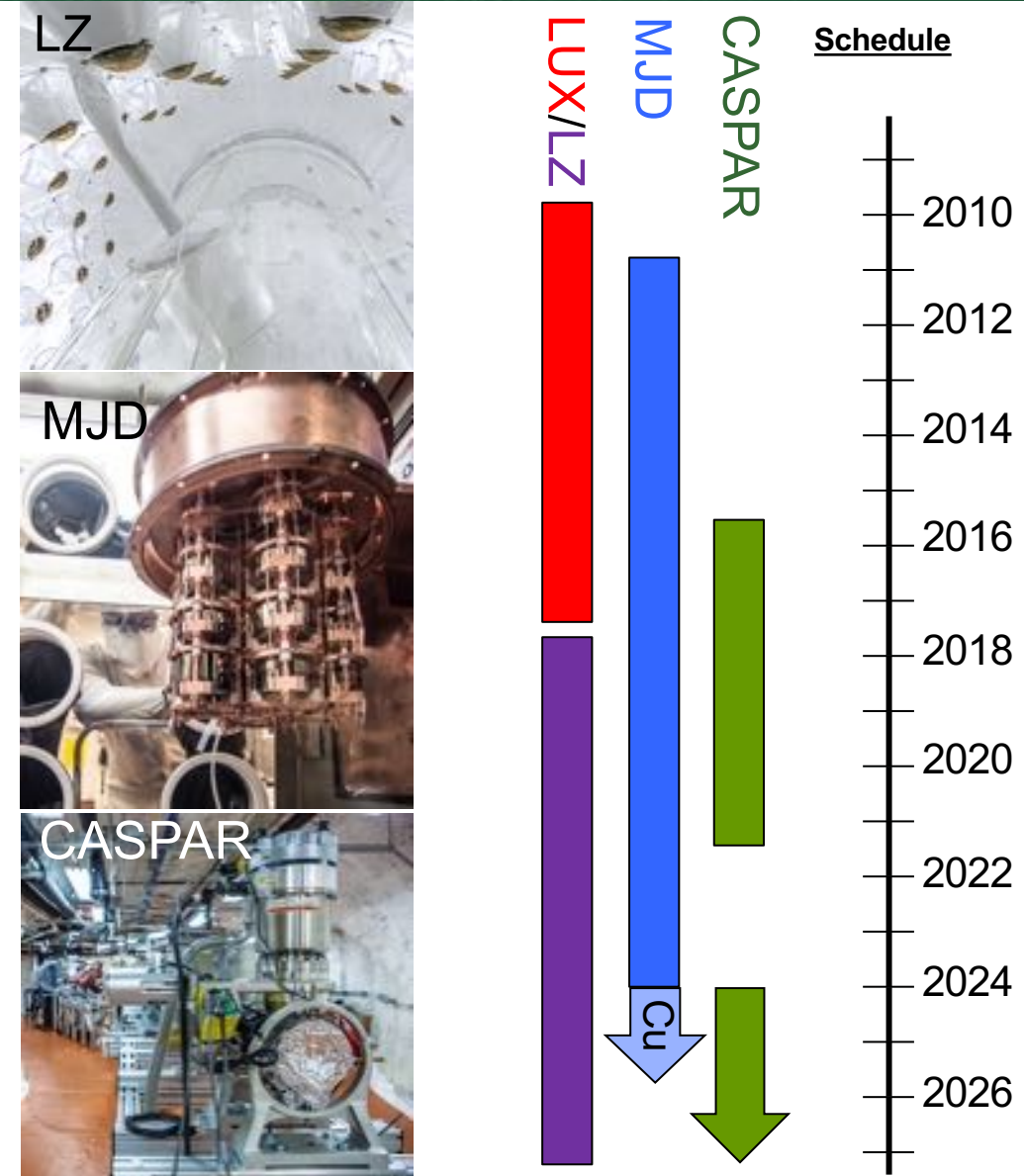


2015-2021, resume FY24

SURF Science Program – Current Physics Highlights

Strong and diverse program with exciting future

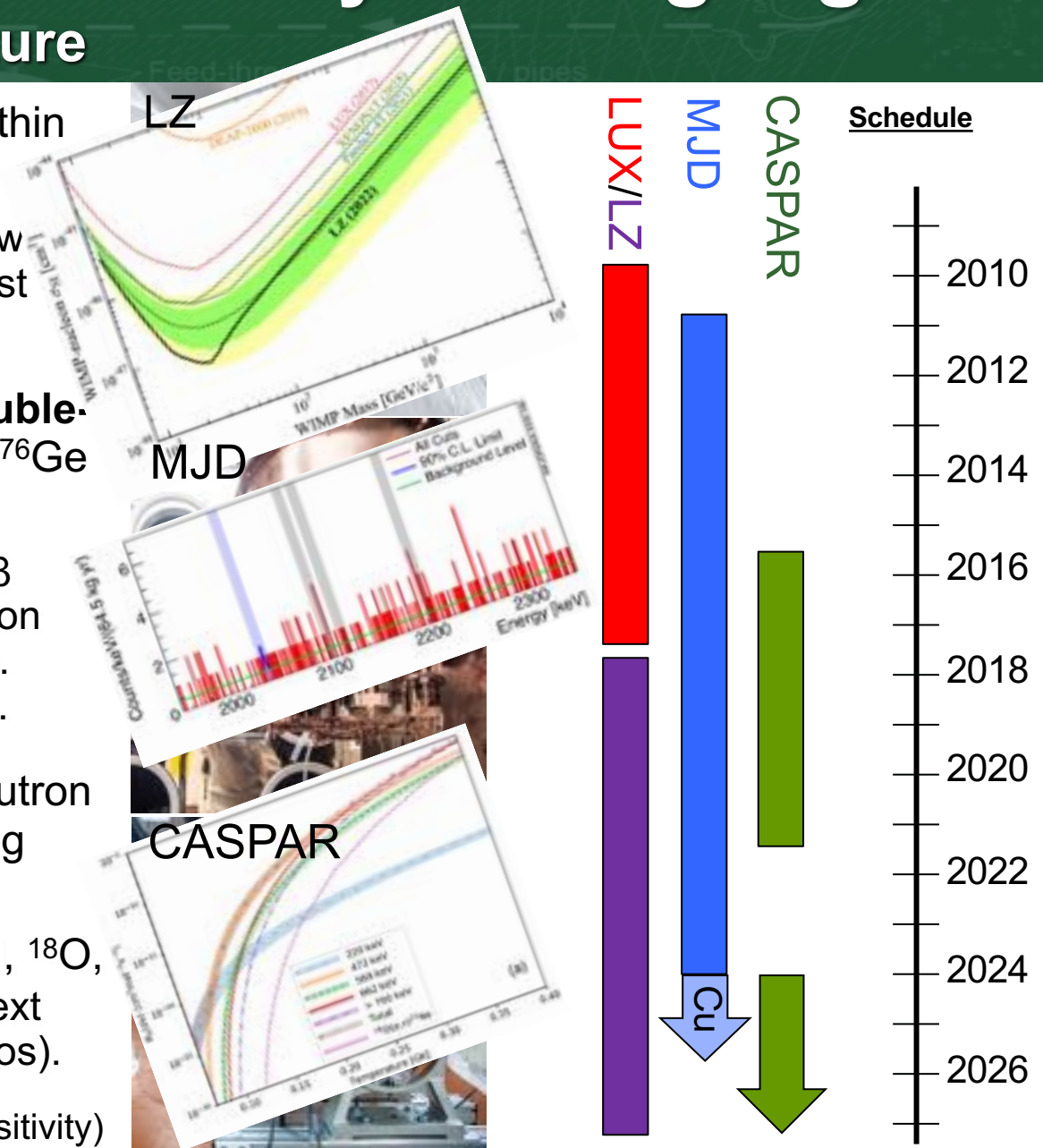
- **LZ:** Direct search for **dark matter** using 10 tonnes xenon within ultra-pure water shield + Gd liquid scintillator veto
Status: Production data started Dec 2021. Detector working well, robust calibration program underway (incl DD generator). First WIMP-search results announced Jul 2022, run for 5 years.
- **MAJORANA DEMONSTRATOR:** Investigate **neutrinoless double-beta decay** using 44 kg Ge in two cryostats, 30 kg enriched ^{76}Ge inside multi-layer compact shield
Status: Data 2015-2021 (exposure goal achieved), final $0\nu\beta\beta$ result posted Jul 2022. Ultra-pure electroformed Cu production continues, also LEGEND detector characterization and R&D. Rare decay search $^{180\text{m}}\text{Ta}$ underway, complete in 2023/2024.
- **CASPAR:** Study of stellar nuclear fusion reactions, esp. neutron production for **slow neutron-capture nucleosynthesis** using 1-MV accelerator
Status: Beam operation 2017-2021, targets incl ^7Li , ^{11}B , ^{14}N , ^{18}O , ^{20}Ne , ^{22}Ne (gas, solid), ^{27}Al . $^{18}\text{O}(\alpha,\gamma)^{22}\text{Ne}$ PRL Apr 2022. Next phase starting FY24, incl ^{14}N (relevant for CNO solar neutrinos).
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SURF Science Program – Current Physics Highlights

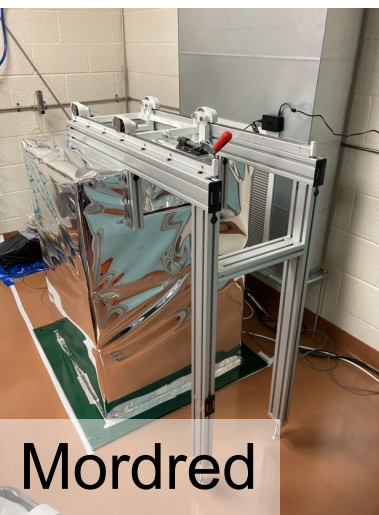
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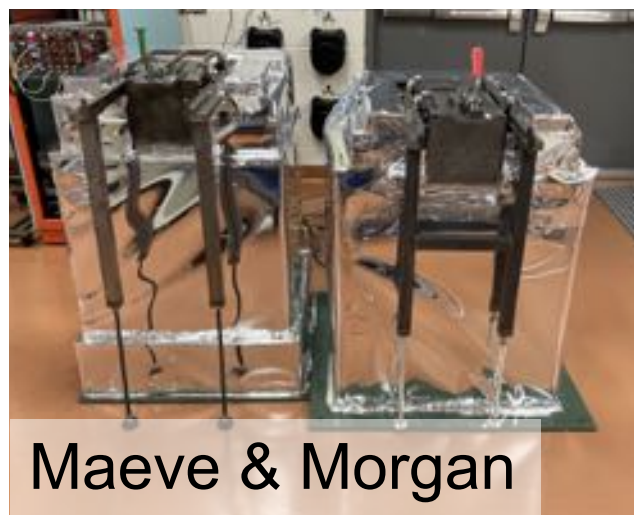


SURF Material Assay at BHUC: Davis Campus

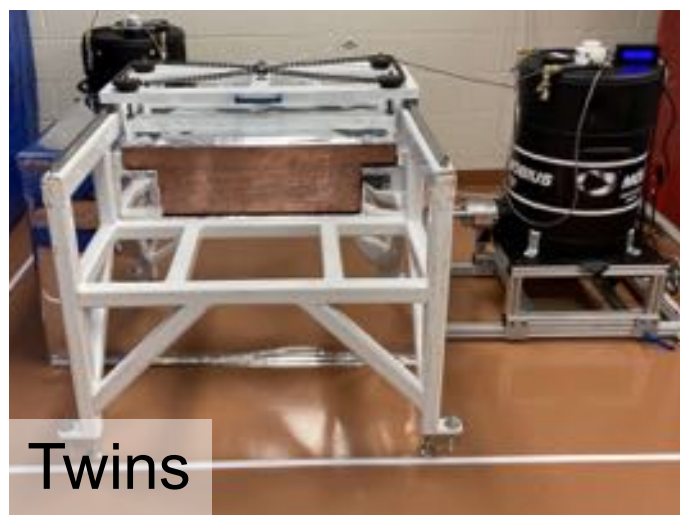
Low-background counting capabilities serving national & international community



Mordred



Maeve & Morgan



Twins



RHYM/RESN



Ge-IV

SURF Material Assay at BHUC

Low-background counting capabilities serving national & international community

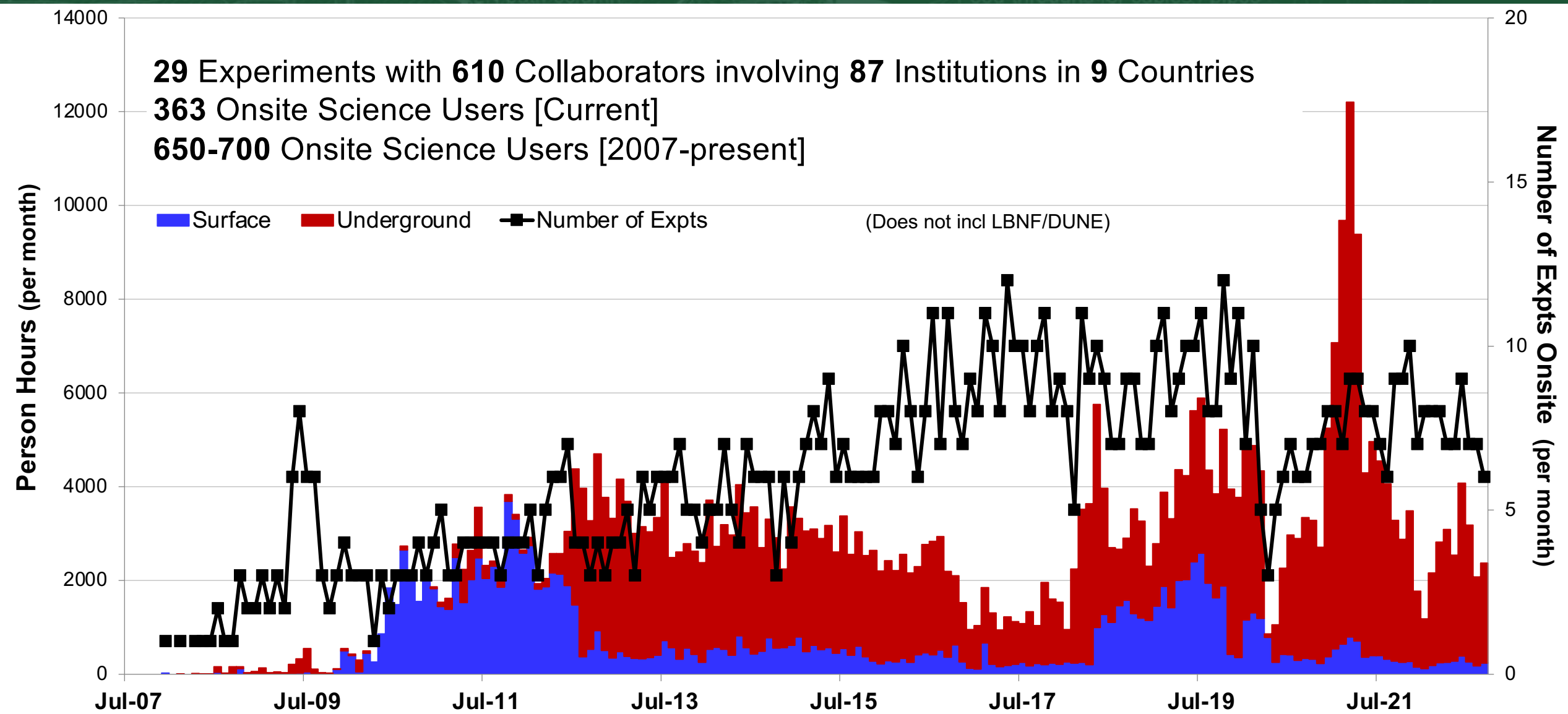
Detector	Crystal		[U] mBq/kg	[Th] mBq/kg	Install Date	Status	Comments
	Type	Size					
Maeve (BLBF)	p-type (85%)	2.2 kg	0.1 (10 ppt)	0.1 (25 ppt)	Davis Campus: Nov 2020 (Ross Campus: Nov 2015; Davis Campus: May 2014)	Production assays	Relocated from Oroville. Old Pb (200-yr old) inner shielding. Cooling 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)	<i>Davis Campus: Fall 2022?, Nov 2020 (initial)</i> <i>(Ross Campus: Jul 2018, Oct 2017 (initial))</i>	<i>Installation underway</i>	<i>Vertical design, requires gantry + hoist. Cooling system upgrades 2020.</i>
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/m² ²¹⁰Po/SD Mines; XIA UltraLo-1800/LZ purchased)

SURF Science Program

Research activities ranging from the surface to 1500+m underground



SURF Science Program

Researchers from 87 institutions (Pre-DUNE), active in bold (61)

United States

- **Black Hills State University, Spearfish, SD**
- **Brandeis University, Waltham, MA**
- **Brookhaven National Laboratory, Upton, NY**
- **Brown University, Providence, RI**
- Caltech, Pasadena, CA
- **Caterpillar Global Mining, LLC, East Peoria, IL**
- Colorado School of Mines, Golden, CO
- **Department of Energy (EERE), Washington, DC**
- **Desert Research Institute, Las Vegas, NV**
- **DTRC, Lead, SD**
- **Duke University / TUNL, Durham, NC**
- **Fermi National Accelerator Lab, Batavia, IL**
- **Golder Associates, Inc., Redmond, WA**
- **Idaho National Laboratory, Idaho Falls, ID**
- **Indiana University, Bloomington, IN**
- Jet Propulsion Laboratory, Pasadena, CA
- **Lawrence Berkeley National Lab, Berkeley, CA**
- **Lawrence Livermore National Lab, Livermore, CA**
- Liberty BioSecurity, LLC, Arlington, VA
- **Los Alamos National Lab, Los Alamos, NM**
- **Mattson Hydrology LLC, Victor, ID**
- McClure Geomechanics, Palo Alto, CA
- **Montana State University, Bozeman, MT**
- National Energy Technology Lab, Albany, OR / Morgantown, WV
- National Renewable Energy Lab, Golden, CO
- **North Carolina State University, Raleigh, NC**
- **Northwestern University, Evanston, IL**
- **Oak Ridge National Lab, Oak Ridge, TN**
- **Pacific Northwest National Lab, Richland, WA**
- **Pennsylvania State University, State College, PA**
- **Primo, Lead, SD**
- **RE/SPEC, Rapid City, SD**
- Rensselaer Polytechnic Institute, Troy, NY
- **Rice University, Houston, TX**
- Rutgers University, Piscataway Township, NJ
- **Sandia National Laboratories, Albuquerque, NM**
- **South Dakota School of Mines & Technology, Rapid City, SD**
- **Spearfish School District, Spearfish, SD**
- **SLAC National Accelerator Lab, Menlo Park, CA**
- **Stanford University, Stanford, CA**
- Tennessee Tech University, Cookeville, TN
- Texas A&M University, College Station, TX
- US Geological Survey, Rapid City, SD / Tucson, AZ

US – continued

- **University at Albany/SUNY, Albany, NY**
- **University of Alabama, Tuscaloosa, AL**
- **University of California Berkeley, Berkeley, CA**
- **University of California Davis, Davis, CA**
- **University of California Los Angeles, Los Angeles, CA**
- **University of California Santa Barbara, Santa Barbara, CA**
- **University of Kentucky, Lexington, KY**
- **University of Maryland, College Park, MD**
- **University of Massachusetts, Amherst, MA**
- **University of Michigan, Ann Arbor, MI**
- **University of North Carolina, Chapel Hill, NC**
- **University of Notre Dame, Notre Dame, IN**
- **University of Oklahoma, Norman, OK**
- **University of South Carolina, Columbia, SC**
- **University of South Dakota, Vermillion, SD**
- **University of Southern California, Los Angeles, CA**
- **University of Rochester, Rochester, NY**
- University of Tennessee, Knoxville, TN
- University of Utah, Salt Lake City, UT
- **University of Wisconsin – Madison / Physical Sciences Lab, Madison, WI**
- **University of Washington, Seattle, WA**
- USDA NCAUR, Peoria, IL
- WD Masonry, Rapid City, SD
- Williams College, Williamstown, MA
- Xilinx, Inc., San Jose, CA
- Yale University, New Haven, CT

World

- **Center for Underground Physics (IBS), Daejeon, Korea**
- Joint Institute for Nuclear Research, Dubna, Russia
- **Imperial College London, London, England**
- **LIP Coimbra, Coimbra, Portugal**
- NRC Institute for Theoretical and Experimental Physics, Moscow, Russia
- Osaka University, Osaka, Japan
- Queen's University, Kingston, Canada
- **Royal Holloway and Bedford New College, Egham, England**
- **Rutherford Appleton Laboratory, Didcot, England**
- Technische Universität München / Max Planck Institute, Munich, Germany
- **University College London, London, England**
- **University of Bristol, Bristol, England**
- **University of Edinburgh, Edinburgh, Scotland**
- **University of Liverpool, Liverpool, England**
- **University of Oxford, Oxford, England**
- **University of Sheffield, Sheffield, England**

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

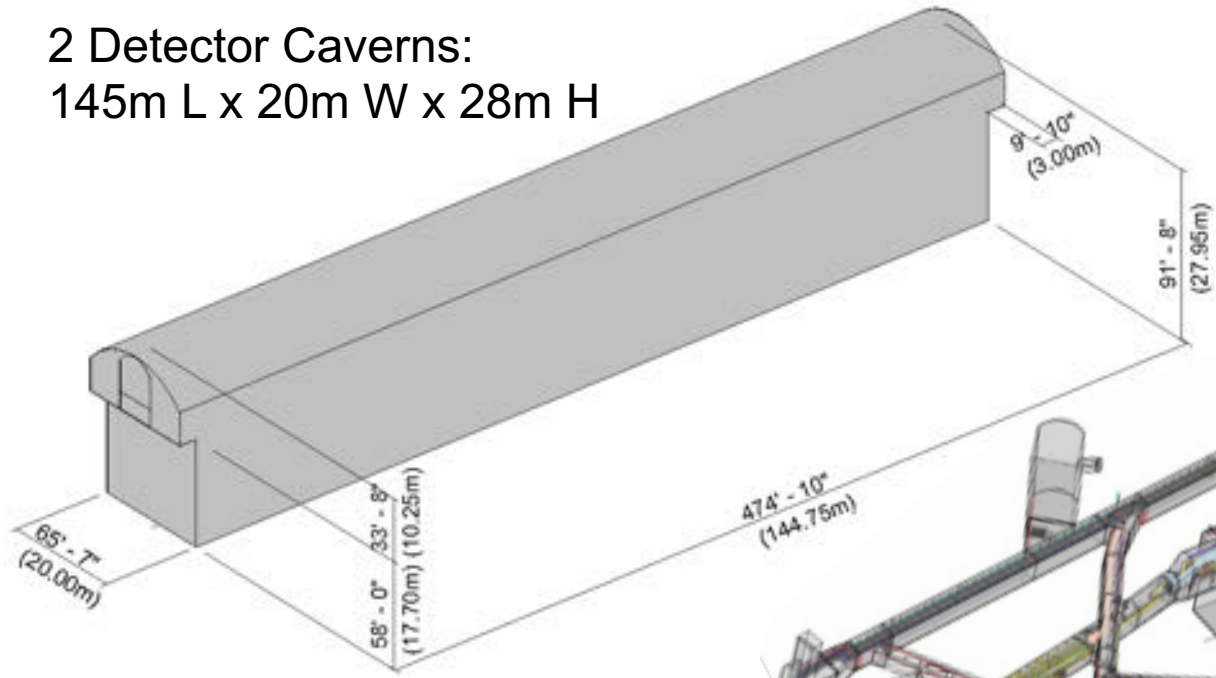


- First internationally conceived, constructed, and operated project hosted by the Department of Energy in the United States. Significant **international** contributions (incl CERN).
- Two detector caverns to host 4 detectors (total of 70 kT/50M liter liquid argon) + utility cavern.
- **Reliability projects** rehabilitated some key SURF infrastructure 2016 – 2020.
- **Pre-excavation construction** at SURF in Jan 2019 – Feb 2021. Transportation system for excavated rock operational (first rock to Open Cut May 2021).
- **Excavation** initial phase started Jun 2020, focused on ventilation. Main excavation phase (caverns, access) started Apr 2021 and will last ~3 years (drill & blast expected to complete by ~Oct 2023).
- **Infrastructure outfitting and cryostat construction** expected 2024-2027, **science starts 2028**.

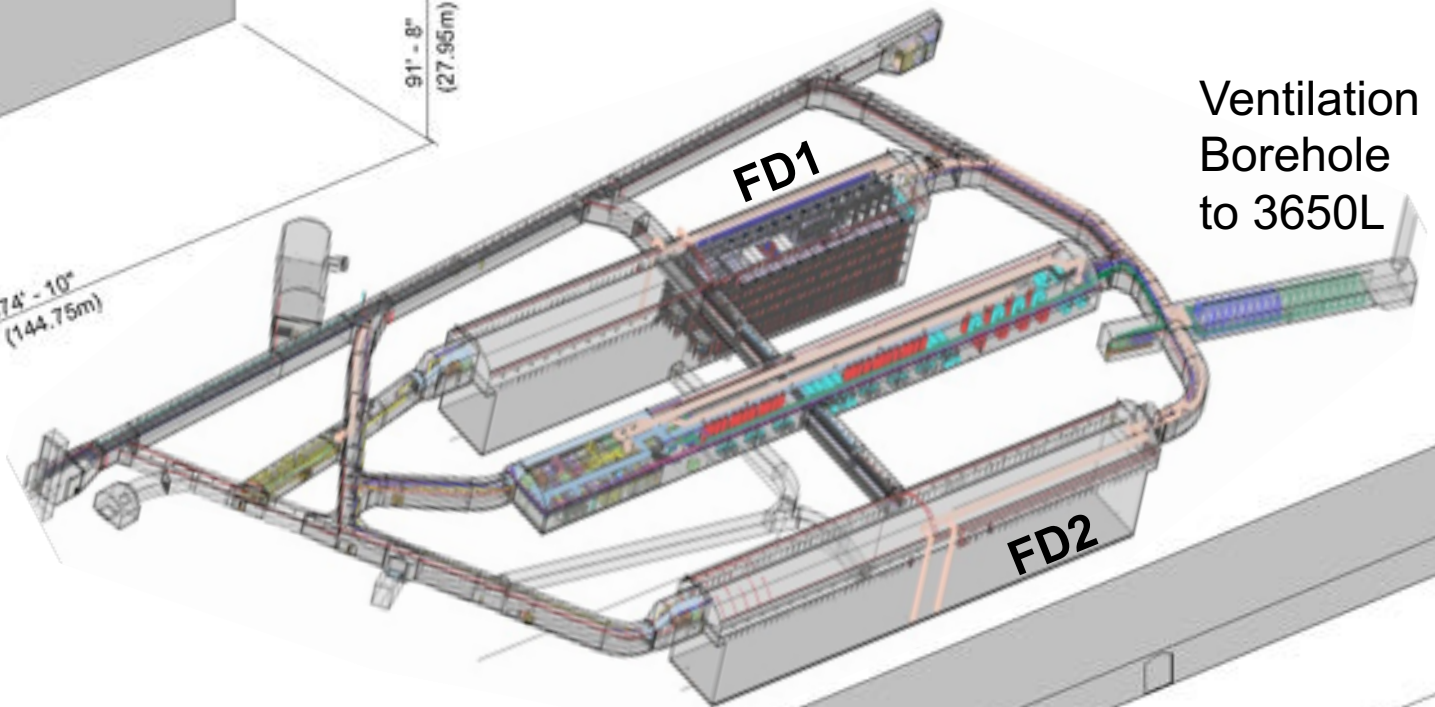
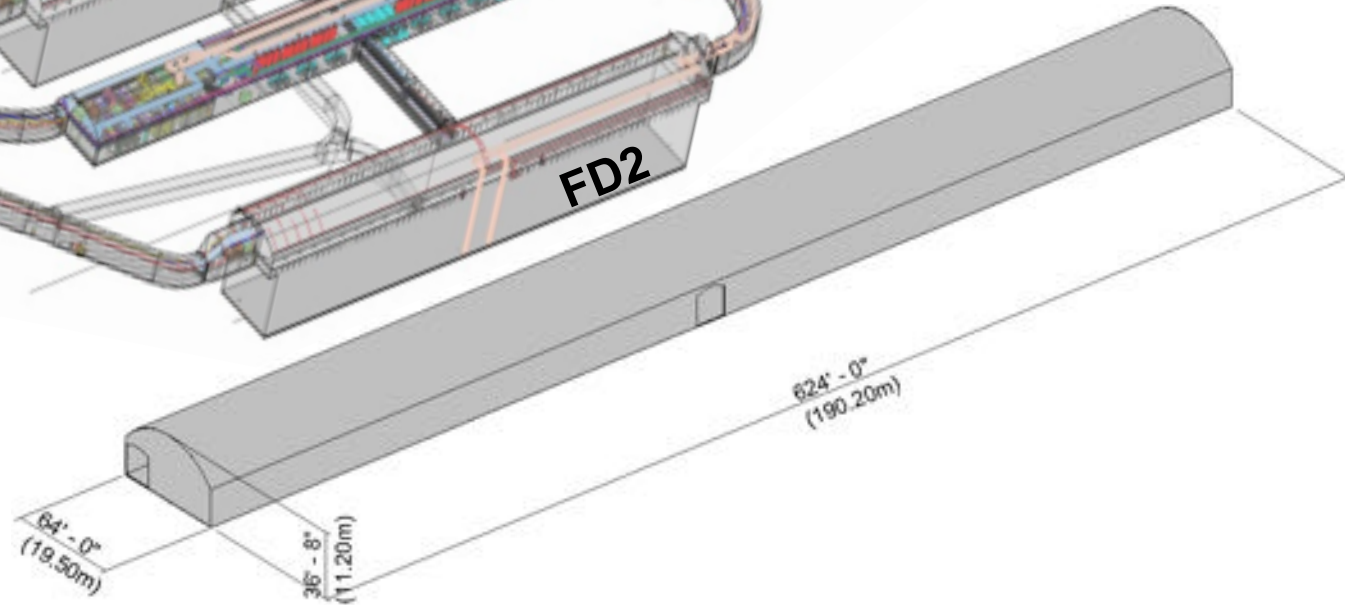
Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

2 Detector Caverns:
145m L x 20m W x 28m H



1 Utility Cavern:
190m L x 20m W x 11m H

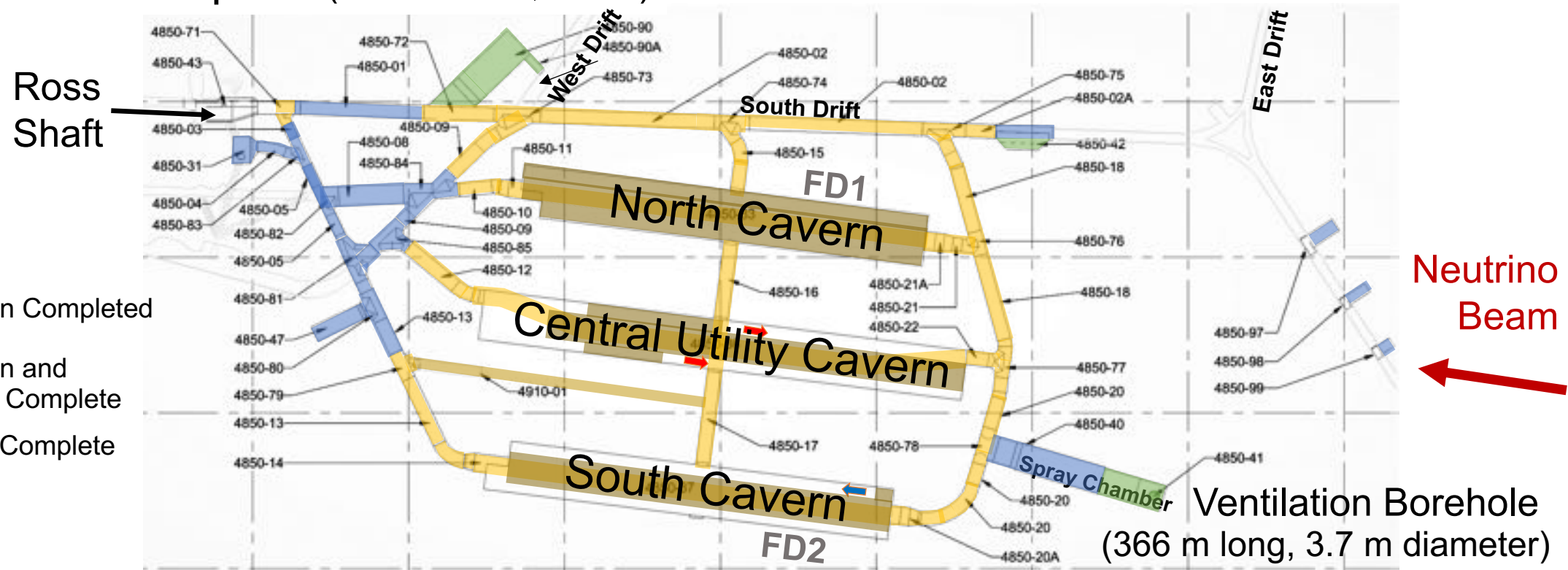


Neutrino Beam

Long-Baseline Neutrino Facility (LBNF)

LBNF will host the Deep Underground Neutrino Experiment (DUNE)

Excavation 42% complete (October 17, 2022)



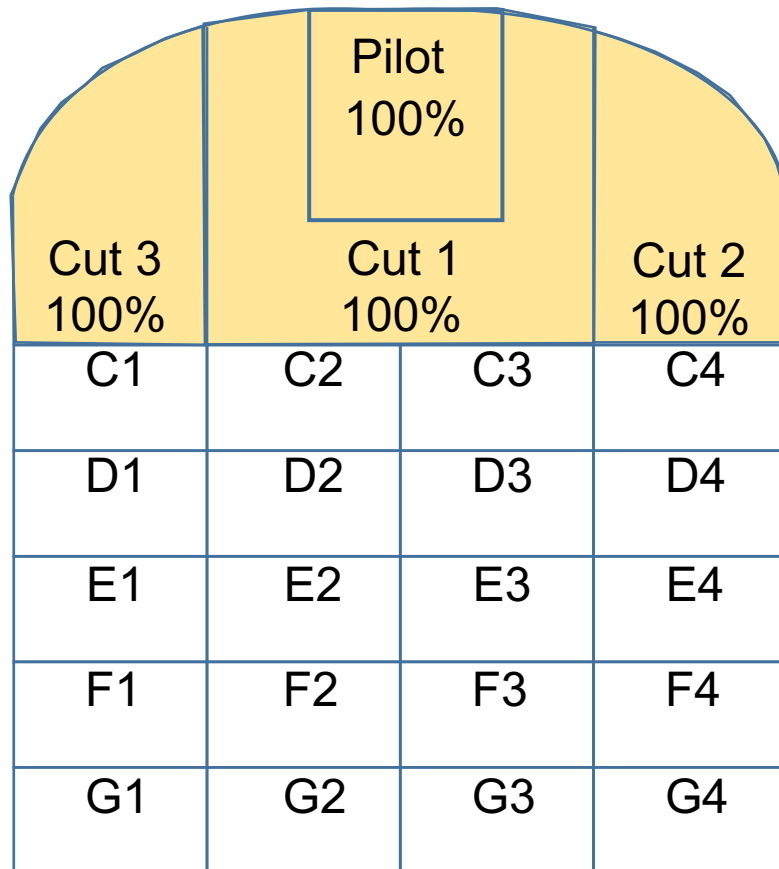
- Aug 2023: North Cavern excavation complete
- Mar 2023: Central Utility Cavern excavation complete
- Oct 2023: South Cavern excavation complete
- Mar 2024: All concrete complete
- May 2024: Infrastructure outfitting (~18 mths), cryostat construction starts (warm ~11 mths + cold ~12 mths)

Long-Baseline Neutrino Facility (LBNF)

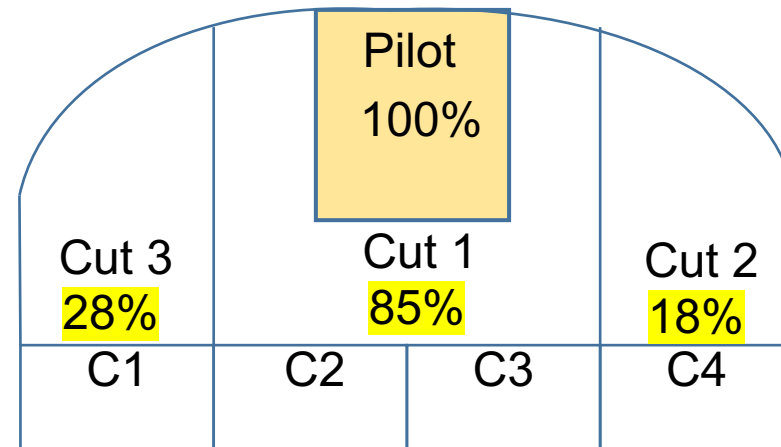
LBNF will host the Deep Underground Neutrino Experiment (DUNE)

Cavern Excavation Completion Percentage

October 17th 2022

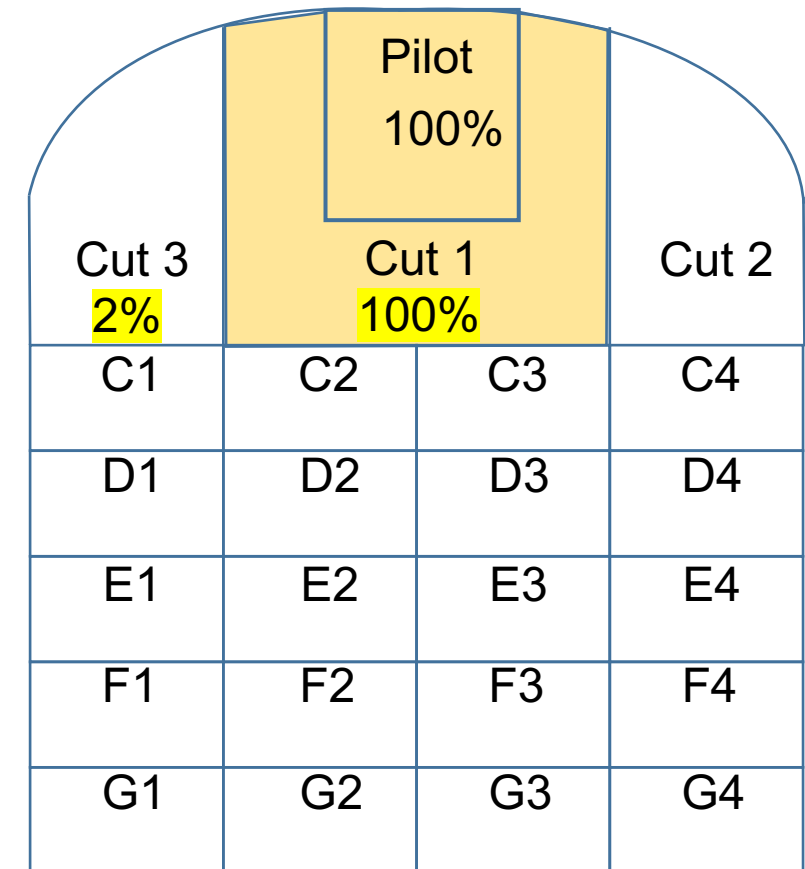


North Cavern



Note: Cut 1 (West end) will be completed after Cut 2 & 3

CUC Cavern



South Cavern

LBNF Excavation Progress

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



LBNF Excavation Progress

North Cavern reaches full width



LBNF Excavation Process



1. Drill Blast Holes



2. Remove Explosive from magazine



3. Charge Face



4. Evacuation



5. Close Blast Doors



11. Ground Support



10. Geological Mapping



9. Mucking



8. Scaling



6. Initiate Blast



7. Ventilate

Drill and Blast Cycle

M. Michael Rounds Operations Center (ROC)



- \$6.5M South Dakota commitment
- 26,000 sq.ft. (2415 m²) total footprint
- Includes warehouse, machine shop, ops/engineering office space
- Dedicated Aug 20, 2021

Sanford Lab Homestake Visitor Center

SDSTA acquired building and land on Jan 7, 2022. Acquisition and ops funded by SDSTA.



SURF Supports Science

Variety of resources to ensure safe and successful science

- **Science**

- Main point of contact for researchers, coordinate and marshal Lab resources to meet expt needs
- Oversight of expt implementation process, scientific/technical expt support (collab members, LBC ops)

- **Operations**

- Maintain infrastructure and access to surface and underground facilities, incl hoists, shafts, drifts, services (power, network, etc); also experiment site preparation
- Transportation of personnel and materials: 24-hr access as needed, typically 10-20 ppl/day for science

- **Environment, Safety & Health (and Security)**

- Manage Safety Manual, incl policies, forms (e.g., oxygen deficiency, hazard analysis/WPC, etc)
- Safety resource (e.g., reviews, training, monitoring, waste, radiation, record keeping, ERT); prox access

- **Engineering**

- Participate in understanding expt requirements, oversight of lab development, contract management, engineering support for Operations (access and maintenance)
- Assessments (incl equip design/certifications, ODH), system process design and troubleshooting

- **Admin / Business Services / Finance / IT**

- User access & support (incl badging, event planning), contracts/rebilling, shipping/receiving, procurement, IT support (VPN, document mgmt, network data/phone), training accounts

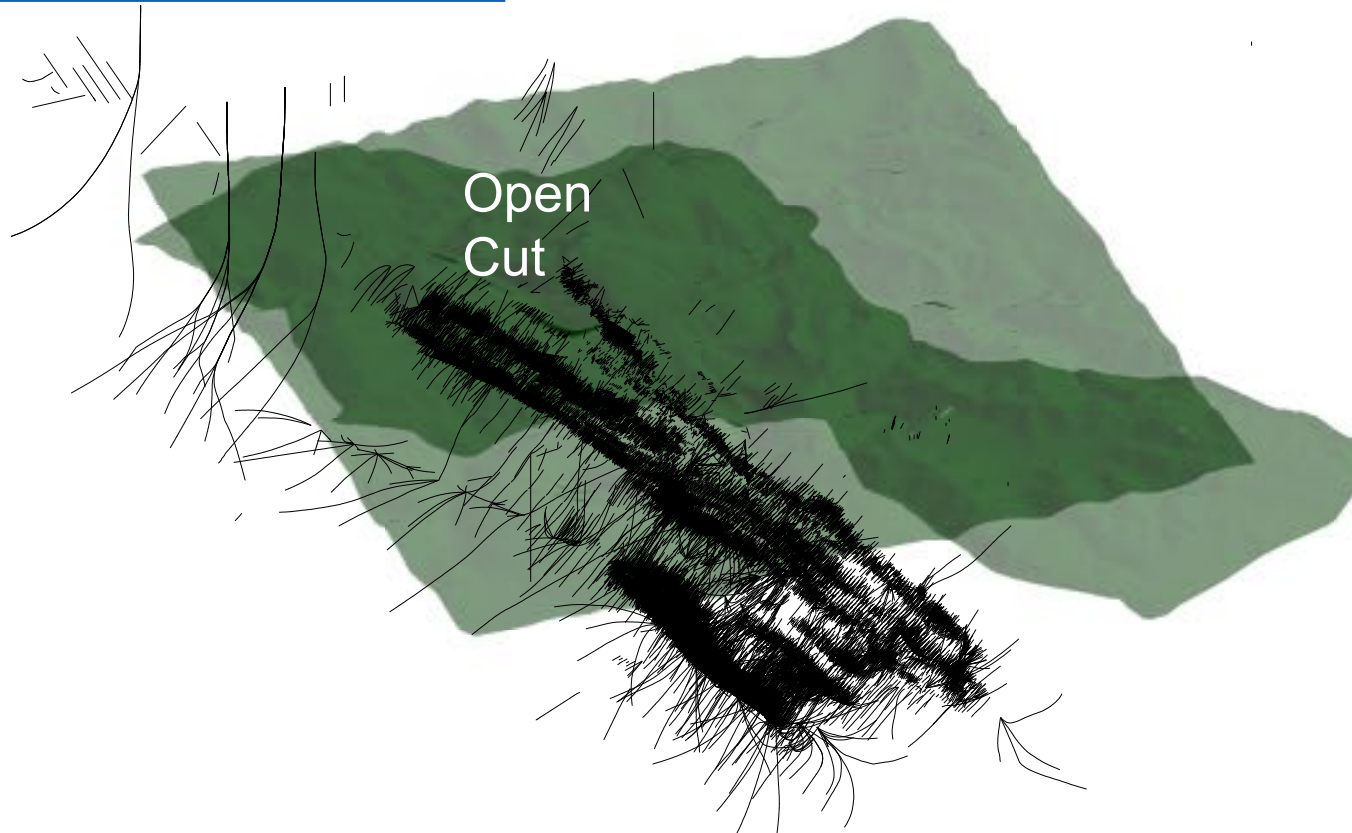
- **Communications / Education & Outreach**

- Interface with media and other groups, coordinate public meetings, outreach showcasing research/ scientists at local, state and national levels (e.g., Neutrino Day), student internships (incl Science interns)

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/>



SURF Science Strategic Planning

SURF Snowmass whitepaper reflects UG science community input

- SURF advocates for DOE panel recommendations:
 - Mission need for **additional deep laboratory space** in U.S. (incl depths > 6000 m.w.e.) in U.S. to support compelling future science
 - Mission need for a next-generation (~100 tonne) **dark matter** and **neutrino** observatory in U.S.
 - Establish process to **optimize scientific use of UG spaces** at SURF, incl temporary use of LBNF module as appropriate
 - Endorse value of **multi-disciplinary underground science** at a dedicated laboratory in U.S.
- Additional underground space proposed:
 - **4850L** (1500 m, 4300 m.w.e), **7400L** (2300 m, 6500 m.w.e.)
 - Initial engineering designs completed
 - Excavation for **100-m cavern(s)** could begin as early as 2027, first cavern **complete by ~2030**
- Other:
 - Operational details (incl conveyance specs, storage/staging, etc)
 - Ross Campus occupancy resuming FY24



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

SURF Experiment Implementation Program

Identify interfaces and hazards within approval framework

- <https://www.sanfordlab.org/researchers/proposal-guidelines>
- **Project Documentation**
 - Expression of Interest, incl support letters
 - Experiment Planning Statement
 - Memorandum of Understanding (space commitment)
 - Access: Request form, risk waiver, insurance
 - Services Agreement(s), if applicable
 - General Services Agreement: Who provides what and who pays
 - Contract(s): Specific expenses, direct use of SURF staff
 - Experiment Decommissioning Plan
- **Environment, Safety & Health**
 - Hazard Analysis: Assessments/analyses, procedures, testing/certifications
 - Inventories: Chemical, electrical, hoisting & rigging, pressure, rad materials
 - Training: Sanford Lab modules, Expt training plan (incl equivalences), records
- **Reviews** (Commensurate with hazards)
 - Facility, walk-through inspections, monitoring, readiness reviews (safety, ops)
- **Authorization**
 - Work planning & controls (procedure reviews/approvals, release), Science/ESH + Subject Matter Experts
 - Authorization To Proceed for significant installation and associated significant hazards

The screenshot displays the Sanford Underground Research Facility website. The main heading is "Proposal Guidelines" with the subtext "All proposals must follow these guidelines". Below this, there is an introductory paragraph and a numbered list of five steps: 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, and 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. A "Document and contact information" section lists several documents for download, including the Experiment Implementation Program, Experiment Integration and Support Standard, Experiment Planning Statement, MOU Template, Publication Policy, and Acknowledgment of Risk and Waiver. The footer contains navigation links for various resources and contact information.

SURF User Association

<https://www.sanfordlab.org/researchers/surfuserassociation>

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 Underground Science Community (initially was limited to active SURF researchers). General meetings held at least annually.
- **Executive Committee** consists of 9 individuals across scientific disciplines, incl early career. Two-year terms (with term overlap), limits per experiment and institution. Quarterly meetings held with SURF Mgmt.

Status

- **Established** Dec 2020, operating well. Two rounds of **Executive Committee** elections conducted successfully (2020, 2021).
- **Charter** updated in Aug 2021 to broaden membership to **global underground science community**. Subcommittee ratified new registration process in Apr 2022, form linked on SURF website and advertised to community. Expanded membership will increase SURF's prominence and leadership in global UG science community.
- **Charter** update in progress to reflect SPAC recommendation to increase **minimum representation** from various disciplines. Change ratified by Executive Committee in Apr 2022 (SURF to formally adopt).
- Association organized SURF **Vision Workshop** Sep 2021. First **General Meeting** Sep 2021, next meeting Oct 26-27, 2022.

1. Brittany Kruger (DRI/**Chair**)
2. Megan Smith (LLNL/**Secretary**)
3. Mark Hanhardt (SDSTA)
4. Kevin Lesko (LBNL)
5. Rachel Mannino (LLNL)
6. Ralph Massarczyk (LANL)
7. Sam Meijer (LANL)
8. Brianna Mount (BHSU)
9. Frank Streider (SD Mines)
10. Wenqin Xu (USD)

SURF Science Program Advisory Committee

Purpose

- **Science Program:** Provide guidance on overall SURF scientific program (incl current, planned/proposed experiments), as well as direction and breadth of program. Peer review per DOE User Facility.
- **Science Support:** Advise on SURF experiment implementation program and organizational capacity to support experiments.
- **Science Facilities:** Advise on capability and capacity of the SURF facility necessary to support the SURF scientific program.

Organization

- SPAC consists of up to **14 members**, representing breadth of SURF research disciplines with strategic and synergistic influences (SDSTA Laboratory and Science Directors *ex-officio*).
- Members: **Two-year** terms (extendable). Chair: **One-year** term (extendable).
- Selection of new members made by SDSTA Laboratory + Science Directors in consultation with SDSTA IDEA Office.

Status

- **Established** Sep 2021, operating well.
- **First meeting held** (remotely) Jan 2022, tracking 17 recommendations (incl conducting planning workshops to strengthen SURF's posture for attracting new science). Next meeting Nov 9-10, 2022 (in-person + some remote).

1. David MacFarlane (SLAC/Chair)
2. Ed Blucher (Chicago)
3. Derek Elsworth (Penn State)
4. Joseph Formaggio (MIT)
5. Hunter Knox (PNNL)
6. Magdalena Osburn (Northwestern)
7. Federica Petricca (Max Planck)
8. Lance Roberts (SD Mines)
9. Hamish Robertson (Washington)
10. William Roggenthen (SD Mines)
11. Kate Scholberg (Duke)
12. Barbara Szczerbinska (TAMU-CC)
13. Mary Voytek (NASA)
14. TBD

SURF Economic Impact in South Dakota

2020-2029 – SURF Ops, LBNF/DUNE and 4850L lab expansion

Net Economic Impact of SURF in South Dakota, 2020-2029

Impact Type	Output (Millions)	Earnings (Millions)	Average Annual Employment
Direct	\$617	\$197	258
Indirect	\$704	\$454	920
Total	\$1,321	\$651	1,178

Source: AEG analysis of base data from SDSTA and Fermilab, U.S. Bureau of Economic Analysis RIMS II Multipliers, U.S. General Services Administration.

Note: Direct and indirect figures may not sum to total figures due to rounding.

SURF COVID-19 Response

Effective measures limiting COVID spread at SURF

- **Protocols**

- SURF COVID-19 response and control requirements documented (currently version 10)

- **Initial**

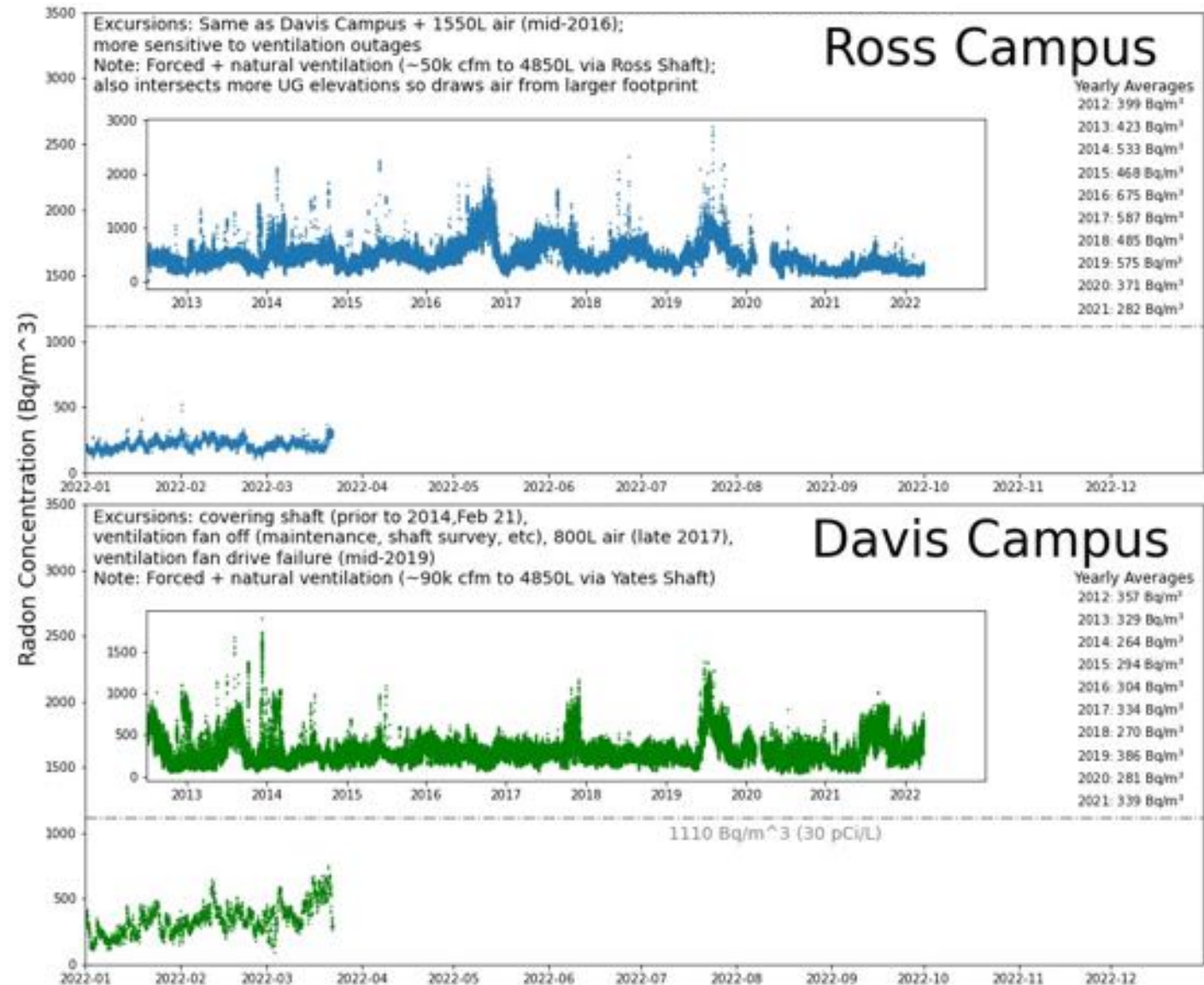
- Brief period of minimal essential operations:
 - Mar 25 – May 6, 2021: Access limited, critical monitoring/maintenance, consumable supplies (e.g., LN) still supported; some surface activities resumed in April
- Monitored data in 100-mile region, scrutiny on travel
- Controls developed based on CDC, OSHA:
 - Masks required in buildings/labs, respirators required on conveyances
 - Reduced #s on conveyances & meeting rooms, telework encouraged
 - Wellness checks at site entrances
- Significant collaboration institutional travel restrictions
- Large in-person events canceled or virtualized (e.g., Neutrino Day 2020 & 2021)

- **Current**

- Masks optional in all areas at SURF per CDC based on county Community Levels (cases, hospitalizations)

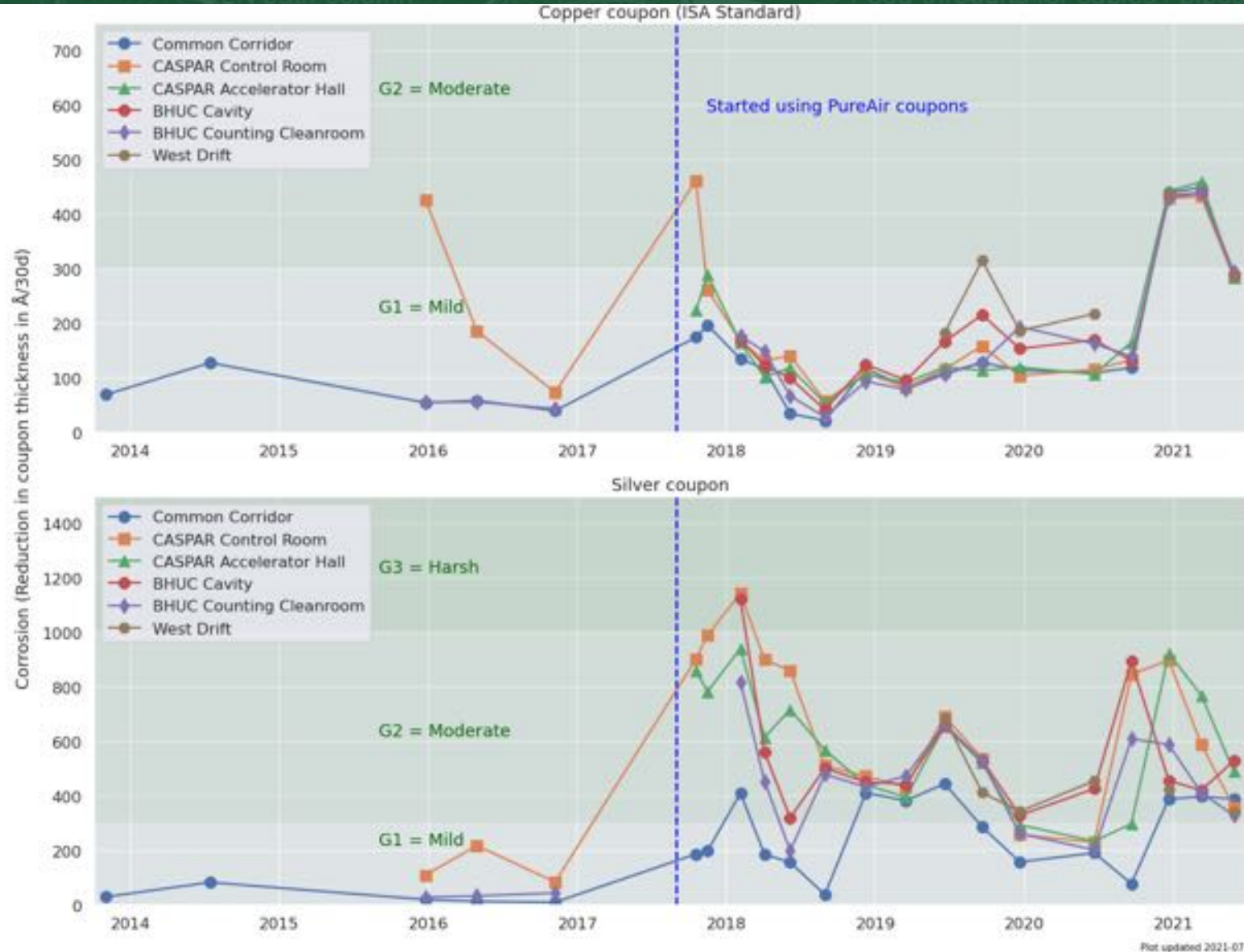
SURF Science Support – Monitoring

Radon concentrations in 4850L laboratories since 2012



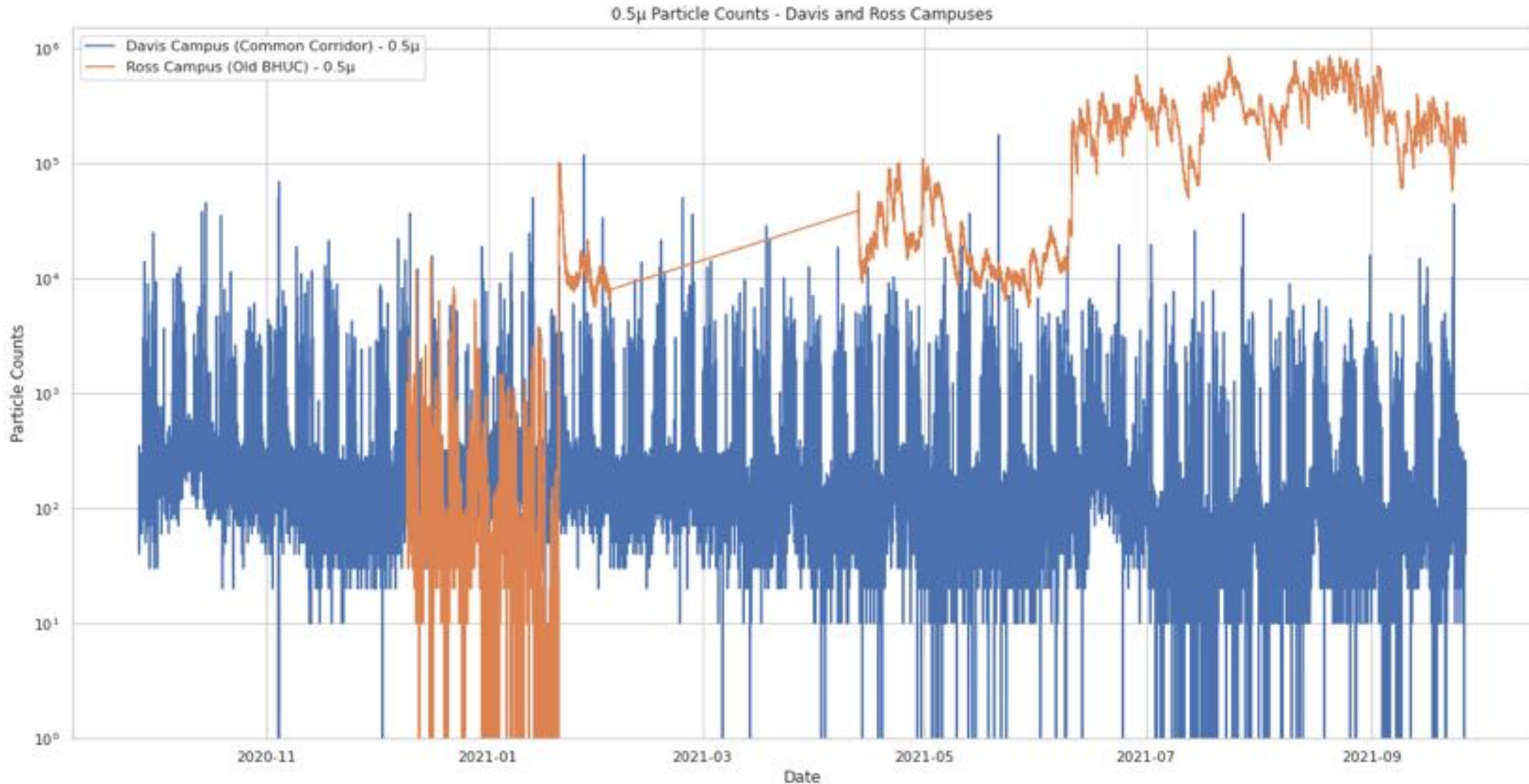
SURF Science Support – Monitoring

Corrosion/reactivity testing in 4850L laboratories since 2013



SURF Science Support – Monitoring

Particle counts in 4850L laboratories since 2013 (past year indicated)



SURF Core Values

Safety Focused: We do not compromise safety or endanger the environment. Period.

Care for Others: We embrace and honor the fundamental value and dignity of all individuals. We listen knowing everyone has something to offer and to learn.

Professional: What we do is important to our community and the world. We sweat the details to achieve big things. Our behavior and ethics exemplify our best.

Team Players: We provide unmatched service. We are respectful and deliver for our customers and partners. We build trust not barriers.